Information Needs and Technology Use for Daily Living Activities at Home by People Who Are Blind

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ABSTRACT

People who are blind face unique challenges in performing instrumental activities of daily living (iADLs), which require them to rely on their senses as well as assistive technology. Existing research on the strategies used by people who are blind to conduct different iADLs has focused largely on outdoor activities such as wayfinding and navigation. However, less emphasis has been placed on information needs for indoor activities around the home. We present a mixed-methods approach that combines 16 semi-structured interviews with a follow-up behavioral study to understand current and potential future use of technologies for daily activities around the home, especially for cooking. We identify common practices, challenges, and strategies that exemplify user-specific and taskspecific needs for effectively performing iADLs at home. Despite this heterogeneity in user needs, we were able to reveal a near universal preference for tactile over digital aids, which has important implications for the design of future assistive technologies. Our work extends existing research on iADLs at home and identifies barriers to technology adoption. Addressing these barriers will be critical to increasing adoption rates of assistive technologies and improving the overall quality of life for individuals who are blind.

CCS CONCEPTS

• Human-centered computing \rightarrow Empirical studies in accessibility.

KEYWORDS

blindness, accessibility, iADL, cooking, assistive technologies

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1 INTRODUCTION

People who are blind face unique challenges in performing instrumental activities of daily living (iADLs), which refer to daily activities that are necessary for independent living, such as cooking, cleaning, dressing, laundry, and managing finances. These tasks are difficult because they rely heavily on visual cues. For example, cooking requires reading recipes, measuring ingredients, and visually monitoring the cooking process to ensure safety. Cleaning requires visually identifying dirty areas and making certain that all identified areas are fully cleaned. Without visual cues, blind people must rely on other their senses, such as touch [29, 42] and hearing [16, 32], or on assistive technology, such as text-to-speech software or Braille displays. In addition, many blind individuals experience social isolation [7], which can limit their access to information and resources that would make performing iADLs easier. This can result in a lack of knowledge about available tools and adaptive techniques, leading to frustration, decreased independence and confidence, and ultimately poorer health outcomes [9, 41].

These challenges highlight the need for user-centered accessible design, as well as user support and training to develop alternative strategies for completing these tasks. Existing research on the strategies used by people who are blind to conduct different iADLs has focused largely on outdoor activities such as wayfinding and navigation [3, 8, 15, 18–20]. Fewer studies have focused on information needs for indoor activities [2, 10, 29, 30], even though most blind people spend a considerable amount of time indoors [30], and even fewer have focused on daily activities within the home [24, 29]. A variety of tools are available to help blind individuals overcome some of these challenges, such as raised bump dots, screen readers, Braille displays, smartphone apps, magnifiers, and voice-activated personal assistants (e.g., Google Siri, Amazon Echo) [13, 22, 31]. However, many of these technologies are not widely adopted or do not work well enough to meet the needs of blind users [1, 2, 38].

Despite a growing awareness of the needs of blind people when interacting with assistive technologies [6, 10, 19, 23, 38], more research is needed to understand the challenges faced by this population in various daily activities around the home and how technology may assist. In particular, cooking presents a significant challenge [24, 29], as it is a multi-step procedure that encompasses many common pain points; such as localizing and measuring ingredients, safety concerns with cutting and chopping, interacting with appliances, and testing food for doneness.

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The goal of this study was thus to further elucidate the strategies that people who are blind employ when performing iADLs at home and to assess the challenges that they face in these activities. In service of this, we conducted a mixed-methods study that combined in-depth, semi-structured interviews with a behavioral task focused on nonvisual meal preparation. The main research questions we sought to explore are:

- (1) RQ1: What are the information needs, strategies employed, and challenges experienced by people who are blind when conducting iADLs at home, such as cooking?
- (2) RQ2: How frequently and in what ways are tactile and digital tools used in daily activities around the home?
- (3) RQ3: What suggestions and considerations can be provided for the development of future assistive technologies?

By answering these questions, we aim to provide a more indepth understanding of the specific needs that people who are blind encounter in their daily lives, and the limitations of existing technology in addressing them. Identifying common strategies that people use to master these tasks may benefit others who are blind, and recognizing challenges faced (even with the use of tactile labeling systems and smart devices) may pinpoint opportunities for the development of future assistive technologies.

2 BACKGROUND AND RELATED WORK

2.1 Daily Activities at Home: Challenges and Strategies Employed

Vision loss is well known to negatively impact an individual's ability to conduct daily activities that are necessary for independent living [12, 24], which may in turn affect an individual's perception of their personal independence, confidence, and quality of life [5, 11, 14]. However, the factors that can impact iADL performance may vary widely across the blind population, due to the diversity of this group [39], and include both functional (e.g., vision-related) and situational (i.e., non-health) factors, the latter of which may be more easily modified [39]. Despite these challenges, individuals who are blind have developed several strategies to more efficiently perform their iADLs; for instance, they may use a cane or guide dog to navigate their surroundings [42], rely on auditory cues to identify objects or locate themselves in space [16, 32], or use haptic feedback from handheld devices to support reading [13].

Nonvisual cooking has received relatively little attention in the literature (as compared to, e.g., orientation & mobility), despite being a multi-step, daily activity that encompasses many potential pain points for people who are blind; such as reading recipes, measuring ingredients, and visually monitoring the cooking process. Jones et al. [24] found that the level of visual impairment strongly correlated with the ability to cook [24]. Participants reported that they lacked confidence and were concerned about their safety, especially for boiling or cutting tasks, for their inability to detect mouldy foods, for determining whether their food was clean before cooking, and for differentiating between undercooked and overcooked meats. In addition, difficulties with procurement, purchase, preparation, and consumption of balanced meals are exacerbated by visual impairment [24], which may negatively impact nutritional status [27] and, in turn, quality of life.

