International Journal of Advanced Smart Convergence Vol.9 No.3 260-271 (2020)
http://dx.doi.org/10.7236/IJASC.2020.9.3.260

IJASC 20-3-34

Understanding Smartphone-based Online Shopping Experiences and Behaviors of Blind Users

Jihyuk Park[1†], Yeji Han[2†], Uran Oh[3]*

[1]*B.S., School of Electrical Engineering, KAIST, Daejeon, South Korea*
[2]*B.S., School of Computing, KAIST, Daejeon, South Korea*
[3]*Assistant Professor, Department of Computer Science and Engineering, Ewha Womans University, Seoul, South Korea*
E-mail: jihyuk@kaist.ac.kr, yejihan@kaist.ac.kr, uran.oh@ewha.ac.kr

Abstract

Smartphones provide blind users with screenreader as an accessibility tool. However, blind users often experience difficulties accessing online shopping malls via smartphones due to their inconsistent and image-based layouts. To enable screenreader users to get access to the detailed information about products while they are shopping online, we have developed BarrierFreeShop, an accessible mobile shopping application for people with visual impairments. BarrierFreeShop has three accessibility features: (1) layout automation, (2) review summarization, and (3) optical character recognition. We conducted a user study with 80 participants with visual impairments where they were asked to use BarrierFreeShop for a month. The findings revealed the effectiveness of our app in terms of speed and post interview feedback. We have also discovered typical shopping experiences that participants had during the test. This research suggests that computer vision technologies can improve accessibility issues in online shopping malls. In addition, we have confirmed that extracting contents from images help people with visual impairments to get better access to product information.

Keywords: *Mobile Shopping Accessibility, Visual Impairment, Optical Character Recognition*

1. Introduction

People with visual impairments (*i.e.*, low vision and blind) have a high demand for online shopping as they find it challenging to purchase products in brick-and-mortar stores [1]. For instance, it is difficult to get to a store. Moreover, they struggle to find and compare products as they have to ask other people onsite (*e.g.*, a clerk) for detailed product information. By shopping online, however, people with visual impairments can

Manuscript Received: August. 21, 2020 / Revised: August. 25, 2020 / Accepted: August. 30, 2020
*Corresponding Author: uran.oh@ewha.ac.kr, †Both authors have contributed equally
Tel: +82-2-3277-6896
Assistant Professor, Department of Computer Science and Engineering, Ewha Womans University, Seoul, South Korea

have time traveling to and from the store and can shop independently by reading product information on the web with a screenreader instead of asking others for help.

Yet, most people with visual impairments experience difficulties shopping online with independence due to various accessibility issues. Figure 1 shows major accessibility problems in a typical product page of online shopping malls, which are inconsistent layouts and images presented without alternative texts (alt-text). First of all, it is extremely time-consuming for screenreader users to find specific information about a product as they need to listen to the entire page from the top to bottom until they reach the information they are seeking. Furthermore, it is confusing to understand where to look for the specific information of products since it is organized in an inconsistent manner in terms of the order and the layout. In addition, screenreader users have limited access to the information because most online shopping malls, provide detailed information about their products in the form of image files which cannot be read with a screenreader without alt-texts which are often missing or insufficient (*e.g.*, "product detail image" or "image01.jpg"). Therefore, people with visual impairments are forced to rely on general information when making purchase decisions, limiting the quality of their shopping experience.

