Facilitating learning by the visually impaired: development and usability evaluation of a specially designed ubiquitous library

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Abstract

Purpose – This study aims to develop a ubiquitous library for the visually impaired (ULVI) application (app) and to explore its usability by collecting feedback from visually impaired participants to analyse the problems they might encounter. Their suggestions for improving the app further are also reported.

Design/methodology/approach – A total of ten participants were recruited in the study. Ten tasks were assigned for the participants to complete using the ULVI app. The system usability scale was adopted to collect feedback on the app, and interviews were conducted to understand the participants' usage behaviours and perceptions of the app.

Findings – The findings indicated that the participants provided positive evaluation of the usability of the app and addressed the functions that might need improvement. Above all, this app was regarded as having great potential. Suggestions and improvements are proposed based on the participants' feedback.

Originality/value – In terms of the studies relevant to libraries and the visually impaired, few have evaluated the usability of the ULVI app from the perspectives of the visually impaired users. The ULVI app provides resources for the visually impaired and serves as the foundation for developing a more effective ULVI app.

Keywords Library services, User interfaces, Usability, Accessibility, Mobile services, Visually handicapped, Visually impaired, Ubiquitous library, System usability scale (SUS), Ubiquitous library for the visually impaired

Paper type Research paper

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1. Introduction

Mobile and wireless communication technologies have tremendous effects on libraries, which integrate existing information and new technologies to provide a reader-centred environment and more convenient services (Joo and Yeon Lee, 2011; Pant, 2015; Tu and Hwang, 2018). However, for the socially disadvantaged (such as the disabled), more specific needs are often neglected, hindering their rights to access digital information services (Kwak and Bae, 2009; Majinge and Mutula, 2018). The trend in international requirements specifically indicates that libraries are committed to providing equal access to collections, services and facilities for all library users, including patrons with disabilities. The advancements of information technologies offer opportunities to solve these problems (Nahar *et al.*, 2019). Take the visually impaired for instance; mobile devices with touch screen interfaces (e.g. smartphones, smartwatches and tablets) have already become essential auxiliary equipment for them to carry out their daily activities (Khan and Khusro, 2019; Nahar *et al.*, 2019).

Nonetheless, some studies specify that providing the visually impaired with intuitive and accessible library websites still poses great challenges, including the accessibility of digital resources (such as academic or general journals) (Bhardwaj and Kumar, 2017; Byerley and Chambers, 2002; Menzi-Cetin *et al.*, 2017). For example, the LG Digital Talking Book Library developed a ubiquitous service for the visually impaired and provided voice book services for them to visit libraries anytime and anywhere via the internet on cellphones. Kwak and Bae (2009) indicated that for the visually impaired, the status of publication updates, asymmetrical subject areas and lack of educational content were the more serious problems, while handy-to-carry information terminals, such as cellphones, were favoured. Yoon *et al.* (2016) and Xie *et al.* (2020) further pointed out that usability is important for digital libraries to support blind and visually impaired users in actively searching for information instead of passively waiting for them to seek help.

In terms of receiving information and learning knowledge, the visually impaired have to rely on visual learning tools, which make it more difficult for them to learn than other able-bodied learners. Because of the physical defects caused by insufficient vision, it makes them step back from receiving information and learning knowledge, and even increases the obstacles for them to access the information (Nahar *et al.*, 2019). In recent years, although there have been numerous studies that have conducted usability tests on library websites, the research relevant to library usability tests from the perspectives of the visually impaired is still scarce (Kwak and Bae, 2009). Researchers have indicated that to improve the accessibility to information for the visually impaired, a ubiquitous library for the visually impaired (ULVI) should be designed, and its usability should be evaluated based on the feedback and points of view of its visually impaired users. This can also enhance the usage rate of the ULVI and the quality and quantity of the services it offers (Bertot *et al.*, 2006; Khan and Khusro, 2019; Kumar and Mohite, 2016; Moon *et al.*, 2020; Peterson, 2017).

Therefore, this study evaluated the usability of the ULVI application (app) from the perspectives of the visually impaired, took advantage of the system usability scale (SUS) to collect their feedback and conducted interviews to understand their usage behaviours and opinions, which could serve as a more effective foundation for developing the ULVI. Accordingly, the following research questions were investigated:

RQ1. Is the ULVI app accepted by the visually impaired participants from the perspective of usability?

