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PAPER

Advantages and Drawbacks of Smartphones and Tablets for Visually Impaired People —— Analysis of ICT User Survey Results ——

Tetsuya WATANABE[†a)], *Member*, **Toshimitsu YAMAGUCHI**[††], *Nonmember*, *and* **Kazunori MINATANI**[†††], *Member*

SUMMARY A survey was conducted on the use of ICT by visually impaired people. Among 304 respondents, 81 used smartphones and 44, tablets. Blind people used feature phones at a higher rate and smartphones and tablets at lower rates than people with low vision. The most popular smartphone model was iPhone and the most popular tablet model was iPad. While almost all blind users used the speech output accessibility feature and only a few of them used visual features, low vision users used both visual features such as Zoom, Large text, and Invert colors and speech output at high rates both on smartphones and tablets. The most popular text entry methods were different between smartphones and tablets. For smartphones flick and numeric keypad input were popular among low vision users while voice input was the most popular among blind users. For tablets a software QWERTY keyboard was the most popular among both blind and low vision users. The advantages of smartphones were access to geographical information, quick Web browsing, voice input, and extensibility for both blind and low vision users, object recognition for blind users, and readability for low vision users. Tablets also work as a vision aid for people with low vision. The drawbacks of smartphones and tablets were text entry and touch operation difficulties and inaccessible apps for both blind and low vision users, problems in speech output for blind users, and problems in readability for low vision users. Researchers and makers of operating systems (OS) and apps should assume responsibility for solving these problems.
key words: *visually impaired people, smartphones, tablets, touch interface, user survey*

1. Introduction

Recently smartphones and tablets have been gaining more Japanese users [1]. By their nature these devices have both advantages and drawbacks for visually impaired people. For example, people with low vision can not only enjoy wide screens but also use these devices as magnifiers [2]. For blind people apps that identify color, paper money, soup cans and so in the snapshots taken by the devices are useful. On the other hand, even with voice feedback provided blind users may find it too hard to perform touch interface operations without tactile cues. It might not even occur to them that they could use these devices without sight [3].

With this background in mind, we decided to carry out a survey on the use of ICT devices by visually impaired people to statistically clarify the advantages and drawbacks of smartphones and tablets, disseminate good usage practices, and appeal to developers and researchers for solutions to usage problems. Out of all the survey results, this paper focuses on the usage of smartphones and tablets and tries to spot their advantages and drawbacks from the different viewpoints of blind and low vision users.

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[†]The author is with the Faculty of Engineering, Niigata University, Niigata-shi, 950–2181 Japan.
[††]The author is with the Graduate School of Science and Technology, Niigata University, Niigata-shi, 950–2181 Japan.
[†††]The author is with National Center for University Entrance Examinations, Tokyo, 153–8501 Japan.
a) E-mail: t2.nabe@eng.niigata-u.ac.jp
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2. Related Work

Although there is a technology news magazine [4] that carries many reviews of smartphone apps that are useful for visually impaired people, we found no survey reports on the use of touch interfaces in major American and British journals on visual impairment [4]–[6].

In Japan, Miura, Matsuzaka et al. conducted a survey to investigate visually impaired persons' usage of touch screen devices and their needs for improvement of these devices [7]. The questionnaire in this survey was made with reference to a previous survey by the authors [8] and a "Survey on Persons with Physical Disability" conducted by the Ministry of Health, Labour and Welfare [9]. In total 140 persons responded to the questionnaire in the former, but with Matsuzaka's support we decided to increase the number with the aim of getting more reliable results.

The Institute for Information and Communications Policy, under the aegis of the Ministry of Internal Affairs and Communications, carried out a survey on the use of the Internet by people with disabilities [10]. This survey covered four kinds of disabilities but did not elaborate on visually impaired persons' use of smartphones and tablets.

The authors had previously conducted three ICT user surveys of visually impaired people, one each in 2000 [11], 2002 [12], and 2007 [8]. The questionnaire in these surveys was modified in accordance with changes in ICT devices.

