I Didn't Know that You Knew I Knew: Collaborative Shopping Practices between People with Visual Impairment and People with Vision

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It is important to support independent living for people with visual impairments (PVI). Part of this can be accomplished with individual assistive technologies. However, in this paper we emphasize the social and collaborative needs for PVI to fully integrate into society as equals. The study assesses how PVI collaborate with different types of sighted partners when shopping together. We chose to study grocery shopping because it is a critical and challenging task for PVI. We conducted field observations and in-depth interviews with five PVI and their sighted shopping partners, including spouses, caseworkers, and store-provided courtesy shoppers. We found several factors that modulated these collaborations with varying forms of common ground: 1) knowledge about how to assist PVI; 2) interpersonal knowledge resulting from common experience and interpersonal relationship history; and 3) knowledge of shopping as a practice. We discuss our findings with respect to the implications for designing collaborative interactions.

CCS Concepts: • **Social and professional topics** → Assistive technologies • **Social and professional topics** → People with disabilities

KEYWORDS: Collaboration, people with visual impairments, common ground, assistive technology, accessibility, grocery shopping

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1 INTRODUCTION

People with visual impairments (PVI) encounter everyday challenges such as restricted social roles and limited access to education, work, technology, mobility, and other activities. Research has called for more, meaningful integration for people with different abilities and needs into everyday settings [13, 39].

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For example, considerable research has addressed the possible supports for PVI to lead *independent* lives by enhancing accessibility and mobility with technological assistance [e.g., 20, 24, 26, 30, 41]. However, consideration of *social and collaborative* interactions between PVI and people with vision is understudied and deserves more attention [2], as many of PVI live with others and work with sighted people [40]. In fact, research has suggested that social and interpersonal barriers experienced by PVI in educational and work settings could lead to social exclusion and problems with psychosocial adjustment [19, 29]. It is important to recognize that independent living does not connote social isolation.

We argue that access and contributions to collaborative interactions is an important element of equal participation; in our case we define this as PVI's active involvement in social contexts for interactive and learning opportunities [39]. Other dimensions of equal participation include taking individual and societal responsibilities, having the ability to support others, developing social connections to the community, and making choices [16, 25]. Full integration does not only refer to independent practices but just as importantly, for PVI to interact and collaborate on an equal basis with others [39].

In collaboration, team members rely on communicating information and coordinating actions to co-construct and sustain distributed cognition [4]. Grounding, or the process wherein team members reach mutual understanding about goals, content, process, and context, is the bedrock of collaboration [8]. For PVI-sighted collaboration, challenges in reaching common ground are present on both sides. On the part of PVI, visually related shared awareness is restricted; on the sighted partner's side, they may lack experience about how to work with PVI. Clark's classic paraphrase of common ground [8] is "I know that you know I know;" this reciprocal "knowing" may simply not be present in some PVI-sighted collaborations. Thus, we have conducted a study of PVI-sighted collaboration in an everyday shopping context, hoping to understand whether and how common ground is created and the corresponding consequences for the shared tasks. In this, we hope to unpack specific requirements or opportunities for sharing, which aid PVI participation and integration. Our overarching goal is to inform technology designs that increase accessibility.

We chose to focus on grocery shopping because PVI have indicated that this task is challenging as it involves multiple sub-tasks such as outdoor and indoor navigation, product information processing, item identification, and acquisition, etc. [24]. Typically, PVI collaborate with a partner in grocery shopping; this may be a significant other, a social services caseworker, or a store-provided courtesy shopper. Many assistive technologies have been designed to support distinct shopping subtasks (e.g., *ShopTalk* [30] or *RoboCart* [24] for in-store navigation; *Trinetra* for product identification [26]; *Third Eye* for item acquisition [41]). However, out study offers a complementary view to research on assistive technology, offering a holistic view of how PVI work with partners when shopping for groceries.

In the remainder of this paper, we first present a theoretical framing for our work; following this we describe a field and interview study comparing collaboration experiences with different partners. We discuss three sources of common ground that contribute to PVI-sighted collaboration: 1) knowledge about how to assist PVI; 2) interpersonal knowledge resulting from common experience and interpersonal relationship history; and 3) knowledge of shopping as a practice. We conclude by considering how our findings inform the design of accessible tool designs.

2 RELATED WORK

CSCW researchers have investigated many dimensions of collocated and distributed collaboration in workplaces [3, 28, 29], learning contexts [32], and informal settings [2]. A small but growing area of research has begun to look into mediated collaboration among people with different abilities [e.g., 2, 32, 33, 35, 38]. Our study extends both lines of work by investigating PVI-sighted collaboration in an everyday but critical setting, grocery shopping. We draw on two bodies of research – the study of grounding in collaboration and assistive technologies for PVI – to contextualize our study.

2.1 Grounding for Collaboration

For efficient collaboration, the parties involved must have constant communication and coordination over the content and process [4, 5, 7, 9, 10, 11, 12]. Individually, collaboration partners must convey and make

sense of the conversation and task. Collectively, they then seek to actively establish and sustain their mutual understanding, or common ground, about one another's communication intent. Common ground enables the partners to process and make appropriate communication acts to ensure a successful and efficient result. Grounding, the process of reaching such mutual understanding, involves steps like: communicating about related references; describing actions to be performed; making repairs to misunderstandings; adapting when grounding purposes or contexts switch; and acknowledging when information is confirmed or actions are completed [7]. The amount of information exchanged during the grounding process should be sufficient enough to maintain communication efficiency [5]; different modes of communication, such as verbal language or nonverbal gestures, postures, gaze, or facial expressions may be used to facilitate grounding [8]. The level of sufficiency depends on the background of the partners, currently shared awareness, and the information needed to make progress toward the current goal [5].

Importantly, successful collaboration demands more than establishing mutual understanding about the content of the collaboration (content common ground). The ways in which common ground are managed, including shared awareness of current collaboration success or failure, and the social relationships that support helpful collaboration initiatives or repairs (process common ground) [10, 11, 12] must also be analyzed as part of group work. Researchers [4, 8, 11, 13, 15, 22] have identified several coordination factors that help to achieve both content and process common ground in collaborative tasks, such as linguistic and physical co-presence for awareness and visual cues; dedicated team members who are committed to tight coordination and careful planning; interdependency among members who conduct sequential or synchronous activities to accomplish a goal; inter-predictability about one another's actions regarding interaction rules, procedures, timing, and manner. Additionally, team members' interpersonal relationships or co-membership may influence the communication processes and strategies [15, 18].