One notable exception is the study by Li et al. [29], which performed a content analysis on 122 YouTube videos to highlight the cooking practices and challenges faced by people with visual impairment. This study revealed diverse challenges ranging from lack of access to necessary visual information to frustration with organization and tracking and safety concerns [29]. Although the findings of this study are highly valuable, it should be noted that a behavioral study, designed to more accurately evaluate the impact of these challenges on cooking performance, is still needed.

2.2 Daily Activities at Home: Assistive Technology Use

Despite advances in the development of assistive technologies for people who are blind [2, 5, 15, 17, 21, 22, 25], many of these technologies are not widely adopted or do not work well enough to meet the needs of blind users [1, 2, 26, 38]. For example, screen readers may have difficulty accurately interpreting certain types of inaccessible web content or uncaptioned images [26], Braille displays can be expensive and require users to learn a new language, and voice-activated personal assistants can pose problems related to identifying and recovering from recognition errors, timeouts, and privacy [2]. Similarly, many sensory substitution devices or visual implants are either still in the development stage or highly invasive and expensive [4, 22, 34].

In tandem, designing accessible technologies for touch screen interfaces remains a challenge. Oft reported pain points include a lack of versatility with device compatibility, learnability and discoverability [26], which may increase rates of abandonment [33]. While many individuals with visual impairment may have their own favorite assistive app that serves their daily needs well, the usability of these apps and their impact on task performance is often not rigorously evaluated with appropriate target populations, [35], making it hard to draw definite conclusions.

According to Shinohara and Tenenberg [38], designers of accessibility technology should take into account the design ethnography of blind users to ensure that the tools they create have appropriate affordances. Failure to do so may result in technologies that do not effectively assist blind users, despite being intended for that purpose. Therefore, it is crucial for designers to consider the experiences and needs of blind users when creating accessible technology.

3 INTERVIEW STUDY: INFORMATION NEEDS AND TECHNOLOGY USE AT HOME

3.1 Motivation

To create better technology in the future, it is important to gain a comprehensive understanding of the needs of people who are blind who use the technology. This includes identifying common strategies and pain points encountered in the performance of everyday tasks in order to identify areas where technology could offer support. While previous research highlighted nonvisual meal preparation as a challenging iADL [24, 27, 29], there is a need to better understand how this activity compares to other iADLs with regard to identified strategies and pain points, as well as to identify specific opportunities for future assistive technology development.

Subject ID	Age	Years Blind	Blindness severity	Diagnosis / Cause of blindness	
A*	71	6	totally blind	glaucoma (congenital)	
B*	52	9	totally blind	multiple sclerosis	
C	67	4	legally blind	diabetic retinopathy	
D	77	53	legally blind	Doyne honeycomb retinal dystrophy	
Е	70	18	legally blind	retinitis pigmentosa	
F	65	65	totally blind	unknown (congenital)	
G	68	10	legally blind	diabetic retinopathy	
H*	74	74	legally blind	glaucoma (congenital)	
Ι	68	3	legally blind	optic neuropathy	
J*	39	4	legally blind	diabetic retinopathy	
K*	51	15	legally blind	diabetic retinopathy	
L*	35	35	legally blind	Leber's amaurosis (congenital)	
M*	44	13	totally Blind	uveitis	
N	34	11	totally blind	vehicle accident	
0	27	22	totally blind	retinoblastoma	
P*	65	47	legally blind	retinitis pigmentosa	

Table 1: Demographic characteristics of our interviewees. Asterisks (*) indicate people who also participated in our behavioral study.

3.2 Method: Semi-Structured Interviews

Therefore, we sought to interview a diverse group of blind individuals to learn more about specific challenges they face when performing everyday tasks. Interviews were conducted either via phone or Microsoft Teams, with each lasting between 45 and 90 minutes. To take part in our interviews, participants had to be over the age of 18 and be fluent in English.

We interviewed 16 adults from the greater Anonymous City area (Table 1), recruited with the help of two local organizations for the blind. Participants ranged in age from 27 to 77 years old, and gender makeup was equally divided between female and male participants. All participants were legally blind, five of whom were totally blind. Furthermore, it was important to us to sample participants from a wide range of diagnosed causes of blindness, ranging from congenital blindness (four participants) to acquired blindness (twelve participants) that was first diagnosed between four and 74 years ago. Our study fully complied with University guidelines for the use of human subjects and was approved by Anonymous University's Institutional Review Board (IRB). Consent was obtained from each participant prior to the start of the interview, and it was highlighted that they could stop at any time, for any reason.

During the interviews, participants were asked about the challenges and strategies or tools they employ for their iADLs.

3.3 Findings

Since our participants differed widely in their age, demographic background, and experience being blind, we opened the interview by asking them to walk us through a typical day in their life. Most participants reported sticking to a daily routine that centered around indoor activities such as housework and cooking, with the occasional trip to the post office, bank, or shopping mall. All participants valued staying active and social, either by going on daily walks with family or friends, or by partaking in regular exercise classes. As we worked closely with Local Anonymous Organization for the Blind to recruit our participants, it was not surprising to learn that most of our participants were frequent attendees at their art, exercise, and assistive technology tutorial classes.

All participants expressed the desire to be as independent as possible in their daily activities. 15 of the 16 participants did not live alone, typically living with a sighted spouse. The participant who reported living along, expressed relying on a hired helper to come by regularly to assist them with cleaning and other potentially unsafe tasks around the house.