3. Procedure

The survey was contracted to "NPO Turtle," a nonprofit organization whose main activity is to help visually impaired people in seeking and keeping their careers [13]. They disseminated the questionnaire to 47 mailing lists to which visually impaired people belonged. The survey started on

September 25, 2013 and ended on November 10.

The questionnaire asked about the respondents' profiles, their usage rate of ICT devices in general and their attitudes towards touch interfaces, and the specific ways they used feature phones, smartphones, tablets, and personal computers.

4. Respondents

The 304 respondents comprised 199 men (65.5%) and 105 women (34.5%) ranging in age from 18 to 90 years, with an average of 48.2. One hundred and ninety-one (62.8%) were registered as grade 1 visually impaired persons, 84 (27.6%) as grade 2, and 21 (6.9%) as grades 3 through 6. Five persons were not registered as visually impaired and the status of three was unknown. Japan's Law for the Welfare of Physically Disabled Persons classifies visually impaired people into six grades. People with grades 1 and 2 disabilities are considered severely impaired and entitled to larger discounts on public utility charges and public transportation fares, greater tax exemptions, and disability pensions.

Among grade 1 respondents, 85.9% stated they were print-disabled. This ratio declined as the degree of disability decreased; 27.4% for grade 2 and 4.8% for grades 3 through 6 respondents (Fig. 1). Hereafter we refer to print-disabled respondents as "blind people" and print-"abled" respondents as "people with low vision." The survey data were categorized into these two user groups and compared with each other and put to the χ^2 Test with a p value of 0.01 or 0.05.

5. Usage of ICT Devices in General

Among the 304 respondents, 246 (80.9%) used feature phones, *i.e.*, flip phones originally developed in Japan, 81 (26.6%) smartphones, 44 (14.5%) tablets, and 290 (95.4%) personal computers. These data were totalized in two user groups: blind and low vision (Fig. 2).

Blind people used feature phones at a significantly higher rate than people with low vision ($\chi^2 = 6.85$, $p < 0.01$). In contrast, people with low vision used smartphones and tablets at significantly higher rates than blind people (smartphone: $\chi^2 = 4.17$, $p < 0.05$, tablet: $\chi^2 = 10.23$, $p < 0.01$). The groups' personal computer usage rates showed no significant difference ($\chi^2 = 0.98$).

6. Smartphone Usage

This chapter describes the responses from 81 (43 blind and 38 low vision) users to smartphone usage questions.

6.1 Models

Seventy-seven of the 81 used one smartphone and the other four used two or more. Thus, in total, 89 smartphones of various models were gathered. Figure 3 shows the number of users for each model.

The most popular models were various Apple iPhones with 59 (72.8% of the 81) users. The second most popular model was Fujitsu's "Raku-Raku (easy to use) Smartphone" which is equipped with a speech output function. However, it had only seven users, a very small number compared to the 59 for iPhones. Twelve people used 18 Android devices.

Blind people used iPhones at a higher rate than people with low vision (81.4% vs. 63.2%) and people with low vision used Android devices at a higher rate than blind people (28.9% vs. 16.3%), but these differences were not significant ($\chi^2 = 3.39$ for iPhones and $\chi^2 = 1.87$ for Android terminals).

6.2 Accessibility Features

Accessibility feature usage rates differed greatly between blind and low vision users (Fig. 4). Forty-one of 43 blind smartphone users (95.3%) used speech output and only two to three used visual aids. On the other hand, for low vision users the most popular features were visual features such as Large Text (65.8%), Zoom (63.2%), and Invert Colors (39.5%). However, speech output was also used by 14 out

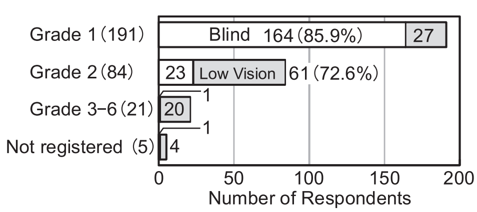

Fig. 1 Ratio of blind to low vision respondents by grade of disability.