Clark [7] assumes that collaboration partners have equal access to information and a common goal, and studies of physical collaboration indicate that members often achieve common ground based on situational awareness and visual cues [15, 22]. However, such premises do not always hold in PVI-sighted collaboration, because 1) collaborators may not have equal access to information, or even compatible knowledge about collaboration content and process; and 2) their goals for collaboration may not be fully shared, for example due to variations in the perceived responsibilities of the partners. In some situations, collaborators work in tandem to complete the tasks but have different personal objectives. For example, a PVI who is shopping may have the goal of finding just the right ingredients for an upcoming meal. A spouse or roommate may share that goal, but a courtesy shopper may be focused on providing any needed support as simply and quickly as possible.

Depending on their role, expertise, and responsibilities in an existing interpersonal relationship, interaction partners may have created a system that supports the encoding, storage, and retrieval of information for different contexts; this has been termed transactive memory [37]. In other words, each member may hold different knowledge elements related to a particular task domain, and it is their responsibility to contribute these to the teamwork. In this sense, we can assume that any individual team member need not know everything there is to know about a task. Distributing knowledge in this way leads to less cognitive load for each individual, thus increasing efficiency of collaboration and the diversity of the knowledge pool [36].

Researchers have shown that the extent to which team members know which of their partners holds pieces of task-relevant information can influence communication and collaboration quality [18, 36]. One would expect that people in close relationships have a history of interpersonal interactions that has led to considerable interpersonal knowledge of one another; as a result, they should have a rich transactive memory for shared tasks, reaching common ground more efficiently [15, 17]. In contrast, smooth collaboration among strangers or acquaintances should depend on exchange of more detailed information about the content and the process of the task [18].

Our study investigates PVI-sighted collaboration. Our research questions deal with *how common ground is built; how grounding processes vary; and the collaboration dynamics for different PVI-sighted relationships.*

2.2 Collaborative Assistive Technology

Assistive technologies for PVI have focused primarily on *single-user* task settings. In the context of grocery shopping, PVI may use smart phone applications to navigate around the store and aisles [1, 30]; text recognition tools to process labels and information on products [26, 27]; and wearable devices to augment spatial perception for item location and acquisition [20, 41]. It is important to support PVI's independence and agency in this way; however, when seeking full integration of PVI into social contexts, it is important to recognize that *PVI-sighted collaboration* is common in many settings. Tools designed for PVI are rarely designed to support collaboration; in situations when collaboration with a sighted partner is needed, work may thus take place separately instead of as an integrated process [29, 32, 33]. As argued earlier, a consideration of how technology might support PVI's equal access to information and awareness of others is key.

Research on assistive technology has started to address the issue of collaboration enacted through socially distributed cognition among people with different abilities, perceptions about the contexts, and strategies to build common ground. For example, tools may add a social dimension to facilitate PVI-sighted collaboration by incorporating other modalities, such as audio or haptic, into visual-driven interfaces. Winberg [38] implemented a system that incorporated visual and auditory interfaces to enable information access, manipulation, and retrieval for both parties; Sallnas et al. [32] used haptic prototypes accessible to both parties to create a shared learning space; Sánchez et al. [33] developed a system that enabled sighted users to access the tool through its graphical interface and PVI users through its spatialized auditory interface for gaming.

Most research studying PVI-sighted collaboration has been in the context of computer mediated cooperative work. One exception is Branham and Kane [2], who looked at PVI-sighted collaboration in domestic settings. Because collaboration is highly contextualized and may change depending on forms, motivations, tasks, and partners, we underscore the importance of studying physical, co-present PVI-sighted collaboration *in situ*, that is in places where it naturally takes place. Grocery shopping is such a setting where we can uncover PVI's needs when working with different types of sighted partners [25].

3 METHOD

The current study is part of a long-term research engagement aimed at understanding and supporting the needs of PVI as independent participants in routine tasks such as grocery shopping [39, 40, 41]. Because shopping is an intimate practice (e.g., participants revealed what they bought and why, what they ate at home, etc.), a long-term engagement is required to build relationships and trust with participants.

To investigate PVI-sighted collaboration, we first asked about the partners PVI typically work with when grocery shopping. We found that their primary partners are family members (in our case, their significant others), caseworkers trained to support PVI, and courtesy shoppers provided by a store. We thus decided to explore these three collaboration types using qualitative methods including field observations and in-depth interviews.

3.1 Participants and Recruitment

In the past three years, our research team has built a relationship with a local chapter of the National Federation of the Blind (NFB), as well as a non-profit organization, North Central Sight Services (NCSS; both are located in a college town in the northeastern U.S.). The local NFB has ten PVIs (three with partial vision and seven with no vision; four male and six female) and we sent out our recruiting message to all members. We also contacted a caseworker from the NCSS and asked her to relay our recruiting message to her 15 PVI clients. Due to privacy concerns, we could not directly access NCSS's client list. We are aware that there are many types of visual impairments, but the PVI who volunteered in this study are all with complete sight loss.

Five PVI participants from these two organizations agreed to participate; we conducted six field observations of PVI-sighted collaborative shopping (we accompanied one PVI on two different trips). Each

trip required significant time and effort to coordinate and arrange, as it was important to us to join a naturally occurring trip rather than setting up a session in a mutually convenient way. Each trip also comprised multiple steps and visits: 1) agreeing on a time for the trip and gaining research consent from the partner; 2) traveling to and from the store (we picked up the PVI in cases where the partner was a courtesy shopper from the store); 3) observing the collaborative shopping; 4) reviewing and organizing field notes to create custom interview probes for both the PVI and the partner; and 5) conducting one-on-one interviews with the PVI and with the partner respectively.

The shopping partners for these six episodes included spouse+spouse (n = 2), client+caseworker (n = 1), and client+courtesy shopper from store (n = 3) (see Table 1). Three shopping partners (the caseworker and the two spouses) had personal connections to the PVI. The three courtesy shoppers who assisted the PVI were store employees assigned by the store at the time of the shopping trip. Note that we did not assign or request types of partners, but rather relied on the natural collaboration practices for the PVI participants. In this sense, we were fortunate to "sample" the three types that we had identified as of interest in advance.

Three of our participants (Mimi, Alexi, and Angel; gender-appropriate pseudonyms are used throughout this report) live with a significant other and usually shop with them; the others (Maureen and Mark) live alone and depend on caseworkers or courtesy shoppers. One important difference in these two options is that a caseworker must be scheduled in advance, whereas a courtesy shopper can be requested on arrival at the store.

At the time when we conducted our study, Alexi's husband was away just as she was about to host a social event. She thus organized a quick shopping trip with the assistance of a courtesy shopper. With the exception of this one trip, all participants collaborated with their usual shopping partners (though of course courtesy shoppers vary from trip to trip).

