Design and Evaluation of Technologies for Informed Food Choices

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Technology increasingly mediates our everyday interactions with food, ranging from its production and handling to the experience of preparing and eating it with friends and family. However, it is unclear whether these technologies support decisions conducive to a healthy diet. In this work, we devised the first heuristics for evaluating a technology's support for food literacy: the interconnected combination of awareness, knowledge, and skills to empower individuals to make informed food choices. We applied an iterative, expert-driven process to derive and refine our heuristics, starting with an established food literacy framework. We then conducted evaluations with Nutrition and HCI experts to show how the heuristics support summative and formative design and evaluations of food-related technologies. We show that the heuristics are valuable design tools, and that they help participants reflect on food literacy challenges. We also discuss tensions between nutrition and HCI best practices.

Additional Key Words and Phrases: food literacy, online grocery shopping, heuristic evaluation, nutrition, healthy eating

ACM Reference Format:
Marcela C. C. Bomfim, Erin Wong, Paige Liang, and James R. Wallace. 2022. Design and Evaluation of Technologies for Informed Food Choices. *ACM Trans. Comput.-Hum. Interact.* 1, 1 (February 2022), 36 pages. https://doi.org/10.1145/3565482

1 INTRODUCTION

Technology is playing a growing role in our everyday interactions with food, ranging from food preparation, via smart kitchens (e.g., [31]) and interactive simulators that foster the development of cooking skills (e.g., [59]), to playful technologies that enhance the experience of eating together [3, 6, 73, 107]. Moreover, with the onset of the COVID-19 pandemic, there has been a massive and sustained shift towards online food orders for groceries, restaurants, and meal kits [53, 67] that offer better availability, variety, and convenience than shopping in person [14]. These technologies offer new possibilities to explore food, but also the potential to influence our everyday habits, to support the development of new food skills, to foster new experiences, and to promote healthier social practices around food.

However, it is unclear whether these technologies support individuals in making choices consistent with healthy eating in practice. That is, consumers receive little support in pursuing a healthy

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1073-0516/2022/2-ART $15.00
https://doi.org/10.1145/3565482

diet when purchasing food online [56, 84]. Indeed, human-food interaction research has to date focused on creating novel technologies [5], rather than social or health-focused improvements, and may promote behaviours that are harmful in practice (e.g., [47, 85]). We argue that a barrier to creating more supportive technologies is a lack of awareness and guidance for designers in identifying and applying best practices from the nutrition community. This guidance is crucial, since a lack of support for healthy eating contributes to sub-optimal eating patterns that may persist throughout one's life, affecting long-term health [10, 34, 38, 78, 111]. An unbalanced diet is the primary risk factor for many leading causes of death including heart diseases, stroke, and type 2 diabetes [10, 78, 109, 111], that are preventable if healthy behaviours are established early in life [28].

In this work, we explore how food literacy — defined as the interconnected combination of food-related awareness, knowledge, skills, and behaviours that empower an individual to make informed food choices [39, 87, 92, 99, 105] — can be used to inform the design of technology and promote human health. For instance, in the context of grocery shopping, food literacy would point to the importance of having an *awareness* of ingredients and macro nutrients, *knowledge* of nutritional guidelines, and *skills* like planning meals in advance [8, 45, 84]. To date, work has demonstrated the effectiveness of food literacy as a guiding principle through proofs-of-concept (e.g., [16]), but there is little guidance surrounding how to apply it in practice, particularly for those without extensive training in nutrition.

To guide the design and evaluation of interactive systems, like online grocery shopping websites, we developed a set of 20 food literacy heuristics. Heuristic evaluation [75, 76] is widely-used, highly effective in a number of domains (e.g., [70, 79, 100, 106]), and can be used as both a formative (i.e., process-focused) and summative (i.e., outcome-focused) design tool [62, 66]. We developed our heuristics through an iterative, expert-driven process that included identifying essential aspects of food literacy from the nutrition literature, conducting interviews and website evaluations with 12 experts with a background in nutrition, and refining that initial set through a qualitative analysis of those interviews.

Then, to explore how the heuristics can be used to guide the design and evaluation of technology, we conducted website evaluations with 12 HCI experts. Through mixed-methods interviews and walk-throughs, we gathered information on how the food literacy heuristics can be used by designers as both summative and formative tools for evaluating and designing digital food retail. In analyzing interview data from the HCI experts, we demonstrate that our heuristics were useful as both formative and summative design tools that enshrine best practices for supporting the awareness, knowledge, and skills needed to make informed food choices. We show how HCI experts used the heuristics to generate novel design ideas for various applications, how they helped participants self-reflect on their own challenges around food literacy, and how they revealed tensions between nutrition and HCI best practices.

In summary, in this work we:

(1) Devise a set of food literacy heuristics to facilitate the design and evaluation of food-related technologies,
(2) Develop those heuristics with nutrition experts through an evaluation of online grocery stores,
(3) Explore their utility as summative and formative design tools through an evaluation with HCI experts, and
(4) Reflect on their strengths, weaknesses, and barriers to use in practice.

2 BACKGROUND

Within the nutrition literature, food literacy is broadly defined as the *awareness*, *knowledge*, and *skills* required to achieve a nutritious diet [9, 103]. These definitions include the awareness required to make educated food choices; knowledge about nutrition and how it affects our health and well-being, food safety, and where food comes from; and the many skills involved with planning, purchasing, preparing, handling, and storing food [9]. Together, these different aspects of food literacy have been shown to enable individuals to navigate complex food environments and make informed food choices, which can potentially facilitate healthier dietary behaviours and improve health throughout the lifespan [39, 101, 105].

When shopping in a physical grocery store, consumers face a wide variety of challenges to purchasing foods that fulfill a healthy dietary pattern. For instance, many people have difficulty understanding nutritional labels [24] and judging appropriate portion sizes [98], which can lead to consumption of the type and amount of foods that are inconsistent with dietary guidelines [21]. Product packaging exacerbates these issues, since it is carefully designed to capture shoppers' attention, rather than to inform [30]. And stores tend to promote foods based on how profitable they are, rather than their nutritional value, leading to impulse purchases, and sales of ultra-processed foods that have a longer shelf life and larger profit margin [46, 71]. Consequently, it can be challenging to balance one's food needs, like nutrition, taste, and hunger, with available resources like time, money, and skills [104]. As a consequence, sub-optimal eating patterns are common, and negatively affect the overall health of the global population [10, 34, 38, 78, 111].

Many of the challenges consumers face in physical stores are exacerbated when making purchases with/through technologies like online grocery stores, food delivery apps, and meal-kit systems. For instance, nutrition information for products is not always available online [80]. When it is available, nutrition facts and/or ingredients are presented inconsistently [64] and are sometimes inaccurate or difficult to interpret without additional scrolling, zooming, or clicking. Consumers tend to look at pictures of products rather than examine detailed product information [12], mirroring their emphasis on packaging in the store. Product placement also plays a significant role in sales; food items that appear on a grocery store's website or the first page of a search result are more likely to be purchased [12, 19]. Retailers take advantage of this behaviour to promote impulse purchases over more nutritious options [15, 64, 84]. For example, a search for 'eggs' close to Easter is likely to return chocolate eggs as a top result instead of chicken eggs. Critically, consumers also tend to browse for foods using built-in navigation, like virtual 'departments', rather than searching for a product by name [12], and so the organization of online stores may have an even *greater* influence on customers' food choices than in physical stores.

However, contrary to the idea that retailers are uninterested in helping consumers make more informed food choices and promoting healthier purchases, recent work from the nutrition literature shows that such changes can increase their profit [20, 68]. For instance, co-design of a food store was shown to improve the acceptance of changes like price adjustment between more and less nutritious foods, positioning healthy products in strategic places, suggesting wholesome alternatives, and using symbols to indicate the product's healthiness [68]. Additionally, a recent randomized controlled trial situated in real-world stores found that restricting merchandising of unhealthy foods and beverages while providing complementary merchandising of healthier foods and drinks increased profit while reducing sales of sugary items [20]. Thus, there is both an opportunity and a need for guidance (and a receptive retail industry) on how to design technologies that promote informed food choices.

3 RELATED WORK

Human-Food Interaction (HFI) researchers have rapidly moved to investigate applications of new and emerging technologies within the context of food. In doing so they have explored myriad technologies and use cases; like robotics for enhanced food preparation in smart kitchens [63, 69], 3D printing of food-based rewards for exercise [61] and as a means to experience computational data [51], multi-sensory food interactions that enhance or augment the experience of eating [77, 95], and the use of virtual reality (e.g., [7]) and social media [33, 35] to enhance social aspects of eating. A comprehensive review of this literature and the potential applications of food technology is beyond the scope of this work; we instead refer the reader to Altarriba Bertran et al. [4, 5] and Deng et al. [40], and here we focus our review on how Human-Computer Interaction (HCI) research has sought to improve health and well-being through technology.

Much of this work has been motivated by the need to improve the health and well-being of individuals — and many have explored different technologies to help consumers overcome the known barriers to healthy eating patterns mentioned in our review above. For instance, researchers have explored persuasive games to promote healthy food choices (e.g.,[54, 81, 83]), and scanning devices to help people quickly identify suitable items for a specific diet [74]. Similarly, researchers have used augmented reality (AR) to help shoppers find healthy items [2], interactive displays to calculate serving sizes and compare products [11], and mobile apps that help shoppers to visualize and interpret the nutritional balance of their shopping cart [13, 16].

Further, HCI researchers have examined how online grocery shopping can motivate healthy food choices. For instance, Dillahunt et al. [42] discussed how online grocery delivery services encourage customers who live in transportation-scarce areas to select more nutritious food options compared to going out to a physical store. DiCosola III and Neff [41] explored how nudging shoppers with social comparisons during checkout facilitated healthier food decisions when shopping online. Similarly, Hollis-Hansen et al. [56] showed that by initiating future thinking, individuals became more goal-oriented, thus tending to make healthier choices and reducing the total calories of their intended purchases. In another study, Epstein et al. [48] found that nutrient profiling, or classifying foods based on their nutrient composition, improved the overall quality of foods selected by shoppers online.

All of this research has shown that technology can help individuals to make more informed food choices — however, they have also noted challenges in developing these technologies, particularly in navigating the complexities of understanding how an individual's needs might influence what is considered 'healthy' [2]. For instance, an individual with diabetes is likely to make different food choices than another with hypertension (i.e., by focusing on a food's sugar or sodium content). Thus, there is a need to unify different strategies and guidelines to promote a more holistic approach to technology design, aligned with best practices from the nutrition literature. However, to date, HFI research has largely been performed by siloed research communities, with different research groups from distinct disciplines working alone rather than together, exacerbating the negative consequences of technology on health.

