Understanding Food Planning Strategies of Food Insecure Populations: Implications for Food-Agentic Technologies

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ABSTRACT

To identify technological opportunities to better support nutrition security and equality among those living in low-socioeconomic situations, we conducted 33 semi-structured interviews and seven in-home visits of lower- to middle-income households from a mid-sized city in northern Indiana. Inspired by assets-based approaches to public health, we investigated technology's role in supporting how participants selected and purchased food, planned meals, and worked through logistical barriers to obtain food. Technology helped participants identify sales and coupons, search for recipes and health-related insights to address diet and health concerns, and share information. We contribute design implications (e.g., amplifying optimization behaviors and social engagement, leveraging substitutions) in support of food agency. We further contribute three emergent archetypes to convey central shopping tendencies (i.e., inventory shoppers, menu planners, and adaptive shoppers) and identify corresponding design implications. We situate our results into nutrition decision-making and education, social psychology, food consumer studies, and HCI literature.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**;

KEYWORDS

food (in)security, food planning strategies, nutritional equality, agency

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1 INTRODUCTION

Healthy food access is associated with lower diet-related chronic diseases such as obesity, cardiovascular disease, and cancer [48, 67]. However, many communities, primarily those in rural areas, urban communities of color, and those experiencing financial constraints, have limited access to healthy food, which limits their ability to optimize health and keep such diet-related conditions in check. In developing structural interventions to address this problem, we must consider the complex interaction of factors related to poverty and its relationship to health behaviors [5]. Such factors include financial challenges, often in combination with other variables such as time constraints, household makeup, and limited food preparation appliances. Inspired by assets-based approaches to public health [10], we turned to these populations for their insight and skills

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in working around compounding constraints to understand their organizational and food procurement strategies. We broadly define food procurement as all activities related to acquiring food. Despite examples of resourcefulness, we also acknowledge that these structural barriers and inequalities are sometimes insurmountable; indeed, we encountered participants who could not work around their range of constraints to achieve healthier eating. At a high level, our goal is to improve nutrition security[1] by exploring opportunities to support healthful choices through technology design, especially among people impacted by economic inequality and those who live in "food deserts."[2] In this study, we specifically aimed to understand households' food selection, purchasing, and meal-planning decisions; how these households worked through logistical barriers to obtain food; and the role of technology in this process. We addressed this broad question by investigating the following sub-questions:

- RQ1: What food procurement planning strategies do residents of food deserts[3] use, and what role does technology play in facilitating these strategies?
- RQ2: How can technology improve nutrition security by bolstering these strategies?

To address RQ1, we conducted 33 semi-structured interviews followed by seven in-home visits from July 2021 to mid-August 2021 in lower- to middle-income households. Participants resided in areas designated as food deserts in a mid-size city in northern Indiana. While our empirical results confirm prior findings on specific logistical barriers, we further convey our population's assets and how our participants worked around logistical barriers. We specify the role of technology in supporting their strategies (e.g., leveraging technology to find sales and social media and search engines to support the consumption of healthful foods to address diet and health concerns, sharing recipes and insights with loved ones). In addition to our empirical results, we also contribute:

- Concrete ways for technology to support food agency, which we describe in the form of design recommendations (e.g., amplifying optimization behaviors, leveraging substitutions, amplifying social engagement). These recommendations aim to empower consumers by reducing the time burden and cognitive load of optimizing purchases across multiple criteria such as health, savings, dietary preferences, and shopping time.
- Three salient "shopper archetypes," which serve as heuristics to help us understand our participants' central tendencies and strategies. The archetypes—menu planners, inventory shoppers, and adaptive shoppers—convey clusters of behaviors that support consumer agency. We further contribute specific design implications and future research suggestions to support the planning strategies exhibited by these archetypes.
- A critical reflection on how "food agency" as a construct is context-specific. Food agency, previously defined in regard to food preparation, does not account for factors involved in food procurement [38]. We highlight how people navigate procurement barriers, linking a process-oriented concept of agency to implications for technology design.

Our work advances the literature in decision-making, social psychology, consumer studies, nutrition education, and human–computer interaction (HCI). Our work is especially timely because the world is facing a potentially disastrous food security crisis given the combination of high inflation, climate change, the COVID-19 pandemic, and the effects of the war in Ukraine [16]. The world's most vulnerable people are facing significantly higher food prices than in the past [24].

2 RELATED WORK

Health and nutrition education researchers have highlighted that very few studies have provided insights about the strategies of low-income families and food security [2]. Although this research was conducted more than two decades ago, similar gaps exist in HCI [74]. Inspired by this literature gap and assets-based approaches to public health [10], we sought to understand strategies from prior literature that low-socioeconomic status (SES) communities used to address food access barriers. Our related work draws from nutrition decision-making and education, social psychology, food consumer studies, and human–computer interaction (HCI). First, we discuss the contextual determinants of diet quality for low-SES households, focusing on the food access strategies they use. Then, we discuss consumer agency and food agency in the context of those strategies. Finally, we conclude with opportunities for technology to support nutrition security—particularly among low-SES households.

2.1 Diet Quality in Context: Food Access Strategies of Low-SES Households

In low-SES communities, systemic factors such as affordable and healthy food access, understanding food labeling, and nutrition education contribute to healthy eating [45]. Frequent availability of healthy foods in low-income households correlates with higher dietary quality and food security, versus less frequent availability of healthy foods [39, 44, 46, 68, 69]. A recent review of the nutrition literature revealed three categories of contextual and behavioral factors contributing to food security and dietary quality among low-SES households: food procurement and preparation behaviors; parental, adolescent, and child behaviors; and psychosocial factors [45].

When these factors present constraints or barriers to food security, low-SES households use various strategies to mitigate and work around them. Numerous qualitative studies have identified four categories of adaptive behaviors, which we refer to as procurement strategies: institutional, social network, food provisioning, and food consumption strategies [33, 35, 56, 62]. Institutional strategies involve using programs from government daycares, churches, and food pantries/banks [19], as well as federal nutrition assistance programs such as Women, Infants, and Children (WIC) and the Supplemental Nutrition Assistance Program (SNAP) [42, 63]. Indeed, food-insecure households often rely on multiple institutional

[1]Nutrition security is defined as "consistent and equitable access to healthy, safe, affordable foods essential to optimal health and well-being" [71, p.1]

[2]Whereas food deserts have traditionally referenced food access, critics explicitly call out how food deserts directly highlight economic inequality and could more accurately be referred to as "food apartheid:" https://www.governing.com/community/critics-say-its-time-to-stop-using-the-term-food-deserts.

[3]As designated by our local county food access organization, which based its definition on USDA standards.

resources to stretch their grocery budget throughout the month [18, 33]. People also leverage social network strategies such as drawing on material and emotional support from family, friends, and faith communities and rely on private and public assistance [19]. Food provisioning (i.e., maintaining a food supply) and purchasing strategies involve making lists, utilizing coupons, purchasing in bulk, buying sale items and store brands, comparing prices within and among stores, and shopping at several stores if necessary to maximize savings [2, 6, 11, 17, 19, 28, 36, 42, 52, 55, 57]. Finally, food consumption strategies include re-purposing leftovers, preparing large-pot meals to stretch ingredients, serving smaller amounts of food [19, 42, 49], or skipping meals entirely [32].

Low-SES households that utilize strategies from all of the above categories notably demonstrate adaptability and resilience; however, food provisioning and purchasing strategies can demand greater personal agency. As Thompson et al. observed about food provisioning, low-SES shoppers enact a range of low- to high-agency behaviors when navigating grocery store environments [66]. Those who enter stores without a plan or particular constraints are prone to impulse buying, whereas those who employ the planning and economizing behaviors listed are more resilient to in-store advertising [66]. Food consumption strategies also involve numerous behaviors to maximize savings and nutrition, though the two are sometimes in tension. Low-SES parents often accommodate their children's food preferences to avoid waste [20, 27], although this practice can compromise dietary quality [28]. Parents monitor food supplies at home to encourage the selection of nutritious options and to limit the availability of less healthful foods [7, 28, 61]. Finally, heads of households might designate nutrient-dense foods for certain individuals due to their age or medical condition [11, 36, 52, 61, 64].

What is unclear from the literature is whether or how technology could support and hone the strategies identified, and whether such strategies could be combined or merged to be more effective. Future research should also explore opportunities for technology interventions to support the procurement of healthy food by increasing consumer agency—an area we discuss next and that our work seeks to address.

2.2 Designing for Consumer Agency in Food-Procurement-Supportive Technology

Agency in the context of food access can be conceived both in terms of how an individual navigates the food environment, as well as how users leverage technology to support food procurement. A handful of studies on food provisioning in low-SES households referenced various social science definitions of agency, particularly those describing agency as a dialogue between individuals and their context. We aim to increase consumers' agency in service of nutrition by improving their ability to plan food purchases through technology.[4] Thus, we consider how agency is conceptualized within human–computer interaction, providing insights for nutrition-focused technology design.

Most of the nutrition science and health equity literature reviewed in Section 2.1 did not account for food procurement and management behaviors through a particular theoretical framework. However, a handful of studies referenced agency-related constructs to explain the corresponding strategies used[5] [8, 30, 33, 38, 52, 70], including two recent articles about agency in the context of food preparation [38, 70]. While previous research identified factors that affect healthful cooking, these studies located participants' efforts to make a habit of home meal preparation within their "socioculturally mediated capacity to act" [1, 70, p. 112]. Thus, Trubek et al. defined food agency as "being *able to act* throughout the planning and preparing of meals within a particular environment" [70, p. 304]. Lahne et al. [38] then developed the Cooking and Food Provisioning Action Scale (CAFPAS), accounting for three components of food agency: food self-efficacy, food attitude, and structure [38, p. 96].