3.3.1 Technology Use for Daily Activities at Home. When asked to rate the difficulty of different daily activities on a scale from 1 to 5, ranging from effortless to demanding, participants rated most activities as moderately difficult, but doable without assistance (Fig. 1). Getting dressed was rated easiest (difficulty 1.44 out of 5),

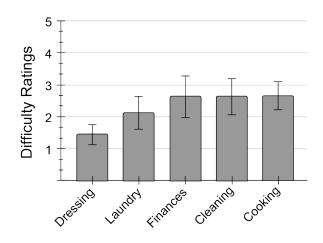
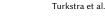


Figure 1: Average self-reported difficulty ratings for different activities of daily living (1=very easy, 5=very difficult). Error bars denote the standard deviation.



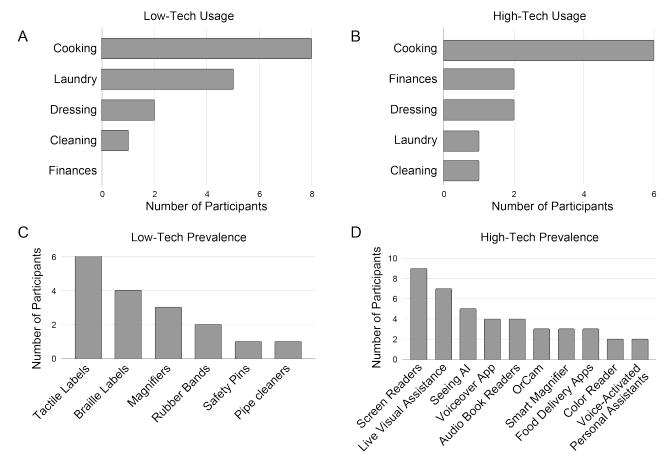


Figure 2: Overview of trends in low- and high-tech usage for daily activities at home from 16 interviewed participants. Panel A and B depict the self-reported frequency of various daily activities for which participants relied on assistive technology. Panels C and D show a breakdown of which low-tech or high-tech solutions were commonly used to support these activities.

followed by doing laundry (2.13 out of 5), and the three equally difficult tasks rated at 2.63 were: managing finances, cleaning, and cooking; with cooking having the most consistent ratings.

We were especially interested in learning about which technologies and services, if any, our participants used in their everyday life. To gain a more systematic understanding of the suitability of various assistive technologies for daily living activities at home, we grouped the applications, devices, and services mentioned by our participants into "low-tech" solutions (i.e., analog tactile and visual aids) and "high-tech" solutions (i.e., digital devices or applications). These results are summarized in Fig. 2.

In general, participants reported utilizing low-tech solutions for cooking, doing one's laundry, dressing oneself, and cleaning around the home; but not for managing finances (Fig. 2A). All participants reported relying on one or more tactile labeling systems (Fig. 2C); be it using bump dots, textured stickers, rubber bands, pipe cleaners, Braille Dymo labels, or professional Braille embossers. These were often used to label kitchen utensils, cleaning supplies, or important buttons on kitchen appliances and the laundry machine.

In comparison, high-tech apps and services proved useful for all five tasks (Fig. 2B). They included live visual assistance (e.g., Be My Eyes, Aira) for cooking and cleaning, voice-activated personal assistants for setting timers and automating certain appliances, voice-over apps (e.g., JAWS) to help with managing finances and reading recipes, and color readers to assist with getting dressed and sorting laundry. Two often mentioned products were the Seeing AI app and the OrCam device, which could be used to scan bar codes, identify objects, and recognize currency denominations.

Importantly, low-tech and high-tech solutions were not used in isolation from each other. For instance, participants may combine tactile labels to label kitchen supplies and appliances, but also rely on digital solutions to scan bar codes and read recipes.

3.3.2 Common Pain Points & Remediation Strategies. Participants had mixed perceptions, comfort ratings, and motivation levels for using technology at home. However, those who routinely relied on technology tended to report higher comfort levels and ease of use. Participants most consistently praised the availability and accessibility of live visual assistance services, magnifiers, and voice-over tools. Below we give a brief overview of common pain points and remediation strategies across iADLs.

Dressing. Participants agreed that getting dressed is not difficult (just time-consuming) and that organization is key. Many participants have developed meticulous systems for sorting their clothes (e.g., by color, by texture, by activity) and use Braille labels and safety pins to tag important pieces of clothing. Still, it is often challenging to determine whether the colors are matched or the outfit looks good. To mitigate this problem, Participant P got creative:

"I design outfits the night before or when the clothes come fresh out of the washing machine, then I put them all on the same hanger so I know which ones go together."

Others use a color reader, ask their partners for help, or rely on live visual assistance apps like Be My Eyes for the final judgment.

Laundry. Doing laundry is time-consuming but doable as well. The most commonly reported pain point is that newer washing machines have touchscreens, which makes it hard to change or verify a setting. Participant E reported that:

"Doing laundry is fairly easy when no settings need changing. But since we have newer machines, it can be really hard if I do have to change settings because the screen is digital."

As with other digital interfaces, people often use tactile markers (e.g., bump dots) to label important buttons. However, there is no good independent solution to deal with stains, which can only be detected visually.

Managing Finances. Managing personal finances can be difficult without vision, as most banks still routinely send paper statements and web-based platforms rarely follow accessible design patterns [40]. Not surprisingly, the majority of our participants relied on the help of their spouse or other family members to pay bills and do their taxes. For instance, Participant A reported unease with using screen readers to parse personal information, which aligned with his general distrust of digital technologies. Therefore, he restricts his financial involvement to physical and phone interactions and trusts his spouse to do the rest.

