Improving Mealtime Experiences of People with Visual Impairments

SeungA Chung*
ewhacsa@ewhain.net
Ewha Womans University
Seoul, Republic of Korea

Soobin Park*
park_sb@ewhain.net
Ewha Womans University
Seoul, Republic of Korea

Sohyeon Park
cookiedough0911@ewhain.net
Ewha Womans University
Seoul, Republic of Korea

Kyungyeon Lee
ruddus716@ewhain.net
Ewha Womans University
Seoul, Republic of Korea

Uran Oh†
uran.oh@ewha.ac.kr
Ewha Womans University
Seoul, Republic of Korea

ABSTRACT

A number of studies have been conducted to understand the accessibility issues that people with visual impairments experience. However, most of these are limited to navigation and object recognition tasks. In this study, we focused on providing mealtime assistance. We first conducted a preliminary online survey with 91 participants and an in-depth interview study with eight participants with visual impairments and two social workers. Based on the findings, we identified various difficulties that people with visual impairments face during mealtimes, and types of dish-related information they wish to get before and during meals. To understand the implications for designing the interaction of a meal assistance system for people with visual impairments, we then implemented a prototype in a virtual environment and conducted another user study with 7 participants for evaluation. Reflecting the findings, we suggest design recommendations for a future meal assistance system for people with visual impairments so that they can enjoy their meals independently.

KEYWORDS

Meal assistance, visual impairments, online survey, interview, assistive technology, system design

*Both authors contributed equally to this research.
†A corresponding author.

1 INTRODUCTION

According to WHO's 2019 statistics [46], at least 2.2 billion people have visual impairments or blindness worldwide, who experience difficulties with various food-related problems[6]. The difficulties include purchasing food in the market or prepare meals [6, 22–24, 27, 44]. Kostyra *et al.* [27], for instance, studied food-related challenges that people with visual impairments (PVI) face focusing on identifying environmental factors that need to be considered when purchasing food ingredients (*e.g.,* assistance of the salesperson, food-related information such as product labelling in Braille). In addition, Jones *et al.* [24] conducted a survey to identify accessibility issues when PVI prepare meals. Based on the survey responses, they found that detecting uncooked meat and spoiled food, cooking hot meals, and reading the oven's display are problematic during meal preparation. Furthermore, several studies also discovered that PVI tend to have unbalanced nutrition due to their limited food choices or restrictions in accessing the nutrition information [6, 23, 44]. For example, PVI have difficulties acquiring nutrition facts since most of the information is available in magazines or newspapers as printed texts which are not accessible to them [6]. Meanwhile, researchers also investigated obstacles that PVI encounter in a restaurant [6, 27, 45]. Based on the semi-structured interview, Bilyk *et al.* [6] discovered that the format of a menu, attitude of a server, and the distance and the familiarity of the route to a restaurant are factors that PVI consider when they plan to dine out. Similarly, Wan *et al.* [45] conducted an in-depth interview and concluded that the server's attitude, facilities of the restaurant, and aids of navigating to or inside a restaurant need to be improved for the PVI. While a number of meal-related accessibility challenges have been identified, little has worked on suggesting solutions. In addition, while eating with others consists of great social implications [39], the social aspects of having meals of others for PVI has not been studied in depth.

In this study, we first investigated meal-related difficulties that PVI face by conducting an online survey with 91 participants and interview with 8 participants with visual impairments in addition to two social workers. The research questions that we hope to be answered by this empirical study are listed below.

- *RQ1. What challenges do PVI face during meals, if any? How do they cope with these issues?*

- *RQ2. What kinds of assistance do PVI receive from others during meals, and how do these differ from what they hope to get?*
- *RQ3. How can an assistive system be designed to provide the information of the dishes and help PVI locate food?*

Based on the participants' responses, we identified difficulties that PVI experience such as identifying and locating dishes. Furthermore, findings revealed that the types of information PVI wish to get differs; the overall information of dishes on a table when starting a meal, and the location of a particular dish during a meal. Our findings also show that assistance is needed for PVI when enjoying meals with others especially when dishes are shared although they wish to be able to have meals with independence. Reflecting the findings of the survey and interview, we designed and implemented a prototype in a virtual environment focusing on the design interaction of the system for understanding how to assist PVI with identifying the name and the location of dishes without getting help from others. We demonstrated the potential of the proposed system through a user study with seven participants with visual impairments.

The contributions of this research are as follows: (i) the identifications of challenges that PVI face before and during meals, (ii) the implementation and evaluation of a system for assisting PVI while having meals (iii) design suggestions of a standalone meal assistance system for supporting PVI's independent meal experience.

2 RELATED WORK

This work builds upon prior studies to identify food-related challenges that PVI experience and provide information about the surroundings to PVI.

2.1 Food-related Challenges

A number of studies have been conducted to understand food-related barriers that PVI experience (see [23] for a review). It can be divided into two main categories: nutrition balance and dining out. As for the balanced nutrition, Vagi *et al.* [44] investigated the factors that affect the nutritional status of PVI. The authors confirmed that it influences one's behaviors in grocery shopping, meal preparations, and food intake. For instance, PVI purchase food without knowing that there are healthier choices, or that do not require cooking (*e.g.*, cutting, boiling), as found in [6, 27]. In addition, Bilyk *et al.* [6] also stated that PVI have difficulties in accessing the nutritional information since most information is provided through visual sources. As a result, nutritional problems have occurred, such as abnormal body mass index (BMI) with a high proportion of obesity and malnutrition.

Meanwhile, the difficulties of visiting restaurants for PVI were also studied [11, 27, 45]. For instance, Chung and Lue [45] conducted an interview study with 10 participants with visual impairments and identified a number of issues; the unfriendly attitude of restaurant servers, inaccessibly designed facilities which make it hard or unsafe for PVI to navigate to or inside a restaurant. Moreover, identifying the location of the dishes and utensils on a dining table was found to be difficult. Similarly, Kostyra *et al.* [27] conducted an interview and a survey with PVI (8 and 250, respectively). They also discovered that the restaurant servers' unfriendly attitude, restrictions for visiting a restaurant with a guide dog as well as

discomfort of asking others for help were common problems. Dias de Faria *et al.* [11], on the other hand, conducted a focus group study and a survey with 203 PVI to determine the attributes of an ideal restaurant that PVI consider to be important and the results are as follows, from the most to the least important attributes: easy access to a server (*e.g.*, a button bell to call a server), low-intensity lights and sounds, round tables, and a customer service.

Despite the large number of studies on food-related accessibility problems for PVI, there have been few studies on how PVI access dish-related information on a table with or without the assistance of others and how their meal experience can be improved. In this study, we focused on providing useful information to PVI while they are having meals so that they can enjoy their meals independently without asking for others' assistance.