"Food agency" as defined above captures the overlooked complexity of food preparation, highlighting internal and external factors that bear on that process. Internal factors (i.e., food self-efficacy and food attitude) include confidence in one's culinary experience, along with perceptions of cooking as either enjoyable or burdensome [70]. External factors (i.e., structure) include financial and time constraints on meal preparation [70]. High-agency individuals are those who persevere despite constraints, relying on prior knowledge or learning new recipes [38, 70]. We asked whether similar factors affect food procurement, specifically time, money, and individual planning capabilities. Improving agency in complex food environments necessitates flexible but robust technology interventions, a concern shared by researchers in human–computer interaction.

Supporting user agency in the context of food procurement varies widely depending on the type of technology assistance provided. Within the emerging field of human–food interaction, Bertran and Wilde et al. used agency to denote a spectrum of decision-making capabilities for technology interventions that give more autonomy to users (human empowerment) versus those that automate tasks [4]. This discussion of agency is particularly relevant for current artificial intelligence (AI)/intelligent systems, which can blur the boundary between user and machine [15]. Bertran and Wilde et al. also recognized that improving agency to support food practices through technology can enhance user experiences without compromising rich, embodied engagement with food [4]. Indeed, critical reflection on the concept of agency is necessary both for general food access interventions and for designing human–food interaction technology [4]. By bridging discussions across nutrition, consumer studies, and human–food interaction, we nuance understandings of how technology can bolster agency for people facing food insecurity. We conclude our related work by exploring how prior technologies have broadened consumer agency by mitigating logistical barriers to grocery shopping.

[4] As noted in 2.1, food procurement also includes non-monetary sources of food. Although we focus primarily on food purchases, we aim to support all types of food procurement, including from food pantries, food banks, and other sources.

[5] For example, Beck et al. explained food consumption behavior through the Capability–Opportunity–Motivation (COMB-B) model [8], whereas Palmer et al. and Henry et al. used self-efficacy to account for dietary behavior change [30, 52]. Jarrett et al. explained food insecurity mitigation behaviors through a family resilience lens [33].

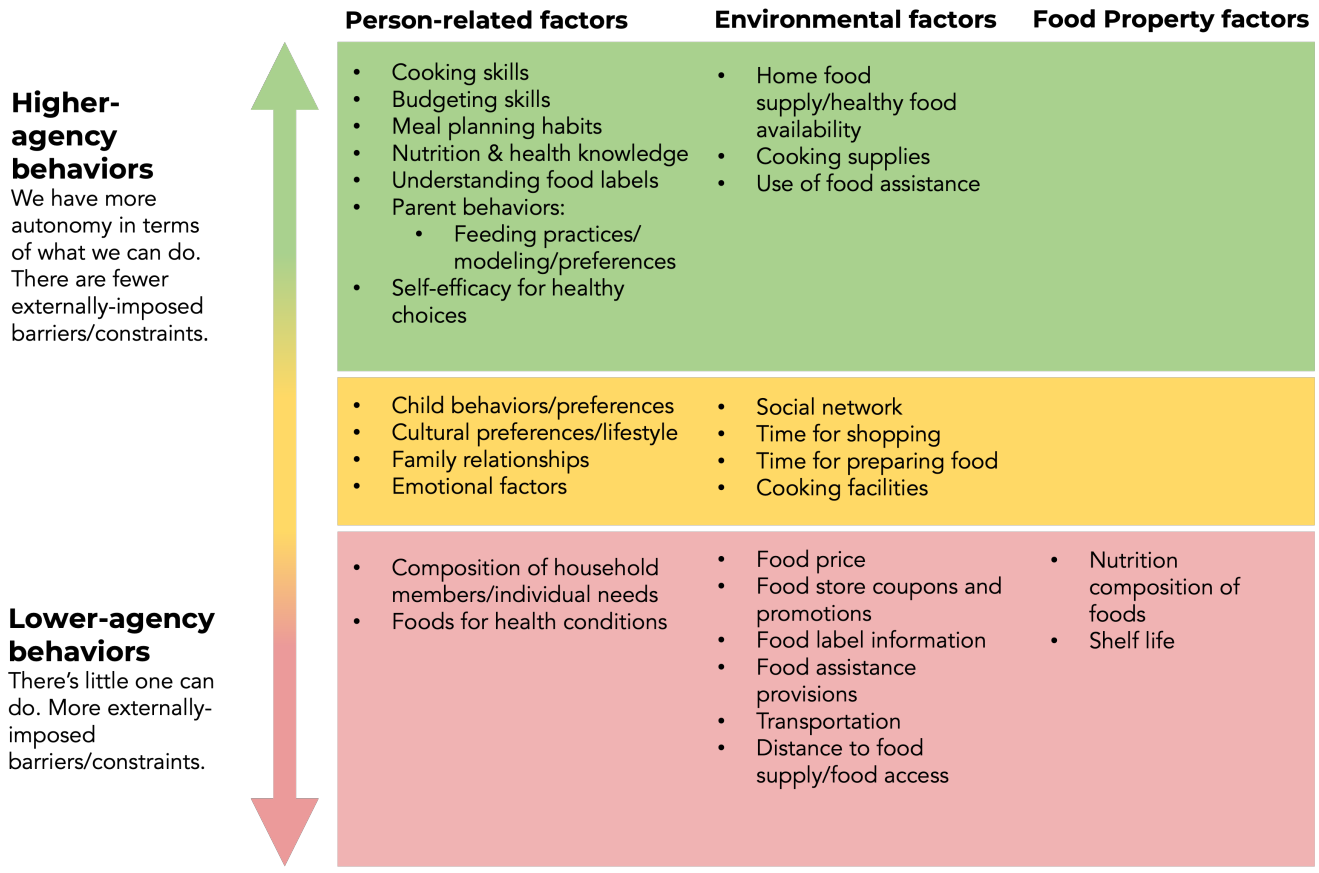

Figure 1: A spectrum of high to low-agency behaviors and how they correspond to three factors related to food consumption as discussed in Marshall et al. survey [43]: Person-related, environmental-related, and food property factors. We subjectively categorized many specific behaviors identified in Sections 2.1 and 2.2 to suggest behaviors associated with having *higher agency* or autonomy or *lower agency*. The figure raises questions about how technologies might facilitate agency and address one or more factors across the spectrum.

2.3 Technological Interventions

Traditional HCI research in the space of healthful food access broadly focuses on persuasion (e.g., [50, 54]), nutrition education (e.g., [13, 23, 31, 72]), and awareness (e.g., [25, 26, 60]). Persuasive computing research aiming to persuade people to change their dietary behaviors has been critiqued because it often fails to motivate change [41] and promotes a one-size-fits-all approach not tailored to specific user groups [50]. Persuasive technologies also inherently suggest that people should modify their behaviors. Motivated by assets-based approaches to public health [10], our work aims to better understand how technology can support what low-SES populations already do to overcome nutrition-related constraints. We turned to the literature to understand how technology supports a healthy diet and food decisions.

Building on the traditional HCI and persuasive computing research, Marshall et al.'s comprehensive survey of food choice technology identified technology's role in *influencing* healthy food choices and opportunities for future work [43]. In their review, the authors identified three main groups of food-consumption factors: person-related factors (i.e., user preferences and biological or demographic traits); environmental factors (i.e., micro-level factors like portion sizes and eating environment; macro-level variables such as food accessibility, market prices, and neighborhood characteristics; and psychological and situational factors); and properties of the food (i.e., nutrition composition). Figure 1 shows a spectrum of behaviors drawn from our related work to convey how they correspond with these three factors, and to one's subjective level of agency. In other words, factors like budgeting and meal planning correspond to higher-agency behaviors, which give us more autonomy regarding what we can do. Fewer barriers are imposed on our

ability to plan meals or budget, for example. On the other hand, factors such as the nutritional composition of available foods or how far we live from a supermarket are associated with lower-agency behaviors. Such factors are externally imposed, and we have little control over them.

Marshall et al. excluded articles that focused solely on food recommendations that did not consider nutrition or health. Prior work has critiqued such technologies because their focus on calorie control can lead to poor nutritional choices [31] rather than considering the nutrients those foods provide [73]. In addition, tools that focus on energy intake alone don't support advanced planning because they are designed to help people log their meals *after* consumption [65]. Many of the behaviors and factors noted in Figure 1 are related to behaviors enacted *before* consumption. Some of the tools included in the literature were intended for dietary assessment, to provide an accurate record of all foods consumed, and not as an intervention designed to influence healthy food choices. Marshall et al.'s survey results identified opportunities to address research gaps in food choice technology, which aligns with several of the higher-agency, person-related factors (i.e., meal planning and understanding food labels). In addition, the authors noted the lack of consideration for person-related factors across the spectrum. Examples include opportunities for food recommendation models to consider habits and routines around food consumption, and food knowledge, skills, and abilities (higher-agency). Others include cultural preferences and lifestyle; food habits, family structure, and food culture; physical health; and social influence and social support (middle- to lower-agency behaviors) (exceptions include [29]). These findings overlap with Bomfim's findings, highlighting that many of these tools don't address food insecurity [9] or the financial challenges to maintaining access to enough food experienced by the 13.8 million (10.5%) U.S. households experiencing food insecurity in 2020 [22]. Another gap is how food-recommendation technologies fail to address environmental factors across the agency spectrum (e.g., higher-agency factors such as cooking supplies or using food assistance to lower-agency factors like food assistance provision). While the authors raised these gaps in food recommendation systems, food delivery services do address lower-agency environmental factors such as having limited transportation access or being farther from a supermarket.

Our work extends knowledge that aims to support healthy eating and raises interesting and timely new questions in light of the coronavirus disease 2019 (COVID-19) pandemic. How do people experiencing food insecurity and financial constraints work around them, and what is the role of technology? How might technology support person-, environmental-, and food-property-related factors across a spectrum of agency?