RQ2. What problems do the participants encounter when using the ULVI app to complete tasks? How can the app be improved?

2. Literature review

2.1 Libraries and the visually impaired

Libraries possess abundant collection and electronic resources, and support learning and education in the long term (Craven, 2003; Kwak and Bae, 2009). Especially for the disabled who have fewer opportunities to acquire knowledge, libraries play an important role of providing services to allow them to access the information fairly, freely and conveniently so as to eliminate the information gap (Hill, 2013; Yoon *et al.*, 2016). Visually impaired students usually come across difficulties when using the university websites and accessing library resources (e.g. PDF copies of books) without additional supports (Hill, 2013; Xie *et al.*, 2020). Thus, researchers have attempted to improve the usability of websites and mobile apps as well as the accessibility of learning resources based on their feedback (Menzi-Cetin *et al.*, 2017; Moon *et al.*, 2020).

However, the development of information technologies promotes learning resources to be more diversified. Libraries have made efforts to achieve the principle of "Books are for all" (Calvert *et al.*, 2019), but it is still challenging to avoid the socially disadvantaged (such as the disabled) to be marginalized or excluded from accessing digital information services (Kwak and Bae, 2009). Calvert *et al.* (2019) investigated the needs of the visually impaired regarding library services by administering a survey about the library of the Blind Foundation of New Zealand to their patrons (including blind and visually impaired readers). The findings showed that the older the patrons, the less computer use ability they had. The study also reported that young readers generally knew how to download books, and the DAISY format was their most used reading format. In addition, only a small portion of the blind and visually impaired readers used the services provided by the library. Accordingly, Calvert *et al.* (2019) suggested that libraries should gain more insights into the reasons why the visually impaired are less likely to download books so as to make improvements. Above all, libraries should provide better accessibility to resources and user-friendly environments for the visually impaired. Only by understanding more about the information usage needs and behaviours of the visually impaired can they be offered better library and information services (Hill, 2013; Kwak and Bae, 2009; Menzi-Cetin *et al.*, 2017).

2.2 System usability scale

The SUS was proposed by Brooke (1996). It is one of the usability scales that is extensively applied, and it is also an effective and reliable instrument for measuring the usability of various systems, websites, apps, products and services (Bangor *et al.*, 2009; Lewis and Sauro, 2009, 2018), such as evaluating the system's effectiveness for users to complete tasks, the efficiency of task execution and subjective reactions (i.e. satisfaction) (Brooke, 1996). The benefit of the SUS is that it can give accurate feedback, even when the sample size is small (Brooke, 2013; Tullis and Stetson, 2004). Some studies have illustrated that five participants are enough to conduct a usability test (Lewis, 2006; Virzi, 1992). For instance, Mattson (2015) invited five art therapists to carry out a usability test of an art therapy app to understand the range that needed improving and modifying through the SUS to facilitate the use of the app.

Duarte *et al.* (2017) indicated that, based on the SUS as the criterion of the usability test, the development of systems relevant to the visually impaired has been effective, including an electronic travel aid system (Skulimowski *et al.*, 2019), an app offering an audio description for mobile devices (Walczak, 2018) and a text messaging app (Duarte *et al.*, 2017). One study also proposed an accessibility-inclusive blind-friendly user interface framework to make it easier for blind people and to give them better control when operating smartphone apps (Khan and Khusro, 2019). Furthermore, researchers have revealed that

when users operated the system smoothly, they would feel more confident and offer more satisfied evaluation than others. They would also score the usability of the system more highly (Skulimowski *et al.*, 2019).

3. Application: ubiquitous library for the visually impaired

To provide the visually impaired with a friendly interface for accessing library resources through smartphones or tablets, the ULVI app was developed in this study by collaborating with the National Taiwan Library. It integrates VoiceOver, TalkBack and text to speech (TTS), and provides digital rights management (DRM) from HyRead for the visually impaired to access the content of e-books. A list-type menu interface is provided in this app to avoid presenting too much information at the same time by putting the relevant functions in the same categories. As shown in Figure 1, the app provides several categories of functions on the start-up interface, such as the latest news, new arrivals, my study room, book browsing, online public access catalogue (OPAC) retrieval, resource classroom, online news and preference settings.