Shifting focus to the shopping partners, the caseworker (Joanne, female, 40) has 10 years of experience assisting PVI in daily tasks, has known Maureen for more than two years, and assisted Maureen with shopping once before. In general, Joanne has 15 clients with visual impairments and generally assists each client every other week. Roger (in his 40s) and Mimi have been dating for four years and have lived together for two years. Collins (in his 30s) and Angel have known each other since high school and have been married for ten years. For all three courtesy shoppers, it was their first time providing shopping assistance to PVI. Joe is a teenager who works as a cashier; Dan is in his 20s and a floor clerk; Benny is in his 40s and a human resource manager.

Our interviewees told us that "store courtesy shopper" is not a designated position with specific training for assisting PVI; instead, whoever is available at the moment is called upon for the task. As a result, PVI may collaborate with different employees in the same store, and in all three cases we observed, it was their first time together.

3.2 Study Procedure

The study was conducted over a period of five months. To ensure our observations were made in as natural a context as possible, we scheduled field observations according to the PVI participants' actual shopping needs with their usual partner. We asked them to contact us when they scheduled a shopping trip and two members of our research team accompanied them.

The participants chose which grocery store to visit. We accompanied two trips to a whole-sale store (e.g. Costco, Sam's Club) with Mimi+Roger and Angel+Collins; two trips to a large national chain store (e.g. Walmart, K-Mart) with Maureen+Joanne and Mark+Dan; and two trips to large regional chain stores (e.g. Weis, Wegmans) with Alexi+Joe and Mark+Benny. Although product variety and store size varied from store to store, we saw no differences in PVI's general shopping practices that could be tied to store details; rather the differences were related to collaborative partners.

Table 1. Information about PVI participants and their shopping partners.

	Gender	Age	Age Vision Lost	Condition of Vision Loss	Living Condition	Shopping Partner	Grocery Store Type	Items Shopped	Shopped Grocery Types
Maureen	F	70	65	Degeneration over the years; total loss 5 years ago	Alone	Case worker (Joanne)	National chain store	25	Beauty products; Home supplies; Vegetable; Dairy; Eggs; Snacks
Mimi	F	42	Since birth	Total vision loss	With fiancée	Fiancée (Roger)	Whole sale store	13	Beauty products; Home supplies; Canned goods; Soft drinks; Meat; Fruit;
Alexi	F	34	Since birth	Light perception	With husband	Courtesy shopper (Joe)	Regional chain store	4	Vegetable; Dairy; Snacks
Angel	F	34	Since birth	Glaucoma; legally blind (can see contour and shape)	With husband	Husband (Collins)	Whole sale store	15	Home supplies; Frozen food; Meat; Snacks; Soft drinks
Mark	M	46	42	Degeneration over the years; total loss 4 years ago	Alone	Courtesy shopper (x2 trips) (#1: Dan, #2: Benny)	Regional chain store (both 2 trips)	17; 12	#1: Beauty products; Sparkling water; Dairy; Baked goods; Sauce; Fruit; Vegetable #2: Cleaning products; Snacks; Coffee; Beauty products; Dairy; Meat; Fruit; Vegetable

During the shopping trip, we took notes about incidents that took place during the trip and documented the interactions. We were guided by several over-arching questions: 1) how were shopping goals negotiated and communicated; 2) how were decisions made or strategies undertaken during the shopping process; 3) how was a shopping list used and what, if any, opportunistic shopping took place; and 4) when something went wrong, such as selecting the wrong product or brand, how did subsequent communication take place.

After the observation, we scheduled a follow-up in-depth interview with the PVI participants and their partners, separately. Among the three courtesy shoppers, only Benny agreed to have the interview with us. The interview usually took place within one week after its correspondent field observation. The interviews were organized into two sections: first, we inquired about specific incidents that we had observed during the shopping trip based on our field notes. For example, we noticed that for the two couples who shopped together, the sighted partner at times announced upcoming items that were not on the shopping list; this did not happen in other pairs. Thus we asked about this practice. In the second part of the interview, we asked more general questions about shopping together, including how often they shopped with different partners (for the partner we asked if they had worked with other PVI before); if they had any preferences or specific strategies for working with different partners/PVI; how easy it was to coordinate and communicate with the

partners/PVI; how complete the shopping task was with different partners/PVI; and the criteria they had for considering a given shopping trip to be a good collaboration.

Our interview protocol was semi-structured so that we could adapt to each set of field observations; we also encouraged interviewees to articulate their experiences regarding the issues related to shopping, challenges they faced in collaborating with different partners/PVI, and strategies. In other words, we asked our participants to share both their specific and general grocery-shopping experience. Each interview lasted 30-60 minutes and took place at a location chosen by the participant, such as a home or office. With the participants' consent, we audio-recorded interviews, except Benny's, as he declined due to store policy. To compensate we took detailed notes during Benny's interview.

3.3 Data Analysis

We used our field nodes in three ways: first, to construct background knowledge about PVI-sighted shopping collaborations; as probes to evoke customized interview questions; they were also integrated with the interview data to provide a context for interview quotes. In the case of Benny, we used the field notes and interview notes in the same fashion.

The audio-recorded interviews were transcribed and analyzed iteratively using a bottom-up approach. One author did a first round of open coding; all authors then discussed the meaning of selected quotes as a team. Several themes emerged, including how participants shopped with different partners, strategies for working and communicating with partners, perceptions of challenges and needs when working with different partners, and strategic solutions to such challenges. Through discussion, the themes gradually stabilized with the same themes seen in multiple interviews, across the comments from both PVI and their sighted helpers. We then did axial coding to connect important themes. We present our findings in the following section.

4 RESULT

4.1 Observation: Collaboration in the Field

The cases involving PVI+spouse and PVI+caseworker used a prepared shopping list. They spent time discussing the items on the list and where to start, using the list and corresponding negotiation as grounding. While the interactions of these pairs mostly focused on the shopping task, the PVI+spouse pairs also discussed their daily lives, which conveyed significant mutual interpersonal knowledge. For the PVI+caseworker case, we also observed social interaction, such as personal remarks or stories about products. More generally, the collaboration process for these two types of pairs involved socializing, clarification ("when you said you wanted eggs, did you mean brown eggs or white eggs?"), and confirmation (the partner ensured the right item was selected, at times handing it to the PVI for confirmation).

One difference between spouse and caseworker was that during the PVI+caseworker trip, the PVI took more responsibility for decisions, because the shopping was for her alone. In the PVI+spouse cases, the partners jointly consume the food and naturally shared the decision-making. When Maureen shopped with Joanne, we saw more frequent evidence of final confirmation, for example Maureen wanted to touch the item after Joanne had picked it up.