2.2 Existing Technologies for Improving Meal Experiences of PVI

Although not particularly designed for improving dining experiences, various technologies have been proposed for PVI, which can be used or extended for the very purpose—from leaving one's house to visit a restaurant, walking inside a restaurant, ordering and identifying food. As for visiting a restaurant, outdoor navigation systems for PVI can be used to assist PVI with the trip [2, 13, 17, 36, 41]. Moreover, for fixed spatial information such as a floor plan, accessible maps [12, 20, 49] and navigation systems for indoors [21, 37, 40, 48] can help PVI to navigate inside a restaurant. Meanwhile, computer-vision based object recognition techniques [8, 15, 16] can also be used to detect and inform objects located inside a restaurant such as obstacles on the way, an empty seat and signs (*e.g., exit, restrooms*). Existing food recognition system, which was designed to support food tracking for anyone who wished to have healthy diet, [30, 31] can assist PVI to identify different food on a table once served. For instance, Ming *et al.* [31] implemented a smartphone application called DietLens, which identifies food photos and tracks users' dietary habits using deep-based recognizer. Also, it links users, doctors, and social media, through which users can get real-time feedback such as medical information related to food nutrition.

Although not particularly for meal assistance, mobile app based assistance for locating objects were proposed [4, 5]. Bigham *et al.* [5] introduced VizWiz::LocateIt, a mobile application which provides audio feedback that conveys the location of a specific object, based on the picture PVI took, and demonstrated how the system can be used to locate grocery items. Similarly, VizLens [18] is a system that provides real-time feedback and guidance of the inaccessible interfaces such as microwaves by combining the technology of computer vision and crowd-based labeling. In the user studies, the PVI were asked to 1) position the microwave's buttons and 2) press the series of buttons to start cooking by utilizing this system. And the result proved that the accuracy and usability of this system. While these prior works on dynamic guidance are shown to be effective for PVI, little has studied how these guidance can be used to convey the location of certain dishes on a table which is known to be important [45].

Inspired by these promising studies and technologies, we study current accessibility issues that PVI face focusing on dining out

experience with others, and how a future system can be built to provide the proper information at the right time and guidance towards a specific dish.

3 PRELIMINARY ONLINE SURVEY

To have a deeper understanding of the barriers PVI face when having a meal at a restaurant with or without others, we conducted an online survey targeting people with visual impairments whose age is between 18 and 65. The survey lasted for 7 days starting from May 1st, 2020.

3.1 Participants

A total of 91 PVI participated in our survey where they are recruited through local organizations and by word-of-mouth. Fifty-two of them were male (*N* = 57.1%) and 39 of them were female (42.9%). Most of them were in their 20's, 30's and 40's; 2.2% were in their 10's, 31.9% were in their 20's, 26.4% were in their 30's, 30.8% were in their 40's, 6.6% were in their 50's, and 2.2% were above 60's. In terms of their vision, 63 participants reported themselves as totally blind, whereas 28 reported that they have low vision.

3.2 Procedure

The survey was conducted using Google Forms, which was designed to take approximately 15 minutes consisted of 20 questions. The questions covered various topics including their frequency of dining out, difficulties in identifying dishes, and types of assistance they get from others during mealtimes. We designed the survey question based on previous studies related to meal experiences [27]. All participants had a chance to opt for a draw for a Starbucks gift card at the end of the survey.

3.3 Findings

3.3.1 Frequency of Dining Out. When asked how often they eat out alone, the majority of the participants (61.5%) answered that they hardly do so. The most common reason was *'difficulties in getting help from others'* (47.3%). Other reasons include *'self-conscious about others'* (36.3%). They also found it difficult to use kiosks for selecting menu items and get information about restaurants. On the other hand, when asked how often participants eat out with other people, almost half of the participants responded to *'at least once a week'*, which is similar to the frequency of United States citizens dining out per week [10]; *'once every two to three days'* and *'once a week'* had the highest number of responses (23.1% each). When asked about their reasons for dining out with other people, the top response was *'an appointment with others'* (81.3%), followed by *'desire to eat a specific menu'* (39.6%), *'a special day'* (23.1%), and *'uncomfortable eating alone'* (14.3%).

3.3.2 Information Needs Regarding Dishes. We also asked participants about the types of information they would like to know before and during a meal, and the responses are presented in Figure 1. When dishes are first served on a table, participants wished to have the following information about each dish such as name, location, price, served amount, ingredients, temperature and calories as well as the total number of dishes. Similarly, participants wished to
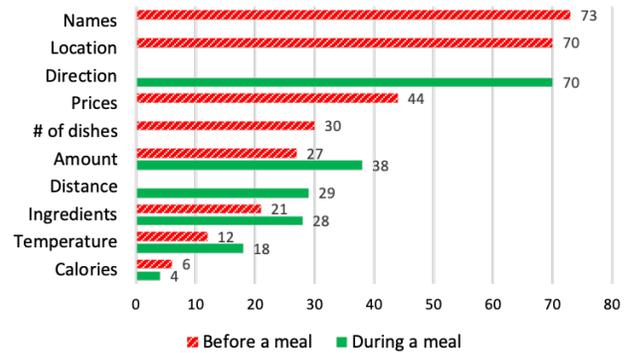
Figure 1: Types of information participants wish to know about served dishes before and during a meal (colored in red and green, respectively). Multiple responses were allowed (*N* = 91).

be informed with the following during a meal: left amount, ingredients, temperature, and calories. However, while participants wished to know the overall location of dishes at the beginning of a meal, they care about a specific *'direction'*(76.9%) and *'distance'*(31.9%) towards a particular dish during a meal.

3.3.3 Difficulties in Identifying Dishes. We asked participants in which situations identifying dishes becomes difficult, and the responses were slightly different depending on whether they have started eating or not. For instance, at the beginning of a meal, most of the participants (82.4%) responded to *'when there are too many dishes'.* followed by *'when dishes or plates are similar'* (33.0%), and *'when not having anyone to explain the locations of the served dishes'* (30.8%). However, as for during a meal, almost half of the respondents (49.5%) replied that it is frustrating when they cannot find the desired dish by themselves. Related, 34.1% of them reported that remembering the location of dishes is difficult. Having to keep asking for help was the next frequent response (33.0%) that was also an issue during a meal.

3.3.4 Strategies for Locating Dishes. Participants were also asked how they locate dishes to ask for help as little as possible. About half of the participants reported that they memorize the dish locations (47.3%), or ask others to bring particular plate closer to them (45.1%). For participants who have residual vision wished to first visually grasp the kinds of dishes served on a table before they start eating (17.6%). Meanwhile, almost 20% of the participants responded that they do not have a strategy; they do not care to look for certain dish (*e.g.*, eating whatever comes in hand) (19.8%).

3.3.5 Types of Mealtime Assistance. When asked for the types of assistance participants receive when having meals, more than three-quarters of the participants (78.0%) answered that they ask others to put small portions of dishes into their plate. As for the assistance of identifying dish locations, 72.5% of the participants said they get help in understanding the overall location of the dishes when served, while only 34.1% get dish-specific location information while eating. There were other responses such as listening to another person's explanation about the location (37.4%) and having

someone lead their hand towards the desired dish (33.0%). Apart from that, respondents also ask others how to eat particular dishes that they are unfamiliar with (20.9%).

3.3.6 Concerns When Dining Out with Others. Although PVI get various types of assistance as above, most of the respondents (79.1%) felt uncomfortable asking for help from others. In addition, one-third of them (29.7%) felt that asking for help is cumbersome, and 23.1% experienced discomfort when the conversation does not go smoothly with someone who is helping them. In addition, 47.3% of the participants were concerned about making mistakes (*e.g.*, spilling food or bothering others for help), which happens more frequently when sharing dishes than having one plate dish for each. Indeed, they felt uncomfortable when they had to share dishes with others.