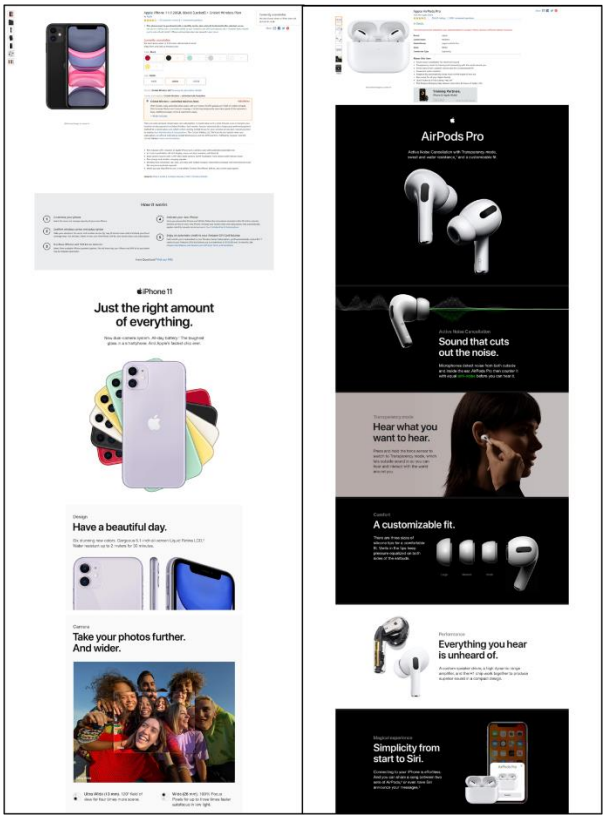


Figure 1. A screenshot of a typical product page of an online shopping mall with inconsistent layouts and images without alt-texts.

Based on the assumption that these accessibility issues are the main reason that prevents people with visual impairments from shopping online, we have developed an accessible mobile shopping application which we call BarrierFreeShop. BarrierFreeShop provides a solution to the aforementioned accessibility issues through machine learning technology. First, the solution makes online shopping experience less time consuming with two functions, layout automation and review summarization. Layout automation function provides product information with consistency in terms of order and layout, while review summarization function allows the

users to navigate various purchase reviews with greater efficiency. In addition, BarrierFreeShop enables screenreader users to access detailed product information by using optical character recognition (OCR) to generate adequate alt-texts.

To evaluate the usability of BarrierFreeShop, we conducted a month-long user study with 80 participants with visual impairments. The results of the study showed that the improvement in accessibility of online shopping malls through computer vision technologies allowed our participants to shop with greater speed and independence. Furthermore, we were able to identify consuming behavior of people with visual impairments when shopping online, such as when and what they are inclined to purchase.

The results of the study imply that the accessibility issues of online shopping that need to be amended and help understanding the online shopping experience and behavior of people with visual impairments. These findings are expected to play a significant role in developing a future barrier-free online shopping experience for people with visual impairments.

2. Related Work

Existing researches have studied accessibility challenges that people with visual impairments face and how assistive technologies for people with visual impairments can be designed to improve their offline and online shopping experience.

While numerous studies on assistive technologies for people with visual impairments have focused on providing navigation aid (see [2] for a review), finding a product in the store was considered to be more challenging than finding and getting to a store [3]. For this reason, some researchers worked on various assistive technologies to provide onsite assistance while shopping for products in offline stores such as barcode readers [4-6], computer vision [7-9], natural language processing [7], and robotics [10-12]. Zhao et al. [9], for example, proposed an wearable assistive device for people who have low vision, which provides augmented feedback with visual cues to direct users to the identified target using computer vision.

On the other hand, others studied the online shopping accessibility for people with visual impairments. Stangl et al. [7], for example, conducted a qualitative study with 28 people who are blind or have low vision and confirmed that the majority of their participants shop online for various products including clothing and electronics. Meanwhile, they also found that participants' expectations for image descriptions on online shopping sites are low due to missing or useless information. A qualitative study conducted by Lee et al. [14] also revealed that it is inconvenient for people with visual impairments to get sufficient information about products when shopping offline and onsite assistance is needed. Specifically, clothes shopping, BrowseWithMe [7], a system designed to assist clothes shopping specifically have also which is considered as inaccessible based on the interview results with 8 participants with visual impairments. To improve the accessibility of online shopping malls for clothing, it employs computer vision and natural language processing techniques to provide visual descriptions about images of the clothes. Moreover, it converts a product web page into a structured format so that people with visual impairments can verbally ask questions to learn about specific information about a product such as its price.

Similar to BrowseWithMe, while BarrierFreeShop is also designed to improve the online shopping experience of people with visual impairments as a mobile app. However, we have developed and distributed a system that is fully functional and conducted a month-long in-the-wild study to collect and analyzed participants' actual

purchasing behavior and their subjective feedback as opposed to an interview after a short-term exploration and use of a system.

3. System Overview: BarrierFreeShop

To solve major accessibility issues in typical product pages of online shopping malls shown in Figure 1, we have designed and developed an accessible mobile shopping application for people with visual impairments, which we call BarrierFreeShop. BarrierFreeShop is intuitively designed to support people with visual impairments to shop online with independence. BarrierFreeShop has three accessibility features: (1) layout automation, (2) review summarization, and (3) OCR.