Moreover, users are able to borrow books through the ULVI app. Before borrowing books (including e-braille books, braille books, audio books in MP3 format, audio books in DAISY format, audio books on tape, large-print books and e-books), they can search for books by using OPAC retrieval or through book browsing. For example, they can search for *Be a Big Fish (The Secrets of Big Business-13 Evolutions of Management)* and borrow braille books (including free postal service). After borrowing, they can go to "my study room" and see the postal processing progress of the book (Figure 2).

In addition, users can also use the ULVI app to listen to or read e-books (PDF or ePud format), e-braille books and audio books. For instance, if they borrow *The Secrets of 25 Roses* (PDF format), they can audio read the content of the e-book through VoiceOver, TalkBack or TTS (Figure 3). Moreover, the ULVI app supports gesture operations (including iOS and Android), allowing the visually impaired to listen to books more comfortably.

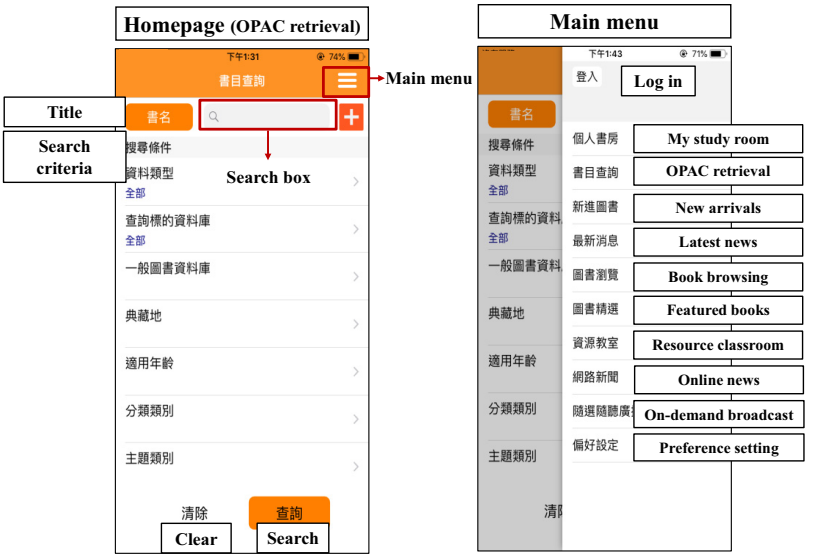

Figure 1.
The ULVI app (list-type menu version)

Figure 2.
Borrow braille books

Figure 3.
Borrow and read an e-book

"Listen to the broadcast" provides users with channel content, including the latest news, channels for children/youth or adults. In "preference settings", users are able to set up personal use settings, which include font colour, items per page, default homepage and so on. For example, users can set up the homepage of the app (Figure 4).

4. Research method

To understand the perspectives of the visually impaired on the use of ULVI and to provide recommendations for future studies on the design of library services for the visually impaired, the authors solicited volunteers from the visual impairment information centre of the library to participate in the task-oriented tests, which were conducted in the locations