4 IN-DEPTH INTERVIEW

Based on the survey findings, we conducted an in-depth interview focusing on identifying implications for designing a meal assistance system for PVI.

4.1 Participants

To recruit the interview participants with visual impairments, we asked the survey participants to leave their phone numbers at the end of the survey if they were interested in participating in a follow-up phone interview. In total, we recruited eight participants with visual impairments for the interview (see Table 1). Additionally, in order to investigate the various eating experiences of PVI on the view of those who often eat with them, we recruited two social workers who eat with PVI almost every day from the social welfare center for PVI. One social worker (S1) was male in his 40s working as a living rehabilitation teacher for PVI, and the other social worker (S2) was female in her 30s working for publishing braille.

4.2 Procedure

We conducted in-depth mobile phone interviews with eight participants with visual impairments. In the interview, we asked follow-up questions based on the participants' responses from our survey as a semi-structured interview. A follow-up question probed for a more specific answer to the participants' initial responses. Moreover, two social workers participated in our mobile phone interviews. The duration of the interviews ranged from 20 to 40 minutes, and each participant was given a Starbucks gift card.

4.3 Data and Analysis

We conducted open coding [35] on transcribed version of audio-recorded interview responses. Two researchers developed initial codebooks, and two researchers independently coded 10% of the randomly chosen responses iteratively. To evaluate the inter-rater reliability of two independent coders, we computed Cohen's kappa, which was 0.94 after the final iteration. Affinity diagramming [19] was conducted to find common themes across the codes.

4.4 Findings

4.4.1 Dish-Related Information Needs. We found that there was a difference in what information participants wished to know before and during their meals. As in the survey, participants wished to know the names of all the dishes, prices, and the total number of dishes before starting their meals. While they wish to know the prices when choosing menu items, they would like to be informed with the total number of dishes and their names and location when dishes are served (N = 3, 8, and 8, respectively). In terms of the amount, more participants preferred to know the remaining amount of food while eating (P1, P3, P5-7) than the served amount of food at the beginning (P1, P7), similar to the survey. Regarding the ingredients, P5 preferred to be informed when the meal is first served, while P3 would ask for the ingredients of a specific food during a meal. Two participants (P1, P7) wished to know the ingredients both at the start and during meals, for instance, to decide whether to eat the particular dish or not.

Unlike the results of the survey, interview participants found meal temperature highly important especially while having meals. For example, half of the interviewees (P3-5, P7) wished to know if the food is too hot. They claimed that rather than knowing the exact temperature of the food, they would like to get informed or warned about hot dishes for safety. Going further, both social workers said that they explain the temperature, and for instance, S1 mentioned that,

> *"I just tell them only the hot ones. Like something's going to be a little hot, be careful. Besides, the temperature of foods that are cold or such are not discussed in great detail. But I tell them that it's hot only for dishes that they need to be careful about and that they can get hurt."* (S1)

4.4.2 Preferred Dish Arrangements. More than half of the participants (P1-2, P6-8) mentioned that they do have a preferred dish

Table 1: Participants' age, gender, visual acuity as well as their frequency of dining out alone and with others.

PID	Age	Gender	Visual Impairment (best eye)	Dining Out Alone	Dining Out with Others
1	40s	Male	Totally blind	Hardly ever	Hardly ever
2	20s	Male	Totally blind	Once in two weeks	Once every 2-3 days
3	50s	Male	Totally blind	Once in two weeks	Once a week
4	40s	Female	Totally blind	Hardly ever	Hardly ever
5	30s	Female	Totally blind	Hardly ever	Once a week
6	30s	Male	Low vision	Once a week	Once every 2-3 days
7	30s	Male	Totally blind	Once every 2-3 days	Once every 2-3 days
8	20s	Female	Totally blind	Hardly ever	Once a week

layout. They mainly preferred the form of a checkerboard or a square, which meant dishes were arranged side by side.

> "It's better to put dishes in the form of a checkerboard. That way, it's easy for me to explain and it's easy to understand others' explanations." (P6)

4.4.3 Difficulties in Getting Information About the 'Location' of Food.
As in the survey, we recognized that participants had difficulty locating dishes, especially when there were too many dishes or similar-looking dishes. According to the interview, buffets were frequently mentioned as a challenging place to visit due to their excessive number of dishes for both participants, which is also mentioned by social workers. Dishes with similar color, size or shapes were perceived to be indistinguishable as well. Four participants (P1,P3,P5,P7) said that it is challenging to locate dishes if dishes are placed too close to each other.

While it was not mentioned in the online survey, three participants (P1, P7-8) reported that it is difficult to know where particular dishes are if its location has changed. In particular, P1 mentioned that despite having listened to the description of the dishes' location beforehand, it was difficult to notice that the position of the dish had changed which made it impossible for him to find the dish.

4.4.4 Strategies for Locating Dishes.
There were three strategies for locating dishes. Memorizing all the dish locations when first served (N = 5), and not having any strategy (N = 4) were mentioned reflecting the survey results. In addition, four participants (P2-3, P5, P7) commented that they try all the dishes one by one to figure out the dish locations if they do not have anyone to get help. For example, P5 noted that,

> "If it's a restaurant I have once been to, then the clerk knows that I'm blind. So if I ask him for an assistance, he would provide help. But it's available only when they are free. If they are busy then this is impossible. Yeah, so in this situation, there's nothing else I can do other than figuring out the location of each food by trying all of them one by one."

4.4.5 Types of Mealtime Assistance.
All participants responded that they get assistance from sighted people, it can be categorized into one of the followings: (i) getting verbal descriptions of the dish location, (ii) asking others to put a small portion of the food into their plate, (iii) having others bring the dish nearby, and (iv) getting others to lead their hands to recognize the location. In addition, social workers suggested that they provide all four types of assistance to PVI depending on the situation, for instance, according to their duration of visual impairments or preference.

- **Describing the dish location (N = 8).** Far from survey results, where only 40% of the survey participants mentioned that they like listening to other's description about the location, all interview participants desired to have the dish location verbally described by someone, especially the directions of the dishes. All participants mentioned that they received such descriptions when all the dishes on a table were first-served. Moreover, all but except P2 said that they sometimes get description of a particular dish as needed. When getting directional information, all liked the direction to be described in relation to the clock but P3, who preferred sequential description from the left or the right without the analogy to the clock.

- **Putting a small portion of food into a personal plates (N = 8).** While it was not indicated in the survey as a way to locate food, all participants had asked others to put some of food into their plates so that they do not have to look for particular food on the table or keep asking others for the location of particular food. For example, P7 noted that if there are many side dishes, his companion would bring small amounts of into his plate.

- **Having dishes brought nearby (N = 7).** Like survey results, all interview participants except P4 have particular dishes brought closer to them. For example, they ask others to bring the entire plate of the dish they like closer to them, mostly before starting a meal. P8 said that,
  > "(...) If I have side dishes that I like, people bring such dishes next to me, really near to my rice bowl [personal plate]. Since these are the side dishes that I eat the most, people are being kind to do so, so I can eat those dishes more comfortably."