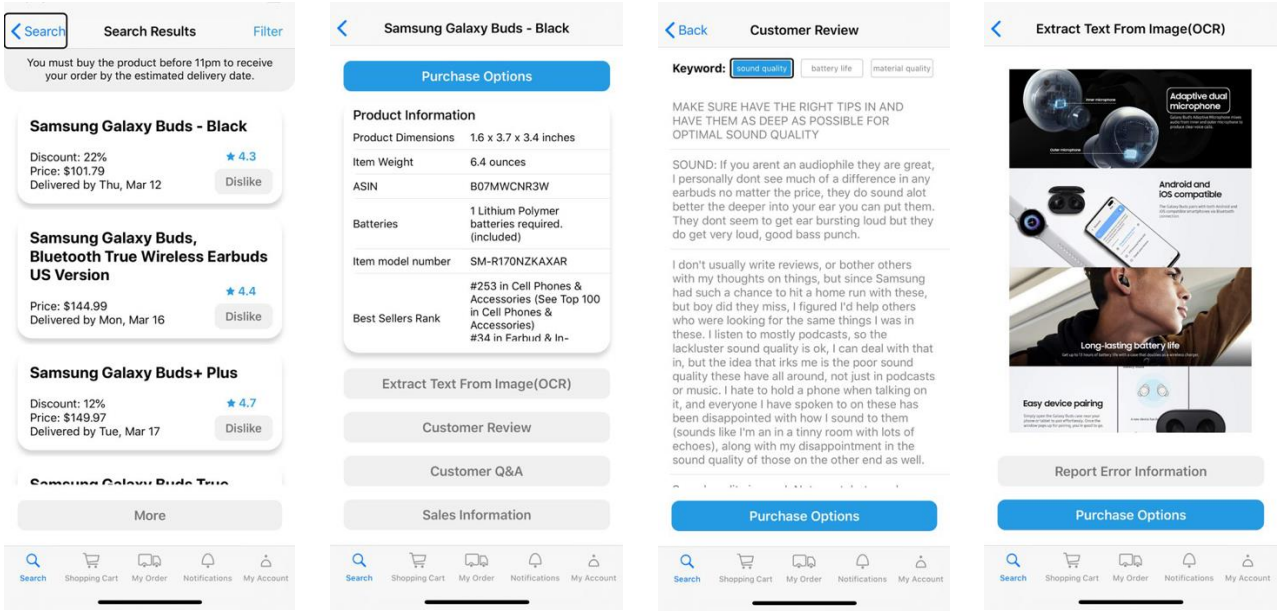
3.1 User Scenario

Bob, a completely blind man in his 20s, gradually lost his vision since he was a teenager. Before completely losing vision, Bob frequently purchased goods online, but he is no longer capable of doing so without the assistance of others. Bob wishes to purchase wireless Bluetooth headphones to replace the wired ones he had been using. Under normal circumstances, he would have asked his parents to help him through the process. This time, however, he remembers hearing about a newly launched mobile shopping application which are accessible to people with visual impairments and decides to give it a go.

Running the app for the first time, Bob is asked to enter his name and phone number. Next, a message including a 6-digit code is sent to his phone, and upon entering the code, he has successfully created an account. After the log-in step, he immediately searches '*Blutooth hedphones*' on the search bar. The typos are automatically corrected and the app displays various Bluetooth headphones available for purchase. To select a single product, he must acquire additional information about each of his options. In his previous experiences with online shopping, he faced difficulties accessing detailed information because they were provided in the form of image files. The lack of information forced him to stick with goods that he was already familiar with. BarrierFreeShop, however, encourages the users to explore diverse options by extracting the text within images. Bob is still hesitant to buy a completely unfamiliar product, so he decides to look through the reviews written about the product. The application provides review summarization function, allowing Bob to narrow down the reviews to those that contain specific keywords. Bob who believes that sound quality is the most important aspect of a pair of headphones, selects the keyword *'sound quality'* to read consumer reviews about sound quality. After reading the reviews, he decides on a product and continues to the payment process. Although entering the address and credit card information can be time-consuming, he is willing to invest time as the information is saved for subsequent purchases.