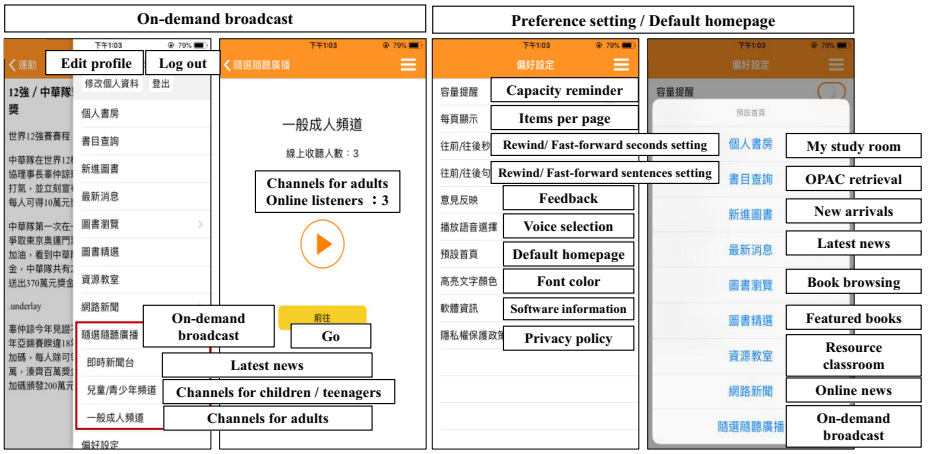

Figure 4.
On-demand broadcast and preference setting

that the participants were familiar with. The participants were all asked to perform the same tasks; following that, they were scheduled to fill out questionnaires and take part in interviews to provide feedback on the app.

4.1 Participants' backgrounds

The ten participants, who were volunteers, were visually impaired, including low vision, perceived very low light and/or totally blind, as certified by the medical institute of the government. All the participants were informed that the whole experiment would be videotaped for the evaluation. The participants were between 22 and 40 years old (Table 1); each had previous experience of using the internet, computers and cellphones as well as the conventional full-screen flat menu, which presents all of the functions on the app interface, enabling the users to have a whole picture of the app functionalities, as shown in Figure 5.

4.2 Tasks

The mobile devices used in the present study were based on the habits of the participants. Every participant was required to take part in ten tasks (Table 2). The experimental process was audio-recorded and videotaped. Participants' feedback and difficulties when operating the ULVI app were also documented.

Table 1.
Participants' code and demographic information

Code	Gender	Age	Information skills	Operating system	Description of vision impairment
P1	Male	24	Advanced	iOS	Blind
P2	Female	22	Basic	iOS	Blind
P3	Male	23	Advanced	Android	Blind
P4	Male	23	Advanced	iOS	Blind
P5	Male	35	Advanced	Android	Low vision
P6	Female	33	Basic	iOS	Blind
P7	Female	40	Basic	iOS	Perceives very bright light
P8	Female	25	Advanced	Android	Perceives very bright light
P9	Female	25	Basic	Android	Blind
P10	Male	26	Advanced	Android	Low vision

Figure 5.
The ULVI app (full-screen flat menu revision)

Task no.	Descriptions
Task 1	Open the ULVI app; please log in first
Task 2	Go to new arrivals, click the third book *The Ninth Flavor* (第九味) and then read it
Task 3	Go to United Daily News, go to international, click the first news item and audio read it
Task 4	Set my study room as the homepage of this app
Task 5	Use my external reading resources; open the MP3 file "Sam Kim- Scent" to listen from the e-books in Google Drive
Task 6	Go to reading history; open an e-book called *Friends of My Youth* (年少友人) in the epub format and check the current reading mode. Please choose VoiceOver/Talk Back to read the e-book
Task 7	Copy a passage and paste it into the browser
Task 8	Switch the reading mode of the e-book to the listening mode and read the e-book
Task 9	Press the buttons on the screen, such as: "Pause/Play", "Rewind/Fast forward" and "Previous/Next"; add an e-book to the bookmark
Task 10	Go to on-demand broadcast; turn on the adult channel to listen

Table 2.
Tasks

4.3 Measuring instruments and interviews

The current study adopted the SUS to evaluate the ULVI app. The SUS was proposed by Brooke (1996); it consists of both positive and negative cross-questioning items. The present study invited two experts in the field of visual impairment to modify the content of the questionnaire (Table 3). The questionnaire adopted a five-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*):

> Items number one, three, five, seven and nine were positive items. Subtracting 1 from the score of each item equals the final score of each item.

Table 3.
System usability questionnaire

No.	Item
Q1	I am very willing to use this app frequently because the ULVI app has friendly interfaces
Q2	I think the ULVI app is too complicated and has extra design
Q3	I think the ULVI app is easy to use
Q4	I think I need someone's help or guidance to use the ULVI app
Q5	I think all the functions in the ULVI app are well integrated, which can help me find the resources I want
Q6	I think there are too many inconsistencies in the ULVI app, which makes me confused while using it
Q7	I think most people can learn how to operate the ULVI app quickly
Q8	I think it is difficult to use the ULVI app; its interfaces are not easy to use
Q9	Regarding the interfaces of the ULVI app, I am confident in using them correctly and in finding the books I want
Q10	I think I need to spend a little more time using the ULVI app

Items number two, four, six, eight and ten were negative items. Subtracting the score of each item from five equals the final score of each item.