3 METHODS

We used a two-phase sequential qualitative approach from July to August 2021 to address our research questions. Phase one included semi-structured interviews; phase two consisted of in-home visits, which also used a semi-structured protocol. Researchers used purposive sampling[6] [12] to identify and recruit participants representative of the demographics of the target geography [51], a census tract designated as a food desert by the local Food Access Council. Our focus area consisted of slightly fewer than 300 households, with nearly 60% of the population living in poverty and more than half receiving Supplemental Nutrition Assistance Program (SNAP) benefits. Most of the population was white, and 40% was Hispanic or Latino and approximately 21% African American. Our university's institutional review board approved our protocol and precautionary plans for COVID-19.

3.1 Participant Selection and Recruitment

To recruit participants for our study, we posted and mailed both physical and digital flyers and shared our recruitment message via social media with 11 needs-based community organizations and more than 15 businesses in the census tract of interest. Respondents were either sent a link to a survey to enter their personal information or screened over the phone. Screening included contact information and demographic data—age, race/ethnicity, income, and household size. We also asked questions about their use of public assistance, driver's license and/or vehicle access, internet access, and ability to participate in initial and follow-up interviews. This information allowed us to screen participants to ensure: (1) that our sample was representative of the census tract and (2) that they lived in or near the census tract.

3.2 Data Collection

In addition to our survey intake form, data collection consisted of 33 semi-structured interviews followed by seven in-home visits. Researchers conducted interviews with participants who represented the demographic categories of the targeted census tract through different methods (i.e., Zoom, phone, or in-person) based on the participant's preference. Although digital options were considered during COVID-19, the approved precautionary plan allowed researchers to conduct all in-home visits in-person. The majority of our interviewees were women (N=28); African Americans (N=17); single-parent households (N=11); and SNAP, and/or Women, Infants, and Children program (WIC) recipients (N=23) (See Table 1[7]). Participants reported a wide range of health conditions for themselves and those they were caring for, most notably diabetes and being overweight (N=8, 24%) followed by high blood pressure (N=5, 15%). Within our larger sample, we followed up with seven households to conduct in-home visits. These included visits with women (n=6), men (n=1), African Americans (n=3), single-parent households (n=3), and SNAP and/or WIC recipients (n=5).

3.2.1 Semi-structured Interviews. Researchers conducted phase one interviews using a semi-structured template.[8] Constructs used in this instrument provided a provisional framing [59] of the issues and extensive conversations with community partners, including the state extension nutritional education programming and local administrators of the federal WIC program.

Interviews elicited participants' shopping behaviors, including how they selected and purchased food, planned meals, and worked through logistical barriers to obtain food. We inquired about the contextual factors that informed their dietary habits, meal preparation,

[6] Purposive sampling is an approach to select respondents that are most likely to yield useful and appropriate information [34].

[7] An accessible version of all tables can be accessed via supplementary material.

[8] All research protocols are provided in the appendices.

		n	(%)			n	(%)
Gender	Men	5	*(15%)*	**Household Income**	Under $20,000	22	*(67%)*
	Women	28	*(85%)*		$20,001 - $35,000	10	*(30%)*
					$35,001 - $50,000	1	*(3%)*
Age	18-30	1	*(3%)*	**Access to Transport**	Owns a vehicle	18	*(55%)*
	30-39	7	*(21%)*		Does vehicle/ride sharing	12	*(36%)*
	40-49	9	*(27%)*		Walks/uses public transport	3	*(9%)*
	50-59	4	*(12%)*				
	60+	12	*(36%)*	**Food Assisstance Programs**	SNAP	13	*(39%)*
					SNAP & WIC	6	*(18%)*
Race / Ethnicity	African American	17	*(52%)*		WIC	4	*(12%)*
	White	7	*(21%)*				
	Hispanic or Latino	6	*(18%)*	**Household Type**	Single parents	11	*(33%)*
	Asian	1	*(3%)*		Two-parent households	10	*(30%)*
	Multiracial	2	*(6%)*		Adults without children	6	*(18%)*
					Individuals 65+ years old	6	*(18%)*

Table 1: Participant Characteristics

and what "healthy" meant for them as a concept or set of dietary principles. To understand their priorities around their health and their family members, we asked questions such as *"Tell me about the last time you bought food or groceries that you warmed or prepared at home for your household; When you're shopping, what's top-of-mind as you're making your choices?; and What does healthy mean to you?"* Researchers also probed about technology use in these domains when and if the conversations led in this direction. In these instances, we probed about how they used technology in their homes and their comfort with technology to gauge the potential for technology in grocery shopping and planning. When appropriate, we also probed for how technology supported their shopping behaviors. In deference to participants who did not have access to or rely on technology, however, we did not probe about technology usage further. As appropriate, interviewers elicited shopping priorities and limitations, health conditions or changes that affected their or family members' diets, and the impact of COVID-19 on shopping routines. Finally, we asked participants about possible delivery services to bolster access to healthy foods.

Interviews lasted 45–60 minutes and were recorded and later transcribed. We conducted five interviews in Spanish (with an interpreter present) and one in Arabic. Interview recordings were transcribed directly or translated into English and stored in a secure Google Drive folder. Researchers thanked participants and compensated them for their time with grocery store gift cards valued at $75 for phase one participation.

3.2.2 In-home visits. The purpose of the in-home visits was to confirm initial interview responses, observe participants' food storage behaviors and preparation environment, and probe into more detail their planning and preparation. Phase two in-home visits were also guided by a semi-structured protocol, which included core questions and areas of focus for environmental observations (see Appendix A). Researchers framed this protocol from phase one findings of the initial affinity mapping (see Figure 2), with areas of focus including planning processes, nutritional considerations, technology usage, and barriers to food storage or preparation.

As an example, to understand core stocks, researchers asked participants, *"Pick three things that you buy all of the time. Why are these staples? What makes it a go-to food item?"* We also asked about technology capabilities at home, the use of technology, and how it was integrated (e.g., *"What is the role of technology in accessing food information? Before shopping? During? After?"*) This step helped to confirm phase one findings as well as glean our design implications.

In-home interviews and observations lasted 60–90 minutes and included two researchers—one to ask questions and the other to record notes. Participants were compensated for their time with grocery store gift cards valued at $200 for phase two participation.

3.3 Coding and Data Analysis

Data from the phase one interviews and the phase two in-home visit protocols included transcripts and researcher observations. To foster interrater reliability and agreement in perceptions from interviews and in-home visits, researchers debriefed immediately after each interview/visit (if conducted in pairs) and at the end of the day if they had conducted them separately. This practice allowed researchers to begin processing data to facilitate the formal analysis. This study used a sequential qualitative approach, with phase one instrumentation informed by the initial literature review and community partner contribution (e.g., [3, 21]). Researchers analyzed data using iterations of affinity mapping, beginning with data collected from phase one interviews and extending to data from phase two. This allowed for refining the provisional coding constructs [58] and integrating emerging themes that were inductively identified.

To analyze information from phase one transcripts, the provisional coding provided the initial categories for the affinity mapping

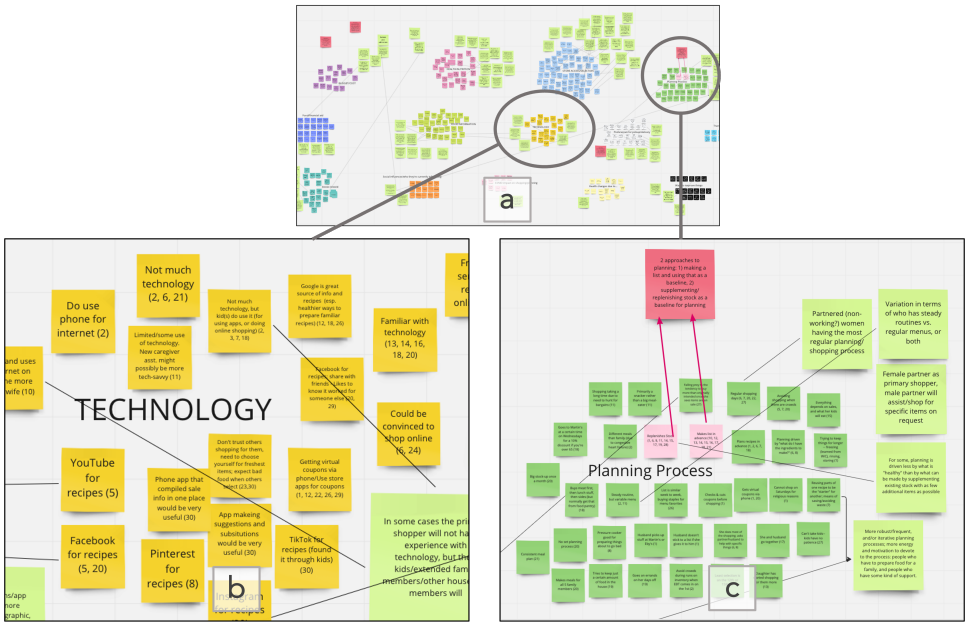

Figure 2: Coding and Data Analysis Process Overview: (a) Fourteen clusters represent visually compiled information along key themes. The two circled clusters represent two key themes: (b) "Technology" and (c) the "Planning Process." Smaller sticky notes represent participant responses, and larger sticky notes represent key insights.

process (e.g., Figure 2). Researchers used Miro.com to facilitate and document this process. In synchronous, dialogue-based sessions, the team clustered digital sticky notes containing observations and quotes from interviews around the categories/themes; this helped resolve differences in interpretation, fostering a consistent understanding of the data. Research team members also noted the participant identification number associated with each quote or insight, documenting cases where the same finding applied to multiple individuals. This, along with data tables organized by participant ID, allowed us to record the frequency of a particular response to a question.