For instance, Altarriba Bertran et al. [5] noted three distinct sub-communities — Food CHI, Multi-sensory HFI, and a community exploring AI approaches to HFI — in their review of HFI literature, lamenting the lack of cross-pollination observed among them. We also note a lack of nutrition research present in HFI research. By definition, human health and food and, consequently, food literacy, require a holistic, integrative approach that ranges from aspects concerning human health but also sustainability, social practices, and financial aspects like food insecurity [91]. There is substantial guidance available from the nutrition literature that has not been fully leveraged in designing new technology. In part, this lack of integration has been driven by the siloed research communities performing the research.

Techno-solutionism [72], the pursuit of technological interventions that unilaterally solve individual or social issues, has been commonly cited as a shortcoming of existing HFI research [5, 32, 44, 72]. In their review, Altarriba Bertran et al. [5] found a dominance of technology-focused papers, with functionality-oriented papers (66%) outweighing experience-related ones (34%), and lamented that "contributions that fix, speed up, ease, or otherwise, make interactions with food more efficient, clearly outweigh those that explore the social, playful, or cultural aspects of food practices" (pg. 9). Cho et al. [32] found that techno-solutionism limits an individual's ability to self-reflect and develop positive behaviours. They noticed, for instance, that current self-tracking technologies do not effectively foster the required self-reflection to promote sustainable food habits and to engage and empower people to notice, learn, and reflect on their actions. That is, if a technology is aimed at promoting healthier choices, it should not only guide individuals to the most appropriate choice but also help them self-reflect on their choices (i.e., "Why is this the best choice for *me*?").

Finally, HCI experts' lack of health-related knowledge may lead to the creation of harmful technologies. While we currently do not have information about the health literacy of, for example, software developers as a population, we do have evidence of harmful practices in the past. For instance, diet self-experimentation guided by personalized food tracking was found to increase nutrition literacy but created health safety risks for promoting meal replacement with a powder mixture [43]. Similarly, weight loss apps have been shown to contribute to and exacerbate eating disorder behaviours [47, 85], and self-monitoring fitness apps promote over-exercising, leading to injuries and burnout, especially among those who do not exercise regularly [108]. These unintended consequences point to the importance of guidance that draws from evidence and best practices from the nutrition and health literature, particularly for those designing and implementing technology.

3.1 Towards Heuristic Evaluation of Food Literacy

To address these needs, we developed a set of 20 food literacy heuristics. Heuristic evaluation is widely used within HCI because it is an easy, fast, inexpensive, and highly effective means of encapsulating expert advice into a versatile and approachable format. For instance, when originally proposed by Nielsen [75, 76], heuristic evaluation provided a readily adaptable set of guidelines for developing usable human interfaces and was shown to be effective at identifying both common and more obscure design issues that have been frequently identified by expert researchers. Heuristic evaluation is also useful throughout the design cycle, and can be used as both a formative and summative design tool [62, 66], and is particularly valuable to smaller teams that may not have a nutrition expert.

In health contexts, heuristic evaluation has been a particularly effective means of bridging domain expertise, and making knowledge derived from the health literature more widely usable by technologists. It has been successfully used to shape the development of technology in a variety of domains, such as health information systems [29], social networking websites centred on health [112], persuasive health technologies [62], and health literacy [70, 79], to name a few. Notably, the U.S. Department of Health and Human Services [79] developed the widely-used Health Literacy Online checklist (HLO guide) as a guide to improving the usability, accessibility, and ease of use of health websites and digital tools.

More context-specific heuristics have also been developed for use in technology development and evaluation. For instance, Monkman et al. [70] extended the HLO guide to create heuristics for assessing the usability of mobile blood pressure tracking applications. Yeratziotis et al. [112] developed heuristics to evaluate the security of online health social networking, and Carvalho et al.

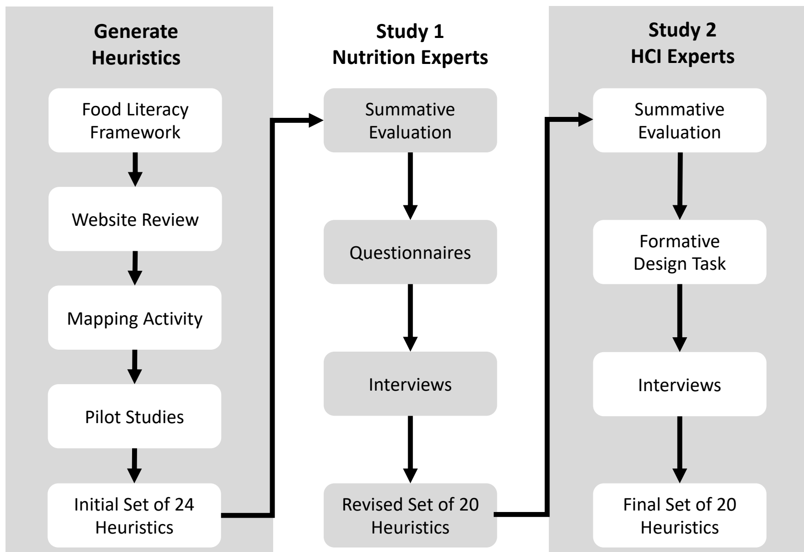

Fig. 1. We developed our heuristics in three phases: First, we identified the most important aspects of food literacy from the nutrition literature, reviewed current grocery websites, performed a mapping activity to generate the heuristics, and conducted pilot studies to calibrate them; Second, we refined the heuristics through a study involving nutrition experts (Study 1) who ran website evaluations and provided feedback. Third, we confirmed the heuristics utility through website evaluations and interviews with HCI experts (Study 2), resulting in the final set of 20 heuristics.

[29] created heuristics to reduce medical errors and promote patient safety. Finally, Kientz et al. [62] developed a set of 10 heuristics to guide the design, adoption, and long-term effectiveness of persuasive technologies. While all of these serve to extend health-related expertise to a technical audience, none so far have provided this support for those developing technology that involves food.

Notably, heuristics can also play an important role in the development of standards and regulation. For instance, website accessibility heuristics [82] have been regulated and are now widely applied into systems to make them more accessible by people with different types of disabilities. Regulation for nutrition labelling of foods sold online is currently on the Codex Committee on Food Labelling agenda [36], motivating both a need and an opportunity to inform current policies and standards.

To address the current lack of guidance for HCI researchers and designers, we devised our own set of heuristics. We identified problems in existing grocery shopping websites that hinder food-literate purchases among shoppers, and consolidated findings from HCI research with food literacy attributes from the nutrition literature. We then used those heuristics to facilitate an expert evaluation of grocery shopping websites, and to demonstrate their utility in performing both formative and summative design activities by HCI experts.

4 DEVELOPMENT OF FOOD LITERACY HEURISTICS

We developed our heuristics with the primary purpose of guiding HCI practitioners in evaluating and creating food technologies that would help people improve their food literacy. Thus, during their development, we focused on general food and nutrition approaches rather than usability issues. That is, we sought to capture knowledge about the types of content and features that technologies should have to promote food literacy, rather than the fine-grained issues typically enshrined in usability heuristics (e.g., [50, 75, 76]).

To ensure our heuristics captured the most applicable food literacy practices, we developed them through a three-phase process (Figure 1). First, we identified important aspects of food literacy from the nutrition literature, and created a first set of heuristics. Second, we performed a website evaluation with nutrition experts (Study 1), and used their feedback to revise the heuristics. And third, we asked HCI experts to evaluate food-related technologies like grocery shopping websites using the heuristics (Study 2) to assess how they would be used in practice.

4.1 Food Literacy Framework: Attributes

In the first phase, we focused on using existing literature to inform the creation of heuristics. In particular, we built upon a food literacy framework from Azevedo Perry et al. [9], considered how it might be applied to technology design, and generated an initial set of 24 heuristics (Table 2). Their framework is a conceptual model that was derived from a scoping review of nineteen peer-reviewed and thirty grey literature sources, to provide a comprehensive overview of food literacy attributes. Their model divides 15 food literacy attributes into five categories: "Food and Nutrition Knowledge", "Food Skills", "Self-Efficacy", "Ecologic (beyond self)", and "Food Decisions". So, for example the "Nutrition Self-Efficacy" attribute is described as "Belief in one's relative ability to succeed in specific nutrition-related situations or accomplish a task like for example, choosing the healthiest dinner recipe for the family; capacity to gain nutrition information; awareness/motivation/self-determination/confidence to prioritize nutrition information in food choices." (Azevedo Perry et al. [9], page 5).

Notably, this framework integrates advice by Vidgen and Galegos [104, 105] and we mainly focused on the "plan and manage" and "select" domains of food literacy proposed in their work. We found that these priorities aligned well with work from the HFI community, where most research to date has focused on food production (37%), eating (30%) and tracking (23%) [5]. These domains are also the most relevant for popular food-related technologies like grocery shopping websites, and meal delivery apps that are used to make decisions and purchases.

4.2 Review of Grocery Websites: Technology Features

Next, we reviewed grocery shopping websites to understand how technology has approached food literacy in practice. Online grocery shopping was a particularly useful context for a number of reasons: First, when shopping, people often plan ahead, make decisions, and select foods not only for themselves, but for multiple meals and often multiple people [105]. Second, it has also been shown that interventions made while shopping (i.e., at the point of purchase) can have an impact on consumer behaviour (e.g., [16, 22, 94]). Third, and perhaps counter-intuitively, the information available when shopping online has the potential to be greater than what's available in a physical store, but a lack of guidance and legislation for nutrition labelling and claims for selling of food online means that it may not be explored effectively for shoppers [36]. And finally, the COVID-19 pandemic caused a sudden and substantial rise in online shopping [67].

We focused this review on technology issues that hinder food literacy development and curb informed food choices, with the aim of identifying features that mediate interactions with food, and which would help us reflect on how food literacy attributes could be integrated with them later. We first searched for grocery store websites in Canada, the United States of America, and the United Kingdom. The first author searched for terms such as "online grocery stores in Canada" using Google Search and created a list of the most prevalent results. Then, they accessed each website to verify it supported selecting and ordering products online, resulting in a list of 18 websites. We

Website Feature	Examples
Product Visualization	Labels, symbols, and rating systems such as traffic light colours.
Shopping Cart Visualization	Summary of items in the cart, such as total price.
Facilitating Comparisons	Side-by-side comparisons of products, such as price per grams.
Product Description	Textual information about the product, including country of origin and brand details.
Filter Products	Applying filters to product search results based on criteria like brand or dietary needs.
Sort Products	Sorting product search results based on criteria such as price or popularity.
Product Nutritional Information	Nutrition facts table, ingredients list.
Promoting and Suggesting Products	Placing banners and advertisements on strategic places of the website, top search results.