- **Hands being led to dishes (N = 4).** Furthermore, as mentioned in the survey, half of the participants wished to find the location by leading their hands by someone to identify the overall location of the dishes. In particular, all of them emphasized that leading their hand to locate the food is helpful when trying to understand the overall and accurate dish location, including the distance of the dishes.

We also asked two social workers about how they inform the location of dishes. Both social workers said that the food's location is described verbally using clock direction. However, for distance information in particular, S1 would lead PVI' hands toward each dish to help them understand how far each dish is instead of describing the distance by words. Social workers also mentioned that the types of assistance vary depending on the PVI's level or duration of visual impairments, sense of spatial awareness, and preference. For instance, S1 mentioned that,

> "Now if the PVI has had visual impairment for a long time or if I know the person very well, um, then only explaining the location by words can be enough for them. Or for those who recently lost their sight or lack of spatial perception, I would just take their hands and if this is not even possible, I would bring a bit of the food to their personal plate. I adjust the method based on the people."

4.4.6 Difficulties When Eating with Others.
We also asked the difficulties that PVI face when eating with others.

- **Making a mess (N = 4).** Half of the participants were worried about making a mess when dining out with others. For instance, one participant mentioned that,
  > "When there are a lot of dishes, even if someone next to me tells me where the dishes are, since I can't see them, I can't grab it correctly. When I'm eating with chopsticks, I can't seem to pick it up correctly and keep dropping it, which is really frustrating. I would feel uncomfortable eating with other people because I keep spilling and dropping food. So yeah, it's really uncomfortable." (P3)

- **Eating pace (N = 4).** In addition, unlike the survey where only 22% were concerned with others' eating pace, half of the participants found it challenging to keep up with the pace of others and ending up being cautious. Participants said,

"I've been eating too fast, so... there was a situation where the other person didn't eat at all." (P7)

"When you eat with close acquaintances, or with co-workers, people try to eat meals in the same pace as others. But it's kind of uncomfortable to ask the other person how much they have eaten so far every time. In my case, I eat really slow, so I tend to eat in a hurry when eating with others. But because of this, I sometimes have digestion problems or spill food." (P8)

- **Self-consciousness (N = 3).** Notably, self-consciousness were mentioned by interview participants. Three participants (P2, P7-8) noted that they are uncomfortable with getting other people's attention and feel self-conscious.

  "You can't even do this? I've heard a lot of things like that. I've often heard people say, like why do you keep asking me to do it for you? You can do it by yourself." (P2)

- **Identifying the amount of food left (N = 3).** Lastly, three participants (P1, P3, P7) commented that they feel uncomfortable in situations where people share food with others because they cannot tell how much food is left. Indeed, S1 said informing the amount of left food is necessary for PVI as they sometimes hover around empty plate when they do not know the amount left during their meals. In addition, P3 commented,

  "I need to know the amount of food left to know how much more I can eat. How can I know that? Well, it would be nice if you could tell us how much this food is left to eat."

4.4.7 Concerns when Getting Assistance During Meals. While we identified assistance PVI had received, all participants felt uncomfortable when getting help from other people confirming the survey results. Herein, we investigated explicitly what types of discomfort PVI felt when receiving help at mealtimes.

- **Distracting others (N = 7).** All participants except P4, felt bad to ask for help when eating. For instance, they felt sorry to ask about the menu when there is a long list of menu items. They are also concerned because they think they might distract others by asking for help while they are enjoying their meals. Indeed, from the view of a helper who eats with them, S2 was concerned about the reduced meal time due to assistance and the desire to help PVI. S2 mentioned that,

  "I feel responsible to help them but still, it is uncomfortable because I have to use my mealtime to help them and explain about the dishes. I can't say that I am helping them with passion but I know it's my obligation."

- **Unfamiliar people (N = 4).** Moreover, half of the participants (P1-4) said they had no difficulty eating with their acquaintances, but they felt uncomfortable to ask for help when eating with unfamiliar people. For example, P2 mentioned that it is difficult to ask people that he hardly know to put some food into his plates when there are many types of dishes on the table.

- **Excessive care (N = 3).** Getting excessive care was expressed as discomfort by three participants (P3, P5, P8). P8 explained that it was a burden when the other person kept spoon-feeding and asking questions, although the participant had only asked for the dish's location. Similarly, P5 said it was uncomfortable when the other person held her hand and led her to the dish, even though words were enough to fully inform her.

- **Inaccurate communication (N = 2).** Finally, two participants (P3, P5) experienced inconvenience due to poor communication when receiving help as shown in one of the survey results. P3 had experienced a hard time communicating when adding the sauce because of the difference in the amount and type of sauce the other person added when providing help.

  "(...) Even though I wished for one particular sauce, they would add something else as a kind gesture. Some people might put two or three sauces, but I only wished one thing..." (P3)

5 DESIGN PROBE STUDY

Meal assistant robots that bring the dishes closer to users or feed users have been studied for people who cannot control their upper body [7, 34, 47]. However, through our survey and interview study, we found that PVI face challenges during mealtimes as well. Thus, we designed and implemented a system that focuses on providing information about the dishes placed on the table to PVI, and guide their hands towards a particular dish without other person's assistance. Then we conducted a user study for evaluation.

5.1 The Design of the Prototype

Since our focus is to understand how to provide information and guidance for PVI during mealtimes rather than recognition of the dishes on the table or tracking users' hand, our design probe system was implemented in the environment of Unity 2019.2.17f with a head-mounted device (*i.e.*, HTC VIVE Pro Eye) based on virtual reality (VR). To get the voice command from the users and provide the output to the users, we used IBM's Watson[1] to receive users' voice input through the microphone and convert it to text. We also used text-to-speech module to provide requested information verbally to the users. The system supports two types of assistance: (1) providing dish-related information on a table, and (2) guiding users' hand towards a particular dish.

5.1.1 Dish-related Information. The system provides the **overview** information of the dishes on a table when it detects the users' voice command saying "overview". It informs the total number of dishes followed by the dish arrangement (*e.g., "There are in total 6 dishes straightly lined up"*), and how dishes are spread about (*e.g., "Starting from 10 o'clock to 2 o'clock."*). Lastly, it notifies the name of each dish one at a time from left to right. It also allows the users to ask the amount of food (*i.e., "How much is the sandwich left?"*)(**food amount**). The system conveys information of the amount of a particular dish in four levels: *Full, Half, Little*, and *Almost None*.

5.1.2 Hand Guidance. The system also helps the users to find a particular dish on a table with audio feedback. For instance, when a user asks for the location (*e.g.*, "Where is the sandwich?"), it first verbally conveys the relative direction of the dish (*e.g.* "It's at 2 o'clock"), which we refer as **verbal guidance**. Then it plays beeps where its frequency gets higher as a user's hand gets closer to the target (**beeping guidance**). If the user finds a dish other than the target, the system informs the location of the target dish in a relative direction from the user, such as whether it is at the left or the right of the user. In addition, the system cautions the user if the temperature of the target dish is too hot.

