

Designing Product Descriptions for Supporting Independent Grocery Shopping of People with Visual Impairments

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ABSTRACT

It is difficult for people with visual impairments to have balanced nutrition, and one of the reasons is because it is challenging for them to shop for grocery items. In this study, we focused on designing descriptions on grocery items to people with visual impairments to help them with making purchase decisions independently. To identify types of information to be provided, we first conducted an online survey with 73 participants with visual impairments. Then we conducted an in-depth phone interview with eight participants to understand how to better design descriptions for different grocery items. Based on the findings, we provide implications for a camera-based wearable grocery shopping assistance system, which is currently in the prototype stage. This system will help taking the next step in providing effective assistance for people with visual impairments when shopping for groceries.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility systems and tools.**

KEYWORDS

Offline grocery shopping assistance, accessibility, visual impairments, online survey, interview

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1 INTRODUCTION

It is important for people to consume food that is nutritionally balanced [9]. However, unlike sighted peers, it is challenging for people with visual impairments (PVI) to shop for groceries because they face difficulties in accessing variety of food items [16]. To improve the grocery shopping experience of PVI, a number of studies have been conducted. However, most of these focused on recognizing products [3, 6, 8], guiding PVI to a particular product on a shelf [6, 17], or to a particular store at a shopping mall [14]. Only a few investigated on how to effectively provide verbal descriptions for grocery products to PVI.

To help PVI with making decisions on purchasing an item at a grocery store, we conducted two studies. First, we ran an online survey and analyzed 73 responses to investigate how PVI shop for grocery products, and to identify types of information PVI wish to receive while shopping. From this study, we confirmed that they often buy items that are easy to cook (e.g., instant noodles, frozen food). We also discovered that PVI tend to purchase a certain set of products whose conditions are guaranteed (e.g., canned food, beverage, snacks), and that PVI wish to have the following information when shopping for groceries: price and discount information, expiration date, freshness and quality, and type (e.g., meat, fish). Moreover, findings suggest that while they seek for others' help, they still wish to be able to shop independently. Then we conducted an in-depth phone interview with eight participants with visual impairments to have a better understanding of their grocery shopping experience, followed by a design probe study where participants were asked to evaluate different product description models devised based on the survey findings. We found that participants desired to receive objective information that is labeled on a product as well as contextual information such as food condition (e.g., the freshness of fruits) and how it is packaged (e.g., trimmed fish), which are difficult to recognize without vision or touch.

Based on the study findings, we designed and implemented a camera-based wearable grocery shopping assistance prototype, and offer implications for such a system. We expect the system to improve the independence of PVI when grocery shopping by supporting the decision making process with well-devised product descriptions.

2 RELATED WORK

Our study is inspired by prior works on camera-based product recognition and guidance towards the recognized products to assist PVI during grocery shopping [6, 7, 10–12, 14, 15, 17]. Some

researchers conducted studies on understanding the difficulties people with low vision experience when shopping offline [15, 17]. Boldu *et al.* [3], for instance, proposed *FingerReader2.0* that can scan letters written on products through a small camera attached to a wrist-worn device that uses optical character recognition during shopping. They conducted a user study at an actual grocery store and demonstrated the feasibility of the system. In addition, Zhao *et al.* [17] presented a head-mounted display (HMD) system called *CueSee*, to assist people who have low vision in searching a particular product at a store. It allows a user to specify an item in advance and performs real-time image-based product recognition of the item at a store. When the item is recognized, the location of the item is notified to the user with visual cues so that they can find a specific product efficiently and accurately without having to bring the product up close to visually identify the product one at a time. Bigham *et al.* [1] also proposed *VizWiz::LocateIt* which is designed to guide PVI to a particular target based on pictures taken through smartphones with audio feedback, and described how their system can be used when shopping for products at a store.

All these studies focused on recognizing certain products that are likely to be displayed at a grocery store, or delivering PVI the precise location of a particular product once it is recognized. However, little has been studied on how to best provide product-related descriptions of grocery items to PVI. Based on the prior study that the most frequent visual questions asked by PVI are related to food and drink [4], our goal is to understand the design of product descriptions of grocery items for PVI during shopping.

3 FORMATIVE STUDY: AN ONLINE SURVEY

To understand the needs, challenges, and preferences of PVI when shopping, we designed an online survey asking questions related to their prior shopping experiences. We had distributed the survey using Google Forms to the largest online community for PVI in South Korea (*i.e.*, <http://web.kbuwel.or.kr/>) for two weeks. We have specified that anyone aged between 18 and 65, and has a visual impairment is eligible to participate in the survey.