Lastly, add up all the scores. Then, multiplying the number by 2.5 equals the total score of the SUS (ranging from 0 to 100). The higher the total score, the more usable the ULVI app is.

Apart from collecting the SUS questionnaires, interviews were also conducted after the participants filled out the questionnaires in an effort to understand their experiences and perceptions after using this app. The interviews emphasized two parts: the participants' perceptions after using the ULVI app and the problems they encountered while using the app. In addition to interviews, observations were also carried out to explore how the participants used the ULVI app to complete the required tasks.

5. Research results

5.1 Findings of the usability test

Based on the formula calculation of the SUS proposed by Brooke (1996), the results are shown in Table 4. The scores of the SUS were categorized into six intervals: best imaginable (86–100), excellent (73–85), good (53–72), ok (39–52), poor (26–38) and worst imaginable (0–25) (Bangor *et al.*, 2009). Researchers have pointed out that the acceptable threshold of the SUS should be higher than 68, and that 80 could be adopted as the criterion for good user experience

Table 4.
Descriptive statistics of the SUS scores of the ULVI app

No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	*M*	*SD*
Q1	4	4	3	5	5	4	5	5	5	4	3.4	0.70
Q2	2	1	3	1	3	1	2	1	1	2	3.3	0.82
Q3	4	4	3	5	5	5	4	4	5	5	3.4	0.70
Q4	1	1	3	1	1	3	3	1	1	2	3.3	0.95
Q5	4	4	4	5	5	4	4	5	3	3	3.1	0.74
Q6	1	1	3	2	1	2	1	2	2	3	3.2	0.79
Q7	3	3	3	5	4	4	4	4	3	4	2.7	0.67
Q8	2	1	2	1	1	1	2	1	1	1	3.7	0.48
Q9	4	4	3	5	5	4	4	5	5	4	3.3	0.67
Q10	3	1	3	1	1	2	3	1	1	1	3.3	0.95
Overall score	75	85	55	97.5	92.5	80	75	92.5	87.5	77.5	81.75	–

(Lewis and Sauro, 2018). As can be seen from Table 4, the highest and lowest score of usability of the ULVI app evaluated by the 10 visually impaired participants was 97.5 and 55, respectively; the average score was 81.75. The mean score for each test item is given in Table 4.

The lowest scored items included:

Q7. I think most people can learn how to operate the ULVI app quickly ($M = 2.7$, $SD = 0.67$).

The highest were:

Q8. I think it is difficult to use the ULVI app; its interfaces are not easy to use ($M = 3.7$, $SD = 0.48$) (reverse-scored).

Q1. I am very willing to use this app frequently because the ULVI app has friendly interfaces ($M = 3.4$, $SD = 0.70$).

Q3. I think the ULVI app is easy to use ($M = 3.4$, $SD = 0.70$).

The majority of the evaluation indicated good consistency. In the item with a lower score, the participants thought that most people would require some time to practice to get used to the app. As for the items with a higher score, the majority thought that the app was easy to use and they were willing to use it.

5.2 Findings of task execution

As shown in Table 5, two of the participants did not complete task 1, and there were three who did not complete task 4. Table 6 demonstrates that the task requiring more completion time was task 5, followed by task 1 and task 6. The average completion time of a task by those participants with basic information skills was more than that for all the participants (including task 1 and tasks 3–10). Furthermore, the participants with low vision performed better on all of the tasks (high task completeness and less task completion time), while those participants who perceive very bright light performed worse on all tasks (low task completeness and more task completion time). Tables 5 and 6 indicate some of the usage situations experienced by the participants; the descriptions are provided below:

- Participants with low vision: They have better task performance; P5 had only one task that exceeded the average completion time of the task, and the performance of P10 was above the standard. They both possessed advanced information skills.