---

[1] https://www.ibm.com/watson
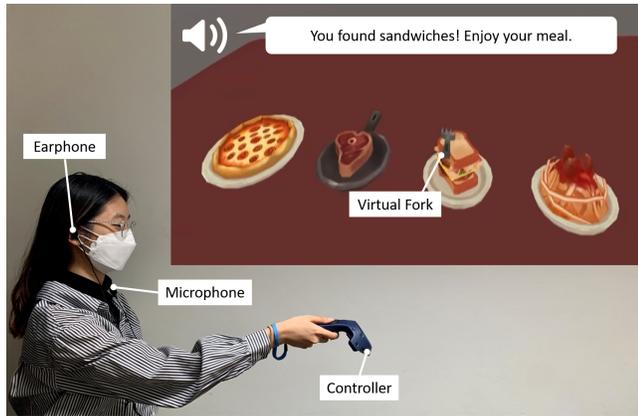
Figure 2: The experiment setting for the *hand guidance* and the screenshot of the virtual environment at the upper right of the figure to demonstrate how dishes were laid out on a virtual table. The virtual environment was not visible to the participants.

5.2 Participants

We recruited 7 participants for the experiment where P1 and P7 had also participated in the interview. Five were totally blind while the other two had low vision; see more details in Table 2. Since our system is run in VR, we also asked the participants' prior experience with VR, and only two had tried it before.

5.3 Apparatus

For the user study, we used our prototype described in subsection 5.1. It ran on a desktop computer running Windows10 which had a CPU of AMD Ryzen 7 1700 with a RTX2080 graphic card and a 16GB of RAM. As shown in Figure 2, we set a virtual environment using Unity where six different food items (*i.e.*, pizza, steak, sandwiches, spaghetti, hot dog, and hamburger) were placed in a straight line on a table. Participants were asked to sit on a chair while holding a controller of HTC VIVE Pro Eye which was used to track the participant's hand. In addition, an external microphone and an earphone were used to get the voice input from and to convey audio feedback to participants. Note that the earphone was plugged into only one ear to allow the participants to listen to instructions during each session. All sessions were video-recorded.
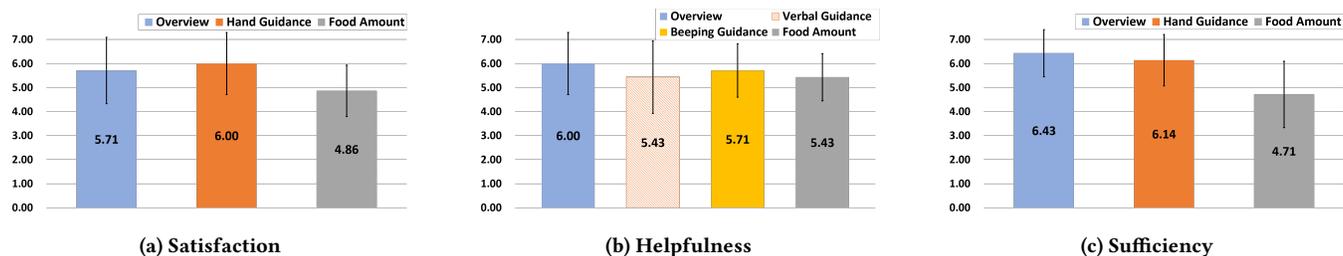
5.4 Procedure

The experiment began by asking the participants about their overall dining experience. Then, we explained how to use each device(controller, microphone, earphone) and the experiment process. The study consisted of three parts, testing each of the following features of the system: *overview*, *hand guidance*, and *food amount*. For each feature, we first explained the purpose and how to use the feature, and the participants were instructed to complete a task on a particular food (*i.e.,* sandwiches) we requested. Then we asked the participants to use the feature freely on different food items. As for the *overview* feature, the task was to issue a voice command by saying *"overview"* and listen to the overall information about the number, types, and the name of the dishes. For the *hand guidance* feature, we asked participants to request for the location of one of the dishes introduced during the overview and reach out for the dish with the help of verbal and beeping guidance. If they found the right food at their first attempt, we asked them to find a wrong dish item so that they know how corrective guidance is provided. Lastly, for *food amount* feature, we requested the participants to ask for the leftover amount of a particular food again, using a voice command. Then for each feature, we collected the participants' subjective ratings on satisfaction, helpfulness and the sufficiency of the information the system provides in a 7-point Likert scale after they finished the task. We also collected the participants' questionnaire responses and comments about the system such as needs of improvements. Lastly, we gathered the system usability scale score from each of the participants at the end of the study. We provided $45 worth of gratitude to each participant.

5.5 Findings

Here we summarize the findings of the design probe study, focusing on the subjective responses in terms of three metrics (Figure 3) and SUS scores (Figure 4).

5.5.1 Overview. Among the three features, *overview* received high ratings in satisfaction, helpfulness, and sufficiency. While P1 and P4 were satisfied with the clockwise description, P6 was concerned that some PVI who are congenitally blind do not know the clock position. Also, three participants (P1-2, P4) responded that the feature is helpful since it provides the location of the overall dishes. However, P7 commented that it is annoying to use the feature repeatedly whenever she forgets the information. Participants gave comments regarding the information the feature provides. P3 recommended

Table 2: Participants' demographics including age, gender, visual acuity, period of their current vision state, and their prior experience with VR.

PID	Age	Gender	Visual Impairment (best eye)	Period of Their Current Vision	Experience with VR
1	24	Male	Totally blind	Since birth	No
2	28	Male	Totally blind	Since birth	No
3	25	Male	Low vision	Since 3 years ago	Yes
4	44	Male	Totally blind	Since 30 years ago	No
5	28	Male	Totally blind	Slowly decreased	No
6	45	Male	Low vision	Since birth	Yes
7	27	Female	Totally blind	Since 10 years ago	No

Figure 3: The number of responses showing the average score of Likert scale for three metrics. Error bar represents the standard errors.

to allow users customize the settings so that they can choose the type of information they would prefer to receive. Also, P5 wished to receive a warning regarding the dish plates that could break easily.

5.5.2 Hand Guidance. Participants were most satisfied with the *hand guidance.* P3 and P7 liked getting directional feedback when they found unintended dishes that were not the one they were looking for. Moreover, P3 mentioned that receiving a description of the dish's location in clock direction (*e.g.,* 2 o'clock) is satisfying compared to in left or right. However, P4 had difficulties in finding the exact dish relying on the beeping sounds since he was not familiar with this type of feedback. Also, it was found that the *beeping guidance* is more helpful than the *verbal guidance.* The main reason was that explaining the location of the dish in clock position as in *verbal guidance* may not be familiar to the blind. Some participants suggested other methods that could replace the beeping sound. P6 suggested a different method in providing the distance information of the dish the PVI wish, which was using a volume of the sound. Moreover, three participants (P3, P5, P7) desired haptic feedback in case of loud and noisy environments. In addition, it is found that the information provided by the feature is sufficient. However, P1 and P5 suggested providing an option between *verbal guidance* and *beeping guidance* in consideration of feedback preferences.