3.1 Survey Overview

The survey consisted of 15 questions asking about demographic information, places they prefer when shopping, and the overall grocery shopping experiences focusing on offline stores where textual descriptions of products are less accessible than when online shopping, since the products' descriptions can be provided through a screen reader. We also asked their opinions on a camera-based system that can provide information about the products. All the questions were multiple-choice questions and also allowed open-ended responses for the participants who felt the need. It was designed to be completed within 15 minutes with a screen reader on. We provided \$5 to the participants as gratitude.

3.2 Participants

A total of 73 participants (63.0% male, 35.6% female, 1.4% preferred not to specify) responded to our online survey where the age group with the largest number of respondents was *between 25 and 34* (37.0%). Fifty-four participants were blind where 28 of them were

congenital, and nineteen of them had low vision. In terms of the screen reader use, fifty-seven participants answered *"always"*.

3.3 Findings

3.3.1 Places for Shopping: Online vs. Offline. To have an understanding of the shopping behavior of PVI, we asked participants where they usually shop for products in general (online vs. offline), and 41 out of 73 participants reported *'online'*. The dominant reason was because offline shopping requires help from others ($N = 32$). The next frequent response was having to physically visit a grocery store ($N = 18$) and thirteen participants responded that it is difficult to receive product-related information written in texts unlike online shopping. On the other hand, the rest 32 participants chose offline shopping. The reasons included *'being able to check the product in person'* ($N = 27$), *'easiness to get help from other people'* ($N = 19$), and *'familiarity with offline shopping'* ($N = 12$).

3.3.2 Shopping Companion: Alone vs. With Others. For a follow-up question asking who they usually go shopping with, 63 participants (86.3%) reported one of the followings: *'family members'* ($N = 32$), *'social service workers'* ($N = 22$), or *'friends'* ($N = 9$). Yet, the majority of the participants ($N = 61$) did not wish to accompany others. The most dominant reason was *'feeling uncomfortable asking for assistance from others'* ($N = 32$). Twenty-six participants chose *'prefer shopping alone'* and twelve participants reported that they do not go shopping by themselves.

3.3.3 Types of Questions PVI Ask Companions. We asked participants to choose any type of questions they ask their companions while shopping offline. Among 73 respondents, 68 of them (93.2%) chose *'specific information about an item (e.g., price, type, location, expiration date)'*, 39 participants (53.4%) chose *'route guidance for an item'*, and 33 participants (45.2%) chose *'information about the store (e.g., discounted products, special sales, giveaways)'*.

3.3.4 Grocery Shopping Information Needs. As found in Brady *et al.* [4], since getting food-related information is found to be one of the most challenging tasks for PVI among any other objects, we asked participants to choose all the type of information PVI ask others when shopping for groceries. The dominant responses were *'price and discount information'* (74.0%), followed by *'expiration date'* (68.5%), and *'freshness and quality'* (52.1%); see Figure 1 for details.

3.3.5 Thoughts on Shopping Assistance System. Confirming prior findings [4], when asked which type of product participants would use an artificial intelligent system that recognizes and informs details of a product in front of them for, *'food'* received the highest number of votes (75.0%), followed by *'clothing'* (58.3%), and *'electronic products'* (50.0%). Other responses included *'stationary, office supplies'*, *'furniture'*, and *'tools'*; see Figure 1 for details.

4 MAIN STUDY: A PHONE INTERVIEW

To better identify the types of information PVI need and how it should be delivered when designing a grocery shopping assistance system, we conducted a structured phone interview. After the interview, we conducted open coding for analyzing the qualitative data. The inter-rater reliability with Cohen's kappa coefficient was 0.86.

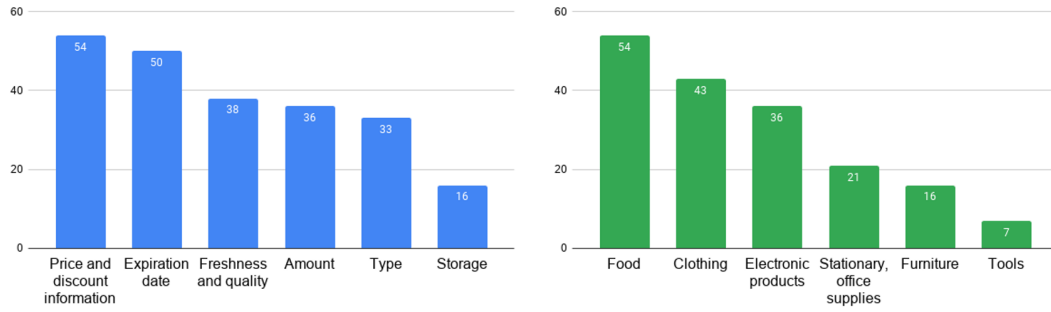


Figure 1: The number of responses for types of information that participants ask when choosing a grocery product (left), and types of product participants wish to get descriptions of the most (right). Multiple responses were allowed ($N = 73$).