Table 1. Examples of website features that we identified during a technology review of grocery shopping websites. We then mapped food literacy attributes to these features to generate our initial set of 24 heuristics.

then performed a walk-through on each website, simulating different shopping tasks (e.g., product search, browsing categories, adding to cart) and noted the various features they offered (Table 1).

4.3 Mapping Food Literacy Attributes to Website Features

Next, we mapped the food literacy attributes from Azevedo Perry et al. [9] to the grocery shopping website features. The first author reviewed the list of attributes and descriptions from Azevedo Perry et al. [9] and, for each description, reflected on how it could be supported by technology by consulting the list of features generated at the end of the grocery websites' review. So, for example, the attribute "Nutrition Literacy", with the description "having the ability to read labels" could be applied by displaying a list of ingredients and/or a nutrition facts table, but also by exploring visualizations (e.g., traffic light colours) to help with its interpretation. Further, "Understanding how foods fit into a balanced diet", described in "Nutrition Knowledge", could be supported by summarizing nutrition information in the shopping cart. Finally, "Making sustainable food choices" could be supported by promoting sustainable foods on search results and website banners.

During this process, some attributes were explored in more than one heuristic (e.g., "Ability to read labels" in "facilitate the interpretation of nutrition facts", "make the products' lists of ingredients available", and "provide the nutritional facts of products"), and some heuristics encapsulated more than one attribute (e.g., "Help the user compare the nutritional value of different products" includes the "Ability to make informed food choices", and "Understanding how to select and purchase nutritious foods with a diverse number of choices"). Appendix A shows the food literacy attribute descriptions that inspired the creation of each heuristic, along with the website feature that we envisioned applying the food literacy attribute.

Some attributes and descriptions were not directly explored into the heuristics list due to their extrinsic (beyond self) characteristics, which is the case of the attribute "Infrastructure and Population-Level Determinants." This attribute involves "Financial capacity to access healthy foods and an adequate amount of food (e.g., food security); access to living wages, affordable housing, food and cooking equipment", which are social aspects beyond the capacity of the heuristics. Other attributes' descriptions also require a more complex approach, and they relate to developing a long-term maturity in the relationship with food. For example, "Prepare to manage food-related activities in a healthy way to adapt to critical points, transitions and trajectories across the life cycle", under "Food Skills Across the Lifespan". Thus, we found no direct way to incorporate such attributes into technology in a practical manner and therefore considered those attributes out of the capacity of our heuristics.

4.4 Pilot Studies

Finally, we ran pilot studies with three PhD students from our University: Two HCI students and one Health student. These pilot studies served to calibrate the wording, similarity, and clarity of our heuristics, and to ensure the set was ready to be refined with nutrition experts. Each pilot study consisted of a website evaluation and then a follow-up interview to gather feedback on the heuristics. Pilot sessions took an average of 90 minutes. As a result of feedback during these sessions, we removed three heuristics. One heuristic was considered too generic ("The website helps users make healthier food choices"). Another heuristic ("The website promotes knowledge of the food groups") was removed because the concept of "food groups" is no longer considered relevant under current global food guidelines. Lastly, we had two heuristics about visualization of the nutrition content of the shopping cart that were considered to be too similar; thus, we dropped one ("Let the user visualize the shopping cart's healthfulness"), leaving 24 heuristics. This initial set of 24 heuristics can be seen in Table 2.

5 STUDY 1: EVALUATION WITH NUTRITION EXPERTS

After devising the original heuristics, our next step was to refine them with food literacy experts. We recruited experts in nutrition because involving them in the development and validation of heuristics has been shown to be an effective way of capturing domain-specific knowledge with heuristics (e.g., [50, 57, 66, 93, 100]). Moreover, nutrition experts regularly work with the general public and can provide feedback on the wording of the heuristics to ensure that they are understandable and usable by a wide range of people, including HCI researchers and practitioners.

We asked the experts to use our initial set of heuristics to evaluate a real-world website and identify the types of problems that might hinder food-literate purchases. We gathered feedback on how easy they were to understand and apply, their usefulness, specificity, and detail level. At the end of this assessment, we gathered feedback on how to improve the heuristics, and to identify any heuristics that would be considered redundant or irrelevant. We also asked them to rank their top 10 heuristics, to reflect and focus on the most significant issues and help us gauge which heuristics were most relevant and essential.

The study received clearance from our local Office of Research Ethics. We pre-registered the data collection protocol, all study materials, and our analysis plan with Open Science Framework in November 2019 (https://osf.io/5dwnz/).

5.1 Participants

We recruited 12 participants (11 female-identifying, 1 male-identifying) through social media networks (e.g., Twitter, Slack, WhatsApp Groups), aged 20 to 45 (median 22.5). Of these, eight identified as dietetics students, three as registered dietitians, and one as a dietetics intern. All participants had between 1 and 20 years of experience in the field of nutrition (median 3.5 years), either professional or academic. A summary of their information is provided in Table 3. All 12 participants completed the study, and each received a CAD$30 honorarium. We did not consider gender to be a confounding variable, and therefore did not control for it. Moreover, dietitians are

Initial Set of 24 Food Literacy Heuristics
Awareness
H1. Promotes sustainable food choices (e.g., plant-based protein).
X1. Promotes foods that are produced locally.
H2. Facilitates the interpretation of nutrition facts (e.g., use of traffic light colours, Guiding Stars).
H3. Facilitates the interpretation of the ingredients list (e.g., highlights added sugar).
H4. Allows the user to sort resulted products from a search based on specific nutritional values (e.g., low to high sodium)
H5. Allows the user to filter products based on specific dietary needs or lifestyle (e.g., vegetarian, halal, organic)
H6. Promotes more fresh foods as opposed to ultra-processed foods (e.g., home page, promotions).
H7. Suggests similar products as substitutions for a specific product (e.g., if it is out of stock).
H8. Helps shoppers visualize an appropriate portion size.
X2. Uses nutrition labels to advertise the benefits of products (e.g., high in fibre, fortified with vitamin D).
X3. Uses nutrition symbols to advertise poor nutritional values on the products (e.g., high in sugar, high in sodium).
Knowledge
H9. Makes the products' lists of ingredients visible.
X4. Acknowledges where food is produced (e.g., country, place, producer).
H10. Provides the nutritional facts of the products.
H11. Incorporates information from Canada's Food Guide (e.g., makes use of the Eat Well Plate).
H12. Educates about individual nutrients (e.g., why limiting sodium, why eating more fibre).
H13. Helps the user compare the nutritional value of different products.
H14. Provides a visualization of the cart's nutrition values (e.g., fibre, sodium, sugar).
H15. Uses symbols on a product's view to highlight specific dietary needs (e.g., no milk, halal, gluten-free).
Skills
H16. Supports strategic planning (e.g., meal planning).
H17. Helps the development of cooking self-efficacy (e.g., link to recipe videos).
H18. Informs how to store the products.
H19. Informs how to prepare the products.
H20. Supports budgeting (e.g., highlighting healthy items on sale, link to local flyers, facilitates price match).

Table 2. Our initial set of 24 food literacy heuristics, organized as groups of heuristics for *awareness*, *knowledge*, and *skills*. Heuristics that were later removed are prefixed with an 'X' to ensure consistency with the final version of our heuristics in Table 7.

predominately female in Canada (95%) [52], thus it is expected to have a sample with mainly female participants.

ID	Gender	Age	Profession	Experience
P1	Female	31	Registered Dietitian	4 years
P2	Female	20	Dietetics Student	3 years
P3	Male	23	Dietetics Student	4 years
P4	Female	22	Dietetic Intern	4 years
P5	Female	21	Dietetics Student	3 years
P6	Female	26	Dietetics Student	8 years
P7	Female	20	Dietetics Student	3 years
P8	Female	20	Dietetics Student	3 years
P9	Female	25	Dietetics Student	1 year
P10	Female	45	Registered Dietitian	20 years
P11	Female	22	Dietetics Student	2 years
P12	Female	44	Registered Dietitian	16 years

Table 3. A summary of participants' demographic information for Study 1.

5.2 Website Evaluation

We selected three websites for evaluation by our participants. We chose Walmart (walmart.ca) and Loblaws (loblaws.ca) because they are two of the largest Canadian grocery stores, and our participants were likely to be familiar with those websites. Moreover, we had already identified some food literacy issues with those sites, for instance, we could not find information on how to store and prepare foods on the Loblaws website. On the other hand, UK-based Morrison's (morrisons.com) is an international website that we considered to better support food skills in their design, since it provided, for example, preparations and recipes, unlike the other websites.

5.3 Procedure

After giving their consent to participate in the study through a link sent by email, participants completed a background survey to collect demographic information and previous experience in nutrition, food literacy, and heuristic evaluation, which served as the competency indicator for each participant. During the interview, the first author gave a brief presentation explaining the main study objectives and what to expect from the study. Participants were then provided with a food literacy heuristics table for consultation, and additional reference material in the form of tasks and personas to illustrate the use of the website.

Participants were then randomly assigned to evaluate one of three websites, with a total of 4 participants evaluating each website. After being provided with an explanation of food literacy and its domains, and given some time to familiarize themselves with the website, they were asked to apply the heuristics while using a think-aloud protocol [102]. For each heuristic, the participant selected 'yes' or 'no' to indicate if the website supported the given heuristic (yes), or if the heuristic was violated (no). After this evaluation, a semi-structured interview was conducted to gather information about the food literacy issues found on the website and how it could be improved to support food-literate decisions.

Next, participants were asked to complete a questionnaire in which they evaluated the quality of each heuristic. They completed a 5-point Likert scale (1= Completely disagree, 5= Completely agree) for each of the following statements: “The heuristic was easy to understand”, “The heuristic was easy to use (i.e., apply to the website)”, “The heuristic was specific and detailed”, and “The heuristic was useful”. For each heuristic with a score lower than 5 in any statement, participants were asked to fill in an open text form explaining how the heuristic could be improved.

After the questionnaire was complete, another semi-structured interview was conducted to collect feedback on their experience carrying out the heuristic evaluation and suggestions of new heuristics and follow-up questions based on their observations during the assessment. At the end of the interview, a feedback letter and e-transfer were sent to participants and they were thanked for their time and participation.

5.4 Data Collection & Analysis

Sessions took place online and were recorded directly using Microsoft Teams™. Qualtrics XM was used to collect demographic information, website evaluation data, and all questionnaire responses. Sessions took an average of 90 minutes, including the evaluation and the interview. After the website evaluation, we asked questions about the participants’ experience, with follow-up questions based on their answers. Some examples were: “What were the most important food literacy issues that you found on the website?”, and “How the website could be improved to support food literacy?”. After evaluating the heuristics’ quality, we asked the following questions and follow-ups based on participants’ answers: “In general, do you think it was easy to carry out the heuristic evaluation? Why?”, and “Can you describe any heuristic(s) you think is missing?”. Interviews continued until data saturation was reached; saturation was considered reached when no new information was obtained from interviewing additional participants that would contribute to forming new themes [88].