3.2 Layout Automation

To provide consistent layout, we designed a layout template and implemented a layout automation engine that converts any product page of popular online shopping malls to fit into the layout template. In this way, product information such as price, purchase options, and seller information were presented in the same relative order on all product pages. Progressive disclosure technique was used to determine the order in which product information was presented. Key information that could have a decisive impact on purchase decision, such as price, were placed up front. Information needed only occasionally, such as refund policies, were placed at the bottom or were hidden so that users could determine their level of access. Figure 2a and 2b show how the lay-out automation function in BarrierFreeShop enhances the accessibility of the search result page and the product detail page.



(a) Product search results (b) Product details (c) Customer review summarization (d) Product image with OCR

Figure 2. Screenshot examples of BarrierFreeShop application. (a) Product search results, (b) Product details, (c) Customer review summarization, and (d) Product image with OCR.

3.3 Review Summarization

While layout automation can provide consistent navigation and identification, we developed review summarization engine to make online shopping even less time consuming. Many people with visual impairments relied on customer reviews for their purchase decisions since most product details were uploaded as images, which are inaccessible. However, they had to spend a lot of time reading each sentence from top to bottom as they were unable to scan through quickly. Our review summary engine analyzes consumer reviews to extract frequently mentioned keywords. The users can narrow down the reviews to those that include the extracted keywords, which helps them to gather information of interest in a much efficient way. Figure 2c is a screenshot example of our review summary engine. As shown in the figure, three keywords (‘sound quality’, ‘battery life’, and ‘material quality’) are extracted from reviews of Galaxy Buds earphones. When the keyword ‘sound quality’ is selected, only sentences that mentioned about sound quality are displayed below.

3.4 Optical Character Recognition

Finally, we developed an OCR engine that generate alt-texts of product images by extracting text information from images. With the use of OCR engine, BarrierFreeShop allows screenreader to detect and deliver the text within images, enabling the users to access to detailed information, unlike in a typical shopping experience where screenreaders describe images as “product detail image” or by their file names such as, ‘image01.jpg’. Figure 2d shows a screenshot example of product image OCR page.

Various companies and organizations have developed their own OCR models that successfully interpret even small and ambiguous text. These models, however, are designed to meticulously examine all text within an image, including those that may be insignificant or irrelevant with the context. On the other hand, we

developed an OCR engine that is capable of extracting information that is specifically in line with the product description.

Our engine can be segmented into three departments: recognition, block and calculation. Text from the image is extracted in the recognition department and grouped into subunits (blocks) in the block department. In the calculation department, non-textual characteristics of the blocks such as length and inclination, are extracted and used to calculate the significance of the content. Through this 3-step process, the OCR engine rates the importance of each text block and only returns those that are considered highly significant.

4. User Study

To assess the use and the effectiveness of our system for improving the mobile shopping experience of people with visual impairments, we had distributed our mobile application to 80 participants who use iPhones and asked them to use the application for a month, from December 30th, 2019 to January 31st, 2020.

4.1 Participants

We recruited participants with visual impairments nationwide through an online community and regional welfare centers. Any iPhone users who identify themselves as blind and have interests in mobile shopping were qualified for participation. Participants were given 50 US dollars as a reward. Before using BarrierFreeShop, the participants were asked to complete a survey that would provide further information about themselves and their shopping experience. Through the survey, we were able to acquire information regarding the participants' age, gender, shopping frequency, average expense, and how confident they were with online shopping. The results of the survey are summarized in Table 1.

Table 1. Participants' demographic information per group in terms of their self-reported confidence in online shopping collected via online survey.

Confidence	20s	30s	40s	50s	Gender	Frequency	Expenses (USD)
High	17	9	12	0	20 M, 18 F	6.3	127.4
Mid	1	4	3	3	10 M, 1 F	5.3	174.2
Low	3	3	4	1	8 M, 3 F	3.0	114.2
Total	21	16	19	4	38 M, 22 F	14.6	415.8

4.2 Apparatus

Every participant was required to install BarrierFreeShop application on their iPhones. The application was distributed to users via TestFlight, a service providing over-the-air installation and app tests[1].

4.3 Procedure

To better understand participants' prior shopping experiences, we conducted an online survey in advance to the app installation. During the test, we let participants to use the app freely. After participants finish online survey, they received a text message of a link for app installation. They were able to search items, add them to the cart, and make a purchase. When a one-month period of app test was done, we conducted a phone interview asking their experience with our app including their satisfaction.