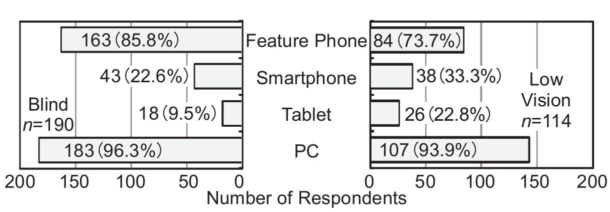

Fig. 2 Usage of ICT devices.

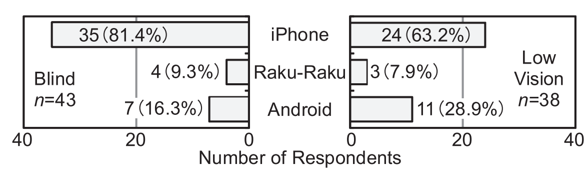

Fig. 3 Popular smartphone models.

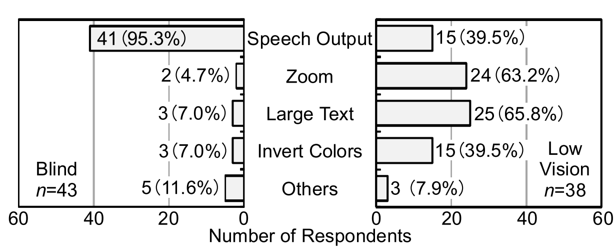

Fig. 4 Usage of accessibility features on smartphones.

Fig. 5 Numeric keypad and flick input (upper left).

Fig. 6 Japanese syllabary keyboard.

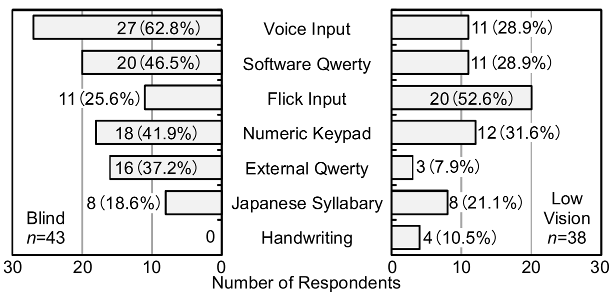

Fig. 7 Usage of text entry methods on smartphones.

of 34 low vision users who used visual features. A similar phenomenon was observed in the use of personal computers: many low vision users used screen readers along with screen magnifiers [8].

6.3 Text Entry

Japanese language uses about 50 "*kana*" characters along with "*Kanji*" Chinese characters. Each *kana* character (with one exception) represents one syllable that is either a vowel or a consonant(s) + vowel combination. With the QWERTY keyboard, one *kana* character is input by typing one or two keys for a vowel and two to four keys for a consonant(s) + vowel combination. For flick input, a numeric keypad is used. Its ten keys are assigned to different consonants and flicking into one of four directions changes the vowel (Fig. 5). The vowel can also be changed by varying the number of keyboard taps instead of flicking. The latter method is called "numeric keypad" and commonly used on feature phones. A Japanese syllabary keyboard (50-syllable table) is similar to a QWERTY keyboard but *kana* characters are allocated to each key in the Japanese syllabary order (Fig. 6).

Popular text entry methods differed between blind and low vision users (Fig. 7). The most popular input method among blind users was voice input with a 62.8% usage rate. This was followed by software QWERTY keyboard

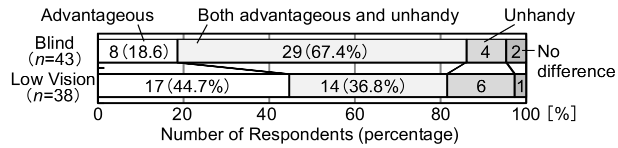

Fig. 8 Usability of smartphones vs. feature phones.