5.5.3 Food Amount. Participants responded that the *food amount* feature is satisfying but can be improved. P1 commented that it felt more convenient than their usual method, using cutlery to estimate the leftover amount. However, majority of the participants (P2-7) mentioned that the description about the amount is ambiguous and explicit criteria should be given with quantifiable units. Six participants (P2-7) recommended that more explicit criteria should be given such as pieces, percentage or grams when providing information about the amount of food. Although it affected the helpfulness and sufficiency of the feature, P3 and P5 mentioned that the feature would allow them to avoid embarrassing situations of not knowing the amount of food and help them divide the food equally with other people.

5.5.4 Preference. The majority of the participants (P1-6) chose *overview* as their most preferred or most likely to use feature. The major reason was that the feature provides the most important information in finding the dishes they desired. However, P7 preferred *food amount* due to embarrassing experiences of not knowing the remaining amount of food.

5.5.5 System Usability Scale. We asked the participants to evaluate the overall usability of the system using system usability scale. As a result, the system was graded as B with the score of 76.1. As shown in Figure 4, participants rated higher in ease and confidence in using the system than the possibility of frequent usage and learnability. On the other hand, the complexity of the system and necessity of other people's support was relatively low. When asked about the inclination to use the system in real life, participants had the willingness to use it in general but mentioned that some improvements should come first, especially considering the social recognition of disability. P3 said he would be reluctant to use voice command when he is without a companion in a restaurant. P6 commented that using the system could be a disclosure of disability. He suggested that the amount or type of food should be told when the cutlery is placed on a dish without having to ask for the amount.

6 DISCUSSION

6.1 Needs and Strategies During Meals

The findings of our study deepened the understanding of accessibility issues of PVI during mealtimes and showed the need for an assistance system for supporting independent eating. We also identified the types of food-related information that should be provided in such a system.

6.1.1 Locating dishes on a table. Our findings confirmed that it is difficult for PVI to find the location of the dishes at mealtimes as in previous studies [22, 24]. In addition, we identified the causes through the survey and interview, such as too many dishes, indistinguishable plates, and changes in the dish location. Furthermore, we investigated PVI's strategies for locating the dishes, which were developed due to their discomfort of getting assistance from others. However, even though they adopted strategies that can minimize the need for assistance, assistance was still required from others except for when they try every dish themselves. (*e.g.,* memorizing the dishes' location once informed, asking others to deliver small portions of multiple foods on their personal plates). Based on the findings from the design probe study, we demonstrated how dish locations should be delivered to PVI: an overview before a meal and guidance towards a particular dish during a meal.

6.1.2 Dish-related information needs. Our survey and interview study revealed not only the types of information that PVI wish to receive but also when they would like to receive such information,
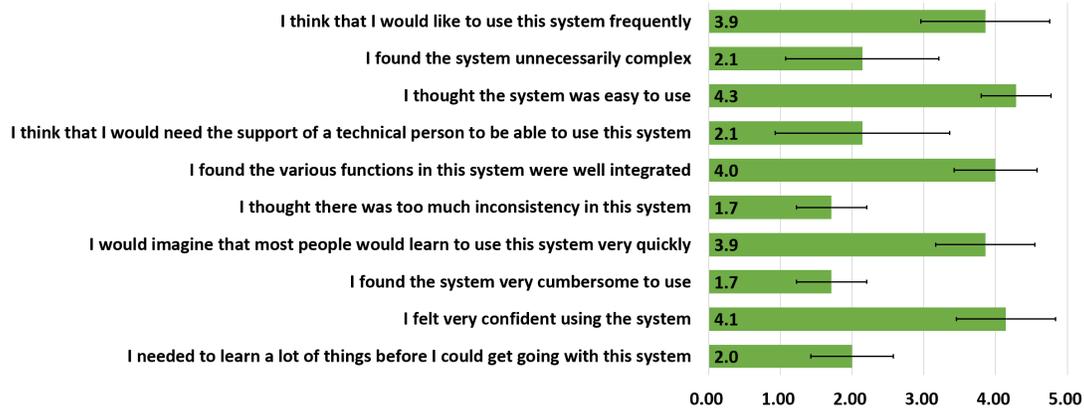
Figure 4: Itemized mean value of System Usability Scale.

which differs depending on whether the meal has started or not. For instance, when the dishes are just served, participants wish to get the overall information such as the number of dishes, names, and locations, while direction and amount were considered more useful once they start eating. We implemented an assistive system based on the findings, and showed its potential usefulness. Moreover, the temperature of the food was considered important when it is hot, reflecting the prior study that PVI are concerned about the safety and fear of burning themselves when dealing with hot elements of food [6]. To provide temperature-related information, one should consider having a thermal camera for a future system.

6.2 The Desire for Social Eating

For PVI, the dining experience tended to be a social event, but they had many concerns when eating meals with others, especially when with someone unfamiliar.

6.2.1 Concerns of Making Others Uncomfortable. Our survey results confirmed that PVI are highly concerned about making mistakes when having a meal with others such as making a mess which reflects prior findings [6, 27]. Additionally, we found that PVI are also concerned with eating pace, disturbing the conversation, and distracting others' mealtime. While the current version of our proposed system does not inform users if they are about to make a mess as they reach out for food, we hope that our system can be used to provide the estimation of the eating pace of others by providing the information about the amount of food on the table. Moreover, we expect the system to relieve the concerns of disturbing others by enabling PVI to get dish-related information themselves.

6.2.2 The Importance of Social Eating. While PVI have various concerns when eating out with others, our findings confirmed that PVI's frequency of eating out is not quite different from sighted people. Together with the prior studies that showed socializing with other people at a restaurant while having meals together was a predominant form of social activity for PVI [3, 6, 14], our study findings highlight the importance of improving the dining experience of PVI.

6.2.3 Difficulties in Getting Proper Assistance. PVI felt uncomfortable asking for help from someone, especially when they are not close. In addition, PVI showed confusion about how we described the food amount (*e.g., full, half*) as it can be ambiguous. The proposed system can be pre-configured to provide adequate and precise information (*e.g.*, the number of pieces, the weight in grams) upon requests, which will be investigated in the future.

6.3 Suggestions for a Meal Assistance System

Findings demonstrated that our proposed system is found to be useful for supporting independent mealtime of PVI. However, several improvements can be made. The system should support subtle interaction depending on the situation, such as PVI's social context. Besides, the system's hardware and features need to be designed for use in a real-world setting.

6.3.1 Supporting Subtle Interaction. Although PVI dine out with other people frequently, they concern about disturbing other's mealtime or keeping the pace of eating with others. While our findings imply that our proposed system can be used to relieve such concerns, it has some limitations when having a conversation with other people during mealtime due to the design of the supported interaction. As for the feedback modality, it is necessary to provide haptic feedback considering that audio feedback may not be delivered properly in noisy environments. Moreover, users may be able to focus more on conversations with haptic feedback than beeping sound as it does not share the same audio channel. Yet, continuous haptic feedback can also be a distraction [9], so a care must be taken. In addition, less obtrusive input mode should be supported other than voice command for having smooth conversation such as subtle gestures including on-body input [33].

6.3.2 System Implementation for a Realistic Scenario. We have investigated how to convey food information in virtual reality settings focusing on the design of interaction to simulate and be aware of how to provide information and instructions during mealtime experiences of PVI. However, to be used in a real-world dining environment, the entire system should be designed as a standalone device.