[1] https://developer.apple.com/testflight/

4.4 Data and Analysis

We collected participants' demographic information (*e.g.*, age) and their prior shopping experiences through the online survey. Moreover, participants' usage data were gathered from application logs, which include timestamps for every page access, searched queries, frequency major features per user, traces of reaching the designated pages like payment, cart, and product information page. Finally, we earned following information from the phone interviews: their confidence in online shopping, the most helpful features of our app, and feedback of our app in free form.

- Proficiency in online shopping: *high*, *mid*, *low*
- Average number of online shopping experiences a month
- Average monthly expenses for online shopping
- Time of the day doing mobile shopping

5. Findings

Here we present the results of our user study in terms of online shopping behaviors, purchased items, and ability to shop online independently. Also, we introduce subjective feedbacks of participants after using BarrierFreeShop application for a month.

5.1 Online Shopping Behaviors

Frequency. Our participants purchased goods from the app 1.6 times on average during a month-period (*SD* = 0.90). Sixty out of all participants made at least one purchase using the app; 53.1% of the participants bought a single item, and 23.8% were involved in multiple payments (*N* = 41 and 19, respectively), which is similar to those for sighted consumers [14].

Expenses. The total financial transactions during the test period was approximately 6,000 US dollars. On average, 100 US dollars were spent per one participant for a month (*SD* = 63.8), which is less than the survey response on monthly online expenses. Note that since we did not prohibit the use of other online shopping malls during the test period, it is possible that the participants used various online shopping malls along with the BarrierFreeShop.

Active Shopping Time of Day. Figure 3 depicts the total amount of shopping activities, which includes searching for a product, adding the product to the cart, and purchasing the product, that takes place at a given time of day. The results show that our participants were noticeably more active in the afternoon, especially at 4PM. It is different from typical consumers who are shop actively online shopping from 9 AM to 11 PM and from 9 PM to 11 PM [14]. Figure 4 chronologically shows the time taken for all purchases that has occurred over the testing period. The time was measured from when the user launched the application to when the purchase was finalized. As shown by the red dotted line in Figure 4, participants took 11.7 minutes on average to complete the shopping process, from searching for a product to making the payment (*SD*=19.3, median=5.0). Considering that it takes about 40 minutes for blind users to make an online purchase [3], the logs show that participants could order a product faster with 80% reduced time using our app.

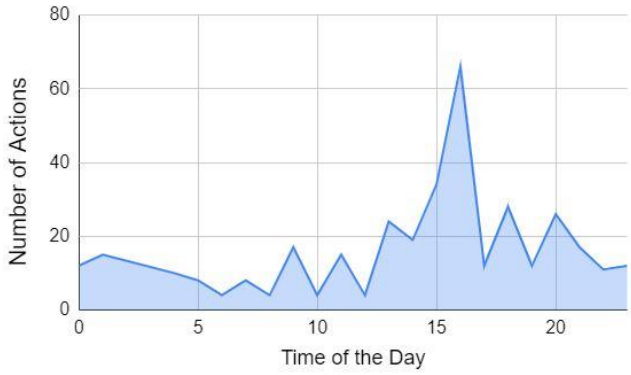


Figure 3. The total number of shopping related activity (*e.g.*, proceeding to payments).

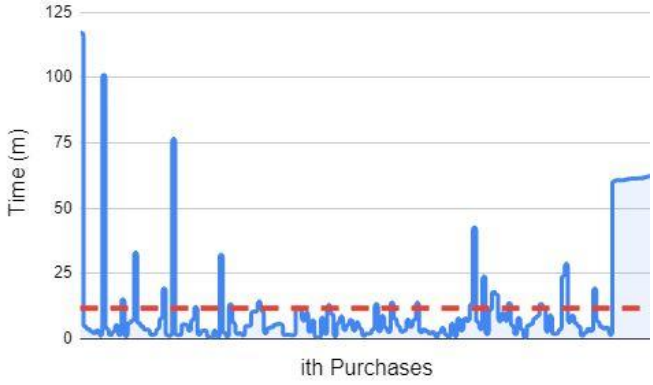


Figure 4. The duration from launching the application to making a purchase in minutes (in blue) compared to average shopping time (in red).

5.2 Purchased Items

As a secondary analysis, we assessed the types of items purchased by participants as shown in Figure 5.