An interesting behavior for the spouse pairs occurred when the partners announced certain items as they were passing by. This practice did not appear in other pairs. We explored this this particular initiative in our interview and share our findings in a later section.

In the three cases with courtesy shoppers, Alexi held the list herself and Mark stored a list on his phone. Neither chose to share the list with their partner. Unlike the other cases, they did not engage in process grounding about where to start and how things should go. Instead, they let the courtesy shopper know what they wanted to buy, one item at a time. In our interview, we learned that they had organized their shopping list according to the store floor plan (they were frequent shoppers at these stores), allowing them to combine route planning with their list. Joe and Dan behaved more as assistants than as collaborators in this

situation, because they did not know what was on the list and simply followed Alexi's and Mark's lead. Importantly, this was the first time they had assisted a PVI in shopping so they did not really know what they should do to fully engage or provide information. For example, it was not until Alexi and Mark asked that they realized that the PVI wanted to touch some of the items for confirmation, or wanted feedback about where they were in the store.

Benny was an interesting case, because while it was also his first time working with PVI and Mark treated him similarly to Dan, he did not simply follow Mark's lead but actively engaged in the shopping process with timely information, clarifications and confirmations. Their collaboration also involved interpersonal interactions, such as talking about the store's displays for an upcoming home game of a local sport.

By combining these in-store observations with interview data, we were able to investigate differences in both grounding and collaboration styles, as we summarize next.

4.2 Shopping Practices for PVI-Sighted Collaborations

4.2.1 The Engagement of Shopping in Person. Shopping is not just a chore, but an active experience that includes learning opportunities wherein the PVI may explore varieties of products to better calibrate their specific needs and practices.

You get to explore new things and you get to know what an item looks like…I mean you can describe something online in words, but unless you see it, you still really don't know what it looks like. (Mimi, PVI)

like stuffing peppers, those peppers should be a certain size, you know they shouldn't be smaller than or bigger than a size. So, you might want to touch that stuff as well, depending on what you're shopping for. (Alexi, PVI)

In-store shopping should be understood as an embodied experience for PVI. Mimi uses the term "see" or "look like" to refer to the experience of exploring the products and environment using her other senses (particularly haptic). Physical visits are rich experiences that evoke past memories associated with products and enhance awareness of what is available and needed at home. Being in the store also supports decision-making, which leverages a broad range of contextual cues (e.g., sales, organic sections, Asian markets).

unless we buy like a different brand or something and realize, wait, that's a big difference in price…because sometimes you just never know…this stuff is on sale this week, go ahead and get it, even though we don't need it yet. (Mimi, PVI)

[Place A] doesn't have this cheese and I just realized that I need feta cheese today. And then this just came to my mind when I was shopping [at Place B] because I shopped for those chocolates before here. It's just like free association came to my mind, "I'm in [Place B], I should get some." (Alexi, PVI)

More importantly, in-person shopping affords social settings in which PVI can interact with people and engage in the broader social context. Visual impairment should not be a factor that isolates PVI, or that inhibits interactions with sighted people [[39]]. Maureen described her experience of being out and about as rewarding for both her and the sighted people around her. While she benefits from being able to do things independently and being integrated into society, other people benefit from seeing and interacting with her.

…when I walk around the neighborhood…I see them, they see me…some people come and say "Hi I've been watching you mow your lawn for two years and I am sorry, do you mind my asking 'are you really blind?'"… I don't see the reason why [a] blind person shouldn't participate. (Maureen, PVI)

4.2.2 Collaborative Shopping Styles: Stakeholding vs. Leading. Our PVI participants usually shop with a partner, such as their significant other, caseworker, or a courtesy shopper. Their interaction styles, practice patterns, and results vary across these partner situations, with different dynamics with different types of partners. Working from our combined analysis of field notes and interviews, we identified two types of shopping collaboration: the *stakeholding* that took place with the two spousal pairs (Mimi+Roger and Angel+Collins); and *leading*, reflective of episodes with a caseworker or courtesy shopper (Maureen, Alexi, and Mark).

In the stakeholding situation, PVI collaborated on every shopping sub-task, starting with preparation and continuing through the trip. At the store, the responsibilities for finding items, checking product information, picking correct and high-quality items, and generally ensuring a satisfying shopping outcome

were distributed between the pair. The PVI did not need to carefully monitor the shopping process to determine whether they were meeting their goals.

I buy certain things in the produce section but I mean now I'll buy more because I know once you buy stuff there's stuff that he'll [referring to her fiancée] eat. So I know he's going to pick something out usually it's going to be pretty good because it's not just me eating it. (Mimi, PVI)

Like a day before or so. And then she'll look at the online flyer and well okay this is on sale, let's buy that. You know, goes by price too... like yeah you might not need cereal that week but if you can get 3 boxes for 5 then go get it then. (Roger, fiancée)

These two interviewees pointed out that when shopping with their significant others, they had the opportunity to explore more about the products and the store, and to obtain sufficient information to (co-)make the decisions.

if you don't know what you are going to get. Let's say I'm going to get cheese. What cheese? There are thousands of different types of cheese. If you don't know exactly what you want to get, it's hard to describe how to find it...[but with her husband], we can just go explore, let's pick this time this one and try, this kind of mutual decision making. (Angel, PVI)

In contrast, when shopping with a caseworker or a courtesy shopper, PVI tend to take the lead; as a result, they feel the responsibility to be more organized in order 1) for their partner to help them; 2) to have a smooth collaboration; and 3) to evaluate whether the shopping task is accomplished successfully. The task outcome (i.e., whether they have collected all the items they need and if the items are of good quality) matters more to PVI than their helpers.

When you go to [a] food store, the people are really nice too. But you try not to occupy a lot of your time. You try to not be too picky. I try to be very clear...I feel that I need to be more organized because if I am going to the store with [a] shopping list, it would be sort of that order, I don't worry about what I forgot. If I forgot to put something on the list, it would come to me. (Maureen, PVI)

It works better if you sort of have a list because some of these people have no idea where stuff is in the store. They may work there, but they have no idea where products are. You would be amazed. So, you know when you do that then you don't get the same experience of knowing exactly what's around because they don't tell you. I mean for one thing they don't realize "oh wait you can't see this maybe you wanna know what's around"...they just don't think about these things. (Mimi, PVI)

Even with extra organization, PVI may encounter situations where they must compromise or be more strategic about some aspects of a shopping trip. For example, they may choose to give up buying some things to avoid conflicts with the partner, simply decide to shop for fewer items, or try to work quickly so as not to burden the partner. Sometimes they may not have other recourse but to trust whoever helps them.