In the next round, we used open coding [58] to inductively generate new codes and categories in response to core questions [66]. Information was visually compiled and collated along key themes. This exercise resulted in 14 clusters (see Figure 2a), with small sticky notes of individual responses composing each cluster and larger sticky notes representing key insights. In cases where participants were divided as to how they answered a given question, we grouped them according to their answer to generate new analytic categories. For example, with regard to food procurement planning, we saw that some participants built their shopping lists around pre-determined household menus. This led to the coinage of "menu planning" as a particular planning style. An alternative style consisted of "inventory shopping," where existing pantry stocks primarily determined meal ideas and grocery lists. We further investigated the correlates of these styles and what factors influenced the food procurement planning styles adopted by participants, considering this key finding.

Technological design implications arose from our observations through this iterative process. The full project team then reviewed and commented on the process, and met with the analysis team to review and summarize the results, take questions, and resolve any discrepancies.

4 FINDINGS

As mentioned in our related work, numerous qualitative studies have identified four categories of adaptive behaviors (i.e., procurement strategies) to circumvent barriers to food security and nutrition [45]: institutional, social network, food provisioning, and food consumption strategies [33, 35, 56, 62]. Our study introduces the role of technology, improving understanding of how those strategies operate within the context of personal, environmental, and food-property-related factors. Here we present findings that address our two research questions: What food procurement planning strategies do residents of food deserts use and what role does technology play in facilitating these strategies? (RQ1), and How can technology improve nutrition security by bolstering those strategies? (RQ2). We confirm prior findings and highlight how participants used technology to facilitate their strategies. We then present findings that counter initial expectations for technology use in COVID-19. We conclude with three distinct shopping archetypes that emerged from the data as an approach to informing design recommendations (RQ2).

4.1 Technology-Inclusive Strategies for Food Access and Nutrition

The strategies that participants used to circumvent barriers such as health concerns, price, time constraints, food preferences, disability, mobility and transportation, and reduced food quality aligned

with those mentioned in past work [45] (i.e., institutional, the use of social networks to overcome barriers like transportation [19], and various food provisioning and food consumption strategies per Table 5). Thus, we focus this section on the novelty of our findings, highlighting how participants used technology within each of the four categories of adaptive behaviors. Technology played the greatest role in facilitating **food consumption**, followed by **food provisioning** (i.e., maintaining food supply). Technology did not play a significant role in connecting participants to **social networks** to overcome food access barriers, especially amid the pandemic, nor did it significantly support **institutional strategies.**

4.1.1 Technology-Inclusive Strategies for Food Consumption and Health. Food consumption strategies included food preparation, finding information about specific foods, and keeping regular items in stock. Food consumption strategies were driven by several factors for our participants. These included their own definitions of health and healthfulness, along with trying to create time efficiencies and monetary resources. Dietary changes aimed at improving health were almost always implemented in response to the onset of medical conditions or other life events and milestones. These turning points included moving away from families of origin, becoming a parent, or having to manage a new health diagnosis for themselves or members of their family. In the first instance, individuals enjoyed more freedom to craft their diet; the latter changes, however, tended to impose constraints. Regardless of the barriers and constraints faced, all participants described having a balanced plate as their definition of health. This signaled awareness of The Dietary Guidelines for Americans recommendations [48], even if their households could only follow those guidelines to a limited extent. Participants consistently responded that healthful foods were fresh; unprocessed; and low in salt, sugar, and fat. Participants also reported fresh dairy and "lighter meats" (i.e., fish and chicken) as healthy.

Most study participants used social media and search engines as go-to resources for information on food and diet. Of the 33 participants who were interviewed, 22 (66%) reported using technology to support dietary choices, learn about unfamiliar ingredients, or find healthier ways to prepare familiar foods. Several participants also described watching cooking tutorials on YouTube. For Henrietta, YouTube was a place where her sons could expand their culinary skills:

> *Both of my boys cook a lot, so it helps me out. My 13-year-old ... he likes to cook, so they let him get on his computer. When he has his quiet time, he'll look on there and watch cooking shows, different things like that. My kids' father is a head chef—a private chef in Atlanta, so food is what we do. ... A lot of that he [her son] gets off of the [sic] YouTube, and we watch the cooking show a lot.* – P15, Henrietta (in-home visit)

In response to a question about online sources of recipe information, Caitlin also answered that she usually consults Pinterest and YouTube:

> *"Binging with Babish"—It's a guy who re-creates meals from like, movies, and TV, and stuff. ... We love it. We have his cookbook, and we've made stuff from, like—we make Cuban sandwiches, which he's, like, done before. We watch that a lot more. Like, me and my boyfriend kind of like inspiration from that and we'll make stuff. And then, in the summer he [her boyfriend] got a smoker. So he's really big into, like, smoking, like, briskets and stuff. So, making sandwiches with that. And with that, too, he'll, like, "YouTube" videos on, like, recipes and that kind of stuff.* – P8, Caitlin (in-home visit)

Participants who were trying to lose weight, manage a medical condition, or keep health problems at bay made the most intentional use of online search engines and healthy eating apps. For example, Don specifically used social media to lose weight after gastric bypass surgery:

> *I use YouTube just about every day for really everything, but yeah, food. I go to YouTube because they have a [sic] step-by-step [instructions on] how to prepare the food that I'm looking for. I Google a lot of things. They give me cooking times because a lot of things you can convert to air fryers [sic]. Every now and then I'll have a potato, but I can't have the fried potatoes. I can air fry them in a little bit of oil. If I cook them in a pan, I can add a little water to some olive oil and cook them in. So, I'll just Google "how to cook bariatric potatoes" on YouTube and then someone else who had the surgery—on how she fixes her potatoes—will come on and it'll give me a recipe.* – P5, Don

Don described how YouTube has become a resource for people to tell their recovery and wellness stories after having had surgery, and to learn how to maintain a palatable and healthy diet.

Participants also reported using search engines and social media for other food-preparation goals. For instance, they used these tools to find information on new or unfamiliar ingredients. They also researched how to rinse and store produce, reduce cooking time, and save money spent on groceries (see Table 2 for their most commonly noted search terms). Perhaps not coincidentally, all five individuals who reported using online resources for this purpose were mothers of small or school-age children and teenagers. Participants in this category used Google to search for "easy recipes" or joined social media groups that featured simple and affordable meals. These dishes could often be prepared using devices such as a crock pot or an air fryer. In her interview, Francesca described various social media pages she referred to for meal ideas:

> *I don't have a TikTok, but they share it on Facebook or I follow a couple pages on there. I think it's Campbell's, and they actually send you recipes to your inbox. So, I've gotten a lot of my Thanksgiving and Christmas side dishes from the stuff that they sent me. … I started with a crock pot 'cause that's, like, the easiest thing. I follow a couple of pages on Facebook. That way you just throw everything in, and it cooks itself.* – P20, Francesca

Our participants reported addressing a variety of concerns using technology. Along with attending to diet and health, they used technology to broaden their culinary skills and to account for time considerations and ease of preparation (often relying on time-saving devices like air fryers and crock pots). Our next section presents

Desired Search	n	*(% Subsample)* (22 Technology Users)	*(% Total)* (33 Study Participants)
• Alternative ingredients, substitutions, preparation styles	5	*(23%)*	*(15%)*
• Time savings, convenience, shortcuts	5	*(23%)*	*(15%)*
• General recipe information	5	*(23%)*	*(15%)*
• Healthy recipe information	3	*(14%)*	*(9%)*
• Using unfamiliar ingredients (e.g., from food pantries)	2	*(9%)*	*(6%)*
• How to extend shelf life of fresh foods	1	*(5%)*	*(3%)*
• Brand comparisons	1	*(5%)*	*(3%)*

Table 2: Most Commonly Noted Internet Searches

how they used technology to acquire food, focusing on price as a key driver in decision-making.

4.1.2 Technology Used to Facilitate Food Provisioning. Food provisioning comprised two subcategories of economizing strategies: searching for and obtaining food, which we refer to as "foraging"; and acquiring one type of food instead of another, which we refer to as "substitution." Foraging entailed visiting multiple locations at specific times to maximize benefits and building meals and menus based on foods acquired either free or at a discount. Substitutions entailed substituting cheaper brands for the same item, or different food items within the same category. Given that participants generally considered healthy food to be more expensive, they maximized their dollars by prioritizing satiety over healthfulness when shopping.

Foraging helped participants economize by maximizing benefits across multiple geographic locations. For example, participants often traveled long distances to buy in bulk or to purchase discounted items. In addition, they optimized food procurement across various local food sources. The retailers and organizations they frequented often met multiple needs (e.g., economizing through participation in loyalty points programs, which were electronically accumulated over time). These needs often included convenience, preference, and quality.

> *So, I go to Kroger's and then whatever they have on sale, that's what I buy. So then, I get points for gas. ... Then Aldi's is pretty cheap. I did just start shopping there, so we do a lot of stuff there. Then Meijer's I have mPerks. So, once I spend a certain amount of money, um, I actually get like $5 or $7 off towards my next purchase. And they have, like, different rewards that you can meet, and they have coupons that you click.* – P20, Francesca

A time element of foraging included planning shopping trips around when supplemental benefits like SNAP would be available. Not planning a shopping trip at the *beginning* of the month meant that others would quickly claim needed items on store shelves. Participants would then have to wait until the items were restocked later in the month.

Participants also spoke of needing to use (sometimes scant) SNAP or WIC benefits and food pantries to cover staples and regular necessities, leaving what discretionary income they had to fill in the gaps. As Francesca also noted during our conversation, planning a meal around discounted turkey sausage meant looking to the Internet for ingredients to complement an unfamiliar item.