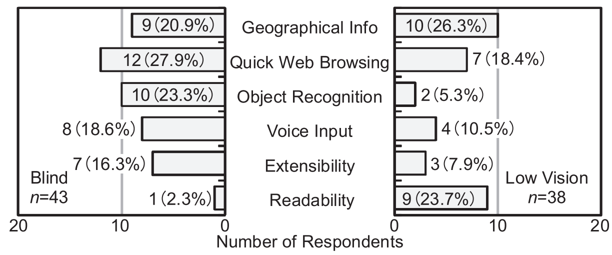

Fig. 9 Advantages of smartphones over feature phones.

(46.5%), software numeric keyboard (41.9%), and external keyboard (37.2%).

The most popular entry method among low vision users was flick input with a 52.6% usage rate. This was followed by software numeric keypad (31.6%) and voice input/software QWERTY keyboard (28.9% both).

Out of 27 blind speech output users, 24 used another input method as well. This suggests that users choose input methods according to the situation. For example, short sentences for searches or messages are input by voice and long sentences for texting by some type of keyboard.

6.4 Usability of Smartphones vs. Feature Phones

The questionnaire asked whether smartphones were advantageous or unhandy compared to feature phones (Fig. 8).

Most blind (86.0%) and low vision (81.6%) users answered that smartphones were more advantageous than feature phones ($\chi^2 = 0.30$, no significant difference). However, half of the low vision (52.6%) and three quarters of the blind (76.7%) users answered that smartphones were unhandy as well ($\chi^2 = 5.19$, $p < 0.05$, a significant difference). This suggests that blind users have more problems using smartphones than low vision users.

Through open-ended questions, respondents were then asked to describe smartphone advantages and drawbacks. These answers were categorized by the first author and an assistant and are presented in the following two subsections.

6.4.1 Smartphone Advantages

Figrue 9 shows smartphone advantages cited in 10 or more blind and low vision user responses. Advantages to blind users were quick Web browsing (12 responses), recognition of objects, light and color (10), accessibility to geographical information including maps (9), voice input (8), and extensibility (7). Those to low vision users were accessibility to geographical information (10), readability (9), and quick Web browsing (7).

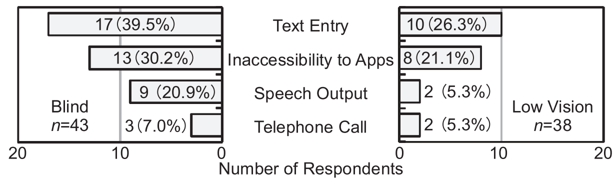

Fig. 10 Smartphone drawbacks.

Example user comments are as follows. "With the map and compass, I can find points of interest in unfamiliar places." "The GPS app tells me the shops and street names on my everyday route." "With a smartphone, I can access the Internet without boosting a PC." "TapTapSee [14] tells me what the objects I can't see are." "VOICEYE [15] tells me what the paper money denominations are." "LightDetector [16] tells me if the room light is on." "Siri [17] is useful for searching." "Useful functions can be equipped just by installing apps." "The screen is wide enough." "I can magnify characters and images as much as I need to."

These advantages are made possible by smartphone features such as wide screen, small sensors (GPS, gyroscope, accelerometer, ambient light sensor), high performance CPUs, and continuous connection.

6.4.2 Smartphone Drawbacks

Figure 10 shows examples of the drawbacks of smartphones compared to those of feature phones. Text entry tops the graphs with responses from 17 blind (39.5%) and 10 low vision (26.3%) users. Smartphones do not have a hardware keyboard that enables the user to input correctly with tactile cues. Without them, selected keys are likely to be incorrect and extra time will be required to confirm their correctness with visual or auditory feedback.

The second largest problem was inaccessibility to and difficulty in using some apps and functions, which was reported by 13 blind (30.2%) and 8 low vision (21.1%) users. Inaccessible apps do not allocate alternative text to controls so that blind users cannot know their purposes.

The third largest problem was poor quality and incorrect speech output of the screen reader, which was mentioned by 9 blind (20.9%) and 2 low vision (5.3%) users.