The second author transcribed audio from the interviews. We applied a thematic analysis methodology using an approach combining elements from both the reflexive and codebook orientations of thematic analysis [17, 18]. Our process consisted of an *a priori* deductive creation of codes, a reflexive perspective on inductive code and theme generation. The first author defined overarching deductive codes at the beginning of our analysis, based on the original heuristics and the interview questions.

The first author then inductively coded the interview data, placing it into the *a priori* codes and creating new codes based on the data. Examples of *a priori* codes include: “Food literacy problems found at Walmart” or “Improvements for heuristic 2”. The first author then developed the final themes from the grouped codes by re-reading and synthesizing the coded quotes. Discussions were grouped according to participants’ descriptions of the problems they found on the evaluated websites and feedback on improving the heuristics.

Analysis of website evaluation feedback consisted of calculating the average number of issues found by the participants for each website within each category. This analysis helped us assess how each website performed in supporting food literacy and what categories had more issues within each website. Finally, questionnaire data were analyzed by calculating average ratings for each of the 5-point Likert scale statements to help us identify participants’ perceptions on the quality of the heuristics.

5.5 Quantitative Results

Participants’ evaluations took an average of 43 minutes, and over the course of the evaluation they identified a variety of food literacy improvements across the three websites included in our study. On average, they identified 13.6 areas for improvement for each website, comprising 7

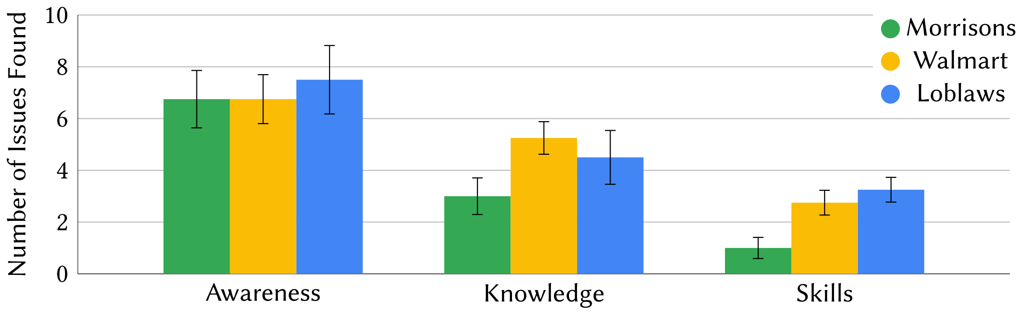

Fig. 2. Number of issues found in each food literacy category for the three grocery websites included in our study. Error bars attached to each column represent pooled standard error term.

Awareness issues, 4.25 Knowledge issues, and 2.33 Skills issues (Figure 2). These issues were also consistently identified between websites, with 15.25 identified for Loblaws, 14.75 for Walmart, and 10.75 for Morrisons. As expected, there was some variability in the types of issues identified with each website, for example with Loblaws having more Awareness and Skills issues, and Walmart having more Knowledge issues. These findings were in-line with our expectations and rationale for including each site in the study.

The most frequently violated heuristic — identified by all twelve of our participants — was the lack of nutrition symbols showing poor nutritional values on products (X3). Eleven (11/12) participants identified a lack of a system to facilitate the interpretation of nutrition facts (H2) and not educating about individual nutrients (H12). These violations are important because they show a high level of agreement among participants in identifying important elements that are missing on these websites. For instance, H2 was also the most voted heuristic in terms of importance to support food literacy. H12 was also present in the top 10 most important. A complete summary of the issues identified by our participants is provided in Appendix B.

5.5.1 Understandability, Ease of Use, Specificity, and Usefulness. Each heuristic's quality score was generally high, with average scores for all heuristics and questions between 3.6 and 5 (Figure 3), which showed a high level of agreement on their understandability, ease of use, usefulness, and specificity. The lowest scores were for specificity and detail in H1 ("Promotes sustainable food choice"), X1 ("Promotes foods that are produced locally"), and H16 ("Supports strategic planning"), and for ease of use of H8 ("Helps shoppers visualize an appropriate portion size"). We interpreted these scores as indications that the heuristics should be revised, and flagged them for closer inspection.

5.5.2 Top 10 Heuristics. When we asked participants to rank the top 10 most important heuristics to support food literacy, the two most commonly cited were "Interpret nutrition content" (H2) and "Support budgeting" (H20), nominated by ten (10/12) and nine (9/12) participants, respectively. A summary of the heuristics ranked as a Top 10 candidate is provided in Table 4.

5.6 Qualitative Results

Our interviews revealed some areas where the usability of our heuristics could be improved. In particular, our expert participants suggested 1) editorial improvements for clarity and specificity, 2) that we provide more examples and images to increase understanding by non-experts, and 3) where some heuristics could be combined or removed. They also explored opportunities for our

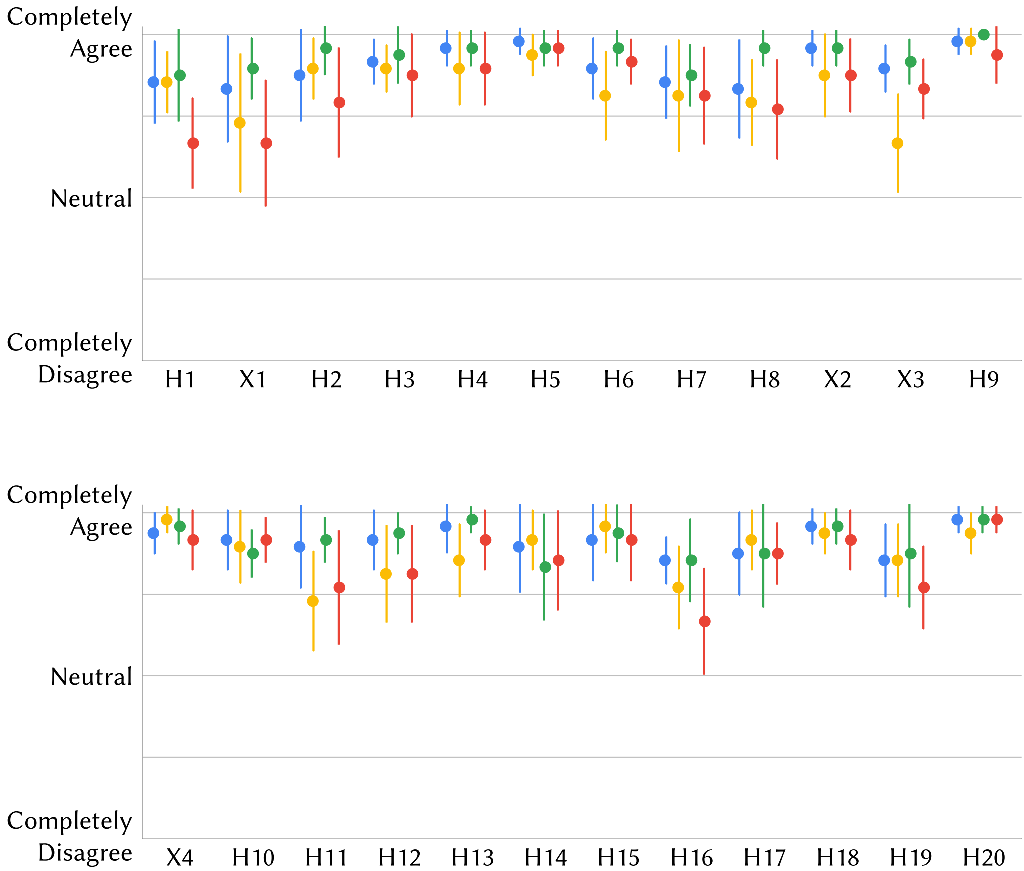

Fig. 3. Average ratings and 95% confidence intervals for 5-point Likert scale questions "The heuristic was easy to understand" (leftmost, blue), "The heuristic was easy to use (i.e., apply to the website)" (middle left, yellow), "The heuristic was useful" (middle right, green), and. "The heuristic was specific and detailed" (rightmost, red). Heuristics that were removed from our final set are denoted with an 'X'.

heuristics to suggest new ways that technology could support food literacy, demonstrating their utility as a formative design tool. We now report on these findings based on our thematic analysis of participant responses.

5.6.1 Improving Clarity and Specificity. Our participants provided a wide range of editorial comments towards improving our heuristics' understandability and applicability, particularly with a mind towards making them usable by non-nutrition experts. For instance, many of our participants were concerned that non-experts would have difficulty interpreting terms like "sustainable", "locally", and "fresh" and "ultra-processed" foods, and suggested some clarifications that we adopted. Likewise, 3/12 participants identified "cooking self-efficacy" as too vague and suggested using a more specific term like "cooking abilities" (P5), which we then adopted in our final heuristics set.

"Locally" was considered particularly unclear by participants since it could mean one's Country, Province or State, or City, depending on an evaluator's context. More generally, these comments helped us ensure that our heuristics were more generally applicable by shifting away from Canada's Food Guide and referencing "the country's food guide" instead.

Heuristic		Category	Votes
H2	**Interpret Nutrition Content** Help customers interpret a product's nutrition content using symbols, stamps, or colours (e.g., Traffic light colours, Guiding Stars, "High in" symbols).	Awareness	10
H20	**Support budgeting** and place emphasis on healthy items. (e.g., highlight healthy items on sale; have a "Sort by" feature combining lower price and more nutritious items).	Skills	9
H4	**Sort by Nutrition Values** Enable customers to sort products according to their nutritional values (e.g., Sodium: Low to High; Sugar: Low to High).	Awareness	8
H5	**Filter by Nutrition Content** Enable customers to filter products based on specific dietary needs or lifestyles (e.g., low sodium, sugar, gluten-free).	Awareness	8
H11	**Follow Food Guides** Incorporate information from local food guides. For instance, a Canadian website should use the "Eat Well Plate", promote balanced meals, whole foods, water as a beverage of choice, and cooking more often, and limiting the intake of processed foods.	Knowledge	8
H7	**Provide Healthy Suggestions** Suggested items should have similar nutritional content or be healthier than the current product being visualized (e.g., Suggest low sodium options when viewing potato chips).	Awareness	7
H13	**Enable Comparisons** Enable customers to compare the nutrition value of two or more products side-by-side.	Knowledge	7
H10	**Show Nutrition Facts** Customers can easily locate a product's nutrition information. A good place is right below the product's picture or price.	Knowledge	6
H12	**Educate about Nutrients** Educate customers about how individual nutrients affect health, with clear statements displayed prominently (e.g., "A high fibre diet reduces the risk of different cancer types"; "Too much sodium increases the risk of developing heart disease.").	Knowledge	6
H15	**Highlight Dietary Needs** Symbols are used and easy to find on the product's description to highlight specific dietary needs (e.g., no milk, halal, gluten-free).	Knowledge	6

Table 4. Top 10 heuristics as ranked by nutrition experts. Based on our interviews, we feel that these heuristics may provide a reasonable short list for rapid evaluations, as a summative tool during later stages of design, or when seeking more immediately actionable feedback.