The few participants who try to manage their finances themselves (e.g., Participants B, H, and M) reported a variety of difficulties that ranged from trouble dealing with checks to being unable to access their online statements due to the bank's poor web interface. These can only be solved with a combination of assistive technologies. For instance, Participant H uses a CCTV to enlarge checks and reading materials, JAWS to navigate the eBanking platform, and Talk Back to navigate the bank's smartphone app. Still, they often depend on their spouse to handle critical or inaccessible transactions such as paying bills.

Cleaning. Cleaning and tidying one's home was another common source of frustration. The experiences of our participants were mostly consistent with the existing literature [6]. Participant N highlighted the need to appropriately label and store their cleaning supplies; since these items were not used every day, it was easy to forget where they put them. Participant I lamented that it was quite difficult to tell whether the floor needed to be swept. Participant M was the only one to report that they actually enjoyed cleaning, and that their organizational skills and tidiness had improved since blindness onset. Many participants reported needing to repeatedly sweep or dust their rooms just to make sure they had not missed a spot. Because of that, most participants relied on the help of a spouse or an external cleaning service. While this might be an acceptable solution to many, it was perceived to be expensive and to reduce the participant autonomy and independence.

Aside from the few apps which may act as live visual aids, there are little to no existing technologies to support visually impaired and blind individuals in ensuring the cleanliness of their homes.

Cooking. Cooking was consistently mentioned as one of the hardest iADLs at home (Fig. 1) that also prompted the most technology use (Fig. 2A, B). Several of our participants love to cook, use several tools to help them, and do not hesitate to get creative and "make a mess" (Participant O). However, most of them report being "slow and meticulous", and they highly value an organized and intuitively arranged kitchen. This required appropriately labeling jars and appliances, and meticulously arranging their cupboards and refrigerator. In the words of Participant G:

"I'm really into my kitchen. I cook all the meals for my family. However, sometimes [my spouse] comes in and accidentally moves something around. Then it takes me a really long time to find it, and no tool can help you with that. It's frustrating."

Other pain points appeared throughout the cooking process, including reading and following recipes, finding the right ingredients, mixing and measuring ingredients, dealing with hot surfaces or liquids, and determining whether food was undercooked or overcooked. This is despite participants relying on a variety of strategies, including an emphasis on preparing all the necessary ingredients before starting to cook ("mise en place") and purchasing specialized equipment (e.g., no-touch instant read thermometers).

Participants who had attended cooking class also tended to be equipped with heat-resistant gloves and long oven mitts, tended to use larger and deeper pans, and tended to know about how to safely gauge the temperature (e.g., feeling how high the flame of a stove is with their hand far above it). In addition, participants with residual light perception reported the importance of lighting, contrast, and color in meal preparation. For example, Participant I noted that natural lighting coming through their kitchen window can be too harsh, and that artificial lighting works much better for them.

Participants were generally focused on utilizing their sense of touch, smell, taste and hearing to overcome challenges in the kitchen. A sentiment shared by many of our participants, and contributing to why several of our participants rely on takeout orders and food delivery services, can be summed up adequately by one particular quote from Participant L:

"While most cooking tasks are usually doable, they are so time-consuming and require that I use a different tool at each step, which makes a huge mess and can be really frustrating." Preprint, 2023, Earth

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			Cooking	Арр	
Subject ID	Age	Years blind	experience level	experience level	Cooks at home?
A	71	6	neutral	somewhat inexperienced	rarely; relies on partner
В	52	9	neutral	somewhat inexperienced	rarely; mostly takeout
Н	74	74	somewhat experienced	somewhat experienced	often; even complex meals
J	39	4	neutral	neutral	often; simple meals
K	51	15	neutral	not experienced	often; simple meals
L	35	35	somewhat inexperienced	somewhat inexperienced	often; simple meals
М	44	13	somewhat experienced	somewhat inexperienced	often; simple meals
Р	65	47	somewhat experienced	somewhat in experienced	often; even complex meals

Table 2: Demographic characteristics of our behavioral study participants. Subject IDs are the same as in Table 1. Experience levels were self-reported on a 5-point Likert scale, ranging from "not experienced" to "very experienced".

4 BEHAVIORAL STUDY: NONVISUAL COOKING

4.1 Motivation

Despite our participants' best effort to master the kitchen, cooking was often mentioned as one of the most challenging activities at home. Based on these responses, we sought to assess which steps in the cooking process were particularly challenging for our participants and thus particularly well suited for existing and future assistive technologies. Therefore, we ran a quantitative study that would allow us to rate the difficulty level and degree to which technology could help at each step of the cooking process.

4.2 Methods

4.2.1 *Participants.* Eight of the sixteen interviewees from the previous study (Table 2) agreed to participate in the cooking study. Participants ranged in age from 35 to 74 years old. Two of them were congenitally blind. None of our participants considered themselves expert cooks ("very experienced"), though most of them often cook simple meals at home.

Participants were invited to the kitchen at Anonymous University's community kitchen. Transportation was provided as needed, and participants were reimbursed for their time at a rate of \$20/hour. This behavioral study fully complied with University guidelines for the use of human subjects and was approved by the local IRB. Consent was obtained from each participant prior to the start of the session, and participants were informed that they could stop at any time, for any reason.

4.2.2 Location, Training, and Accessibility Considerations. The two (sighted) lead authors of the study were trained by a cooking instructor at Local Organization for the Blind prior to the experiment. The community kitchen was outfitted with a refrigerator, an oven, a sink, a kitchen island, and other standard household appliances not used in this study.