A different question on smartphone use difficulties due to visual disability brought mostly the same answers as those in Fig. 10, except some low vision users complained about difficulties in reading. This is because some apps and functions do not allow their characters to be magnified or their colors to be inverted.

6.5 Wishes

The survey asked as an open-ended question on user wishes for smartphones to compensate for visual disability and we categorized the answers as shown in Fig. 11.

Half of the wishes were for means to remove the above-mentioned drawbacks: better speech output, better readability, better touch interface usability, and easier text entry.

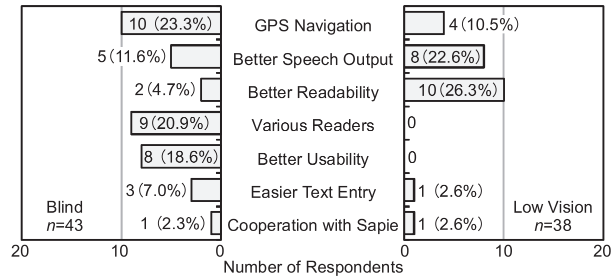

Fig. 11 Wish list for smartphones.

New functions wished for were GPS navigation apps (14 people), various readers (9), and cooperation with Sapie (2), an online digital library operated by the Japan Braille Library [18]. Various readers would enable users to read things such as clinical thermometers, scales, blood pressure gauges, karaoke lyrics, and how and by when foodstuffs should be cooked.

6.6 Discussion

6.6.1 Usage Differences between Blind and Low Vision Persons

The reasons people with low vision used smartphones and tablets at higher rates than blind people can be explained by the answers to the attitude questions on smartphone and/or tablet usage (For detailed information, refer to the full survey report [19]).

The second most cited reason people with low vision used smartphones and/or tablets was "readability" (11 responses, 25.0%). (The topmost answer was "useful apps and functions" both for blind and low vision users.)

The top two reasons blind people did not use a smartphone or tablet were "(anticipated) use difficulties" (38 responses, 33.9%), especially "difficulty in using touch screens" (36 responses, 32.1%). (The third most cited reason for blind people and the topmost one cited for people with low vision was "satisfied with conventional devices.")

Uncertainty about the usability of touch screen devices cannot be wiped away as there is "no opportunity to try these devices and learn how to use them" (11 blind people, 9.8%). Thus, workshops for visually impaired people on the use of these devices are necessary [20].

6.6.2 Popular Smartphone OS

In Japan's smartphone OS market in 2013, Android's share, 24.6%, was almost double that of iOS, 13.2% [1]. In contrast to this, the most popular models among visually impaired people, especially blind people, were iPhones (Fig. 3). One of the main reasons for this is that an iOS device has a built-in "VoiceOver" screen reader [21]. Although

Android has a built-in "TalkBack" screen reader [22] users have to install a text-to-speech engine to have it "talk." This installation process is a burden to the users and is thought to be hindering visually impaired people from using Android devices.

6.6.3 Difficulty in Text Entry

For both blind and low vision users, the topmost problem was difficulty in text entry. According to the respondents' answers, the main reason for this is the absence of a hardware keyboard. With a software keyboard, input is slow and many mistakes are made. This caused one of the blind respondents to say, "I cannot use a smartphone for important purposes like shopping."

To address this problem various input methods have been devised and researched, including BrailleTouch, which enables Braille keyboard-like typing on a touch screen [23], Ippitsu, which enables Braille-based one-stroke swiping [24], and Touchplates, which provides tactile guides placed on the screen [25]. However, all these methods have their own drawbacks as well as benefits. Among these, BrailleTouch is a good choice since it is easy to learn to use and requires no extra hardware.

7. Tablet Usages

This chapter describes the responses from 43 (17 blind and 26 low vision) users to the tablet usage questions.

7.1 Models

Thirty-nine out of 43 respondents used one tablet and other four used two or more. In total, 49 models were gathered. Figure 12 shows the number of users for each model.