Lastly, for H2, some participants suggested including general terms in the heuristic's description such as "using symbols, stamps, or colours" (P11) or "grocery store classification" (P8), so evaluators could abstract from the given examples of traffic light colours [94] and the guiding stars [97].

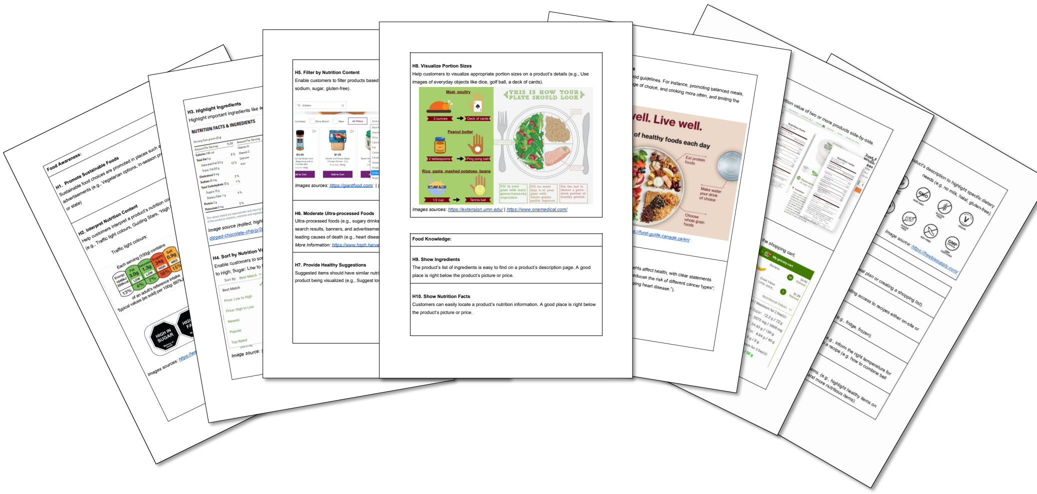

Fig. 4. The extended version of our heuristics includes additional detail, examples, and images. We developed this seven page resource based on feedback from participants.

5.6.2 Providing Examples and Images. The majority of participants (8/12) mentioned that examples were crucial to understanding and applying the heuristics and emphasized their importance for non-experts in nutrition. Thus, every heuristic without examples had comments from at least one participant asking to include them. For instance, four participants were unsure if "Informs how to prepare the products" (H19) related to preparation methods or how to integrate specific products in a recipe. Similarly, a lack of examples in "Helps the user compare the nutritional value of different products" (H13) made two participants question how the comparison should be made (e.g., table, side-by-side, looking between open tabs). Moreover, some participants suggested changing examples to be more in-line with best practices and more clarity for non-experts. P2 raised the point that "Plant-based" might not be the best example of a sustainable food (H1) because these products are also often ultra-processed. P7 suggested changing this term to "vegetarian". Thus, we made those changes and included examples in some heuristics that lacked them.

We also noticed that even our experts tended to limit their evaluation when we provided only one example. For instance, we initially prompted looking for "out of stock" products in H7 when substitutions might need to be made, but this recommendation was difficult to apply because it is typically impossible to search for out-of-stock items. Thus, we re-framed this heuristic by removing the "out of stock" option.

Our experts also highlighted the need for visual examples in some heuristics, especially to support understandability by non-experts. For example, traffic-light colours and guiding stars are well-known systems for simplifying nutritional information in the nutrition literature (e.g., [94, 97]), but their interpretation may not be familiar to, for example, HCI experts. Some participants specifically asked for images to illustrate the traffic-light colours and guiding stars (P6, P11). Thus, we included images to illustrate the given examples in the extended version of the final heuristics (Figure 4), that can be found in Appendix C.

5.6.3 Combining and Removing Heuristics. When we asked participants which heuristics should be removed, due to lack of relevance, the two most commonly cited were "Promotes foods that are produced locally" (X1) and "Acknowledges where food is produced" (X4), with both mentioned by four participants (4/12). We thus decided to remove both heuristics from our final set. Three (3/12) participants voted to remove "Uses nutrition labels to advertise the benefits of products" (X2), "Helps shoppers visualize an appropriate portion size" (H8) and "Provides a visualization of the cart's nutrition values" (H14). We removed X2 but did not remove H8 and H14 from our final set because some participants (5 and 3, respectively) included these heuristics in their top 10. Thus, we instead revised these heuristics based on our qualitative results.

Two participants (2/12) identified similar heuristics that we considered merging and also recommended removing unimportant ones. Among the similarities, P1 mentioned that "Facilitates the interpretation of nutrition facts" (H2) and "Uses nutrition symbols to advertise poor nutritional values on the products" (X3) were too similar. Thus, we removed X3 and incorporated its examples into H2.

Further, two heuristics were deemed redundant or irrelevant by our participants. Four participants suggested removing "Promotes foods that are produced locally" (X1) due to perceived irrelevance, while some participants suggested expanding the examples in H1 to include terms such as "seasonal" and "local". Thus, we removed X1 but included "local" as an example in H1. On the other hand, "Uses nutrition labels to advertise the benefits of products" (X2) was considered irrelevant, since websites already promote the positive ingredients of a product (e.g., made with whole-grain), whereas emphasizing the product's negative characteristics would be of utmost importance to the consumer. Hence, three participants voted to exclude X2. We therefore removed this heuristics from our final set, as we agree with these arguments.

Additionally, four participants (4/12) voted to remove "Acknowledges where food is produced" (X4), as they consider it to be insufficient. They mentioned that this information is not relevant to most shoppers and P4 claimed that very few people look for this data. P1 and P2 also said that knowing where the food is produced is not sufficient. For instance, P1 argued that "orange juice might be made in Canada, but the oranges used might be from Mexico", which adds many environmental footprints to its transportation. Similarly, P2 pointed out that "bananas might come from New Zealand but could also be on the shelf for four weeks, which could also reduce their nutritional value". Therefore, we also removed X4. The four heuristics that we ultimately removed are labelled as X1, X2, X3, and X4 in Table 2.

6 DISCUSSION & REVISED HEURISTICS

Study 1 showed that the proposed heuristics are effective for evaluating how grocery shopping websites support food literacy. The feedback we collected from nutrition experts demonstrated their effectiveness in assessing grocery shopping websites and showed their support for their quality and ease of use. Based on this feedback, we then revised the heuristics, included additional examples, reference material, and images. We now discuss the rationale for these changes in detail, and how they were shaped by the heuristics' utility as summative and formative design tools.

6.1 Use as Summative Design Tool

Our study demonstrates how the heuristics can be used as a guide for summative evaluation of food-related technologies, like retail grocery websites. Our participants identified an average of 14 issues over a period of about 45 minutes, indicating that the heuristics serve as both an efficient and effective evaluation tool.

Importantly, our tool also elucidates both fine-grained, actionable usability issues as well as more conceptual aspects of food awareness, knowledge, and skills. For instance, we found that the heuristics most frequently ranked in our experts' top 10 lists (Table 4) are reflective of current legislation and best practices in non-digital contexts [25, 27, 58]. Since these heuristics are oriented towards practical issues, like use of traffic-light colours (H2), or filter search results based on dietary needs (H5), they may point to more immediately actionable changes. We feel that the "Top 10" heuristics in Table 4 are likely a useful short-list for rapid evaluations, during later stages of design, or for those seeking only immediately actionable feedback.

On the other hand, many of the heuristics also point to deeper considerations about not only the food, but how a technology *approaches* food. For instance, "Provide Healthy Suggestions" (H7) requires a deep understanding of a food's ingredients and nutrients, and how they might intersect with an individual's preferences, dietary needs, and other health considerations. Similarly, "Promote Sustainable Foods" further requires careful consideration of what foods are currently in-season, and an individual's geographic region. The nutrition literature has well-established the importance of the awareness, knowledge, and skills required to select and purchase foods [9, 39, 87, 92, 105]. Our heuristics provide guidance for creating technologies that develop those aspects of food literacy.

6.2 Use as Formative Design Tool & Revisions

Moreover, we saw that the heuristics were effective at provoking discussion about novel features that designers might incorporate into grocery shopping websites, and thus their utility as a formative design tool. Our interviews revealed that that a number of heuristics were more controversial, and involved complex discussions about trade-offs between nutrition research, current practice, and personalization. Thus, we now discuss these complexities, how they shaped specific heuristics, and how they point to the potential of our heuristics to support future work in designing technologies around food.

H8: Visualize Portion Sizes. Five participants (42%) included this heuristic in their Top 10, but three participants (25%) indicated that we should remove it. Those in favour of the heuristic cited the known difficulty consumers have in visualizing serving sizes [37], and the need for some type of aid to help them with this issue. Those against it cited the need for examples (4/12 participants), that they had difficulty suggesting how a website could implement these representations, and that they have never seen this feature on a website in practice (3/12). Additionally, P11 was concerned that the heuristic is confusing because a serving size might not be the portion size that the individual needs; appropriate servings can be highly personalized due to dietary conditions such as activity level or an associated disease.

Ultimately, we decided to keep and revise the heuristic, to reflect best practices in the nutrition community. We now suggest the use of everyday objects like dice, a golf ball, or a deck of cards for easy comparison [23, 49]. Other pictorial representations could also be explored, such as the proportion that the food should be placed on a plate (e.g., eat well plate). These visualizations would help to avoid over-serving and "portion distortion", where people mistakenly perceive large portion sizes as appropriate [90].

H14: Summarize Nutrition Information. When we set out to develop these heuristics, we were motivated by some of the difficulties in visualizing nutritional information when shopping online. Based on our own experience, and previous research (e.g., [16]), we knew that visualizing the contents of a shopping cart was something uniquely difficult when shopping online. Websites typically only offer a shopping cart icon with a numerical indicator of how many items you've selected — with no information about the items themselves.

Our interviews confirmed some of this intuition, but also pointed to challenges facing a universal heuristic. Some participants were enthusiastic about the potential of having features on retail websites that would allow customers to better engage with cart-wide nutritional information, stating "that would be fantastic!" (P11); and "that one is perfection!" (P10). However, others were unsure about how the heuristic would be applied in practice and argued that it needed clarification (4/12). We feel that these divergent opinions might in part be due to the novelty of such a feature, which is not commonly found on retail websites. But, three participants also noted that such a feature would only be relevant if the website had information about the customer, such as for how many people or how many days they are shopping. Based on those challenges, three participants voted to remove this heuristic altogether.