Another strategy, often used alongside foraging, was to maximize budgets by making point-of-purchase substitutions to an intended selection. Participants who compiled shopping lists—either beforehand or mentally—often used these lists as points of departure rather than fixed selections. Shoppers often had a particular product in mind when entering the store (e.g., chicken breast or black beans) to add to inventory or for a planned recipe. However, ongoing sales often compelled them to substitute either different brands or items within the same category once in the store. When asked about the topic, Bob recounted the following:

> *If I see that the pork tenderloins are on sale that week, I will forgo the chicken breasts or something like that to get two—two of the tenderloins, which are cheap.* – P14, Bob

Numerous participants used technology to find information like sales or alternative product brands and substitutions to maximize savings. Shoppers expect and depend on these substitutions and closely scan product selections to find them. In some cases, participants suggested their preferences for in-store shopping were related to the ease of making these quick substitutions at the point of purchase. In such instances, technology was generally not used for, or did not facilitate, such substitutions.

4.1.3 Technology, Social Networks and Food Access amid the COVID-19 Pandemic. Participants in our sample demonstrated robust use of social network strategies to share food-related information and overcome food-access barriers. These included sharing recipes, highlighting sales and deals, sharing extra food with others, and overcoming transportation barriers through carpooling. Technology use was more prevalent in the context of information-sharing than in overcoming physical barriers to food access. As Julisa noted:

> *I'm on the little [Facebook] group ... I show my meals that I cook, and I get a lot of people ask me how I cook it, and I get a lot of likes on it too 'cause I share my pictures on Facebook when I be cooking.* – P23, Julisa

Other participants, such as Hala, used WhatsApp both to share recipes and to coordinate running errands:

> *This, uh, this [is] rice [showing us a picture of the dish], and ... my sister-in-law use [sic] it, and she said it's*

> *good. She send me the picture and ... she saves it to my chat. ... she cook [sic] sometimes and my kids eat in her home, and they like it. ... When I asked her, she said those were there the leftovers. I never made it, so she sent me a picture.* – P28, Hala (in-home visit)

Later, Hala showed us previous chats where she and her daughter had taken stock of their kitchen inventory. They had communicated back and forth to compile a shopping list while she was preparing to go out.

Despite how COVID-19 exacerbated physical barriers to food access, online ordering and delivery did not become more prevalent among those in our sample. Rather, three of the four participants who lacked vehicle access continued getting rides from friends or family to shop in person. The one exception to this rule was Valerie, who had limited physical mobility in addition to not having a vehicle. For her, both online ordering and rides from her daughter or caregiver helped her buy groceries.

> *Um, when I do need groceries, my caregiver—either her and I ... I'll have it already on the computer and just go pick it up ... She gets here at 10 in the morning, and she has to leave at 1:30 ... I think it's 30 or 35 dollars [minimum order] ... to have it delivered, like, here, to the apartment.* – P32, Valerie (in-home visit)

Valerie mentioned using online ordering to save time for her caregiver, though the trade-off was having to spend $30–35 each time she ordered to avoid paying the $7 delivery fee.

The trend with social network strategies and food access during COVID-19 was that technology was selectively used in certain strategies but not others. For instance, people continued sharing food and recipe information online when in-person contact was reduced. In contrast, social network strategies like carpooling or ride-sharing were not typically replaced by online ordering, even though that was an option.

4.1.4 Technology Used to Support Institutional Strategies. We found limited evidence of technology being used to support institutional strategies. Confirming prior work, our participants used institutional strategies in the space of food access and nutrition. However, those institutions were not treated with equal authority, and only one institution offered regular engagement through technology. As stated, some participants passively referenced the USDA Dietary Guidelines for Americans when asked to describe what it meant to have a "balanced plate" [48]. Other participants—particularly mothers of small children—made much more intentional use of the classes and nutrition information available through the federal WIC program. They did so by utilizing both online and in-person venues for learning and communication.

In our sample, five of our 33 participants had past or current involvement with WIC. One expressed interest in participating but could not because of her work schedule. The main form of technology use for WIC was accessing federal benefits online. As Caitlin explained, the WIC app provides a list of items that are covered by program funds:

> *I get the same things over and over, because I know that they're WIC approved cereal—like, Chex Mix. ... I have the most ... like, the healthy options, and ... on their app, you can actually scan the barcode. They'll tell you if it's, like, approved or not, which is nice.* – P8, Caitlin (in-home visit)

Despite the convenience of being able to plan purchases using WIC in advance, the list tended to be repetitive. Another drawback to the WIC app was that it only provided a list of benefit-approved items but did not indicate what stores had those items in stock. Finally, participants could not use WIC benefits to pay for online orders or delivery fees. Another feature of the WIC program was online or in-person nutrition education. Caitlin chose to take classes online via the app, and other WIC participants took part in in-person learning. For Mariela, technology provided ways to keep in touch despite physical distance, or to circumvent COVID restrictions on face-to-face interaction:

> *When I was pregnant with my second child, I took [WIC] classes on nutrition. A lady would come and teach us how to make things like brown rice, grilled meat, vegetables. It was good. But they got rid of it all because of the pandemic. They would also teach us about portions, all of that. It was really good, but they ended it. ... They were online ... I was signed up for some, but they cancelled them. ... A lot of the moms left to live near Chicago or Michigan. I have a lot of friends [through WIC], but we talk through Facebook messenger. I have two friends here...their kids are the same age of my youngest son. The two boys are the same age. We took classes on diapers, about nutrition, how to take care of a baby. It was really nice. We just talk on Facebook. We used to see each other a lot. But now with the pandemic, we don't see each other.* – P6, Mariela (in-home visit)

Among the institutional strategies utilized for food access and nutrition, those associated with the WIC program were the most varied and the most technology-inclusive. Whereas the USDA dietary guidelines served as a benchmark for how people passively thought about health, young mothers actively referenced WIC and its program instructors as a source of health knowledge during the early stages of child-rearing. Notwithstanding the limited advantage gained by using the WIC app to plan shopping trips, program participants still used available technology to acquire food items and to maintain relationships with people from their nutrition classes.

4.2 Planning Strategies—Three Salient Archetypes

Section 4.1 presented our participants' strategies, behaviors, and shopping tendencies from a more general perspective. This section presents a set of archetypes or heuristics to describe participants' central tendencies. These archetypes, described in Table 3, help to visualize motivations and constraints and inform design recommendations. Many logistical barriers, and the ways our participants worked around them, informed our archetypes. As an indirect result, these categories were associated with temporality, or how much time participants had available in their schedules. Most of our participants exhibited behaviors from more than one shopper category; however, most shoppers also leaned toward one style. Table 3 records the total number of participants in each category

Type	n	*(%)*
Inventory Shoppers	17	*(52%)*
Menu Planners	13	*(39%)*
Adaptive Shoppers	3	*(9%)*

Table 3: Distribution of Shopper Archetypes (n=33)

according to their dominant style. We include Table 4 to show that archetypes used technology across the board and in many ways. However, we focus here on participants' shopping strategies to better understand how technology might better support their motivations and planning strategies overall.

4.2.1 Inventory Shopper. The inventory shopper was our most popular shopper category, and 52% of our participants fell into this group. Inventory shoppers "took stock" of their existing products from their pantries and/or refrigerators and created a list based on what they were missing. Inventory shoppers adhered to a standard set of items given their constraints. This approach enabled children to adapt to a standard menu and was great for expectation setting. Inventory shopping also lent itself to saving time. Thus, inventory shoppers primarily consisted of single parents and those managing significant time constraints such as childcare and work priorities. Inventory shoppers prepared their shopping based on items they already had or that were missing from their pantries. In response to a question about how she planned before going shopping, Mariela stated:

> *When I see what I'm missing, I grab a pencil and paper and note down what's not there, like onions, rice, beans, or bread, like that, for the kids. Or milk, all of that I write down on the list. And then when I go to the store ..., I get what I'm missing at home.* – P6, Mariela

Inventory shoppers were generally amenable to making lists.

Three participants made lists based on pantry stocks, but their shopping practices reflected varying degrees of constraint. Those who had time available leaned toward planning. However, they and their more time-constrained counterparts recognized the advantages of inventory shopping when saving time, money, and space. The following section turns attention to participants who planned their menus as a preferred strategy, considering factors that influenced their behavior.

4.2.2 Menu Planner. Among our participants, 39% were menu planners, the second largest group of shoppers. Menu shoppers used menu planning and lists as a concerted strategy to organize their trips. These shoppers had more time for planning and organizing their menus. They were either older than our average-age participants or young and partnered. They also did not have young children and were regimented shoppers. Rather than letting their pantry or refrigerator stocks drive the construction of their lists, as was the case for most of the inventory shoppers (e.g., based on what staples or produce items were running out), menu planners determined what meals they or their family members were going to eat before going shopping and developed their lists of ingredients based on that menu.

For some menu planners, having additional household support (e.g., a partner to help with childcare) alleviated the time burdens that single parents faced, allowing them to think through weekly menu planning. For instance, Aliyah and Cristina stayed at home full-time with their children and had spouses who brought in enough income to support regular menu planning.

> *It's been a little bit off lately, but normally I would either think of specific recipes first that I want to do and I would try and get at least three or four dinners planned out, and then I would put all that in the list. Um, if I don't do recipes, then I would just look in my kitchen and see what I should replenish, and then we would. I would clip my coupons before going to the store. Maybe a day or two beforehand. It's usually a three-day planning period for me.* – P1, Aliyah

> *I make the menu for seven days. I make a list of everything we're going to eat and then I look from there at what I'm going to need ... I use whatever is left over and make it into something different.* – P7, Cristina

Alternatively, members of this category were older or did not have children living at home. For older adults who were not taking care of young children, developing a menu to build a list was driven less by concerted effort. Rather, adults in this category seemed to have solidified their diets to the point where weekly shopping and meal planning were rote.

In cases where an older adult managed a health condition, participants planned menus that would include substitutions and alternatives to their usual go-to foods. For instance, Elizabeth described how she started to monitor sodium intake to manage high blood pressure and followed her doctor's advice of eating frozen rather than canned vegetables.