4.1 Participants

We recruited in total eight people among the respondents of the survey who had shown interest in participating in the follow-up in-depth phone interview. Five of them were totally blind (three of them were congenital) and the other three participants had low vision. All but P4 had prior experience with a screen reader. For further details, see Table 1.

4.2 Procedure

The phone interview began by asking about their demographic information such as age, gender, and visual acuity. Then, we asked them about their offline grocery shopping experiences including challenges they had faced and types of assistance they receive from companions when purchasing food items at a grocery store. We first played two different versions of recorded descriptions. As presented in Table 2, the descriptions are devised based on the survey results so that the desired information gets delivered in the following order: price, expiration date, and condition. Then we asked them to grade the usefulness and reliability of each description in a 5-point Likert Scale and to provide subjective feedback. Next, we played item-specific descriptions of four grocery items to the participants as presented in Table 3. For the selection of items, we picked three grocery items where freshness and quality matter the most in addition to representative processed food. For each description, we asked them again to provide subjective ratings and comments for

improvements. Finally, we asked them about their overall satisfaction with the item-specific description. The interview took about 30 minutes, and a \$5 gift card was given to participants as gratitude.

4.3 Findings

4.3.1 Most and Least Purchased Grocery Items. To learn the types of grocery items that would need the most support for getting detailed information, we asked participants for their frequently purchased items when shopping for groceries offline. The responses were fruits (P2, P3, P5, P6), vegetables (P1, P5, P8), and meat (P1, P8). As for processed food, they mentioned instant noodles (P2, P3, P5, P8), snacks (P4, P6, P7), and beverages (P2, P4, P7). Five out of eight participants mentioned that they tend to purchase food items that can easily be consumed without any complex cooking process as found in [2]. P5 specifically mentioned,

"It's hard for me to know food freshness. So I tend to settle for items that don't require any of this, like frozen food or instant noodles."

4.3.2 Challenges in Offline Grocery Shopping. We asked participants about the challenges they face when shopping groceries offline, and the responses were similar to those from our survey: identifying 'freshness' (P1, P2), 'expiration date' (P2, P5), and 'price' (P3, P8). Other responses included getting discount information and identifying new products.

4.3.3 Desire to Shop with Independence. Reflecting on the survey findings, six participants (P2, P4, P5, P6, P7, P8) said that they felt uncomfortable getting help from companions even if it is difficult for them to shop alone. For this reason, some participants mentioned that they developed a strategy to avoid getting help or minimize the assistance from others such as only buying the products they are familiar with or going to the same grocery store and asking the same store employee for help. Regarding this, P7 said,

"I only go to a small grocery store near my house. The clerk there knows my situation and brings the groceries I need."

4.3.4 General Description: Labeled vs. Contextual. We provided two different explanation models for the same food item: beef. For the labeled description, participants gave 4.3 for usefulness and 3.6 for reliability, which are less compared to the ratings for contextual description; 4.9 for usefulness and 4.4 for reliability. Reflecting on the scores, a total of six participants (P1, P2, P3, P4, P7, P8) mentioned that they preferred the contextual description as

Table 1: Participants' demographics including age, gender, visual acuity, shopping preference, and their occupation. *P3 did not wish to provide his exact age.

PID	Age	Gender	Visual Impairment (best eye)	Job Title	Shopping Preference
1	27	Female	Totally blind	Instructor	Online
2	55	Male	Totally blind	IT related	Offline
3	40s*	Male	Low vision	Teacher	Offline
4	30	Female	Low vision	Barista	Offline
5	42	Female	Totally blind	Masseuse	Offline
6	35	Male	Totally blind	IT consultant	Online
7	29	Male	Totally blind	Unemployed	Offline
8	28	Male	Low vision	Office worker	Online

Table 2: The labeled description provides basic information as in the product label while the contextual description provides additional contextual information such as the amount in servings. The differences are highlighted in colors.