We ultimately decided to keep the heuristic, but to make it more general, with less of a focus on the shopping cart itself. We envision that, like other applications where personalization is the norm (e.g., food trackers), grocery websites could offer more precise recommendations. For instance, P1 pointed out that this heuristic could also be applied to meal delivery applications. Thus, we hope that the revised version will be useful to others in creating digital food environments more generally.

H7: Provide Healthy Suggestions. While this heuristic originally was labelled as "Suggest similar products", our participants indicated that it should be further refined to focus only on healthy items. Grocery shopping websites have the potential to improve food suggestions and recommendations, like many other retailer websites. For instance, like Amazon suggests similar products based on a customer's search history, grocery shopping websites could offer comparable but perhaps healthy options based on previous purchases to help customers discover and buy a variety of products. As mentioned by P1 during their interview, if a shopper searched for tofu, the website could suggest other plant-based products. Suggestions can be placed while searching for foods or during check-out. For instance, Walmart suggests missing products to shoppers, including previous purchases or food that other shoppers usually buy. Social comparisons could be further explored, as they have been shown to influence purchases [41]; however, they should be concentrated on whole foods and not impulse buys.

Other basic design elements that could be better explored to foster more healthful choices are "Sort By Nutrition Values" (H4) and "Filter by Nutrition Content" (H5). For instance, filter by nutrition content is already present in some grocery stores, such as Walmart, but sorting by nutrition values is not very common. However, websites like the Giant Food Stores (giantfood.com) offer a way to sort products by values such as dietary fibre, cholesterol, sodium, and sugar, and other grocery websites could offer this option too. And of course, combining both could ultimately help consumers make more informed choices.

7 STUDY 2: EVALUATION WITH HCI EXPERTS

Having found that our heuristics can be used as a guide for summative and formative evaluation of food-related technologies, we next sought to investigate their utility for HCI experts without a background in nutrition. To do so, we replicated our mixed-methods study with HCI experts. We specifically recruited participants with at least one year of experience in HCI, to understand how they might be used by technologists. As in Study 1, We asked the experts to use our heuristics to evaluate a real-world website. At the end of the website evaluation, we asked participants to reflect on and explore the heuristics as a formative tool, and how they might use the heuristics to assist in the design of other food-related technologies. Our study design received clearance from our local Office of Research Ethics.

As this was a replication of Study 1, we pre-registered the data collection protocol, all study materials, and analysis plan with Open Science Framework in November 2019 (https://osf.io/5dwnz/).

7.1 Participants

We recruited 12 participants (7 male-identifying, 5 female-identifying) through social media networks (e.g., Twitter, Slack, WhatsApp Groups), aged 22 to 45 (median 29). Of these, four identified as students, four as PhD student/researcher, three as software engineer/developer, and one as UX

ID	Gender	Age	Profession	Experience
P1	Male	29	PhD Student	3 years
P2	Female	28	UX Researcher	2 years
P3	Female	25	Software Engineer	1 year
P4	Female	22	Student	2 years
P5	Male	41	PhD Student	1 year
P6	Male	32	Student	1 year
P7	Male	29	PhD Student	4 years
P8	Female	35	PhD Researcher	1 year
P9	Male	25	Student	1 year
P10	Female	25	Software Developer	2 years
P11	Male	45	Software Engineer	10 years
P12	Male	25	Student	1 year

Table 5. A summary of participants' demographic information in Study 2.

researcher. All participants had between 1 and 10 years of experience in the field of HCI (median 2 years), either professional or academic. A summary of their information is provided in Table 5. All 12 participants completed the study, and each received a CAD$30 honorarium.

7.2 Procedure

After giving their consent to participate in the study through a link sent by email, participants completed a background survey to collect demographic information and previous experience in HCI, which served as the competency indicator for each participant. The first author then briefly explained the study objectives and what to expect from the study before providing participants instructions and links to the food literacy heuristics. For this study, participants were able to choose between the one-page version of our revised heuristics and the extended version with visual examples created based on feedback from Study 1 (Appendix C). They then performed two design activities: a summative website evaluation, and a formative design activity of a technology of their choice.

For the summative evaluation, participants were randomly assigned to evaluate one of three websites, with a total of 4 participants evaluating each website. We selected the same three websites used for the previous study with nutrition experts, which were Canadian-based Walmart (walmart.ca), and Loblaws (loblaws.ca), and UK-based Morrison's (morrisons.com). We provided them with an explanation of food literacy and its domains and gave them some time to familiarize themselves with the website. We then asked them to apply the heuristics using a think-aloud protocol [102]. We instructed participants to run the summative evaluation the way they preferred, indicating when they found that the website supported or violated each heuristic. After the website evaluation was complete, we conducted a semi-structured interview to collect feedback on their experience carrying out the heuristic evaluation and suggestions of improvements and follow-up questions based on their observations during the assessment.

For the formative evaluation, we then asked participants to reflect on how they would use the heuristics to improve the design of different technology of their choice. They were first asked to perform a new walk through the same website that they evaluated and explain how they would enhance the website, identifying what heuristics they would use, how they would apply them, and why they chose to apply them to the website. Then, they were asked what other food-related technology they would think would benefit from having these heuristics applied to them. Following, we asked them again to walk through the mentioned system and asked the same questions on how they would improve this technology to support food literacy using the heuristics. Follow-up questions were included to explore the design ideas and reasons for choosing specific heuristics. Lastly, participants were asked if they would use these heuristics again in the future. At the end of the interview, a feedback letter and e-transfer were sent to participants, and they were thanked for their time and participation.

7.3 Data Collection & Analysis

Sessions took place online and were recorded directly using Microsoft Teams™. Qualtrics XM was used to collect demographic information. Sessions took an average of 60 minutes, including the evaluation and the interview. Interviews continued until data saturation was reached; saturation was considered reached when no new information was obtained from interviewing additional participants that would contribute to forming new themes [88].

The second author transcribed audio from the interviews. We applied a thematic analysis methodology using an approach combining elements from both the reflexive and codebook orientations of thematic analysis [17, 18]. Our process consisted of an *a priori* deductive creation of codes, a reflexive perspective on inductive code and theme generation. The first author defined overarching deductive codes at the beginning of our analysis, based on the original heuristics and the interview questions.

The first author then inductively coded the interview data, placing it into the *a priori* codes and creating new codes based on the data. Examples of *a priori* codes include: "Design idea for heuristic 2" or "Example of system to apply the heuristics". The first author then developed the final themes from the grouped codes by re-reading and synthesizing the coded quotes. Discussions were grouped according to participants' descriptions of the problems they found on the evaluated websites and feedback on how to improve the heuristics and how they would use the heuristics to improve different technologies.

Analysis of website evaluation feedback consisted of calculating the average number of issues found by the participants for each website within each category. This analysis helped us assess how each website performed in supporting food literacy and what categories had more issues within each website. Since our heuristics were revised after analysis of Study 1 data, we did not perform statistical comparison of data between studies.

7.4 Summative Evaluation Results

Evaluations took an average of 35 minutes, and over the course of the evaluation participants identified a variety of food literacy improvements across the three websites. On average, they identified 16 areas for improvement for each website, comprising 6.75 Awareness issues, 5.58 Knowledge issues, and 3.25 Skills issues (Figure 5). These issues were also consistently identified between websites, with an average of 17.50 identified for Loblaws, 15.75 for Walmart, and 13.50 for Morrisons. The HCI experts in this study identified more issues on average than the Nutrition experts in Study 1. However the issues identified by both groups were consistent for each website. For instance, both groups identified more awareness and skills problems for Loblaws (7.75 versus 5, and 4.25 versus 3.25, respectively) and more knowledge problems for Walmart (6.25 versus 4.5). Similarly, Morrison's was the website with the fewest issues found by both groups (13.5 versus 9).

There was a high level of agreement among participants in identifying similar issues on these websites. The three most frequently violated heuristics — identified by all twelve of our participants — were "Highlight Ingredients" (H3), "Sort by Nutrition Values" (H4), and "Enable comparisons" (H13). Eleven (11/12) participants identified violations in "Interpret Nutrition Content" (H2), "Limit Ultra-Processed Foods" (H6), "Provide Healthy Suggestions" (H7), "Follow Local Food Guides" (H11), "Educate about Nutrients" (H12), and "Summarize Nutrition Info" (H14).

On the other hand, two heuristics (H9: "Show Ingredients" and 'H10: 'Show Nutrition Facts") demonstrated a lower level of agreement among participants, with half of participants identifying a violation. We attribute these differences due to distinctions between the websites. For instance, Walmart and Morrisons only display nutrition facts and ingredients for packaged products, which excludes produce and meat. On the other hand, Loblaws shows the nutrition facts and ingredients of produce and meat. Moreover, some participants judged violations of these heuristics from different perspectives. One participant who evaluated the Walmart website (P07) and two who evaluated the Morrisons website (P06 and P12) did not consider the lack of nutrition facts and ingredients of unpacked products as an issue, given that this information is also not displayed at the store. And one participant (P02) considered violations in Loblaws' site because there is a need to click to expand to visualize these two pieces of information, which was not considered "easy to find", as described by the heuristic. A complete summary of the issues identified by our participants is provided in Appendix B.

Participants were optimistic about non-experts' use of the heuristics, their relevance, and their ease of use. All twelve participants mentioned that the heuristics were easy to use on the website they evaluated. Participant 4 said, "I feel like the example and the images as well helped to evaluate the website. It feels comprehensive and covers a lot of things." Four participants mentioned that a general audience could quickly work through the heuristics, and three participants used the word "straightforward" to describe them. P4 said, "I don't have any experience with health specifically, but it was easy for me to go through the heuristics and evaluate the Walmart website based on whatever heuristics."

Moreover, all twelve participants indicated they would consider using the heuristics again in the future. P5 mentioned that they are crucial for people who have unhealthy eating habits "probably because they have a really poor nutritional literacy". He added that this is an issue that "affects society in general" and indicates the importance of applying the heuristics in technology for educating people. Finally, Participant 3 mentioned that performing the formative exercise made her realize how websites such as grocery stores, restaurant delivery and meal kits need improvements to support food literacy, and that "it would be great if all those sites had those heuristics applied."