The most popular model was iPad with 23 of 43 users (53.5%). iPad mini and iPod were also used. Ten people used 11 Android devices.

No significant usage rate differences between blind and low vision people were found for any of the models (χ^2 = 0.32, 0.42, 0.04, and 0.001 for iPad, iPad mini, iPod, and Android devices respectively).

7.2 Accessibility Features

The usage of accessibility features on tablets resembled that of those on smartphones (see Fig. 4 and Fig. 13). All blind users used speech output and only a few of them used visual features. Low vision users used both visual features and speech output at high rates.

7.3 Text Entry

Usage of text entry methods on tablets differed from that on smartphones (see Fig. 7 and Fig. 14). Usage rates of flick and numeric keypad input, which were developed for small screen input, dropped for both blind and low vision users

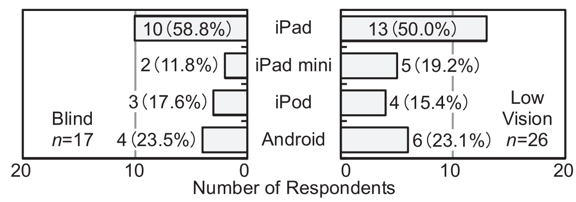

Fig. 12 Popular tablet models.

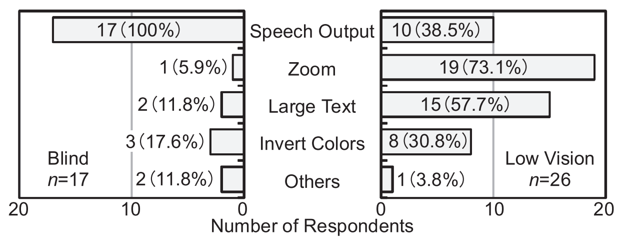

Fig. 13 Usage of accessibility features on tablets.

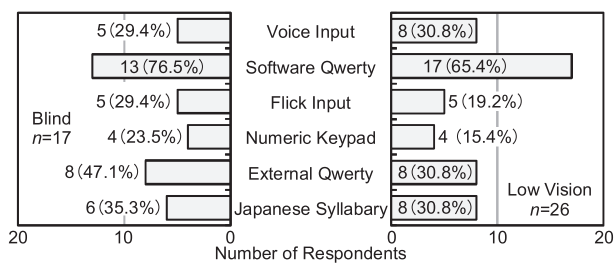

Fig. 14 Usage of text entry methods on tablets.

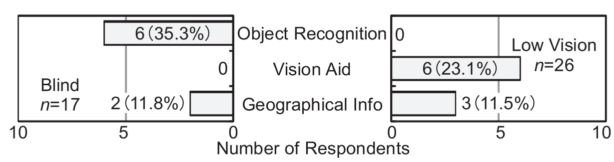

Fig. 15 Tasks achieved with tablets.

(except the flick input rate for blind users). The voice input rate for blind users dropped by half.

As a result, the most popular text entry method on tablets for both blind and low vision users was software QWERTY keyboard with 76.5% (blind) and 65.4% (low vision) usage rates, followed by external QWERTY keyboard (47.1%) and Japanese syllabary keyboard (35.3%) for blind users and voice input, external QWERTY keyboard, and Japanese syllabary keyboard (30.8% each) for low vision users. No one used handwriting.

7.4 Tasks Achieved with Tablets

The questions referred to in the following subsections were open-ended. The answers to them were categorized by the first author and an assistant and are presented in Fig. 15-18.

Figure 15 shows the tasks that were achieved for the first time with tablets (five or more responses).

"Object recognition" was cited in six blind users'

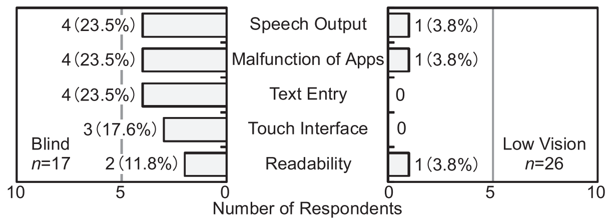

Fig. 16 What was not achieved with tablets.