Participants in this shopper category either had the luxury of time and some freedom from pressing demands, or they might have gained more time because they were so organized. Either way, having a steady income that was generated by at least one member of the household appeared to separate both the inventory and the menu planners from the third category of adaptive shoppers.

4.2.3 Adaptive Shopper. The adaptive shopper was our last shopper category, and 9% of our participants fell into this group. Money primarily constrained adaptive shoppers and drove their shopping. Adaptive shoppers were between jobs and were primarily employed in the service industry (i.e., local hospitality industry). Because our study took place during the COVID-19 pandemic, these participants' shopping behaviors and meal preparation were disproportionately

Technology Platform	n *(% Total)*	Shopper Archetype	n *(% Category)*
Grocery Chain & Couponing Apps	13 *(39%)*	Inventory Shoppers	6 *(32%)*
		Menu Planners	6 *(46%)*
		Adaptive Shoppers	1 *(33%)*
Search Engines	13 *(39%)*	Inventory Shoppers	5 *(26%)*
		Menu Planners	6 *(46%)*
		Adaptive Shoppers	2 *(67%)*
Social Media	15 *(46%)*	Inventory Shoppers	7 *(37%)*
		Menu Planners	6 *(46%)*
		Adaptive Shoppers	2 *(67%)*

Table 4: Technology Use Trends by Shopper Archetype

impacted by the increased prices and limited supplies. Thus, these shoppers primarily made decisions based on what foods were on sale and available at discount shops.

Some participants, such as Henrietta, relied heavily on discount stores in their area and the discounts they provided:

> *It just depends. I might go to Walmart. I might go to Lowery's. It just depends. ... Discounts is just the thing. ... It depends on how much money I have in my pocket. ... It depends on the discounts that they provide. Like Kroger's has 10 for 10, depending on how much money I have, and depending on what I'm eating, Walmart might have it, and Kroger's might not have it, so I might just go there instead.* – P15, Henrietta (in-home visit)

While technology did not drive many of the behaviors of the other two archetypes, we did see how technology applications' sales advertisements helped adaptive shoppers save money:

> *When I shop, I really just buy stuff that's on sale, and then ... that's what I use to make [meals]. ... I have the Kroger's app on my phone. I have the Meijer's app on my phone. So, I clip coupons from both of those, so I get rewards. Um, so, I buy strictly on sale, or if I have a coupon for it sometimes, I'll pay full price if it's something, like, I use regularly.* – P20, Francesca

We see from the quote how Francesca also benefited from the digital coupon applications available at some food store chains.

5 DISCUSSION

We conducted 33 semi-structured interviews followed by seven in-home visits among low-SES households. We aimed to understand participants' strategies to access healthy foods despite personal, environmental, and food-related challenges (RQ1). Our goal was to understand how they used technology to support their strategies and in turn contribute ways for technology to bolster nutrition security (RQ2). Findings from our work suggest the need to further translate our understanding of agency and perseverance to the context of constrained food environments. To do this, we begin by discussing concrete ways for technology to support food agency. We then offer more critical insights into the concept of food agency. We conclude by contributing design implications and future research suggestions to support the meal-planning styles of our emergent archetypes.

5.1 Technology and Food Agency: Designing for Planning and Resource-Management

Our findings strengthen Bertran and Wilde et al.'s premise that technology interventions should support and augment, rather than displace, human agency in the food procurement domain. On one hand, prior literature indicates that most technological interventions are designed for logging *after* consumption for dietary assessment, which is less impactful in supporting our participants and the type of agency described in our related work. On the other hand, our study has uncovered insights into the importance of planning in agency. Our results demonstrate the importance of reducing the time burden and cognitive load of the complex optimization that individuals must undertake to stretch their resources (money and time) under sometimes complex health and dietary constraints and preferences. We offer several concrete design recommendations across a spectrum of agency (See Figure 3). The first recommendation covers ways to better support participants' *existing* technology use. The remaining recommendations are ways for technology to bolster food-procurement strategies among those who do not utilize technology but who could benefit from technological strategies—i.e., missed technological opportunities.

5.1.1 Amplify Optimization Behaviors. The recommendations to target technology *before* consumption to influence healthy food choices and support advanced planning align well with our findings because they uncover ways to design for consumers' agency before they step into a grocery store. Specifically, the studies by Trubek

et al. and Lahne et al. captured a nuanced conception of agency in meal planning and preparation.

Drawing from Table 4 (and Tables 5 and 6 in the Appendix), our participants mostly used mobile applications from retailers, search engines, and social media tools to identify sales, utilize coupons, and to find information to support decision-making, promoting agency. Likewise, Tables 2, 4, and 6 illustrate how our participants often used technology to find information about food.

In particular, participants appeared to be gathering information needed to make an optimal choice—information about recipes, pricing and sales, ingredients, and nutritional value. Per Figure 3, interventions designed to amplify optimization—that is, to reduce the time burden and cognitive load of optimizing purchases across multiple factors such as person/family, environment, and education (i.e., shopping time and budget, dietary preferences, health goals, sales and cost savings, and nutritional value)—could bolster agency across the full spectrum. Notably, amplifying optimizing behaviors to support lower-agency behaviors might be promising, for instance by filtering for health goals, items on sale, and social networks to overcome physical access barriers.

5.1.2 Leverage Substitutions. Our work suggests a crucial need for technology interventions to support and augment the shopping strategy of point-of-purchase substitutions to maximize budgets and prioritize health, particularly in the context of optimization. With price being the foremost consideration for low-SES groups, technology that suggests similar or alternative lower-priced or on-sale products within the same category, other brands of the same item, or better-value options such as bulk products would support their in-store strategies. These food-agentic technologies, including online shopping applications, could facilitate more seamless substitutions, including healthier options that are more affordable than perceived, by optimizing the best value for increased nutrition.

While leveraging substitutions is salient, it does not cut across all factors or the full spectrum of agency-like optimizations. There is a need to explore, going forward, how to center user optimizations so that the user has agency in determining how to balance considerations when making substitutions.

5.1.3 Design to Re-introduce and Amplify Social Engagement. Past research identified the use of social networks as a strategy for overcoming food-insecurity-related challenges [19], which our results confirmed. However, *we did not* find ways in which technology facilitated this strategy in particular. When considering social engagement on the agency spectrum in Figure 3, one might have less agency because of their environment and who they are surrounded by and have access to. Given the timing of our study, one could argue that the COVID-19 pandemic further limited participants' agency (e.g., by virtue of overcrowded stores, which led to long wait times and increased risk and fears of contracting the virus). According to a nationally representative survey, 34% of households reported grocery shopping online more since the beginning of the pandemic [40]. However, some of our participants, particularly our older adult households, chose not to use these services. They found value in the social aspects of in-person shopping, which presented a potential barrier to their adoption of online grocery shopping. This aligns somewhat with Dillahunt et al., who raised how their most senior participant described that online grocery delivery removed the social experience of in-store shopping and took away from their physical activity [20].

On the other hand, some households in our study leveraged their social networks to overcome physical access barriers by arranging rides or a surrogate shopper. These two very different considerations of the social aspect of food procurement suggest that designers must carefully consider how technology fits into this larger social structure. Perhaps technology can be designed to support agency but still operate within the bounds of in-person shopping. Consider technology that supports planning *before* shopping, which could help generate a grocery list to be referenced in store. Designers could also consider the value of a food-centered social engagement component to amplify the local community network that people might use to overcome access barriers.

Such insights suggest the need for interventions that leverage social support. Drawing from recent HCI and computer-supported cooperative work (CSCW) literature in light of the COVID-19 pandemic, local US citizens facilitated mutual aid via online groups to address long-term food security [37]. Support consisted of community gardens, food cultivation education, grassroots-led community fridges, and little pantries [37]. Some groups established community donation funds to support those who needed to pay for food, enabling the purchase of specific foods that were not always available at food banks. These funds also facilitated online food delivery for those in isolation with COVID-19 symptoms or who were immunocompromised. Such online groups leveraged the community's capacity and integrated social support and planning (similar to how Mariela found support with other WIC participants). Long-term efforts to provide food support consisted of community fridges and free little pantries and empowered food cultivation among residents to grow their food through community and container gardens.

5.1.4 Design for Nutritional Awareness and Leveraging Institutional Resources. Our participants expressed the desire to eat healthy food. They defined healthy in many ways ranging from "unprocessed" to containing ingredients they were familiar with, to not containing allergens, to having a balanced plate. Designing for nutritional awareness could support lower-agency factors like the cost and nutritional composition of food and higher-agency factors like food preferences. For instance, designers could consider ways to ease the cognitive load of understanding the nutrient contributions of a food item and perhaps how one item compares to others. Helping users better understand nutrient contributions or how a particular item contributes to the balance of their overall purchase could help inform decisions and amplify agency. The digital medium provides new opportunities for design in this regard. Consider, for example, visual representations of ingredients and/or nutritional information to better support identifying allergens, comparing nutrient composition profiles, or identifying more healthful foods. Hyperlinking provides the ability to quickly link an ingredient to an explanation of it. Designers could also explore the value of the wisdom of the crowd concerning likes or dislikes about an ingredient or particular food item. However, nutrient quality and composition information should link to nutrient composition databases (e.g., the Food and Nutrient Database for Dietary Studies [53]) to ensure accuracy. The digital medium provides new capabilities that can be leveraged to