We followed best practices as suggested by the cooking instructor to make the kitchen more accessible, which involved the use of Wikki stix (removable sticky plastic yarn) and rubber bands to label task-relevant objects and common appliances. First, we used Wikki stix to label the top of task-relevant jars (e.g., "T" for tomato sauce; Fig. 3A), which were then placed at random locations in a cluttered cabinet (Fig. 3B). Second, we tied rubber bands around smaller items such as spices (Fig. 3C), and the cabinet where the jars were placed was labeled with a horizontal Wikki Stix above the cabinet handle. Third, since the oven used a touchscreen instead of physical buttons, we used Wikki stix to label the buttons needed to set the temperature and timer ("B" for bake, "S" for start, "C" for cancel, "T" for timer; Fig. 3D) as well as the number pad (a dot was placed on each number; Fig. 3E). We chose not to use Braille for these labels, as not all participants were fluent in it. Fourth, the measuring spoons were angled such that the scoop was perpendicular to the handle of the spoon (a practice suggested by Anonymous Local Organization to simplify the process of scooping out ingredients from jars).

Once participants arrived on campus, they conducted a training session where they were familiarized with the layout of the community kitchen, the different appliances (e.g., "Here is the fridge, and the vegetables will be in the bottom drawer"), and the tactile labeling system. The participants were shown and told what the tactile labels were and what they meant, and were given ample time to find their way around the kitchen and to get used to the labeling system.

Some experimental conditions required the use of a free smartphone app (iOS: Microsoft's Seeing AI, Android: Google Lookout). Both of these apps are very similar: they provide AI-based assistance for people who are blind, for example by reading bar codes or spelling out the name of the object that the phone's camera is pointed to. We walked participants through the app's interface and explained how the app might be used for cooking. For example: "All of the sauce jars will be located in this cabinet. You could use the barcode reader of the app to determine which jar you are holding." Participants were welcome to use their own smartphones, but those who did not wish to download the app or use their own phone were provided with one. As it turned out, all participants already had one of the two apps installed on their device and reported having "some" prior experience with it, though none of them had used it much for cooking.

Once participants indicated that they felt comfortable with the kitchen, labeling system, and smartphone app, the session began.

4.2.3 *Task Design.* To make cooking more controllable and feasible in a research setting, we chose a fairly simple, easily customizable, relatively safe, and quite popular meal: pizza. To ensure the safety of our participants, we provided pre-cut vegetables and helped participants with putting the pizza in the oven and taking it out.

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Figure 3: Examples of the tactile labels used for important appliances and task-relevant items. A) Task-relevant jars were labeled with Wikki Stix, such as the jar of tomato sauce shown here (with a label "T" on the lid). B) These items were placed among other items in the cupboard or fridge. Their exact position was randomized on each trial. C) Smaller items were labeled with rubber bands, such as the garlic powder shown here. D–E) Task-relevant buttons on the oven's touch screen were labeled with Wikki Stix, either to spell out the first letter of the button's function (D) or to form raised dots on the number pad (E).

The task was broken up into different steps that the participants were instructed to follow:

- (1) Dough: Participants needed to locate the pre-made pizza dough in the fridge (plastic package), remove the dough from the package, roll it out, and place it on the baking sheet. We asked participants whether they thought the dough was spread out evenly and placed in the center of the baking sheet. Once they confirmed that they were done with the step, we moved on to the next one.
- (2) Toppings: Participants needed to retrieve the sauce (either red or white, depending on the trial) in the cupboard and to locate one of two cheeses and two toppings (pseudo-randomized: different on each trial, but still a sensible and enjoyable combination) in the fridge. We asked participants whether they thought the toppings were spread out evenly and covered the whole pizza. Once they confirmed they were done with this step, we moved on to the next one.
- (3) Baking: Participants needed to set the oven to the correct temperature and set a timer. The safety assistants placed the pizza in the oven to avoid any safety concerns. Participants needed to determine whether the pizza was done. We asked them whether the pizza was undercooked, overcooked, or just right. Once they confirmed they were happy with the outcome, the task was considered complete.

Every pizza had the same number of ingredients to control for task complexity across trials. To make the process more enjoyable, we had sighted assistants perform additional steps that were deemed either unsafe or too repetitive to include in the main task (e.g., drizzling olive oil, adding additional toppings and spices as desired).

Based on our interviews, we expected to find a measurable variation in task performance as a function of the available assistive technologies. We therefore crafted two different task conditions:

- Low-tech condition: Participants relied solely on tactile labels (Fig. 3). Wikki Stix and rubber bands were used as tactile labels for jars (e.g., pizza sauce) and necessary buttons on the oven's touchscreen.
- (2) High-tech condition: In addition to tactile labels, participants were able to use an AI-based smartphone app (iOS devices: Microsoft Seeing AI, Android devices: Google Lookout). Both

of these apps provide AI-based services such as barcode scan-

ner, object recognition, and a text-to-speech voice generator. To account for learning effects, we randomized both the order of conditions and the locations of the sauce, cheese, and toppings between participants. Although we always kept the ingredients in the same general area (e.g., fridge, cupboard), their exact location was randomized on each trial.

Participants were asked to verbalize their thoughts while conducting the task, and to perform all steps as independently as possible. They could ask for human help if needed. In the high-tech condition, participants could use all functions of the smartphone app as desired, in combination with the tactile tools. Each participant performed one session with both conditions (within-subjects design), with ample breaks in-between steps and a longer break between conditions. During the breaks, participants had the opportunity to eat the meals that they made, use the restroom, or go on a short guided walk through campus with the investigators. Each session lasted about 2–3 hours (each condition: 30–60 minutes) including breaks and feedback collection at the end.