Every two weeks on [caseworker's] day or whenever she is free. That may not be a day when I need things or need to shop...I shop large but I can't squeeze myself into somebody's schedule. (Maureen, PVI)

a lot of times you know you tend to avoid produce and vegetables and stuff because well I'm sort of picky about those anyway. And I'll buy more either canned or frozen or something like that. (Mimi, PVI)

So with parsley and dill they are like sold in bunches. I don't care if I touch it or not because I won't be able to understand anything differently...(Alexi, PVI)

4.2.3 Teaming up! Equal Partner for Engaged Shopping. The *leading* style of collaborative shopping, and its notion of taking charge, does not necessarily indicate independence or empowerment of the PVI. In a similar vein, the *stakeholding* style does not indicate a reliance on their spouse. What is more important to our participants is the ability to be an equal partner in the collaboration to fully engage in shopping.

You are responsible if you are shopping with the store assistant. If it's with [husband], you share responsibility. I would feel more independent with [husband] because I can ask any stupid question...in our relationship I don't feel restricted as well. (Alexi, PVI)

It's a team approach. It's more of working together versus a domineering style of going through...the things that I want, I want it to be more of a give and take...Or at least to check out and see new things too. (Angel, PVI)

The sense of independence is associated with the ability to explore, share responsibility, and engagement in decision making without having to impose on the other (e.g., taking the other's time, making "extra"

requests, etc.). The participants, who are married or in a relationship, gain the sense of independence from working with their significant other and from being able to contribute. On the other hand, our participants who are single and live alone, explained that they might reach a similar state by having a sighted partner with whom they can derive a sense of equal partnership.

In our next section, we discuss the aspects of collaboration that seemed to contribute to a sense of equal partnership. Our results indicate that three sources of common ground contribute to more effective collaboration.

4.3 Common Ground for PVI-Sighted Collaboration

4.3.1 Anticipating the Needs of PVI. According to our PVI and their partners, the collaboration can go more smoothly if the partner knows the specific kinds of information a PVI cannot access themselves. In the context of grocery shopping, such information might include an awareness of what is currently stocked in the store shelves or elsewhere, special opportunities like sales or seasonal offerings, and details about products like price or weight.

because she doesn't know necessarily what's going to be there. And I know that - even though we are pretty organized when we make a list of what we need, there's always something that you didn't think of and she's not gonna be able to make the connection of seeing it that 'oh we need that too.' I tell her what's coming up so it's partly for that because she might like to know what else is around. (Collins, husband)

if there are sale items. Maybe they typically get Lays potato chip and I see that generic brand it's on sale so I will say, oh I know you like this brand but this one is on sale. Some people go for it some people don't. (Joanne, caseworker)

When products are available in different varieties or brands, PVI need a general awareness of the options to help them make decisions. This specific piece of information may vary from store to store, and what people want to buy this time may not necessarily be the same as what they bought last time. In other words, situational awareness derived from these pieces of information, is important to PVI to make real-time decisions, including opportunistic consideration of products. However, such information is not always provided.

if you shop with someone else [other than her fiancée] you have to say "oh well what varieties do they have", you have to, or else they're like "well what do you want". Well I'm not real sure exactly which ones I want because I don't know what there is. And they don't think about, I can't see it, I don't know what there is... I mean you all get to look. (Mimi, PVI)

For some types of items, the participants preferred to touch for final confirmation; this was typical when the size of the item mattered or when a new type of product was being considered. This final confirmation is one indication of equal engagement in shopping because the PVI make the final decision based on this information.

...[husband] makes me touch, like "see these (onions) are this big" so I will say okay or not. So if it's something that needs to be decided by seeing like if the greens has yellows or strawberries are not looking good, you cannot touch the strawberries, then he's deciding. (Alexi, PVI)

if I know exactly what she's looking for... I'll just grab it because I know that's what it is. If I have some uncertainty, maybe it's a new product or different packaging...(Collins, husband)

Without such confirmation, it may be difficult for the PVI to ensure whether the partner has chosen the right, high-quality item. For Angel, this may even lead to a lack of trust:

*You want blackberries. Great. *plunk* in the cart. No feedback on price, ounces, quality of the berries, or even showing me what the container might look like. Maybe it was the one that got stepped on. (Angel , PVI)*

Making detailed arrangements beforehand, such as efficient route planning, can reduce unnecessary actions, like repeated backtracking at the store. Our participants mentioned that constant backtracking without spatial details can result in a sense of disorientation. Also, some sort of communication in advance over the desired type of assistance helps to enhance PVI sense of agency.

before I would go into a store and I would just wander up and down aisles and whatever looked good that's what I would just grab. But now it's like "well okay we need milk, we need bread, we need all these items. (Roger, fiancée)

I always try to make sure not interfering too much. I just want to support her and that's the other part too, get to know somebody better you know if they want to kind of take charge or just be here and help me when I need it...(Joanne, caseworker)

It can be difficult for the partner to understand whether the PVI receives all of the information that they need or whether the level of assistance is appropriate, especially caseworkers or courtesy shoppers, where their interactions with PVI tend to be too infrequent to develop a common understanding. Miscommunication may result in *faux pas* that influence both social relationships and collaboration outcomes.

I was very upset 'cause I found out I offended a lady one time, she called me and told me she was very offended...all I did was just describing to her where some things were...she took offense that I didn't think she is smart enough to understand or figure out how to make coffee. I thought I was helpful...she didn't really know me very well and I didn't know her very well...(Joanne, caseworker)

when you deal with courtesy shoppers...there are a very wide array of types of people...you can have the person kind of likes to shop and could spend frigging two hours comparing...[another courtesy shopper] is my style, he could tell I didn't need to know price of everything. But there are things good to know, like telling me the size of the almonds and ounces... (Mark, PVI)

People who have no experience in assisting PVI, e.g., a courtesy shopper, may not realize that these types of assistance practices are of importance, or even possible to provide. In such cases, PVI need to take the initiative to address information gaps by *asking* for information to prompt the partner to realize that it is not part of their common ground. This extra step may influence collaboration process and results.

You have to figure out the person when you meet them. Especially if you meet a shopper you know you have to figure out how much information you have to give them. (Mimi, PVI)

I try to educate the person as best I can if they are open to the idea and say...you don't want to say "hey" in a confrontational way "you're doing this wrong", but I try to shape the conversation. "Oh this is great, but could you tell me how much it is?" Because then sometimes they'll get it and maybe they're not so lousy, they just don't know. (Angel, PVI)

4.5.2 Shared Experiences and Interpersonal Relationship History. Our PVI told us that knowing about shared experiences helps them communicate with their partners and facilitates collaboration. For example, Maureen reflected about experiences with two caseworkers, one in her 20s and the other in her 40s. She noted that the older caseworker (Joanne) has a background similar to hers (same gender, similar age, experienced family shopper); this lets her make assumptions that help ground their collaboration.