Task no.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Task 1	C	C	C*	C	C	U	C*	U	C	C
Task 2	C*	C	C	C	C	C*	C	C*	C	C
Task 3	C	C	C	C*	C	C*	C*	C	C*	C
Task 4	C	C	C	C	C	C*	U	U	U	C
Task 5	C	C	C	C	C	C*	C*	C	C*	C
Task 6	C	C	C*	C	C	C*	C*	C*	C	C
Task 7	C	C	C	C	C*	C*	C*	C*	C*	C
Task 8	C	C	C*	C	C	C*	C*	C	C*	C
Task 9	C	C*	C*	C	C	C*	C*	C*	C	C
Task 10	C	C	C	C*	C	C*	C*	C*	C	C

Notes: C, task completed; C*, task completed, but the completion time is more than the average completion time of the task; U, task uncompleted

Table 5.
Participants' task execution

- Participants who perceive very bright light: They have poorer task performance than participants in other categories. P7 with basic information skills did not complete task 4, and she spent more completion time on most of the tasks. The participant revealed that because she could perceive strong light and could distinguish a few colours, she was more accustomed to identifying functions by colours as well as the full-screen flat menu interfaces of the ULVI app. Another participant with advanced information skills, P8, did not complete tasks 1 and 4; she spent more time completing tasks 2, 7, 9 and 10 compared to the average completion time of each task. She commented that she was not familiar with the list-type menus interfaces, so she repeatedly performed the same operations, such as swiping left and right. On the other hand, when using the list-type menu interface, she felt curious about the functions in each category; she constantly checked each function menu and asked about relevant operation issues. During the interview, the interviewer asked her to use the functions again, and she performed them more smoothly and was satisfied with the functions of the tasks.
- Totally blind participants: P6 with basic information skills did not complete task 1, and spent much more time accomplishing other tasks when compared to the average completion time for each task. The participant expressed that she was not familiar with the app. After she came across difficulties in the first task, her confidence in using the app was influenced. Another participant with basic information skills, P9, did not complete task 4, and spent more time on tasks 3, 5, 7 and 8 than the average completion time of each task. She mentioned that she had less experience using the apps. Moreover, researchers found that a participant with advanced information skills, P3, spent more than the average completion time on tasks 1, 6, 8 and 9. He reported that it was smoother to use the operation interfaces and functions of the full-screen flat menu of the ULVI app, and the interface of the list-type menu in the ULVI app should be more intuitive.

5.3 Interview findings about ubiquitous library for the visually impaired app interface and functions

The interviews were based on the task completion situations of the visually impaired (including the difficulties and the task completion time). Both the list-type menu and full-screen flat menu operation interfaces of the ULVI app were favoured by the participants. There were six participants who enjoyed the list-type menu interface owing to its efficiency

Table 6.
The average completion time of each task (seconds)

Category	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Task 9	Task 10
Average completion time	101.38	30.40	56.30	31.57	154.60	86.90	58.60	67.40	79.30	42.90
Information skills										
Basic	138.33	28.25	88.50	46.00	226.00	109.00	75.25	123.75	112.00	50.00
Advanced	79.20	31.83	34.83	25.80	107.00	72.17	47.50	29.83	57.50	38.17
Description of vision impaired										
Low vision	49.50	22.00	17.50	23.50	117.50	58.50	41.00	5.50	26.00	19.50
Perceives very bright light	283.00	33.00	90.50	U	237.50	119.50	90.50	129.00	149.50	54.50
Totally blind	85.80	32.33	57.83	34.80	139.33	85.50	53.83	67.50	73.67	46.83

Notes: U, task uncompleted. Average completion time, only the times of completed tasks were counted

(e.g. fewer steps in the operational procedure and a powerful information-search function), flexibility (e.g. allowing users to decide their own homepage) and style (i.e. the interface design). Besides, the ULVI app provides the default homepage, allowing users to decide on their own homepage (task 4). Although the participants (P7, P8 and P9) had not used a similar function before, they could operate it on their own after the researchers explained this function to them.

On the other hand, four participants were fond of the full-screen flat menu interface owing to its clear structure (e.g. showing the list of functions) and ease of use (e.g. it is easy to find the required functions with coloured blocks).

In terms of the ULVI app login function, some participants suggested that the log-in function should be more intuitive (Figure 6), such as automatically displaying the log-in function when starting the app, and providing an audio reading of the automatic log-in function.