4.2.4 Data Collection. Two research assistants took note of the steps that required the use of the tactile labeling system, the smart-phone app, or human help. The frequency and type of questions that participants asked was used as a proxy measure of the importance of different visual cues.

The assistants also assessed the difficulty of each step by rating participant performance on a 4-point scale that included "easy" (i.e., the step was accomplished effectively), "moderate" (i.e., the step presented only minor difficulties, but no human help was requested), "difficult" (i.e., the step was accomplished, but with mistakes and/or human help), and "impossible" (i.e., the participant could not complete the step, even with human help, or gave up).

Participants were also asked to rate their confidence level regarding whether they believed that they had executed the step correctly, on a scale from 1-5 (1: not confident, 5: very confident). After finishing each condition, we asked participants how happy they were with their final product and asked them to rate the overall task difficulty as well as the helpfulness of the tactile labeling system and smartphone app.



Figure 4: Challenges in the pizza making process. A) Participant having difficulty making their dough circular and opting to use their hands instead of the rolling pin. B) Participant spreading sauce and cheese, unable to determine edges of dough. C) Tasty completed circular pizza with uneven sauce, cheese, and topping distribution. D) Delicious completed pizza with scattered toppings and irregular shape.

4.3 Findings

In general, our participants demonstrated a high level of independence in the kitchen, completing most tasks with minimal technical assistance and rarely seeking human help.

However, navigating the kitchen was initially challenging for some, particularly due to the presence of an island in the middle of the room. To locate the fridge, for example, individuals often used their hands to feel along the wall or cabinets. Some participants were hesitant and asked for guidance on their proximity to their desired target, while others displayed more confidence. With practice, everyone was able to navigate the kitchen effectively so that their task performance was unaffected.

To our surprise, there was no measurable difference between their task performance, difficulty rating, or confidence level—despite them having different tools available.

4.3.1 Dough. Working with the dough was rated as the most difficult step in the pizza-making process for both conditions.

Finding the dough package in the fridge was not an issue, since it could be easily distinguished from other products by touch. However, determining the type of dough (seasoned or plain) was challenging as both types felt and smelled quite similar. When asked to determine the type of dough, most participants chose to use the app. However, the flexible plastic bag packaging made it near impossible to scan the barcode or read the label on the front of the bag, leaving most participants to taking a wild guess.

Participants also expressed frustration with rolling out the dough into a circle. While many preferred to use their hands instead of a rolling pin (Fig. 4A), they found it challenging to assess the dough's overall shape and thickness consistency regardless. As a result, not all pizzas were round or rolled out evenly (Fig. 4C, D).

4.3.2 *Toppings.* Spreading the sauce posed a similar problem. Given the unevenness of the rolled-out dough, participants had difficulty spreading the sauce evenly. Three participants decided to forgo the sauce spoon and just used their hands so they could feel the sauce on the pizza. However, this did not help with assessing how

well they had completed this step, because: "as soon as you have touched the sauce in one place, you can't tell whether you're touching sauce or dough", one participant explained. Adding cheese and other toppings was relatively straightforward, and participants had minimal issues locating the toppings in the refrigerator using just their hands. Seeing AI was frequently used to confirm that they had selected the right package containing the topping they wanted.

4.3.3 Oven. The oven presented accessibility challenges for all participants, and an especially steep learning curve for some. The oven model used in the community kitchen was relatively new, featuring a flat screen with no clear markings for buttons to start, cancel, or use the number pad. Thus, the Wikki Stix markings on the oven's menu interface were integral to complete this step.

Participants generally used both hands to the read the keypad, start the oven, and set the timer. The buttons on the digital interface had to be pressed in quick succession or the oven would go back to its default settings. With practice, participants were able to press the buttons quickly enough for them to register in time, but this was made possible primarily with the aid of the Wikki Stix and by using both hands (Fig.5A).

One participant experienced difficulties with the number pad, entering the wrong numbers a few times due to an incorrect understanding of the layout. However, the research team was able to assist and correct the issue. Some participants mentioned that they would have rather used an app to set a timer instead of dealing with the number pad.

4.3.4 Tactile Tools & Pain Points. Overall, participants expressed enthusiasm and appreciation for the tactile labeling system, praising its simplicity and effectiveness. Three participants reported never having used Wikki Stix or raised dots before, and we gave them some to take home. All three individuals expressed excitement about the tools and stated that they looked forward to using them to label items in their own kitchen.

Rubber bands and Wikki Stix were effective in labeling important ingredients, and participants had no trouble locating them in a cluttered fridge or cupboard. However, there were instances

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Figure 5: Examples of participants interacting with appliances. A) Participant is using both hands to operate the touchscreen buttons of the oven. B) Participant is using the smartphone app to recognize a sealed package. C) Participant is trying to use the smartphone app to read the label on a jar, but is not correctly angling the phone.

where participants were confidently wrong in their ingredient selections. The veggie toppings had the highest false positive rate in ingredient selection, likely due to the bags feeling similar to one another. Conversely, no issues were reported with locating the sauces. Participants were able to verify their veggie selections using the smartphone app, but found the process to be time-consuming and arduous. As a result, some participants expressed a preference for relying on their sense of taste to confirm their selections.

The tactile labeling system received minimal complaints from participants. When issues were reported, they typically related to the impermanence of the low-tech labeling tools on kitchen appliances or food items.