I would feel more in control with [Joanne] anyway...The age thing or you know the difference. I don't know how long [Joanne] was doing this, length of time, dealing with people, put you in a certain mode...I don't have any requirements but there is just a relaxation...(Maureen, PVI)

In the case of Mimi, shopping with a female courtesy shopper adds to her comfort when buying female-specific products:

Well generally if you get people in the store, it tends to go better usually when you get female shoppers because a lot of the males either don't pay attention to where stuff is or they just don't shop normally most of them...there's products that you really don't want them to help you shop for. (Mimi, PVI)

In addition to common and shared experience, interpersonal understanding can arise through long-term relationships and a shared knowledge of daily practices; this also facilitates grounding and coordination. The more knowledge one has about the different facets of an individual, the easier and more efficient the grounding process will be. For example, both spousal pairs conducted a "screening" practice wherein the sighted partners selectively announced items they noticed. These announcements were based on their knowledge of their PVI spouse's preferences. Such a practice can lead to a very satisfying and efficient shopping experience. Similarly, Joanne (a caseworker) said that she knows Maureen likes to bake so she attempts to facilitate opportunistic shopping by reminding her that they were in the baking aisle.

I know specific things that she doesn't like so why waste the time saying "oh do you want prune juice?" (Roger, fiancée)

even though she didn't have anything related to baking on her list but I know she likes to bake. "Hey we are here it's the baking aisle." (Joanne, caseworker)

However, as Collins pointed out, strong interpersonal knowledge of a person (i.e., even a wife) does not always entail smooth grounding because shopping practices can be very specific: grocery shopping and clothes shopping relate to different aspects of an individual's preferences and habits. For example, in the case of Joanne, she did not know exactly why Maureen wanted different types of needles, so she did not know how to describe the varieties to Maureen. These incidents illustrate that interpersonal knowledge is not necessarily comprehensive, but rather must be accessed or updated to fit different collaboration tasks/contexts.

It's one thing to be friends with someone and have things to talk about and share experiences. It's another to adapt to how that person thinks in their shopping. (Collins, husband)

I didn't know how to describe some of it to her. And I didn't know what she was doing with that necessarily. So I think if I understood better what exactly she was doing I will be able to find the thing better. (Joanne, caseworker)

4.5.3 Knowledge about Shopping as a Practice. We observed information gaps between PVI and sighted partners with respect to shopping practices. For example, an understanding of likely products in a store and its layout facilitates collaboration. However, when gaps are present in what each partner knows, communication may not be smooth or successful, and frustrations can arise for both parties. PVI were never completely uninformed or unaware, nor were they completely reliant on the sighted partners' help. In fact, PVI sometimes knew more about a particular store's products or layout. In these cases what they need is fine-tuned assistance with item location and acquisition.

if you're in the right section it's kind of hard because I mean there's not really much else you can do. You know, because I don't know exactly what packaging and stuff looks like so [that's when the shopping partner does the job]... (Mimi, PVI)

Other times it was the partner who had relevant information but was unable to properly deliver it to the PVI, as they may not have experienced the same things or shared the same vocabulary, and in some cases may be experiencing new shopping items for the first time.

...they don't know the color. For someone who knows the color then they can easily connect that. Somebody who is blind from the birth mostly don't care about the color...also packages you can't see the item. Sometime it is solid you can't really see. (Joanne, caseworker)

Starfruit...I don't know how to describe it to someone. I don't even know what it tastes like. I've seen a picture of it, but it's not the same thing as knowing. (Collins, husband)

Our participants pointed out that knowledge about aspects related to grocery shopping, such as information about products or an understanding of store layout, is key. Mark described how Benny provided extra information about the products and the store layout; this helped Mark enjoy an enriched experience. In the store, we noticed that Benny worked with Mark to first plan an efficient in-store shopping route without backtracking. While Mark had already organized his list according to the store layout, he had the list on his phone, making it difficult to share directly with Benny. However, despite not being able to view the shopping list, Benny managed to co-develop a navigation plan, while also providing opportunistic shopping information, drawing from his knowledge about the store and the products.

he went to extra effort in explaining where we were in the store and what was in the aisle, even though he knew I didn't say I needed it anything specifically. Even that last aisle...he still took me to the last aisle and told me everything in that aisle, in case something triggered, you know what I need this. So you could tell he was willing to go extra effort, make sure I didn't forget anything. (Mark, PVI)

In our interview with Benny, we found that unlike the other courtesy shoppers we observed, or heard about from our PVI participants, he was an experienced store employee who has served in several positions, including stock, retail in different sections, customer service, etc. As a result, he has considerable knowledge of store offerings and their locations. He said that this knowledge helped him assist Mark despite it being his first time working with PVI.

5 DISCUSSION

We have shared our qualitative analysis of PVI-sighted collaboration in a grocery-shopping context. We observed shopping practices *in situ* to uncover and articulate the collaboration and accessibility needs for PVI shoppers. We established that a satisfying shopping experience involved equal participation by the two parties. Our study identified three sources of common ground that specifically facilitate PVI-sighted collaboration. We discuss the significance of our findings and suggestions for more accessible technologies.

5.1 Socially Embodied Experience

Our study suggests that a smooth shopping collaboration requires engagement and contribution from both PVI and their partner. During a smooth collaboration, PVI are able to learn more about product options and the store in general. In other words, we found that an embodied product experience is reinforced with the socially embodied experience of collaboration. As we have suggested [39], when PVI are grocery shopping, they not only buy things they need but also want to interact with the environment, store employees, or even other shoppers. These socially embodied experiences present social and learning opportunities for PVI, contributing to their true and full integration into the society. We posit that the forms of knowledge that support better grounding in collaboration are key to enhancing these socially embodied experiences.

5.2 Grounding for PVI-Sighted Collaboration

It is well established that collaboration is more efficient when people share greater common ground [4, 5, 8, 9, 10, 11, 12, 14, 22]. While physical co-presence provides rich cues for awareness and conversational grounding [8], the most salient feature of PVI-sighted collaboration is the absence of a shared visual space. Generally speaking, co-present collaborators rely on visual information to monitor one another's actions, the task setting, and the surrounding context [22]. With respect to PVI in general, different individuals may have different levels of visual impairment (e.g., partial or peripheral sight loss [6]). While those with partial vision may share some of the visual space with their collaborators, none of this information is available to PVI who are totally blind like our participants.