Frequently bought items. Figure 5 presents the top 10 shopping categories purchased by blind and total consumers. It shows that the most frequently purchased items by our participants were processed food and daily supplies such as laundry soup, toothpastes, and cups. On the other hand, purchase related to fashion items topped the list of total expenses of domestic online shopping malls [15].

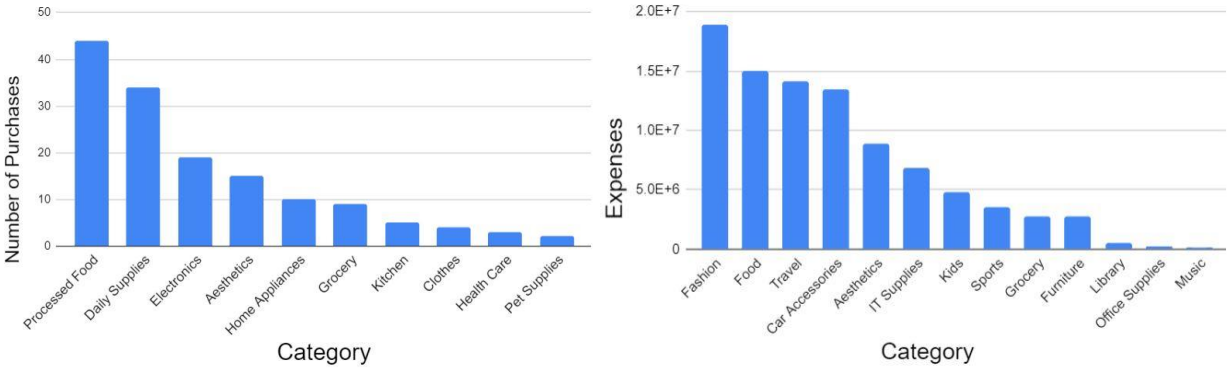


Figure 5. The number of purchases made by participants via BarrierFreeShop for top 10 categories (left), total expenses used in online shopping malls for top 10 categories (right).

Gender Difference. When categorizing financial transactions by gender as Table 1, male participants spent greater amount of money for purchasing goods than female participants on average. However, female participants purchased greater number of goods. While male participants bought 2.79 goods on average (*SD* = 2.5) female participants purchased 3.48 goods (*SD* = 3.0). Also, male participants bought average 2.7 items at one purchase (*SD* = 2.34), female participants bought average 3.4 items at one purchase (*SD* = 2.38).

Figure 6 shows that items that male participants purchased were processed food, electronics, and daily supplies while female participants bought items of daily supplies, kitchen supplies, and process food.

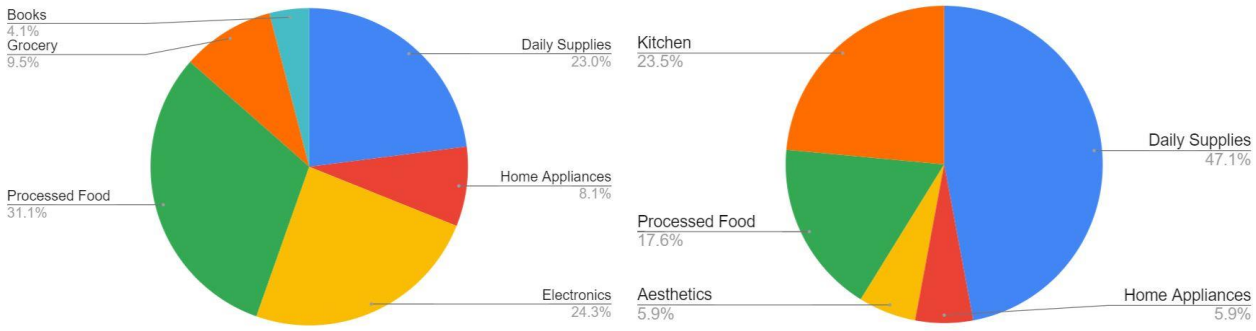


Figure 6. Category of purchased items of male participants (left) and female participants (right).

5.3 Ability to Shop Online Independently

To understand participants' prior shopping experience before using our app, we asked their confidence in online shopping (*i.e., high, mid, low*), the number and the expenses of online purchase a month, the typical time of the day they use mobile shopping app from the online survey; see Table 1 for the summary.