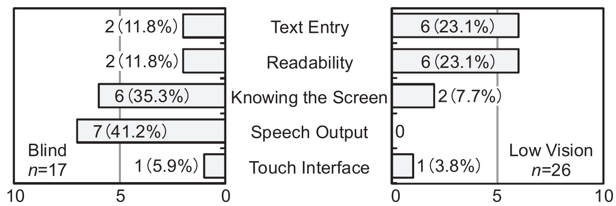

Fig. 17 Difficulty in using tablets due to visual disability.

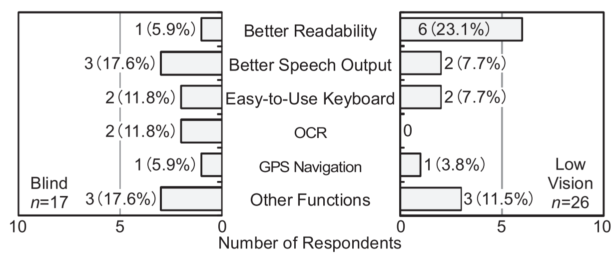

Fig. 18 Wish list for tablets.

responses. A user comment is as follows: "TapTapSee enables me to select what I am going to wear."

"Vision aid" was cited in six low vision users' responses. A user comment: "I can take a snapshot of the menu at a restaurant and magnify it. Thus I can select dishes by myself."

"Accessibility to geographical information" was cited in two blind and three low vision users's responses. User comments: "BlindSquare [26] gives me information about facilities newly built near my house." "By using maps on the big screen, I can reach my destination without getting lost."

The object recognition and accessibility to geographical information functions provide the same advantages as smartphones. The vision aid function is unique to tablets, due to their having bigger screens than smartphones.

7.5 What Was Not Achieved with Tablets

Figure 16 shows the answers to a question (three or more responses) about what was expected of tablets but not achieved. From the figure it is obvious that blind users claimed more dissatisfaction than low vision users.

"Speech output malfunction" was cited in four blind and one low vision users' responses. Their comments are as follows: "Screen reader cannot read some picture characters and game apps." "While the screen reader is on, some buttons become unusable."

"Malfunction of apps" was also cited in four blind and one low vision users' responses. They claimed that apps such as the OCR function, the barcode reader, the GPS navigation function, and the video player did not work in the way they expected.

Other problems were difficulty in text entry (4 mentions), difficulty in touch operation and file management (3), and difficulty in reading characters on the screen (3).

7.6 Difficulty in Using Tablets due to Visual Disability

Difficulty in using tablets due to visual disability differed between blind and low vision users (Fig. 17).

The most severe difficulties for low vision users were text entry and readability. Claims were voiced that eyesight was necessary when inputting text to see the software keyboard, that some screens could not be inverted, and that bright light made reading difficult or impossible.

For blind users the most severe difficulties were speech output malfunction and difficulties in finding out what was on the screen. We received complaints that VoiceOver was reading incorrectly, that CAPTCHA test was not usable, that the screen was so big that finding target buttons took a lot of time, and that the screens had to be memorized app by app and screen by screen.

7.7 Wishes

Figure 18 shows the wish list for tablets to compensate for visual disability. Half of the wishes were for means to remove the above-mentioned difficulties: better readability (7 responses), better speech output (5), and an easy-to-use keyboard (4). New functions wished for were OCR (2), GPS navigation (2), and other functions such as a means to check whether accessibility features were on or off, a barcode reader, a DAISY search and play app compatible with Sapie.

7.8 Discussion

The main differences between smartphones and tablets are the phone function equipment and the screen size. In this section we discuss how the screen size affects the usage by visually impaired people.

7.8.1 Text Entry

The most popular text entry methods were different between smartphones and tablets. For smartphones small screen input methods such as flick and numeric keypad input were popular among low vision users while voice input was the most popular among blind users. For tablets, on the other hand, a software QWERTY keyboard was the most popular among both blind and low vision users.