Type	Description
Labeled Description	"Type beef sirloin, origin Australia, price 8,000 won, amount 600 gram , expiration date September 1, grade Choice ."
Contextual Description	"Type beef sirloin, origin Australia, price 8,000 won, amount 2 servings , expiration date September 1, 2 days left until the expiration date , good condition and little fat ."

Table 3: Item-specific descriptions of the four different grocery products were provided during the interview. Boldface indicates unlabeled visual description.

Type	Description
Processed Food	"Type canned tuna, manufacturer Dongwon, price 10000 won, amount 200 gram and 12 cans, expiration date November 1 2021 not safe-lidded and two chili tuna giveaway ."
Fruit	"Type apple, origin Gyeongbuk, price 8,000 won, amount 1.5 kilogram, contains many scratches and is not glossy ."
Meat	"Type beef tenderloin Prime for grilling, origin Korea, price 36000 won , and 15800 won per 100 gram amount 2 servings, expiration date November 11 2020, refrigerated, appropriate marbling, consisted of one piece "
Fish	"Type Mackerel for grilling, origin Norway Price 6000 won, amount 400 gram, expiration date September 11, refrigerated, seasoned, and trimmed "

it would help them to make decisions when purchasing food items. Yet, three participants (P1, P2, P3) also commented that it would be better to provide contextual information in a more objective way (600g instead of two servings). Likewise, P5 and P6 remarked that the labeled description seemed more concise and intuitive.

4.3.5 Item-Specific Description: Subjective Ratings. The average usefulness of item-specific description was 4.3 out of 5. Furthermore, as found in prior work that PVI do not like receiving long-winded information about a product [3], 5 participants (P3, P4, P6, P7, P8) wished to have the item-specified description provided only when requested, while the remaining three participants preferred to receive the entire description as a default. The followings are a summary of the comments per presented items:

- **Processed Food.** This description received 4.3 out of 5 for usefulness and 4.4 for reliability on average. Half of the participants (P2, P4, P6, P8) remarked that receiving information about giveaways is extremely useful. Meanwhile, two participants (P2, P5) said that the description of "safe-lid" is confusing as they were not familiar with the term.
- **Fruit.** Fruit-specific description received 4.3 out of 5 for usefulness. However, the reliability score was 3.9, which is relatively low. Six participants mentioned that the description would be more informative if details about the size (P2, P5, P8) or the quantity (P1, P3, P5) were included. Overall, most participants (P1, P3, P4, P5, P6, P8) were satisfied with receiving the description of the item's condition.
- **Meat.** Meat-specific description received 4.0 out of 5 for usefulness and 4.3 for reliability. In total, half of the participants (P3, P4, P7, P8) favored the information about how it is stored and three participants (P2, P4, P6) liked the information about the amount of fat but negative about the term "appropriate" because it can be subjective.

- **Fish.** Fish-specific description received 4.1 out of 5 for usefulness and 4.3 for reliability. Participants liked the details about whether the fish are trimmed (P1, P2, P4, P5) or seasoned (P1, P2, P4) as well as cooking usage such as if it is for steaming and for stew (P1, P2). Meanwhile, three participants (P2, P3, P6) commented that they also wish to know its size and the number of slices similar to fruit-specific descriptions.

5 DISCUSSION

5.1 The Needs for Shopping Assistance for PVI

Survey and interview findings revealed that PVI tend to purchase processed food because it is hard for them to identify the freshness of a food product. This can cause malnutrition threatening one's health condition. To enable PVI to have a healthy diet, it is important to allow them to easily access information about nutritious food products such as fresh food and not limited to processed food. Moreover, the results also confirmed that the majority of the participants wished to shop groceries independently although most of the participants go shopping with others to get assistance at the moment. While little research has been conducted on assisting PVI on providing detailed descriptions about the various food products, the findings imply that there is a high demand for such a system.

5.2 Improvements for Product Descriptions

Based on the study findings, we present a guideline for the types of information that need to be included when describing items as shown in Table 4, which is a revised version of our original descriptions. Most of the participants remarked that it is important to receive the information they easily overlook such as sales promotion (e.g., buy one get one free). Therefore, it is recommended to have this information included in item descriptions in addition to basic information labeled on processed or packaged products. In

Table 4: A guideline on types of information to be included when describing grocery products.