Participants rated the tactile tools as extremely helpful in completing the cooking task, with some steps being impossible to complete without them. An example of this was the use of Wikki Stix on the oven's touchpad. Given that participants were unfamiliar with the kitchen and its appliances, all of them expressed that they would not have been able to complete the cooking task without the provided tactile tools.

4.3.5 Smartphone App Usage & Pain Points. Participants tended to use the AI-based smartphone app in situations where they could not rely on their senses or the tactile labeling system. They were particularly likely to use the app during steps that involved searching and object identification, such as locating and identifying the correct toppings in the refrigerator.

The most commonly used app features were the barcode reader and the object recognition function. However, participants faced difficulty in scanning items as they were unable to see where their phone was pointing (Fig. 5B). The app also struggled with wrinkly packaging and serif fonts. This resulted in some participants relying on the object recognition feature instead (Fig. 5C), but it often misclassified objects. In one instance, a tomato sauce jar was repeatedly misidentified as a beer bottle, which caused frustration and led the participant to exclaim that they would not want to use the app again. In another instance, a participant tried to use the app to read the remaining time on the oven's LCD display, but the app failed to read out the correct time (possibly due to glare).

For other steps of the cooking, there simply was no good app option available. Participants were unable to determine the shape of their pizza, whether they had applied enough sauce and cheese, or whether they had spread out the ingredients evenly.

There were mixed perceptions associated with using the app in this task. Many participants lamented regarding the time it took to become proficient with the app and that they needed to use both hands to make use of it (i.e., one hand to hold the item and the other to hold the phone). Most participants were familiar with the app before the experiment, but confessed that they rarely used it in their daily lives. Others reported that they relied extensively on it. One participant outright refused to use the app even though we repeatedly explained that it was part of the experiment.

On the other hand, several people felt empowered by participating in this study, because they were unaware how useful the app could be, especially in the kitchen. Participant M expressed:

"I had no idea how helpful Seeing AI could be! I was frustrated with it when I first downloaded it and couldn't figure out how to use it in a helpful way, so I never touched it again. After this study and learning how I can use Seeing AI in my kitchen and around my house to make my life easier, I'm excited to start using it more often!"

Overall, these results underscore the heterogeneity in user preferences and app usage patterns across individuals.

5 DISCUSSION

5.1 Information Needs for Daily Activities at Home

Through semi-structured interviews and a behavioral study, we learned about the diverse strategies and information needs of people who are blind when performing iADLs at home. The interview results present and confirm common practices, challenges, and strategies of people who are blind (Section 3.3), whereas the behavioral study (Section 4.3) exemplifies the user-specific and task-specific nature of these issues. While most iADLs were reported to be doable, participants often found them to be tedious and time-consuming. This was especially true for cooking, cleaning, and managing finances, which were rated the most difficult and were thus the most likely to be outsourced to partners, other family members, or professional services. In particular, both the interviews and behavioral study suggest that personal factors (e.g., vision level, onset of blindness, task motivation, comprehension goals, and past experiences) contribute to an individual's unique needs at home. These findings are consistent with previous literature that explored the various factor that may impact iADL performance [2, 10, 24, 27, 29, 30, 40]. To obtain the visual information that is necessary to effectively perform these iADLs, our participants relied on a variety of tactile and digital tools (Fig. 2) that would inform them about the physical layout of their home, the location of objects and furniture, and the state of appliances and household systems. Additionally, access to information could be enhanced through the use of tactile or auditory feedback, which can help to reinforce and confirm successful completion of a particular task.

A recurring theme that frustrated many of our participants was dropping or misplacing an object. This can be challenging even with residual vision, especially when the dropped object is the same color as the surface or the object falls into a shady spot. Whereas some participants drop to their knees and crawl on the ground, others rely on live assistance apps such as Be My Eyes. Participant I has reportedly given up on both of these options:

"Once you drop something and it rolls away, you've lost it to nowhere land."

While not an iADL *per se*, we found that needing to locate a lost, dropped, or misplaced object was a struggle reported to be pervasive in almost every daily activity. It is one example of a whole class of challenges and unmet needs that cannot be neatly categorized as any of the standard iADLs [39]. Finding lost or dropped objects may be of no note to a sighted individual, but is of express importance to individuals who are blind or otherwise visually impaired.

5.2 Implications for the Development of Digital Assistive Technology

Our study adds to a growing body of literature [35, 38, 39] that underscores the heterogeneity in user needs and app usage patterns across individuals who are blind. While this diversity presents a challenge for developers, it also suggests that there is potential for greater app usage if developers can better understand and meet the unique needs and preferences of people who are blind.

Interestingly, despite the diversity in preferences and strategies, participants shared an almost universal problem-solving approach:

- (1) Try to do it independently. All our participants emphasized their desire to be independent. Thus, before relying on external help, they would attempt to perform the task themselves. Many participants expressed frustration with their dependence on spouses and family members, especially for daily activities that "seem so basic".
- (2) Try a tactile aid. Only if their first attempt failed would our participants consider an external aid. When given a choice, they would typically reach for the tactile aid.
- (3) Try a digital aid. Only if relying on their own senses and any available tactile labels failed would our participants consider a digital aid such as a smartphone app. Participants displayed different preferences for their "high-tech" visual aid: whereas many preferred live visual assistance aids (e.g., Be My Eyes,

Aira), others preferred AI-based solutions (e.g., Seeing AI, Amazon Echo).