This difference is thought to stem from different size key pitches. The key pitches of a software QWERTY keyboard on a smartphone are 8 mm horizontally and 6 mm vertically in the landscape orientation and 5mm horizontally and 8.5 mm vertically in the portrait orientation (measured on a 4-inch iPod touch). These are one-third to half the size of standard keyboard pitches. The key pitches of a software QWERTY keyboard on a tablet are 16 mm horizontally and 17.5 mm vertically in the landscape orientation, nearly the same size as those of standard keyboards, and 13.5 mm horizontally and 12.5 mm vertically in the portrait orientation (measured on a 9.7-inch 4th generation iPad). Key pitches of these sizes lead to making text entry easier. Actually, the number of blind respondents who complained about text entry on tablets decreased to only two (Fig. 17).

Still, text entry without tactile cues is so inaccurate and slow that more than one third of tablet users used external keyboard and voice input (Fig. 14). Respondents also requested "a built-in hardware keyboard, a numeric keypad, or buttons," and "a position-free gesture input method." Easy-to-use eyes-free text entry is surely one of the major issues in the usage of touch interface devices by visually impaired people.

7.8.2 Knowing and Searching in the Screen

When the user touches the screen, the screen reader voices what is under the finger. If it is an operable item such as an icon, button, pull-down list, or text box, double-tapping or tapping another place with another finger will activate it. This way of operation, which we refer to as "direct manipulation," requires that the user know which items are where on the screen.

Tablet screens measuring 8 to 10 inches are too wide to remember and to search for items on them. They are "too large for a totally blind person" (A description by a blind respondent). Although with "sequential accessing," another way of operation, flicking takes the user to every item in order, finding the target item takes a lot of time. This operation resembles browsing the Web on a computer with the "Tab" key. Overall, smartphone screens measuring 4 to 5 inches seem to be suitable for blind users.

7.8.3 Vision Aid

Tablets, especially iPad devices, are expected to work as a "cool" vision aid for people with low vision. Many workshops have been held in Japan to disseminate information on how to use iPad devices effectively [27]–[29]. This goes a long way toward explaining why the usage rate of tablets by people with low vision was two times higher than that by blind people.

8. Conclusion

The results of an ICT user survey statistically revealed the smartphone and tablet advantages and drawbacks for visually impaired people.

The smartphone advantages were access to geographical information, quick Web browsing, voice input, and extensibility for both blind and low vision users, object recognition for blind users, and readability for low vision users. The tablet advantages resemble those of smartphones except that tablets work as a vision aid for people with low vision. These facts should be disseminated more through workshops and speeches.

The smartphone and tablet drawbacks, on the other hand, were text entry and touch operation difficulties and inaccessible apps for both blind and low vision users, problems in speech output for blind users, and problems in readability for low vision users. Interface researchers should devise user-friendly text entry methods and OS and app makers should assume responsibility for improving speech output and readability.

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Tetsuya Watanabe received the M.S. degree in Biomedical Engineering in 1993 and the Doctor's degree in Information System Engineering in 2001 both from Hokkaido University. He stayed at National Research Institute of Fisheries Engineering 1993–1994, National Institute of Vocational Rehabilitation 1994–2001, and National Institute of Special Needs Education 2001–2009. He is now an Associate Professor at Niigata University, teaching and doing research in assistive technology.

Toshimitsu Yamaguchi received the M.S. degree from Kanagawa Institute of Technology in 2004 and became a Scientific Research Assistant at National Institute of Special Needs Education. Since 2009 he has been a Project Research Assistant at Niigata University and engaged in development of assistive technology for visually impaired people and IT support for people with disabilities.

Kazunori Minatani received the Doctor's degree in Political Studies in 2009 from Gakushuin University. He was a Scientific Research Assistant at National Institute of Special Needs Education in 2008 and a Limited-Term Researcher at National Rehabilitation Center for the Disabled in 2009. Since October 2009, he has been an Associate Professor at National Entrance Examination Center.