Type	Elements of the Description
Common	Type, Price, Expiration Date, Manufacturer/Origin, Amount, Sales Promotion
Fruit	Freshness/Condition, Size, Quantity
Meat	Freshness/Condition, Storage, Price per 100g, Usage, Grade
Fish	Freshness/Condition, Size, Quantity, Trimming/Seasoning, Storage, Usage

terms of fruit-specific, and fish-specific descriptions, PVI wished to know about the size and quantity including the number of slices in addition to its freshness. Moreover, for ones that can be cooked (*i.e.*, meat and fish), participants considered the usage information relevant to cooking, such as whether the fish is trimmed or seasoned or the meat is refrigerated, to be extremely useful. In addition, one should avoid using words that are ambiguous such as "appropriate" or jargon such as "safe-lid", and should provide further information upon users' requests about specific descriptions or terms if needed.

5.3 The Design of Offline Grocery Shopping Assistance System

Based on the study findings, we propose a mixed-reality based wearable offline grocery shopping assistance system as shown in Figure 2. To support hands-free interaction, we decided to use Microsoft's HoloLens2. We built a prototype to detect products with its built-in camera, where the software is run on Ryzen 2700X CPU with 32GB Ram, and RTX 2070s Graphic card.

5.3.1 Product Image Recognition with Hand Tracking. We used Vuforia and a depth camera in HoloLens2 to track users' hands and identify images of grocery products. The HoloLens's front camera identifies the marker of an object which is closest to the hand. After the recognition is complete, the description of the object is brought from the product database and the verbal explanation is played.

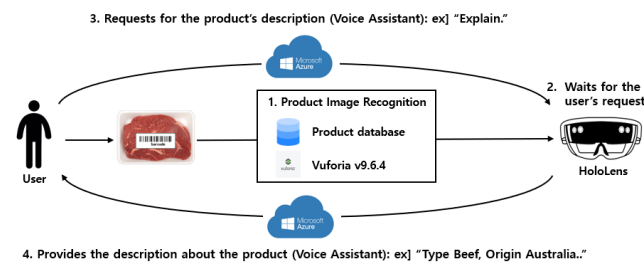


Figure 2: The overview of the offline grocery shopping assistance prototype and its process: (Step1) the system recognizes items with the camera built into HoloLens2, (Step2) it waits for the user's voice command "Explain" and identifies the item the user is pointing with their hand, (Step3) the user's request gets sent to the system, and (Step4) it plays verbal descriptions to the user.

Note that while the current system requires registration of grocery product images or visual markers, the process can be replaced with an advanced deep learning model.

5.3.2 User-friendly Voice Assistant. As the majority of the participants preferred to receive the product description upon request, we decided to provide the descriptions in a familiar and user-friendly way by using a voice assistant. After informing users about the recognized product, they can then request for basic labeled information as well as item-specific information using voice command (*e.g.*, 'Explain', 'Tell me the price', 'Tell me the condition').

5.3.3 Additional Features: Bookmarking and Recommendations. As a number of PVI shop online, we also present Bookmark feature so that users can save frequently bought products or compare multiple items before making a purchase decision as in online shopping. They can also verbally request information about the differences between two items while holding them in both hands. In addition, again similar to online shopping, we provide Recommendation feature that informs better deals for users who are experiencing difficulty in comparing similar items.

6 CONCLUSION & FUTURE WORK

We focused on studying the difficulties PVI face and the types of information they wish to receive when shopping for groceries offline. From the online survey, we discovered that PVI have the desire to shop with independence although they usually rely on others' help to get information about the expiration date, price, and freshness. Based on the findings, we designed two versions of general descriptions and four additional item-specific descriptions to be used for the offline shopping assistance system for PVI, then played the recordings of the descriptions during the phone interview to collect subjective feedback. As a result, we discovered that PVI favored contextual information such as freshness, condition, and promotions. Based on this, we finalized a guideline for generating product-related descriptions and designed a camera-based wearable grocery shopping assistance prototype. As a future work for constructing the optimal descriptions that can be generalized, we plan to conduct the interview with more participants and run a user study with a greater number of participants with more variety of products beyond the four types of items we examined in this study. Also, we will work on implementing a standalone system with an advanced image-based deep learning model [5, 13] which can visually identify the condition of a grocery product, particularly fresh food that is not labeled on a product. Once implemented, we hope to conduct a user evaluation of the system in a realistic scenario. While the functionalities of the current prototype are limited, we expect the future system to improve the independence of PVI in grocery shopping experiences by receiving detailed product information that has not been accessible before.

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