There were 38 participants in high group, 11 participants in mid group and 11 participants in low group. However, when participants were asked again after the test period, 93.3% of participants responded that they were able to shop independently using BarrierFreeShop (*N* = 56). Particularly, 81.8% of participants who previously could not purchase goods online were now able to order products by our app (*N* = 18).

5.4 Subjective Feedback on BarrierFreeShop

Through telephone interviews with the participants, we asked what features of the BarrierFreeShop improved their online shopping experience compared to existing online shopping malls. 48% of participants were satisfied by the consistent navigation and identification compared to existing shopping malls. 32% percent of participants answered that OCR function helped them shop with independence as they allow access to detailed information within images. Finally, 20% percent of participants responded that they could compare diverse product information with less time.

6. Discussions

6.1 Inaccessible Items in Online Shopping

Analysis on purchases of the participants showed that item categories blind consumers preferred were different from those preferred by typical consumers. Blind participants bought items belong to daily supplies, processed food and electronics, but typical consumers mostly bought fashion items from online (see Figure 5). Such deviation occurs because selecting goods related to fashion depends heavily on vision while processed

food and electronics do not. For example, when sighted people use online shopping apps to buy a cap, they compare different caps through images. Among those, sighted consumers choose one that fits best to their style. However, comparing items only through images are not available to blind consumers. Therefore, during our test, participants purchase items that their quality and usage do not change upon their appearances. Goods like instant noodles and snacks have same taste regardless of their images on the shopping mall. Also, electronic gadgets such as headphones do not require thorough inspections on appearance but features like sound quality and noise cancellation matter.

Moreover, the fact that processed food does not need additional cooking allows blind participants to purchase them frequently. While food like vegetables and fruit need to be cooked or inspected through eyes to ensure quality, processed food do not.

6.2 Active Online Shopping After Work

Time that the participants engaged in the app most actively was 4 PM, while sighted consumers were most actively during 9 AM to 11 AM and 9 PM to 11 PM. Although the absolute time scope is different, it is analogous that both groups had online shopping after work. Majority of our participants took classes in regional welfare centers which end at 4 PM, while most sighted consumers return from work at 9 PM. Consumers from both groups preferred to buy goods after their works were done.

However, our participants did not show active app uses in the morning. A reason for such difference is that to listen to screenreader outputs, participants need stationary condition. Our participants were usually exposed to public places in the morning while on their way to work or welfare centers, which is a bad environment to use smartphones using screen leaders. Therefore, morning would not be an ideal condition for screenreader users to shop online.

6.3 Design Recommendations

Layout automation. Our test results and subjective feedbacks of our participants show that user interface of BarrierFreeShop were recognized to be convenient to blind consumers. 48% of participants were satisfied by the consistent navigation and identification, which proves that layout automation is the key feature in improving online shopping experience of screenreader users. However, layout automation forces users to adapt to certain form of layout that they may find unfriendly in some extent. If layout can be personalized based on the user experience and behavior, it would provide optimal usability to screenreader user.

Review Summarization. 20% of our participants answered that they could compare diverse product information with less time in BarrierFreeShop. Although review summarization was a way to increase time efficiency of finding information of interest, this feature did not extract specific information that participants want. Rather, it extracted information that most users would want to see. If a system provides advanced features such as searching words inside reviews sentences will make information be more personalized.

OCR. Since screenreader users cannot access to information within product images, OCR technology was regarded as necessary in designing BarrierFreeShop. As expected, 32% of the participant considered OCR as the most impressive function of BarrierFreeShop, since it gave access to detailed information within images. Despite extracting texts from images via OCR helped participants purchase goods online, restrictions of participants' shopping categories show that non-textual information such as color and texture should be provided in order to expand online shopping experiences of blind consumers.

7. Conclusion and Future Work

To improve online shopping experience of blind users using their mobile phones, we have designed and developed BarrierFreeShop, an accessible smartphone application for online shopping. We conducted a user study with 80 participants who reported themselves as blind where they were asked to use our app for a month. Based on the analysis of users' logs and their subjective feedback, we have found that three accessibility features of our app (i.e., layout automation, review summarization, and OCR) allows blind users to shop more efficiently. Moreover, our findings suggest that extracting contents from images using OCR technology helps blind people to get better access to product information. As a future work, we plan to conduct a follow up study on how visual description about product images beyond OCR can help improve the online shopping experience of blind people. As a future work, we plan to conduct a follow up study on how visual description about product images beyond OCR can help improve the online shopping experience of blind people. Furthermore, we are going to develop own computing technology that will aid people with visual impairments through users' data we previously gathered [16, 17].