- **Hardware.** For the implementation, one should note that if the system itself is too large or conspicuous, it can appear as a stigma for PVI [42]. Therefore, we recommend a form factor to be camera-equipped eyeglasses such as OrCam [32]. In addition, mobile phones, which have the advantage that everyone has, can also be supported. However, it would be difficult to hold a mobile phone while eating, so there is a way to solve it with a tripod on one side of the table. Also, as for the output, we suggest using bone conduction earphones for audio feedback as in other assistive devices for PVI not to disturb the conversation with other people. In addition, haptic feedback can be delivered through the smartwatch.
- **Identifying food information.** To identify and retrieve food information from a camera, a deep learning model trained with an excessive amount of food data can be used to identify different dishes' information [25, 26, 43]. Especially to get informed about the remaining amount of food, 3D food volume estimation modules can be implemented [38].
- **Locating dishes and tracking hands.** To get the location of dishes, we suggest using a depth-camera and performing 3D object detection [1, 28] to check the positions of the dish in a 3-dimensional space. Also, by performing real-time hand tracking [29, 50], hands can be detected in 3D space. Once the location of the dish and hand are identified, the system should be able to support the guidance feedback that we demonstrated in the study for PVI to distinguish the location of the dishes.

7 LIMITATIONS

While we present the findings related to PVI's dining experiences, our study has several limitations. First, the restaurants' environments and dietary culture may vary depending on different regions. However, we conducted the study only with those who have grown up in South Korea, failing to reflect the variety of dining experiences people from different cultures may have. Also, the sample size is too small for social workers, who we recruited to broaden our investigation on types of assistance close acquaintances provide when eating meals with PVI. Furthermore, the various dish layouts have not been explored. Instead, the proposed system only dealt with one table configuration with a single row of the dishes and thus further investigation is needed to understand how to convey the dish locations for different layout. Lastly, the user study was conducted in a virtual environment and for a short period of time. The findings could be different in a long term study in a real-world dining environment. In this way, one should be able to understand how diners feel about using the system and what additional features are needed to support social eating, for instance, having conversations during meals.

8 CONCLUSION

We conducted an online survey with 91 participants who have visual impairments and phone interviews with eight PVI and two social workers to understand the dining experiences of PVI. Through the survey and interview, we found that the majority of PVI experience difficulties identifying dishes' locations in several situations (*e.g.*, overly number of dishes, similar-looking dishes, or changes in the location of food) and that most of PVI rely on others for help.

The most general types of assistance include explaining location through words, transferring food to their plates, having the dishes brought nearby their plates, and their hands being led to dishes. PVI also wished to acquire the various types of dish information, and the desired information was different between at the start of the meal (*e.g.,* the total number of dishes, overall names, and location) and during the meal (*e.g.,* location, temperature, and amount of food left). Based on the findings, we implemented and evaluated a prototype to demonstrate how information and feedback should be delivered to help PVI with enjoying meals independently. As a result, we showed the potential of the system while identifying possible improvements. While we focused on understanding the feedback design of the system of a prototype using a virtual environment without concerning the accuracy of dish recognition and hand tracking results, we plan to extend our work by implementing the other parts of the system as a wearable device, which will be evaluated in a real-world situation over a long term.

9 ACKNOWLEDGMENTS

REFERENCES

[1] Adel Ahmadyan, Tingbo Hou, Jianing Wei, Liangkai Zhang, Artsiom Ablavatski, and Matthias Grundmann. 2020. Instant 3D Object Tracking with Applications in Augmented Reality. *arXiv preprint arXiv:2006.13194* (2020).
[2] Dragan Ahmetovic, Masayuki Murata, Cole Gleason, Erin Brady, Hironobu Takagi, Kris Kitani, and Chieko Asakawa. 2017. Achieving practical and accurate indoor navigation for people with visual impairments. In *Proceedings of the 14th web for all conference on the future of accessible work.* 1–10.
[3] Michael Baker, Andie Strickland, and Nicole D Fox. 2019. Choosing a meal to increase your appeal: How relationship status, sexual orientation, dining partner sex, and attractiveness impact nutritional choices in social dining scenarios. *Appetite* 133 (2019), 262–269.
[4] BeMyEyes. n.d.. https://www.bemyeyes.com/. (Accessed on 02/23/2021).
[5] Jeffrey P Bigham, Chandrika Jayant, Andrew Miller, Brandyn White, and Tom Yeh. 2010. VizWiz:: LocateIt-enabling blind people to locate objects in their environment. In *2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition-Workshops.* IEEE, 65–72.
[6] Marie Claire Bilyk, Jessica M Sontrop, Gwen E Chapman, Susan I Barr, and Linda Mamer. 2009. Food experiences and eating patterns of visually impaired and blind people. *Canadian Journal of Dietetic practice and research* 70, 1 (2009), 13–18.
[7] Alexandre Candeias, Travers Rhodes, Manuel Marques, Manuela Veloso, et al. 2018. Vision augmented robot feeding. In *PROCEEDINGS of the European Conference on Computer Vision (ECCV).* 0–0.
[8] Kabalan Chaccour and Georges Badr. 2016. Computer vision guidance system for indoor navigation of visually impaired people. In *2016 IEEE 8th International Conference on Intelligent Systems (IS).* IEEE, 449–454.
[9] SeungA Chung, Kyungyeon Lee, and Uran Oh. 2020. Investigating Three-dimensional Directional Guidance with Nonvisual Feedback for Target Pointing Task. In *2020 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct).* IEEE, 206–210.
[10] Daniela Coppola. 2020. Dining out habits in the U.S. 2019, by frequency. https://www.statista.com/statistics/1085326/dining-out-habits-in-the-us/. (Accessed on 09/07/2020).
[11] Marina Dias de Faria, Jorge Ferreira da Silva, and Jorge Brantes Ferreira. 2012. The visually impaired and consumption in restaurants. *International Journal of Contemporary Hospitality Management* (2012).
[12] Julie Ducasse, Anke M Brock, and Christophe Jouffrais. 2018. Accessible interactive maps for visually impaired users. In *Mobility of visually impaired people.* Springer, 537–584.
[13] Navid Fallah, Ilias Apostolopoulos, Kostas Bekris, and Eelke Folmer. 2012. The user as a sensor: navigating users with visual impairments in indoor spaces using tactile landmarks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* 425–432.

[14] Christina Fjellström. 2009. Food's cultural system of knowledge–meals as a cultural and social arena. *Food in Contemporary Society* (2009), 19.

[15] Giovanni Fusco and James M Coughlan. 2018. Indoor localization using computer vision and visual-inertial odometry. In *International Conference on Computers Helping People with Special Needs*. Springer, 86–93.

[16] Giovanni Fusco and James M Coughlan. 2020. Indoor localization for visually impaired travelers using computer vision on a smartphone. In *Proceedings of the 17th International Web for All Conference*. 1–11.

[17] João Guerreiro, Dragan Ahmetovic, Kris M Kitani, and Chieko Asakawa. 2017. Virtual navigation for blind people: Building sequential representations of the real-world. In *Proceedings of the 19th International ACM SIGACCESS Conference on computers and accessibility*. 280–289.