Because of these limitations, our PVI participants reported a need for situational awareness of store layout and product displays. Other needed information includes product varieties and availability, new or seasonal products, promotions, and product details (e.g., color, weight, price). If PVI are aware of such details, they can more easily form a mental model of the store, be reminded of what they need to purchase, evoke past experience, consider opportunistic product selections, and confidently perform behaviors like store navigation, item location, and object acquisition. In addition, our PVI participants indicated that reaching an agreement with their partner on *how* to carry out the task is important (e.g., saving the dairy and the frozen food for the last so as to keep them fresh), reflecting a desire for initial construction of process common ground [10, 11, 12].

A major contribution of our study is our identification of three sources of common ground that help to bridge the gaps in PVI-sighted collaboration: 1) *assistance knowledge*: how to assist PVI (e.g., in the case of PVI+caseworker); 2) *interpersonal knowledge*: knowledge derived from common experience (co-membership such as being female and knowing about female products) as well as interpersonal relationships history (e.g., PVI+spouse); and 3) *domain knowledge*: shopping as a practice (e.g., knowledge of the store in the case of PVI+skillful courtesy shopper). Note that these contributions to common ground were not specific to any particular type of partner. Any partner will hold some degree of any of these sorts of knowledge, and the collaboration will benefit from whatever is known.

We observed that the caseworker (Joanne) established common ground with Maureen through *assistance knowledge*. Based on her ten years of experience and professional training, Joanne understood what types of information PVI needed and when to ask in order to provide assistance, which shows some ways of achieving *process common ground* [10, 11, 12]. Other examples included that she discussed Maureen's list with her, organized the items based on store layout, and optimized their shopping route before they started. She provided information about the sections and the aisles as they passed them to help build and maintain Maureen's situational awareness. Joanne was very specific about collaboration structures and processes, such

as setting a goal with Maureen (discussing shopping list), constructing a plan to fulfill the goal (planning routes), providing product/store information when needed, giving heads-up about subsequent actions (entering specific aisles or sections), and soliciting feedback from Maureen from time to time (asking what Maureen wanted and giving her the items for haptic confirmation). We observed that Joanne made this sort of assistance knowledge salient to Maureen through explicit actions, which facilitated collaboration.

In the case of the courtesy shoppers, while all three were completely inexperienced with PVI collaboration, Benny provided assistance through his extensive *domain knowledge* about products and the store, which Joe and Dan did not have. Based on his prior experience as a front-end retail manager, he knew the locations of the products Mark wanted, what was near them, and what kinds of seasonal display the store would carry around the year. So, he could provide not only navigational guidance but also additional product information for Mark to do opportunistic shopping. He clarified different varieties of a product (e.g., ground coffee vs. whole bean) to Mark and asked for confirmation because he handled product exchanges before when he was a customer service manager. Benny's domain knowledge may have contributed to *content common ground* [10, 11, 12], as his rich knowledge meets what PVI would like to know in grocery shopping collaboration.

Our participants mentioned that general commonalities shared by the partners also contributed to initial mutual understanding (i.e., being female, of similar age, having similar shopping experience, etc.). However, as shopping is a contextualized and individualized practice, this specific source of common ground may need to be re-negotiated and augmented with additional information related to different facets of the activity [17].

Among all types of partners, significant others leveraged *interpersonal knowledge* and provided the most efficient grounding process due to their long-term relationships and prior understanding. The most significant example is that they were able to provide "personalized" information screening about the store and the products to their PVI spouse for awareness. Instead of offering all-inclusive information and risking an overload, the sighted partners collaborated with their PVI spouses based on their previously acquired knowledge about each other's preferences and needs, in this sense serving as a transactive memory for the PVI. This action also exemplifies the concept of *least collaborative effort* by efficient and economical grounding [9], while maximizing PVI's situational awareness.

In addition, a spouse has a clear stake in the outcome of a grocery-shopping trip. That is, the spouse will actually eat the food that is bought. This meant that the PVI and spouse had a higher level of collaboration and made decisions together. This is in contrast to other partners who might not have had a perceived stake in the shopping outcome (they were not going to eat the food). In other words, working with a spouse not only ensures the spouse's commitment to and engagement in the practice, but also alleviates the PVI burden of being extra organized and wary about the quality and accuracy of items procured. While shopping with a spouse, the PVI participants reported that they got to explore more and feel more equal.

Previous research that investigated independent shopping has demonstrated that an ideal shopping experience to PVI encompasses more than just accomplishing purchase tasks but also the ability to explore, learn, and make social connections [39]. Our study extends the previous research by showing that collaborating with a partner that makes PVI feel they are equal through sources of common ground can contribute to engagement and collaboration performance. Each three sources of common ground can be leveraged to compensate the lack of the others, which points potential facilitation of collaboration with PVI for collaborators beyond closed ones.

5.3 Design Implications

Based on our findings, assistive designs for PVI need to consider how to leverage the different sources of common ground we identified, including: *assistance knowledge*, *interpersonal knowledge*, and *domain knowledge*.

In a *collaborative* shopping scenario, the focus of this study, assistive technology may be used to better inform and support both PVI and their partners. If a shopping partner is missing some degree of *assistance knowledge* (e.g., how to promote PVI's situational awareness), a set of technology features might be activated to help the PVI ask informed questions to the partner, thereby contributing more equally to the collaboration experience.

For example, computer vision technologies implemented in tools like *IRL SmartCart* provide context awareness through RFID, indoor navigation, image projection, and 3D representations [34]. This assistive cart was designed to augment shopping experience for the sighted, through list management and location-based product recommendations; the addition of computer vision could turn *IRL SmartCart* into a multi-user system for both PVI and the sighted. Such system can leverage *assistance knowledge* via notifications to the sighted partner about what and when to share information and actions toward item acquisition with PVI. Based on our results, most courtesy shoppers are first-timers to provide assistance to PVI; they may be benefited from such support to promote PVI's situational awareness and provide the types of information PVI especially need. The same computer vision techniques could also support PVI's temporal and spatial awareness about the visual space so that they can engage with partners about product varieties, promotions, and other information conveyed by the cart. A set of features might be turned on by the PVI so that they can ask more informed questions to the assistant. A multi-user system such as this might enhance efficacy and independence of PVI, helping to ensure equal participation. Meanwhile, direct access to PVI's feedback enabled by the system may also save time and effort in grounding for the sighted assistant; the time saved for figuring out how to provide basic assistance to PVI can be in turn spent on more meaningful interactions, such as communicating over specific needs, concerns, or even interpersonal interactions. Such a system also benefits from prompt and continuous representations of each other's actions because they can increase mutual awareness and improve collaboration effectiveness [28].