In terms of the "external reading resources" of the ULVI app, some participants could play the file from Google Drive through the ULVI app, and they suggested modifying the name of this function (e.g. "open resources" or "read my books") so that they could better understand its meaning (Figure 7). Also, they recommended moving this function to the main menu. In addition, they suggested that the push notifications can be collected in a personal folder, such that the visually impaired can easily find the relevant push messages. They also suggested that several function names in the app can be modified to avoid confusing the users. As a result, the term "my cloud reading resources" was used to replace the original function name, "my external reading resources".

As for other functions, when expanding/collapsing the main menu, audio reading is required. Moreover, the name of "on-demand broadcast" should be reconsidered (e.g. "audio book reading") so that users can easily perceive its function.

In terms of the e-book reading function, the ULVI app integrates DRM and audio reading to enable participants to read e-books in different modes (Figure 8). When asked about the perceptions of the "opening and reading an e-book" function, four participants stated that they enjoyed the voice of TTS (the listening mode) to audio read e-books because they thought it was very convenient to use. Also, two participants indicated that they preferred an audio player because its interface and functions were similar to those of the listening

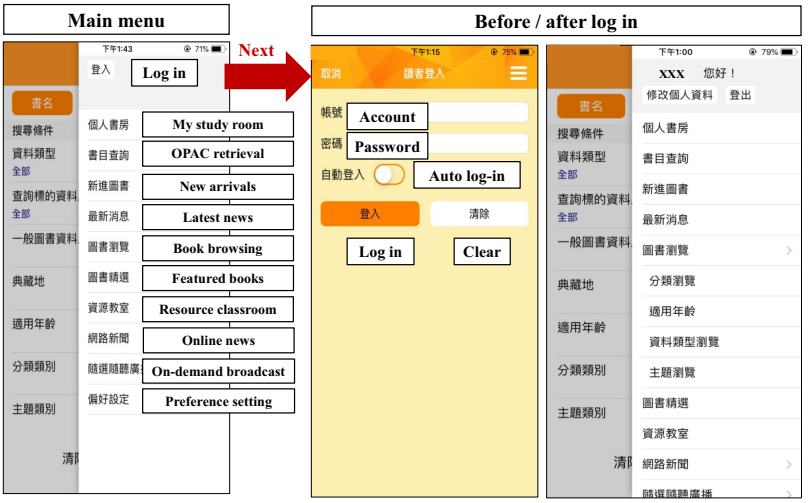

Figure 6.
The ULVI app login function

Figure 7.
The my study room and external reading resources functions of the ULVI app

mode they were familiar with. Another two participants, however, did not like the voice provided by the cell phone (i.e. TalkBack) as they could not get used to the voice generated by the computer. Six participants expressed that they enjoyed using VoiceOver/TalkBack on the cell phone (the free mode) to audio read e-books. They explained that they had more control in free mode. The other two participants also indicated that they liked the free mode; however, before going to bed or while doing other things, they would use the listening mode.

Additionally, as for switching the e-book reading mode, participants suggested setting this function on the reading page of e-books, and proposed adjustments for some functions, such as replacing the name of the "close" button with "confirm" and providing feedback regarding reading e-books (e.g. prompt message of bookmark and adjustment operations) as well as enlarging the operation buttons and using different colours for individual buttons.

6. Discussion and conclusions

6.1 Discussion

With the usability test of the app, the present study provides better understandings of the behaviours and perceptions of the visually impaired while operating the ULVI app so as to improve the usability of this app as well as the accessibility of the learning resources (Menzi-Cetin *et al.*, 2017). According to the findings, the average score of the SUS was 81.75, which reached the criterion for a good experience (Bangor *et al.*, 2009; Lewis and Sauro, 2018). From the participants' feedback on the ULVI app, it indicated that the majority of the participants thought that the ULVI app was easy to use. In addition, the smoothness of using the ULVI app for the visually impaired influenced their evaluation of its usability (Skulimowski *et al.*, 2019). Nonetheless, most of the participants rated lower in item 7 (I think most people can learn how to operate the ULVI app quickly). The participants believed that most people would require some time to get used to the app. During the task execution, it was found that the participants needed some time to adapt to the list-type menus interfaces,

Figure 8.
Open and read an e-book

especially those participants with basic information skills. However, P3 rated 55 and thought that the operation interfaces of the ULVI app should be more intuitive, for instance, when opening the app, it should be on the log-in interface, which would make it smoother to use.