[18] Anhong Guo, Xiang'Anthony' Chen, Haoran Qi, Samuel White, Suman Ghosh, Chieko Asakawa, and Jeffrey P Bigham. 2016. Vizlens: A robust and interactive screen reader for interfaces in the real world. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology*. 651–664.

[19] Bruce Hanington and Bella Martin. 2012. *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions.* Rockport Publishers.

[20] Leona Holloway, Kim Marriott, and Matthew Butler. 2018. Accessible maps for the blind: Comparing 3D printed models with tactile graphics. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–13.

[21] Rosen Ivanov. 2017. An approach for developing indoor navigation systems for visually impaired people using Building Information Modeling. *Journal of Ambient Intelligence and Smart Environments* 9, 4 (2017), 449–467.

[22] Jason Chaw Jay. 2018. FOODWAYS OF THE VISUALLY-IMPAIRED: TRAVERSING THE BLIND KITCHEN. (2018).

[23] Nabila Jones and Hannah Bartlett. 2018. The impact of visual impairment on nutritional status: A systematic review. *British Journal of Visual Impairment* 36, 1 (2018), 17–30.

[24] Nabila Jones, Hannah Elizabeth Bartlett, and Richard Cooke. 2019. An analysis of the impact of visual impairment on activities of daily living and vision-related quality of life in a visually impaired adult population. *British Journal of Visual Impairment* 37, 1 (2019), 50–63.

[25] Hokuto Kagaya, Kiyoharu Aizawa, and Makoto Ogawa. 2014. Food detection and recognition using convolutional neural network. In *Proceedings of the 22nd ACM international conference on Multimedia*. 1085–1088.

[26] Yoshiyuki Kawano and Keiji Yanai. 2013. Real-time mobile food recognition system. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops*. 1–7.

[27] Eliza Kostyra, Sylwia Żakowska-Biemans, Katarzyna Śniegocka, and Anna Piotrowska. 2017. Food shopping, sensory determinants of food choice and meal preparation by visually impaired people. Obstacles and expectations in daily food experiences. *Appetite* 113 (2017), 14–22.

[28] Michael Laielli, James Smith, Giscard Biamby, Trevor Darrell, and Bjoern Hartmann. 2019. LabelAR: A Spatial Guidance Interface for Fast Computer Vision Image Collection. In *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology*. 987–998.

[29] Vincent Lepetit. 2020. Recent Advances in 3D Object and Hand Pose Estimation. *arXiv preprint arXiv:2006.05927* (2020).

[30] Deborah Lupton. 2018. 'I just want it to be done, done, done!'Food tracking apps, affects, and agential capacities. *Multimodal Technologies and Interaction* 2, 2 (2018), 29.

[31] Zhao-Yan Ming, Jingjing Chen, Yu Cao, Ciarán Forde, Chong-Wah Ngo, and Tat Seng Chua. 2018. Food photo recognition for dietary tracking: System and experiment. In *International Conference on Multimedia Modeling*. Springer, 129–141.

[32] Erez Na'aman, Amnon Shashua, and Yonatan Wexler. 2012. User wearable visual assistance system. US Patent App. 13/397,919.

[33] Uran Oh and Leah Findlater. 2014. Design of and subjective response to on-body input for people with visual impairments. In *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility*. 115–122.

[34] Daehyung Park, Yuuna Hoshi, Harshal P Mahajan, Wendy A Rogers, and Charles C Kemp. 2019. Toward active robot-assisted feeding with a general-purpose mobile manipulator: Design, evaluation, and lessons learned. *arXiv preprint arXiv:1904.03568* (2019).

[35] Michael Quinn Patton. 1990. *Qualitative evaluation and research methods.* SAGE Publications, inc.

[36] En Peng, Patrick Peursum, Ling Li, and Svetha Venkatesh. 2010. A smartphone-based obstacle sensor for the visually impaired. In *International Conference on Ubiquitous Intelligence and Computing*. Springer, 590–604.

[37] Darius Plikynas, Arūnas Žvironas, Andrius Budrionis, and Marius Gudauskis. 2020. Indoor Navigation Systems for Visually Impaired Persons: Mapping the Features of Existing Technologies to User Needs. *Sensors* 20, 3 (2020), 636.

[38] Manika Puri, Zhiwei Zhu, Qian Yu, Ajay Divakaran, and Harpreet Sawhney. 2009. Recognition and volume estimation of food intake using a mobile device. In *2009 Workshop on Applications of Computer Vision (WACV)*. IEEE, 1–8.

[39] Paul Rozin. 1990. Social and moral aspects of food and eating. *The legacy of Solomon Asch: Essays in cognition and social psychology* 97 (1990), 110.

[40] Adam Satan. 2018. Bluetooth-based indoor navigation mobile system. In *2018 19th international carpathian control conference (ICCC)*. IEEE, 332–337.

[41] Daisuke Sato, Uran Oh, Kakuya Naito, Hironobu Takagi, Kris Kitani, and Chieko Asakawa. 2017. Navcog3: An evaluation of a smartphone-based blind indoor navigation assistant with semantic features in a large-scale environment. In *Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility*. 270–279.

[42] Kristen Shinohara and Jacob O Wobbrock. 2011. In the shadow of misperception: assistive technology use and social interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 705–714.

[43] Jianing Sun, Katarzyna Radecka, and Zeljko Zilic. 2019. FoodTracker: A Real-time Food Detection Mobile Application by Deep Convolutional Neural Networks. *arXiv preprint arXiv:1909.05994* (2019).

[44] Z Vági, Kitti Deé, Zsuzsanna Lelovics, and É Lakatos. 2012. Nutritional status of blind and visually impaired patients. *Zeitschrift für Gastroenterologie* 50, 05 (2012), A82.

[45] Chung Wan-Chen and Lue Chi-Chuan. 2012. Barrier-free dining environment for the visually impaired: A case study of restaurant in Taichung, Taiwan. *Current Issues in Hospitality and Tourism: Research and Innovations* (2012), 125.

[46] WHO. 2019. *Blindness and vision impairment.* Retrieved October 8, 2019 from https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

[47] Akira Yamazaki and Ryosuke Masuda. 2012. Various foods handling movement of chopstick-equipped meal assistant robot and there evaluation. In *International Conference on Social Robotics*. Springer, 158–167.

[48] Zuwei Yin, Chenshu Wu, Zheng Yang, and Yunhao Liu. 2017. Peer-to-peer indoor navigation using smartphones. *IEEE Journal on Selected Areas in Communications* 35, 5 (2017), 1141–1153.

[49] Limin Zeng, Gerhard Weber, et al. 2011. Accessible maps for the visually impaired. In *Proceedings of IFIP INTERACT 2011 Workshop on ADDW, CEUR*, Vol. 792. 54–60.

[50] Fan Zhang, Valentin Bazarevsky, Andrey Vakunov, Andrei Tkachenka, George Sung, Chuo-Ling Chang, and Matthias Grundmann. 2020. MediaPipe Hands: On-device Real-time Hand Tracking. *arXiv preprint arXiv:2006.10214* (2020).