Moreover, to provide better embodied product experience, *IRL SmartCart* or *RoboCart* [23] might leverage the value of *domain knowledge* by serving as an expert in identifying product location and information. The cart could be enhanced with features for social navigation (e.g., recognizing different sorts of human groupings or activities in the store) that can be shared back to the PVI for enhanced awareness. This might better simulate the situation where a spouse provides custom information to the PVI as guided navigation. In addition, with indoor navigation and RFID, the tool might use a shopping list to suggest optimal shopping routes based on current store stocks and floor plan. Instead of just guiding the PVI on the route, it could also explain why it is optimal.

Also, the system can build on *interpersonal knowledge* by supporting information sharing and making transactive memory, or the awareness of "who knows what," more salient to each other using multi-modal interfaces. For example, a multi-model system might implement a private and a public interface for both PVI and sighted users to organize individual knowledge and shared information so as to facilitate communication and task coordination [28, 33, 38]. If a new caseworker or a courtesy shopper does not (yet) have knowledge derived from *a personal relationship* with a PVI, perhaps a set of features that help to maintain awareness of any relevant opportunistic opportunities can be enabled to provide *in situ* information to the PVI. In either of these situations, the increased technological support can help the PVI to prompt the partner in a more equal way regarding the information that is helpful to them, as well as providing the partner with more information about items of interest. Importantly, the PVI should be able to turn these sorts of extra supports off when the partner is already providing rich support.

A range of input and output interfaces can be implemented to support information access, manipulation, and retrieval for both PVI and sighted partners, such as written text, haptic sense, voice recognition, etc. For example, digital signage [23] might be added to traditional printed tags for more dynamic product information and price display. Such tags might even deliver push notifications through mobile devices via either text (to sighted partner) or voice messages (to PVI) to communicate product location on a shelf or a product's ingredients or other useful information. An overlap of input and output modes may also help the sighted partners to promptly engage in PVI's activities, interact with them, and provide tailored assistance [28].

5.4 Limitations and Future Work

We are among the first to explore collaborative shopping between PVI and the sighted in a natural setting. While this study provides an initial understanding of PVI-sighted collaboration dynamics, it is not without limitations. First, due to the practices of the PVI who offered to participate, we did not observe cases with other collaborators such as family members or friends who may have different interpersonal knowledge about our

PVI participants. These "less connected" family members may practice and build common ground differently than significant others.

Also, we were not able to interview the least skillful courtesy shoppers in the study (Joe and Dan). While we sent them interview invitations, they did not respond. We surmise if the less skilled courtesy shoppers declined to be interviewed in part because they were not actually participants in the collaborative shopping practice, and thus did not feel like a stakeholder. Both less skillful courtesy shoppers were assigned to perform this task by their manager, despite having no experience. Although Joe and Dan were not part of our interview data, our participants did talk about their experience with them, as well as other inexperienced courtesy shoppers. These general comments indicated that the less skillful courtesy shoppers do not act like and are not experienced as "equal collaborators," perhaps because they have less of a stake in the shopping outcome. This may lead to reckless practices (throwing delicate fruit in a shopping cart), or failing to provide product and store information.

We have noted that different PVI have different visual impairments, but our participants were people with complete sight loss. We do not know whether our findings would generalize to PVI with partial vision who may start with a higher level of equal participation as well as the issues of how a combination of visual and other impairments present common ground challenges.

While studying people who are totally blind allows us to investigate how complete lack of visual space influences grounding in collaboration, it is also important to study how partial or peripheral vision loss influences grounding or collaborating. We hope our study paves the way for future studies to investigate PVI with different visual impairments. Such an investigation might also consider how people who are totally blind collaborate with people who have other types of visual impairments in grocery shopping scenarios.

The majority of our participants were female. When we set out to study collaborative shopping, we hoped to include all members from the local NFB (four male; six female). However, we discovered that shopping as a practice might not be a routine for every PVI in our cohort. Some participants, and especially males, rely on family members or partners to meet this need; others shop but only rarely. The participants recruited in the current study were overlapping with those in our prior studies [39, 40], which suggested that grocery shopping is a routine practice for our current participants. To ensure the validity of our study, we chose to investigate shopping behavior as a *developed practice* that takes place naturally. Thus we did not ask participants who do not shop for groceries on a regular basis to stage or perform the task. While it is a limitation that we studied primarily female PVI, we were concerned that the bias introduced by an unnatural setting would make such data less revealing.

General privacy concerns and store policies prevented us from recording the actual conversations and interactions that took place during the shopping trip, thus preventing any conversation- or interaction-based analysis. Without shared visual space in physical co-present collaboration, PVI and their partners rely heavily on verbal communication to compensate the lack of visual cues and engage in grounding. Conversational grounding for physical tasks is intricate and requires constant attention and adjustment as part of a dynamic protocol [13, 22]. Our initial findings merit a further study that could capture and analyze the PVI-sighted conversational grounding in detail, providing a more comprehensive view of when and what is communicated.

Last, we focused on a very specific type of collaboration in grocery shopping scenario, which is very different from other types of collaborative shopping such as shopping for clothes or even collaborations that take place in educational and work settings. We focused on grocery shopping because it addresses people's everyday needs and has been identified as one of the most challenging tasks to PVI [13]. Future study may consider different tasks or domains, while also leveraging and generalizing the three common-ground sources we have identified. It will be interesting to examine the shopping assistance knowledge, interpersonal knowledge, and domain-specific practices that are present in other naturalistic settings. Also, there may be other issues and challenges in addition to reaching common ground in PVI-sighted collaboration. Future research should start to look into this area for the purpose of full social integration for all populations.

Future study might also consider specific dimensions of coordination regarding temporal, spatial, content, and process supports: PVI need to let the partners know what and when specific assistance is needed based on

collaboration stages; when and how to deliver information when repairs are needed to bridge information or action gaps; negotiations about whether the message has been understood as intended.

6 CONCLUSION

It is important to support PVI to live independently and free of the burdens of disability. This study emphasizes that social and collaborative living also constitutes an important aspect of universal accessibility and full integration. We investigated how PVI collaborated with different partners in grocery shopping context to understand how PVI communicate and work with the sighted people. Our findings pointed out three sources of common ground contributing to successful collaboration: 1) knowledge about how to assist PVI; 2) knowledge about common experience and interpersonal relationship history; and 3) knowledge about shopping as a practice. We discuss how these common ground sources can be built into single and collaborative assistive technologies.

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