In terms of the participants' performance on the tasks, those with basic information skills spent more time accomplishing most of the tasks than the average completion time of each task. Moreover, those participants who perceive very bright light performed worse on tasks than those in other categories, because they were mainly used to identifying the functions of the ULVI app by colour. Thus, it took more time for them to complete the tasks. However, list-type menus interfaces and full-screen flat menu interfaces were both favoured by the participants. The current study discovered that the participants with low vision and who perceive very bright light would use the coloured blocks in the operation interfaces as the basis for identifying the functions while using the ULVI app. Besides, some participants were curious about the list-type menus interfaces, so they spent some time exploring new functions during the testing. If they had any questions, they could operate it smoothly after

the explanation. The names of the functions and buttons of the ULVI app should be clearer for visually impaired users to distinguish their functions, such as "my external reading resources" and "on-demand broadcast". Furthermore, the ULVI app provided audio books in many electronic formats which could be listened to online; the audio reading in the ULVI app could support the speech corpora offered by users' cellphones, or they could choose TTS offered by the app. Some participants were fond of adopting the listening mode (TTS) to read e-books because they were used to the audio player, while others were used to the voice of VoiceOver/TalkBack or were fond of the free mode (VoiceOver/TalkBack) because they would like to control the reading functions. In terms of switching the e-book reading mode, the participants suggested setting this function in the reading page of the book so that it would be smoother and more convenient to operate. Without vision, users would use hearing as the primary communication channel for accessing information; thus, the design of the auditory feedback is far more important (Shoaib *et al.*, 2019).

6.2 Theoretical and practical implications

The study findings may help libraries improve their understanding of the usage behaviours and perceptions of visually impaired users of the ULVI app. Some suggestions regarding the usability of the app are proposed; for example, the log-in function should be more intuitive, and the place of the function for switching the reading mode should be adjusted. In addition, the names of functions should be more accurate so that users can better understand the functions. This can be a serious limitation in electronic accessibility evaluations and selection by visually impaired users (Kleynhans and Fourie, 2014). Therefore, it provides practical implications for ULVI designers. Khan and Khusro (2020) have pointed out that user-centred design tools are critical to the success of assistive technologies for the blind, especially in the design process, where user feedback is the most critical success factor, and the interactions with the adopted technologies should be available in a simple, easy-to-remember, easy-to-learn and consistent way.

6.3 Conclusions

This study indicates the problems users encounter while using the ULVI app; for example, some visually impaired users who can perceive bright light or who have low vision have different requirements of the ULVI app operation interfaces than those of the totally blind. The navigation menu design of the ULVI app is the most important component for guiding visually impaired users to efficiently and effectively access information. Different operation modes and interfaces should be taken into consideration so as to allow visually impaired users to choose a suitable way. Moreover, to enhance the usage rate of the ULVI app, it is important to collect feedback and opinions of visually impaired users during the promotion or training process to improve the functions or interfaces, especially for visually impaired users with basic information skills and those who have used the ULVI app before. Besides, the ULVI app provides a great deal of e-book content. Apart from strengthening the usability of this app, it should be considered whether the accessibility of the e-books and the diversity of the content can meet the needs of the visually impaired (Byerley and Chambers, 2002; Menzi-Cetin *et al.*, 2017).

However, there are some limitations in the present study. The participants of the current study were categorized into low vision, perceives very bright light and totally blind. It is recommended that their ULVI app needs and usage behaviours be more thoroughly examined based on each category (Kleynhans and Fourie, 2014). The current study explored the usability of the ULVI app for the visually impaired and focused on their usage behaviours and perceptions when adopting the app. In the future, the usage conditions of the

ULVI app or the content of e-books from the perspectives of the visually impaired can be further investigated. Finally, the design of the research method emphasized the data collection at a specific time. It is suggested that data continue to be collected in an effort to understand the needs and behaviours of visually impaired users regarding the ULVI app, and to improve and expand the ULVI services. Furthermore, a quantitative study such as a questionnaire survey can be conducted in the future as ULVI becomes more important among the visually impaired.

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