When participants had the choice to use either low-tech or hightech tools, six out of eight participants stated that they were more likely to use the low-tech tools, if anything. Even when the digital tool was specifically designed for the task (e.g., barcode reader), many participants stated that they would rather rely on the tactile system or their own senses to ensure that they had the right product in hand. Participant L said:

> "I determined that I chose the right sauce for my pizza using the tactile label on top of the jar, and proved this by using my sense of taste and was confident in my choice. I chose not to use the app because it wasn't necessary to prove it again, and using the app would have taken longer to double check anyway."

These findings have important implications for the design of future digital assistive technology. First, our results suggest that designers of digital solutions should focus on addressing problems that low-tech solutions cannot effectively solve. Rather than competing with existing tactile solutions (that are often praised for their simplicity and efficiency), digital solutions could be designed to complement or augment existing tactile aids. Second, our results add to the well-established literature on user-centered design [28, 36, 37] that promote active engagement with the target population throughout the design process, to ensure that the resulting products are informed by the unique perspectives and requirements of their intended users. Third, our participants were outspoken about their thoughts on current AI-based smartphone apps, which offer a plethora of functions that do not always work as intended outside of ideal use cases. Concrete examples included the barcode scanner, which struggled with wrinkly packaging, and the object recognition feature, which stubbornly misclassified certain objects.

However, it should be noted that most of the AI-based features were still officially in *beta* mode, meaning that development is ongoing. In fact, whenever the app was successful in identifying an object, participants got excited and were tempted to use it again.

Therefore, there is reason to remain optimistic that, with continued research and innovation, app developers can create more effective tools that are better tailored to meet the diverse needs of their user base, resulting in greater adoption and engagement.

5.3 Barriers to Adoption of Digital Assistive Technologies at Home

Through our interview and behavioral study, we identified a number of potential barriers to adoption of new digital technologies for iADLs at home:

• Lack of awareness. Many of our participants were not aware of the availability or usefulness of assistive technologies, such as Participant M, who exclaimed "I had no idea how helpful Seeing AI could be!" (see Section 4.3.5). Other participants felt overwhelmed with the sea of options in the field of accessible tech, none of which seemed to work particularly well for their needs and desires. Participant A exclaimed:

"By the time you learn one thing, there is a new thing!"

The most common ways that participants reported acquiring their technology knowledge were through various organizations, demonstrations, and word of mouth. However, knowledge of technology did not necessarily relate to the use of technology. The ever-increasing prevalence of difficult-touse touch screens and voice-over apps, which are not always effective, seemed all too often to contribute to frustration, technology abandonment, and a return to simple and familiar tactile tools that were known to be effective and safe. In the words of Participant D:

"I know that there is technology out there to use, but I don't use it because I would rather rely on the tools that I already have and the strategies I have already created that work pretty much every time."

• *Training and support.* Participants lamented the amount of training and support that would be required should one desire to become an expert user. Some struggled even with basic usage, as Participant G stated:

"I have a lot of apps on my phone, but never use them because they take too long to learn and too long to even pull up."

- *Accessibility.* Most participants had at least one example to share of a time when they tried to adopt a digital technology, such as a particular smartphone app, but could not get it to work due to accessibility issues. In tandem with this, many apps and devices have updates to their software that may result in changes to the user's interface and experience, which can be quite frustrating to navigate.
- *Technical issues.* The most appreciated aspects about technology were reportedly navigation technologies, AI-based apps, live visual assistance technologies, and voiceover tools. Participants shared their appreciation for these apps and high-tech tools when they passed the high learning curve it took to become proficient. However, not all participants got to that point, as technical issues, such as compatibility with other devices and the low accuracy of some apps, further discouraged adoption. Participant K was the only participant without any major tech complaints.

Other commonly mentioned barriers to adoption were *stigma* associated with certain "fancy" accessibility aids, their relatively high *cost*, and concerns about *privacy* as technologies are increasingly collecting personal data.

Addressing these barriers will be critical to increasing adoption rates of assistive technologies and improving the overall quality of life for individuals who are blind.

6 LIMITATIONS AND FUTURE WORK

In our work, we chose to focus on exploring the information needs and technology use practices of blind people only (i.e., people who are legally blind or totally blind). People with other low-vision conditions (e.g., central or peripheral visual field loss) may have different practices, perceptions, challenges, and needs. In addition, since we relied on the help of Local Organization for the Blind for our recruitment, many of our study participants had already attended a cooking class or frequently cook at home. However, most were not too comfortable with the smartphone app, which could at least partially explain why our participants largely preferred tactile solutions over digital ones. We therefore recommend future studies to critically consider how our findings may apply to a wider range of people with low vision.

In addition, the behavioral study necessitated participants to travel to campus and get accustomed to an unfamiliar kitchen. Even though we provided ample time for participants to get acquainted with the layout of the kitchen, the appliances, the smartphone app, and did not start the session until our participants confirmed that they were comfortable in their surroundings, it is likely that participants would have performed differently in their own kitchens. Future research could therefore focus on less-controlled environments and possibly performing the desired task in a familiar environment.

7 CONCLUSION

In this paper, we describe the findings of an interview study involving sixteen blind individuals and a follow-up behavioral study with eight participants to understand their current and potential future use of technology for daily activities around the home, especially for cooking. While most iADLs were reported as doable, participants often found them to be tedious and time-consuming. In particular, we identified common practices, challenges, and strategies that exemplify user-specific and task-specific needs for effectively performing iADLs at home. Despite the heterogeneity in user needs, we were able to reveal a near-universal preference for tactile over digital aids, which has important implications for the design of future assistive technologies. Our work extends existing research on iADLs at home and identifies barriers to technology adoption. Addressing these barriers will be critical to increasing adoption rates of assistive technologies and improving the overall quality of life for individuals who are blind.

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