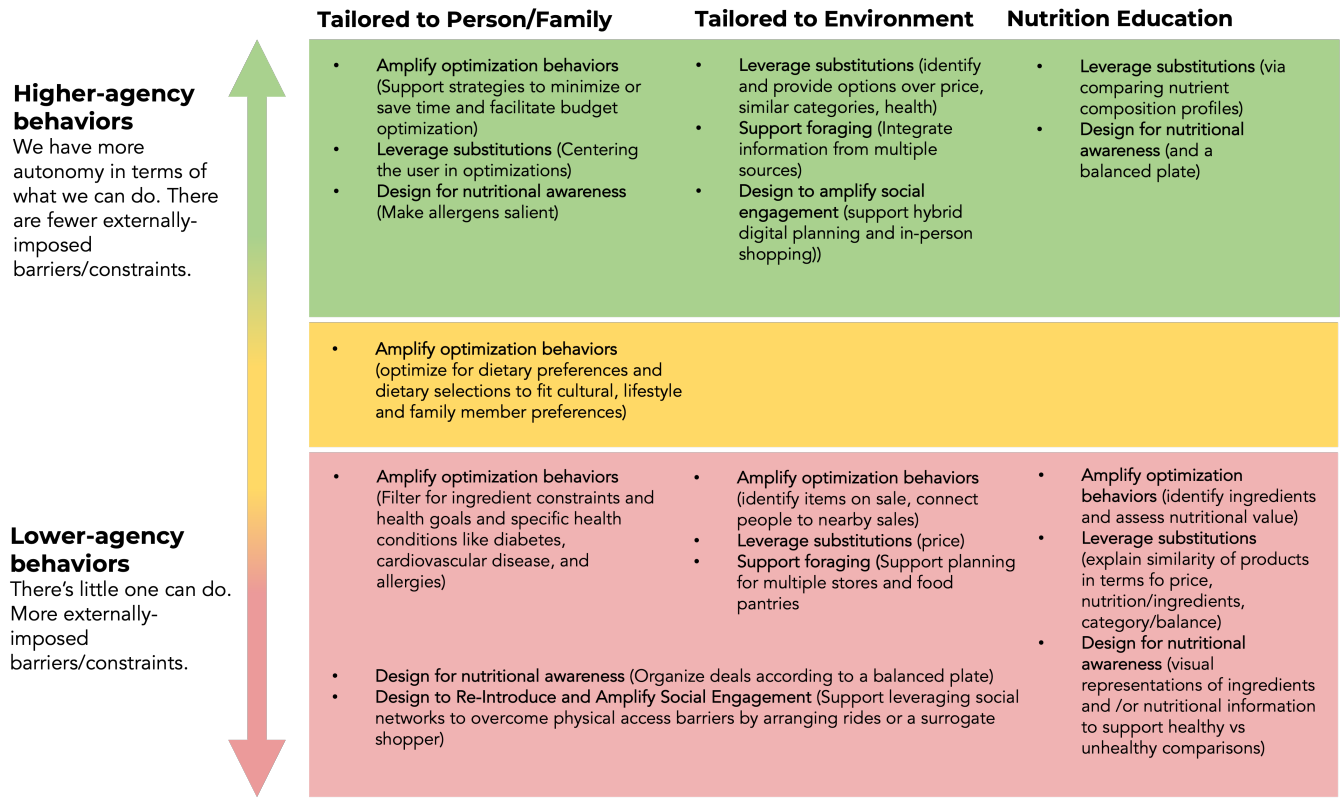

Figure 3: Application Features Addressing Person, Environment, and Nutrition Factors within Higher and Lower-Agency Behaviors: This figure highlights the recommended design implications and application features to support higher and lower-agency behaviors

tip the balance of relevant information in favor of users to support their decision-making challenges.

5.1.5 Support Foraging. Many participants utilized multiple sources to procure food, including free sources such as food pantries. Interestingly, such strategies were tailored to the environment, which might be more challenging than tailoring to more personal factors or supporting nutrition education. How can technological interventions be developed to support foraging behavior? To maximize these trips and obtain the most healthful bag of groceries for the price, users would ideally know what was available where and at what price. Technological solutions to aggregate inventory information in real time over multiple food sources could prove useful and present compelling research opportunities.

5.2 Taking a Closer Look into Food Agency

We draw from Lahne et al.'s definition of food agency from 2017, which built on Bandura's definition of agency to theorize food agency as the "capacity to set and achieve food-related goals" [38, p. 97]. This definition considers how the person in charge of cooking employs cognitive and manual skills and sensorial perceptions while navigating and shaping societal structures, including money, time, and mobility, while meeting their meal preparation goals [70]. While this work stemmed from case studies reflecting populations with diverse backgrounds (race, ethnicity, and socioeconomic status), age diversity, and geographic areas, Lahne et al. acknowledged that their scale, derived from their definition of food agency, did not correlate to income [38]. Our findings suggest that one's ability to set and achieve food-related goals may be correlated to income and socioeconomic status. As framed, the authors focused on confidence in preparing foods and knowing oneself in the kitchen [38, 70]. Therefore, interventions to improve food agency and security focus on acquiring skills, shopping, and cooking. Indeed, some of our participants used social media to acquire cooking skills. However, our work contributes to a broader perspective of shopping, planning, and the role of agency. Agency in the former case is outcome-based, while our view of agency is based on procurement, and there are differences between the two. Socioeconomic status, income, and access to resources heavily influence the types and kinds of food one can acquire. Our work raises questions about the limitations of shopping and contributes insights into how participants from our study maintained their agency, despite their constraints, to work around them.

5.3 Using Technology to Support Emergent Archetypes and their Planning Strategies

We contribute three novel archetypes, which emerged from our findings of low-SES populations experiencing food insecurity. When comparing our archetypes to wealthier shoppers classified in prior research, no archetypes aligned with impulsive purchasers or partial planners. Instead, our shoppers were more aligned with the "resilient" shoppers described in Thompson et al.'s investigation of households living in poverty. Shoppers who were restricted by financial constraints and followed a budget most closely resembled our inventory shoppers and menu planners. Consistent with research identifying affordability as the primary challenge versus the traditional "food deserts" narrative, all archetype behaviors were guided by economic criteria, exhibiting higher levels of agency. Inventory and menu planners created itemized lists, and adaptive shoppers did not display chaotic or reactive behaviors. The archetypes serve as heuristics to help us understand our participants' central tendencies and strategies. We describe these strategies and provide design implications (versus specific recommendations) for each.

At a high level, our archetypes used planning strategies that suggest the importance of designing for ease of planning, better access to relevant information, time savings, and familial context to better facilitate and maintain agency. Agency is supported when people have the information they need to make informed decisions and are not overburdened by marketing information. In an exploratory investigation consisting of direct shopper observation and personal interviews, Cobb and Hoyer assessed individual planning before grocery shopping to better understand impulse shopping or the difference between planned behavior and action [14]; their key suggestions for future research included further investigation of pre-purchase planning behavior to better understand the nature of one's intent to purchase groceries.

5.3.1 Resource Management Strategies. Along these lines, our results showed that inventory planners were primarily single parents for whom time was of the essence. Their planning strategies aligned well with minimizing or saving time. Both inventory and menu shoppers used lists, and they planned and organized trips in ways that created more time in their schedules. Menu planners in our study revealed *new* factors supporting access to nutritious food. These factors included whether someone has a partner, how much time is available (e.g., to identify and procure healthy food), and individuals' planning styles. In addition, both inventory and menu shoppers expressed the need to balance resources (e.g., time and money) across the competing constraints of cost, nutrition, and preference.

However, the causal pathways and potential feedback loops of these variables are unclear. For instance, is being well-resourced a prerequisite for having time to plan? At what point can good planning mitigate the impact of scarce resources? Another nuance to consider is how time savings might be valued differently across various groups. For example, someone with a large family might value the time they saved through online grocery delivery; however, as discussed earlier, an older adult might not appreciate the time saved in the same way. Thus, time is not only a quantitative factor but also a qualitative one. Understanding these distinctions is important in informing new technological interventions, and our investigation raises new research questions to explore.

5.3.2 Strategies to Leverage Deals. Adaptive shoppers were most impacted by price increases and available sales, both out of their control. Because adaptive shoppers were employed primarily in the service industry, they likely faced more severe income constraints, especially given the COVID-19 pandemic. In contrast to inventory shoppers and menu planners, who were less financially constrained, adaptive shoppers' options were often limited to highly discounted and free food sources. Information access is critical to this shopper, who needs to prioritize deals over all else. We found that online ordering and delivery did not become more prevalent among our participants despite COVID- 19's impact, likely due to financial constraints. However, Valarie, who had limited physical mobility, bore the costs. Future systems that utilize strategies to leverage online deals and shopping must keep such constraints in mind. Technological interventions could more efficiently optimize for budgetary constraints and offset the increased cost of online shopping online. A shopping app, for example, could be designed to aid in identifying lower-priced items or appropriate substitutions more effectively than someone shopping in person.

5.3.3 The List as a Planning Device. It is no surprise that list-making is a common planning strategy both identified in the literature and articulated by our participants. As noted in Section 4.1, while people may have specific products in mind for menu and inventory shoppers, lists are a starting point. They are made of generic items supporting the idea of point-of-purchase substitutions. The inventory and menu archetypes built their lists based on the contents of their pantry/refrigerator or on the ingredients in their recipes/menus, respectively. Sometimes, these lists were consistently updated as a "running list" between shopping trips. Considering the familiarity and ubiquity of lists for those who do plan their food procurement, we suggest any planning technology be built around the grocery list metaphor. For online shopping, interesting questions surround how to design for the space between a list and a cart where a list is a planning tool, holds history from week to week, typically consists of generic items, and is regularly updated, and a cart is a container of specific products for purchase. Lists also provide the starting point for optimization, as mentioned above. Many questions exist around when to make specific product recommendations and how far those recommendations can be from the original generic item in the list (e.g., different brand vs. completely different food category).

In contrast to menu and inventory planners, adaptive shoppers have less of a need to form lists but could benefit from lists that make the relevant information salient to them. Designers should consider how to organize deals to be most effective for this most vulnerable shopper. For example, consider organizing sales according to a balanced plate to help shoppers prioritize balance and nutrition.