7.5 Formative Evaluation Results

During the formative evaluation, we asked participants to freely explore the heuristics they would use to improve the design of the systems of their choice. Participants chose to perform formative design tasks for a variety of domains, including grocery and meal kit delivery apps, restaurant and meal kit delivery services (Table 6). During their formative design activities, participants used the heuristics as a starting point from which they suggested improvements or new features that would better integrate and promote food literacy by design. For instance, "Interpret Nutrition Content" (H2) and "Enable Comparisons" (H13), were each used by eight participants to generate idea for how to enable side-by-side comparisons between products; functionality that is often lacking to help consumers interpret nutrition content. On the other hand, no one explored "Follow Food Guidelines" (H11) during the formative design activity.

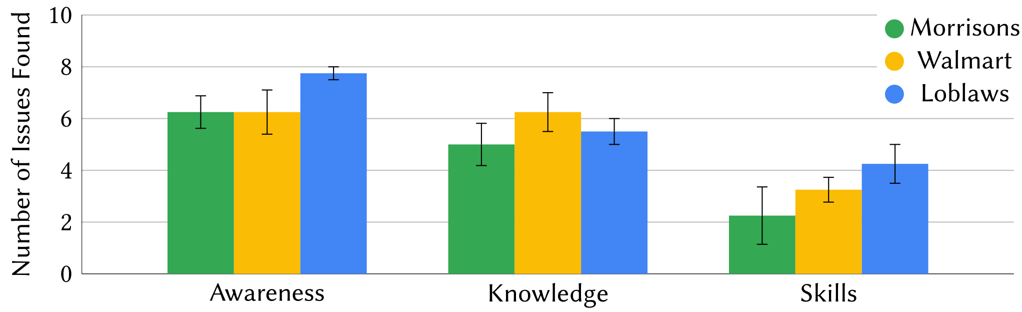

Fig. 5. Number of issues identified by HCI experts in each food literacy category for the three grocery websites included in the study. Error bars attached to each column represent pooled standard error term.

ID	Application	Heuristics Explored
P1	Grocery	H2, H3, H5, H6, H7, H8, H9, H10, H13, H14, H16
P2	Grocery	H2, H8, H14
P3	Meal Kit	H2, H13, H15, H20
P4	Grocery	H2, H4, H13, H14, H15
P5	Restaurant / Meal Kit	H2, H4, H7, H12, H13, H15, H16, H20
P6	Grocery	H4, H5, H7, H8, H12, H13, H14, H17, H18, H19
P7	Restaurant / Meal Kit	H1, H5, H7, H12, H16, H17, H18, H19, H20
P8	Grocery	H2, H8, H16, H18
P9	Grocery	H14, H20
P10	Meal Kit	H2, H8, H10, H13, H17, H18
P11	Restaurant	H13, H14, H17, H18
P12	Grocery	H1, H2, H3, H6, H13, H15, H16, H17, H18

Table 6. A summary of participants' formative design activities.

At the end of the interview we asked participants whether they might envision using the heuristics in other applications or domains. They responded that they would, and expressed their potential to inform the design of meal kits, restaurant delivery apps, digital restaurant menus, food trackers, recipe websites, gym membership websites, college and university websites, and food and cooking websites or blogs.

Following the formative design activity, we developed the following themes during our thematic analysis of participant interviews: They generated novel design ideas and considered different food literacy domains, including strategic planning, decision-making, and understanding the impact of food decisions (Theme 1); participants self-reflected on their own knowledge and skill gaps around food literacy (Theme 2); and the heuristics helped to reveal tensions between nutrition and HCI best practice (Theme 3). We now report on these findings based on our thematic analysis of participant responses.

7.5.1 Theme 1: Participants generated novel design ideas that considered different stages of food literacy. Participants used the heuristics to explore how design solution could promote strategic planning, support consumers' decision-making process, and help to understand the impact of their food decisions. They explored these design ideas by considering a variety of applications, including online grocery stores, meal kits, and restaurant delivery.

Participants explored how grocery websites or apps could support consumers in creating a strategic plan for their shopping. A common approach was to consider how technology could support the creation of grocery lists. P7 and P8 both suggested that websites or apps could support personalization, where details like a person's family size, specific dietary needs, or preferences would be factored into recommended recipes and items, and ingredients could then be added to a shopping cart in correct proportions for the desired number of people and servings. P6 further suggested that websites or apps might help to validate a consumer's grocery list, and provide feedback on whether they have a well-balanced meal plan, and suggestions for alternatives to balance their cart if needed. By integrating these recommendations at the time of purchase, consumers would be provided with key opportunities to develop planning skills based on personal needs, grounded in best practice.

Similarly, participants explored support for consumers' decision-making; decisions like choosing between alternative foods while weighing their nutritional needs, moderating the consumption of components like sugar or fat, or optimizing intake of fibre. "Enable Comparisons" (H13) inspired them to suggest different types of side-by-side comparisons based on nutritional values. These options included comparing individual products from a grocery store (P4, P6, P10, P11, P12) or entire meals from a meal kit box (P3, P5), from a restaurant (P5), or finding nutritious options from a variety of restaurants (P8). In exploring design ideas to support navigation between multiple restaurants, P5 suggested having a "healthy customer rating" so customers could visualize which nearby restaurants might offer nutritious food, for example, with less fat and more fibre. He explained that this feature should work like Google Reviews but emphasize nutrition content. Consumers could add pictures, report ingredients, and then rate meals based on their nutrition, and this data could in turn be used to generate scores for meals or restaurants. This example demonstrate how our heuristics often served as a 'launching pad', from which our participants generated new ideas, improvised, and created novel systems that supported the key components of food literacy.

Finally, participants explored how the heuristics could help consumers understand the impact of their decisions and to reconsider their choices. For example, "Summarize Nutrition Info" (H14) inspired participants to reflect not only on how to present summaries of nutrition information, but also how to nudge consumers to think about it. Three participants (P1, P4, P6) considered how reminding consumers to reflect on their grocery cart before check-out would help them to consider buying more nutritious products and making them more knowledgeable about their health. P4 said, "It reminds you that, 'ok, do you really want to proceed with this amount of added sugar?", and P6 said, "Maybe you'll think twice, maybe I don't need the extra bag of chips". P7 and P5 considered similar features in the context of restaurant delivery and meal kit boxes, respectively, and suggested having a breakdown of how each ingredient contributes nutritionally to a meal, to prompt customers to consider substitutions. For instance, a customer might realize that soy sauce was contributing too much sodium to their meal, and then ask to make a substitution, reduce the amount they are requesting, or remove it entirely from the meal. These comments demonstrate how our heuristics helped participants envision different situations where consumers could perceive the impact of their choices on their health needs.

7.5.2 Theme 2: Participants used the heuristics to self-reflect on knowledge and skills gaps they have around food literacy. Many participants shared personal experiences from when they had faced problems around food literacy themselves, and reflected on how the heuristics could inform improvements in those contexts. For instance, portion size was something that three participants mentioned having a hard time visualizing (P6, P8, P10). P8 said, "I've been trying to find out what's the perfect way to portion my meals, so it'll be nice if they told me as well. Say if I buy like a pack of chicken thighs. It would be nice if they could tell me that maybe two pieces per meal is a good portion for me." P6 and P10 also mentioned that having portion sizes in grams is not helpful for them to visualize, and having a pictorial representation would be beneficial for them.

Two participants also shared personal experiences about when they started living independently and had difficulties navigating the food environment. In both cases, they consulted their mothers for advice. When reflecting on the heuristic "Teaching Food Storage (H18)", P10 shared a story about when she bought some vegetables that spoil quickly. After talking with her mother about that fact, she learned that, to last longer, she should have removed them from the plastic bag before placing them in the fridge. P12 also shared a similar story. He said, "I have never cooked in my home country. It was my mom's duty, so I had absolutely no idea before I came here about food storage, about cooking, about all these things. So every time I buy some product that I never bought before, the first thing I do I call my mom and ask how to store a type of food, after cooking that food, or after opening a container, how long should I consume it, how long can I store it in the fridge or the freezer? I would really appreciate it if they (the websites) were telling me this information." In addition, P7 also mentioned about being unsure how to properly store leftovers from a prepared meal, for how long they can be stored, and what containers to use to last longer.

The lack of nutrition information online was also a problem that many participants mentioned they had faced when discussing the heuristics "Show Ingredients" (H9) and "Show Nutrition Facts" (H10). This missing information hindered them when shopping online, especially if they had dietary restrictions such as allergies, food intolerance, or religious considerations. They mentioned moments when the grocery websites did not support them finding healthy or adequate products for their diets. P4 said "It's hard for me to find things that are healthy using their website (due to the lack of nutrition information), which makes me feel like maybe it's better to actually go to Walmart than use the Walmart website to buy things online, 'cause it's missing a lot of important information (online)." Three participants also mentioned concerns about a lack of halal information on products' descriptions, which makes them unaware of if certain products would fit into their diets (P2, P10, P12). Even if a halal symbol is not included in the product's description, it is essential that at least the list of ingredients is present because halal restrictions include factors like a product's alcohol content or the types of shortenings used in bakery items. For instance, P12 said he follows a halal diet and is usually very frustrated when the ingredients list is not shown on the bakery section, which is common in some grocery websites.

7.5.3 Theme 3: Tensions between nutrition and HCI best practice. We identified some disagreement between participants' personal opinions and best practices from the nutrition literature. For instance, three participants (P5, P6, P7) recommended framing messages positively instead of emphasizing harms when designing for "Educate about Nutrients" (H12). P5 argued that this approach would be more beneficial for consumers since they distrust nutritional recommendations that often conflict or change over time. She said, "I know there are so many things they say like saturated fat is bad for you, but now some people think saturated fats can be good for you. And I've heard about studies where they say they don't think sodium causes hypertension any more. So I think that if you see something which tells you one thing and you've heard something else, there's a conflict between them so that you might distrust it more. So I think positive things would be more encouraging".

Interestingly, we removed the heuristic "Uses nutrition labels to advertise the benefits of products" after Study 1 because it was considered irrelevant, since websites already promote the positive ingredients of a product (e.g., made with whole-grain), whereas emphasizing the product's negative characteristics would be of utmost importance to the consumer [65].

The HCI experts felt that designers would interpret specific heuristics and the implication of certain words on user experience. Three participants (P4, P7, P9) were concerned that 'limiting' (i.e., H6) a shopper's consumption of ultra-processed foods is directly opposed with UX best practices that seek to support their choices. P7 explained that such limitations could make it more difficult for shoppers to find ultra-processed products and provide a poor shopping experience, "I don't like to be limited as a customer, but I like to be informed". As an alternative for 'limiting' ultra-processed products to customer, P8 suggested that designers should "structure the website so that it teaches and creates awareness for people". This suggestion of providing information and creating awareness align with central ideas from food literacy, and are present in many other heuristics (e.g., H2, H3, H12), which shows that there are different ways that designers can support food literacy without necessarily having to use all the heuristics.