Acknowledgements

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2018R1C1B5084295).

References

[1] S. Szpiro, Y. Zhao, and S. Azenkot. Finding a store, searching for a product: a study of daily challenges of low vision people. In ACM International Joint Conference on Pervasive and Ubiquitous Computing. ACM, (pp. 61–72). 2016.

[2] Fernandes, H., Costa, P., Filipe, V., Paredes, H., and Barroso, J. A review of assistive spatial orientation and navigation technologies for the visually impaired. *Universal Access in the Information Society*, *18*(1), (pp. 155-168). 2019.

[3] An article from AbleNews about a survey results on the usage of online shopping of people with visual impairments conducted by Korea Blind Union.
http://ablenews.co.kr/News/NewsContent.aspx?CategoryCode=0006&NewsCode=000620180312112546134726

[4] H. Jethava, S. Zafar, and M. Saini. Electronic Shopping Cart Facility for Blind People Using USB Firmware. In International Journal of Emerging Technology and Advanced Engineering, Vol. 4. (pp. 647–651). 2014.

[5] Lanigan, P. E., Paulos, A. M., Williams, A. W., Rossi, D., and Narasimhan, P. Trinetra: Assistive Technologies for Grocery Shopping for the Blind. In *ISWC* (pp. 147-148). 2006.

[6] Nicholson, J., Kulyukin, V., and Coster, D. ShopTalk: independent blind shopping through verbal route directions and barcode scans. *The Open Rehabilitation Journal*, *2*(1). 2009.

[7] Stangl, A. J., Kothari, E., Jain, S. D., Yeh, T., Grauman, K., and Gurari, D. Browsewithme: An online clothes shopping assistant for people with visual impairments. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 107-118). 2018.

[8] T. Winlock, E. Christiansen, and S. Belongie. Toward real-time grocery detection for the visually impaired. In Computer Vision and Pattern Recognition Workshops (CVPRW), 2010 IEEE Computer Society Conference on. IEEE, (pp. 49–56). 2010.

[9] Y. Zhao, S. Szpiro, J. Knighten, and S. Azenkot. CueSee: Exploring Visual Cues for People with Low Vision to Facilitate a Visual Search Task. In ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp). (pp.73–84). 2016.

[10] C. P. Gharpure and V. A. Kulyukin. Robot-assisted shopping for the blind: issues in spatial cognition and product selection. Intelligent Service Robotics 1, 3 (2008), (pp.237–251). 2008.
[11] H. Jethava, S. Zafar, and M. Saini. Electronic Shopping Cart Facility for Blind People Using USB Firmware. In International Journal of Emerging Technology and Advanced Engineering, Vol. 4. (pp. 647–651). 2014.
[12] Kulyukin, V., and Kutiyanawala, A. Accessible shopping systems for blind and visually impaired individuals: Design requirements and the state of the art. *The Open Rehabilitation Journal*, *3*(1). 2010.
[13] Lee, J., Kim, J., and Jung, H. Challenges and Design Opportunities for Easy, Economical, and Accessible Offline Shoppers with Visual Impairments. In *Proceedings of the 2020 Symposium on Emerging Research from Asia and on Asian Contexts and Cultures* (pp. 69-72). 2020
[14] Walker Sands. 2018. The Future of Retail 2018: How Technology is Expanding the Scope of Online Commerce Beyond Retail. In Walker Sands Resources. https://www.walkersands.com/resources/the-future-of-retail-2018/
[15] Statistical data from KOSIS (Korean Statistical Information Service) about transaction value of online shopping mall by commodity groups/sales channels.
http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1KE10071&conn_path=I2&language=kr
[16] Lee, S., Lee, J., Jung, K., Behavior recognition system based fog cloud computing, The International Journal of Advanced Smart Convergence, Vol. 6. (pp. 29-37). 2017
[17] Hwang, C., Kim, H., Lee, J., Jung, K., A study on BSN data collection technique through mobile devices in a cloud environment, The International Journal of Advanced Smart Convergence, Vol. 6. (pp. 82-88). 2017