6 LIMITATIONS

We discuss several limitations to our work. First, because the study occurred in a single geographic region (i.e., a single neighborhood in a single city), it is unclear whether the archetypes that emerged from our research are generalizable to other locations and populations. Going forward, we will investigate whether factors such as

income, access to affordable and healthy food, and level of agency are associated with these archetypes. In addition, our study took place during the COVID-19 pandemic; however, we drew from much of the pre-pandemic literature for comparison. While our work is a novel extension of this work, it is unclear which aspects of our work will generalize post-pandemic. We also acknowledge that most of our participants were women, and we recommend future efforts in reaching out to men. Finally, agency was an emergent theme in our literature review, and it would be beneficial to explore the next step of agency—goal setting—in our future work. Taking a deeper and more critical look into whether and how aspects of goal setting or goal achievement (e.g., resilience, self-control, and perseverance) surface would be important to explore. As a next step, we are planning a deeper analysis of these themes, as well as the core properties of agency (i.e., intentionality, forethought, self-reactiveness, and self-reflection) to see in what ways, if any, these factors arise in our results and to continue to critically reflect on conceptions of agency. Finally, as we raised in our related work, the scope of this area has focused on and is limited to an individual-centric view.

7 CONCLUSION AND FUTURE WORK

We conducted 33 semi-structured interviews followed by seven in-home observations of middle- to lower-income households in areas designated as food deserts in a mid-size city in northern Indiana. We investigated their food selection, purchasing, and meal-planning decisions; the ways they worked through logistical barriers to obtain food; and the role of technology in this process. We situated our findings within related work across decision-making, consumer studies, nutrition education, and HCI to uncover three shopper archetypes and contribute implications for the technology design to support nutritional planning. Our work acknowledges and incorporates missing elements of agency from social science research to reach a more nuanced understanding of food agency than had been defined in the HCI literature [38]. Several opportunities exist to build on this work going forward. We suggest teasing apart nuances in understanding resilience and time constraints within these spaces, as they relate to food agency, and exploring these findings within broader behavioral theories such as the Integrated Behavior Model [47]. We recommend further investigation of whether the three archetypes generalize to other settings and exploration of the intersection of food agency and social support. Finally, a system-centric view is worth exploring in this space, emphasizing that market economies shape the food environment. Our contributions are timely given the issues around food security amid ongoing crises such as the COVID-19 pandemic, high inflation, climate change, and the war in Ukraine [16], all of which exacerbate the food insecurity faced by the world's most vulnerable [24].

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8 APPENDICES

A PHASE 1 AND PHASE 2 PROTOCOLS

The protocols for Phase 1 (Initial Interview) and Phase 2 (Follow-on / In-home Visit) are included on the next two pages.

INITIAL INTERVIEW (1 hr)

- **Introduction / Establish Rapport:**
  - Project Intro
  - Informed Consent
  - Participant background - Introduce yourself (Demographic Info)
  - Are there any health concerns or issues in your household that may impact how you or your family shop?

- **Tell me about the last time you bought food or groceries that you warmed or prepared at home for your household?**
  - Where did you shop? (Store accessibility)
  - How did you get there? (Transportation - car, public transportation)
  - How much planning (Planning and Approach)
  - How often visited? (Frequency)

- **Expand to other grocery stores:** What other stores do you visit as well? Why?
  - Probe for what do certain stores mean to people (Stock up, food selection, convenience, location and access, accept EBT, low on funds)
  - Geographic range of stores they frequent
  - Probe transportation, planning, frequency
  - Impact of Covid, if any (food initiatives, pantry usage, free lunch pickups, etc.)

- **Food choice:** When you're shopping, what's top of mind as you're making your choices?
  - (Price, taste, shelf-life, preferences, children, WIC/EBT, health)
  - Probe for prioritize/rank?
  - When choosing something, what do you want to know? (information needs)
  - How do any existing health conditions impact choice? (ex. Diabetes, HBP)

- **Importance of Healthy Food:** What does healthy mean to you? *or* Does and how might health play a role?
  - Describe what a healthy meal might look like to you? What makes it challenging to shop for and prepare healthier meals?
  - Probe awareness of nutrition info, Food Pyramid, My plate, Food groups
  - Foods to eat more of/avoid (What they know)
  - How have you learned about these issues? Probe for information sources, networks, social media and trust (Where they learned it)

- **Role of Technology:**
  - How do you access the internet? What devices do you use?
  - Probe for Limitations (data plans, wifi spots, devices, comfort level, etc.)
  - Have you accessed food information or shopped for food online? Tell me more.
    - Information, education, shopping, recipes, meal planning
    - Barriers to wanting to shop online

- **Conclude Interview:**
  - Follow Up (Appropriateness of individual for in-home) and honorarium

Figure 4: Phase 1 Protocol: Initial Interview

FOLLOW-UP INTERVIEW: In-Home Visit (1 hr)

- **Introduction:**
  - Informed Consent
  - In-home expectations
  - From our first interview, we learned alot about your approach to shopping and cooking, but now that we're in your kitchen, we're gonna dig deeper.

- **Inventory Tour:** Let's start in your kitchen and walk me through how you have set up your kitchen and your groceries.
  - Food (kitchen, pantry and other food storage areas)
  - Look for patterns and contradictions in retail purchases that point to underlying values, barriers and access
  - Inventory environment and resources available (appliances, storage, available prep space, refrigeration). Probe for environmental barriers.

- **Go-To Groceries:** Pick out 3 things you buy all the time.
  - Why are these staples? What makes it a go-to food item?
  - When and why are you willing to compromise? Probe purchasing decisions and tradeoffs, barriers and challenges.

- **Nutritional Awareness:** Now pick out 3 things that are healthy to you.
  - What makes them healthy to you?
  - Let's look at the packaging? What information do you look for before purchasing? How do you know if it's healthy?
  - Preferences and health issues of household on food choices in the home

- **Meal Preparation:** Walk me through your approach to getting food on the table.
  - Probe role of planning, recipe search, extent of meal prep & cooking technique
  - Role and impact of household members on food selection and preparation

- **Technology Familiarity:** Probe role of technology in food selection, decisions and prep.
  - Inventory and confirm access to technology in the home
  - Tech devices: Probe apps/social media related to cooking and shopping
  - Information & education: Role of technology in accessing food info? Before, during, after shopping? Price info, comparison shop, reviews, health info
  - Trust: sites visited, trusted sources
  - 4: Online shopping: Has participant shopped for food online? Other products?
    - Barriers & frustrations

- **Conclusion:**
  - Thank participant and provide honorarium

Figure 5: Phase 2 Protocol: Follow-on / In-home Visit

B LOGISTICAL CHALLENGES FACED AND STRATEGIES USED TO OVERCOME THEM

Table 5 below shows the logistical challenges that our participants faced and the strategies (technology and non-technology resources used to overcome them). These empirical results confirm prior findings as outlined in prior work (e.g., [2, 17, 41]).

Strategies (Colors match the barriers addressed)	**Barrier / Constraint**	**Common among**	**Resources Utilized** (Technology resources in bold)	
Institutional:				
• Plan shopping around benefit schedule • Use benefits to source staple items • Use pantries to source staple items	Price	• All Participants	• **Benefit Apps (e.g., WIC)** • Food Pantries	
• Use govt. or other transport / mobility support	Mobility	• Transport / Mobility Challenged	• Disability Services	
Institutional / Food Consumption:				
• Refer to USDA health guidelines	Health Concerns	• 24% of All Participants	• Nutrition Education	• **Appliances (e.g., Air Fryers)**
Social Networks:				
• Share sale information with contacts • Share extra pantry goods with others	Price	• All Participants	• Friends and Family	
• Shop while others provide childcare	Time	• Employees, Child Caregivers		
• Shop via caregivers / delivery services	Mobility	• Child Caregivers	• Caregivers / **"Meals on Wheels"**	• **Mobile Shopping Apps**
• Carpool long distances for quality / sales	Quality / Selection	• Transport / Mobility Challenged	• Friends and Family	
Food Provisioning:				
• Inventory shop -- save meal planning time • Inventory shop -- base meals on kitchen stocks • Organize kitchen -- avoid buying extra items	Time	• Employees, Child Caregivers		
• Spend all benefits before using own money • Substitute cheaper brands • Substitute items within product category • Buy "strictly on sale"	Price	• All Participants	• **Benefit Apps (e.g., WIC)** • **Mobile Shopping Apps** • **Digital Coupons** • **Mobile Shopping Apps**	• **Social Media** - Sales • Paper Coupons • **Digital Coupons**
• Travel farther for better-quality items	Quality / Selection	• Not Limited to One Group	• Friends and Family	
Food Provisioning / Food Consumption:				
• Cater to children's tastes; avoid food waste	Child Preferences	• Child Caregivers	• **Web Search** - "Kids' Favorites"	• Recipe Guides
• Repurpose leftovers to make a new dish	Time	• Employees, Child Caregivers	• **Web Search** - "Easy Recipes"	• **Social Media** - Recipes

Table 5: Logistical Challenges Faced and Strategies and Resources Used to Overcome Them. The colors correspond to the barriers addressed (e.g., green = price, pink = mobility, lavender = health concerns)

C TECHNOLOGY USAGE BY HOUSEHOLD TYPE

Usage Category	Two-Parent Households (n=10) *(%)*	Single Parents (n=9) *(%)*	Adults without Children (n=7) *(%)*	Individuals Ages 65+ (n=6) *(%)*
Sales/couponing apps	5 *(50%)*	3 *(33%)*	2 *(29%)*	1 *(17%)*
Online ordering/delivery	2 *(20%)*	2 *(22%)*	1 *(14%)*	1 *(17%)*
Ingredient/recipe search	7 *(70%)*	7 *(77%)*	5 *(71%)*	2 *(33%)*

Table 6: Technology Usage by Household Type