Despite the positive suggestions for creating designs to educate and create awareness, the given reasons for avoiding the word "limit" in H6 are problematic from a public health perspective. For instance, two participants mentioned that limiting ultra-processed foods would impose barriers for buying these products for children, arguing that they should, instead, be more accessible to this population. P9 said, "I don't think that limiting ultra-processed foods would be a great idea because, for example, some people have children and they might want to see some advertisements (about ultra-processed foods aimed at children). It could help the business owner advertise some ultra-processed foods, such as chips, sugary drinks, ice creams and that sort of stuff". Additionally, P7 complemented her previous quote by adding, "For example, if I have kids and I wanna feed my kids cookies and ice cream, I already know that this isn't the greatest option, but if I want to find a specific one and it's low in my search, I don't think that brings a great user experience, you know?" This association between ultra-processed foods and children is concerning from a nutrition perspective due to their vulnerability to marketing, and the potential long-term implications of establishing unhealthy eating patterns at an early age.

8 DISCUSSION & IMPLICATIONS

Our quantitative findings demonstrate how researchers and practitioners without expertise in nutrition can quickly and easily identify design problems using our heuristics. In Study 1, our nutrition expert participants identified an average of 14 issues over a period of about 45 minutes. In Study 2, our HCI expert participants identified an average of 16 issues over a period of about 35 minutes. Together, these findings point to our heuristics being an efficient and effective method of identifying concerns around food literacy during summative evaluations.

It is important to acknowledge that our two studies were *not* designed to support direct comparisons between nutrition and HCI experts. Thus, comparing the number of issues identified by nutrition experts in Study 1, and the higher number of issues identified by HCI experts in Study 2, requires some interpretation. We attribute these differences to two key factors. First, the heuristics used in Study 2 were refined based on feedback from Study 1, and were intended to improve their utility. In particular, we expect that the additional detail, examples, and illustrative images would be helpful to HCI experts. Second, HCI experts are likely to be more experienced with heuristic evaluation, and therefore may be expected to identify more issues as a population than nutrition experts. For these reasons we did not perform a statistical comparison of the two groups, and instead view our results as indicative of a general efficacy. We also note that both groups identified a similar distribution of problems among the websites and categories Figure 5.

Our qualitative findings further point to the heuristics' utility as a formative design tool that is useful in designing various food-related technologies. HCI experts generated novel design ideas considering different stages of food literacy for different applications (e.g., online grocery stores, food delivery apps, and meal-kit systems), and used the heuristics to self-reflect on knowledge and skills gaps they have around food literacy. We believe that this self-reflection is positive and might inspire HCI experts to put themselves in the consumers' shoes and propose designs that benefit themselves as consumers as well. Moreover, we encountered complex discussions about trade-offs between the interests of nutritionists, HCI researchers, and retailers and the heuristic's applicability to online food sales. Thus, we now discuss these applications, tensions, and complexities, how they shaped the design suggestions, and how they point to the potential of the heuristics to support future work in designing technologies around food.

8.1 Different Ways of Using the Heuristics

We set out to support a wide range of food-related technologies by grounding our heuristics in a comprehensive food literacy framework [9], and our participants confirmed this. During the formative evaluations in Study 2 our participants applied our heuristics to a range of different technologies, including applications to grocery shopping, meal kit delivery, and restaurant dining. Participants further envisioned using the heuristics for applications like food trackers, cooking websites, and digital restaurant menus. We expect that given the rapid rate of research in human-food interaction that these examples are only the beginning [5], and that in the future an even wider variety of technologies and applications will be explored. However, this wide range of applications also raises the question of whether the heuristics should be applied in the same way for each of these contexts.

In many contexts the framework of Awareness, Skills, and Knowledge provide a means of identifying heuristics that may be most relevant to a technology or group of people [9]. For instance, our HCI experts felt that 'Skills' might be a useful area of focus for meal kit systems, where consumers purchase foods but need to prepare themselves at home. Similarly, 'Awareness' might be more relevant to restaurant delivery apps where the consumer's role is simply to consume, and not prepare or handle foods.

Alternatively, as we observed in our HCI experts in Study 2, a handful of heuristics can be used to consider different stages of food literacy, particularly when used as a formative design tool. We saw participants explore how technology might promote strategic planning, the decision-making process, and how it might help consumers understand the impact of their food decisions (Theme 1). In these cases, our HCI experts used the heuristics to self-reflect and to generate novel design ideas.

Finally, our top ten heuristics (Table 4) may be useful for rapid evaluations of 15 or 20 minutes for those working under time constraints. The majority of these top ranked heuristics were used by HCI experts during their formative evaluation or mentioned during the interview as essential to support food literacy, showing the utility and applicability of this sub-list. These core heuristics may also be particularly useful as a formative design tool, since they provide a shortlist for the most salient considerations, as identified by our nutrition and HCI experts.

When looking individually at the heuristics the HCI experts used during the formative evaluation, we noticed that some were used more than others, and we may interpret this result in different ways: (1) The most used heuristics might reflect the most pressing issues on those systems, and participants find those issues essential to be resolved. e.g., Current systems do not help consumers interpret nutrition facts (H2) and do not offer side-by-side comparisons (H13); (2) Some under-used heuristics might mean that those systems do not have issues to be solved with those heuristics. e.g., Those systems already display ingredients (H9) and nutrition facts (H10); (3) Some under-used heuristics might not have been considered as essential to apply on those systems, or participants did not have design ideas to explore how to apply them. e.g., Although 11 participants found issues with "Follow Local Food Guides" (H11) during the summative evaluation, no one used this heuristic during the formative evaluation.

8.2 Tensions between Public Health and HCI Practices

Our analysis of qualitative data showed that our heuristics helped participants to self-reflect on problems they faced around food literacy and to take on others' perspectives in their design process, but it also identified tensions between nutrition best practices and HCI experts' design thinking. In particular, we now discuss three tensions: lack of awareness, differences in perspective, and misconceptions about health research.

First, many of our HCI experts were not aware of these nutrition concerns, as indicated during our interviews. While this was somewhat expected, it further demonstrates a need to educate software developers themselves about food literacy. We largely interpreted these findings as indicative of the technosolutionism identified by Altarriba Bertran et al. [5], and the need for cross-pollination between siloed research communities. They also point to a need for tools like our heuristics to help HCI researchers identify gaps in their own knowledge, and to be aware of when they need to ask for help.

Second, our findings point to a need to reconcile differences in perspective between HCI and nutrition practitioners. While HCI practitioners often develop technologies from a user-centred or individual perspective, the nutrition community approaches their guidance as a population-level intervention. In short, HCI is focused on what we *can* do, whereas nutrition is focused on what we *should* do. For instance, some of our HCI experts argued that technology should not be designed to limit consumers' choices, whereas nutrition experts and public health practitioners express concerns about over-exposure to ultra-processed foods and the burden of non-communicable diseases caused by unhealthy dietary patterns [1]. There is a consensus among nutritionists that retailers already aggressively communicate positive messages when promoting their products, but do not communicate the negative aspects. For instance, a white chocolate bar is 'high in calcium', but those benefits are undermined by its high levels of added sugars when not consumed in moderation, and it would be disingenuous to advertise it as such.

Third, some comments from our HCI experts are concerning from a nutrition perspective, such as those normalizing the consumption, promotion, and marketing of ultra-processed foods for children. Two participants gave examples of shopping with children as a reason for *not* limiting ultra-processed foods, as their parents would want to buy those products for them. Early exposure to ultra-processed food for children is a critical issue in the nutrition literature, as it promotes long-term brand-favouritism that persists through adulthood [86, 96]. Therefore, there are a variety of public health interventions aimed at educating children and adults about the dangers of marketing to children and making them more aware of these advertisements [55, 110]. Moreover, even global food guidelines incorporate awareness about this issue [26].

Overall, we interpret these tensions as a real opportunity to improve the design process for food-related technology, and as re-enforcing the need for knowledge transfer between the nutrition and human-computer interaction communities. Our findings reinforce previous calls for cross-pollination of human-food interaction research, and the need to make nutrition science a consideration earlier in the design process. And importantly, we feel that our heuristics can serve a critical role in facilitating this knowledge transfer, promoting awareness of food literacy concerns in software development, and in making nutrition knowledge more accessible to HCI researchers and designers.

8.3 Revisions to Heuristics

As in Study 1, this evaluation with HCI experts provided us an opportunity to consider revisions to help technical experts better apply the heuristics. We were particularly focused on revisions that helped to alleviate the differences in perspective between the nutrition experts in Study 1, and the HCI exerts in Study 2, as well as to improve HCI experts' awareness of the implications of their design choices to consumers' health. Based on the feedback we received, we made adjustments in three heuristics. The final text for each heuristic is shown in Table 7. The extended version of these final heuristics is provided in Appendix C.

H11: Follow Local Food Guides. We removed the word "local" from "Follow Food Guides" (H11) because we found that some of our HCI experts interpreted the heuristic as supporting local producers, rather than placing the emphasis on following a food guide. To place greater emphasis on the need to follow food guidelines, be they local, regional, or global, we also now provide examples of these in the extended version of our heuristics.

H6: Limit Ultra-Processed Foods. Some participants disliked the word 'limit', as they felt it was limiting consumers' choices and ran counter to best practices in the HCI community. To avoid this concern, we changed the heuristic to "Moderate Ultra-Process Foods", to better capture the sense of consuming these goods in moderation. We also added an explanation for the importance of this heuristic in its description, to help technical experts be better aware of its importance.

H12: Educate about Nutrients. To address some of our participants not being familiar with the implications of the public health guidance behind this heuristic (Theme 3), we have also included a brief explanation for the reasoning. In particular, we have added two examples: "Too much sodium increases the risk of developing heart disease." and "A high fibre diet reduces the risk of different cancer types".

9 LIMITATIONS AND FUTURE WORK

In this work, we devised a set of heuristics that can help technologists design and evaluate food-related technology, with a particular focus on the holistic development of food literacy. Our findings indicate that these heuristics provide some valuable support to a rapidly growing area of research. However — like any newly developed tool — these results should be interpreted within the context of their limitations. Several of these limitations arise from the necessarily focused nature of our development process. First, we elicited feedback on our heuristics in the context of online grocery shopping, and had our experts speculate on their use in other domains of interest and with other technologies. Second, while our participants were able to use our heuristics to identify issues and generate design ideas with third-party websites, they have not yet been used in practice, with existing teams or products. These limitations point to a need to establish the heuristics' ecological validity, and for future work to establish our heuristics' utility in designing and evaluating new technologies and in new domains.

We also focused on creating heuristics for food literacy's domains of planning and selecting foods, because they are most representative of the current applications of technology and HCI research. However, there are clearly exceptions, such as work in HCI that aims to enhance the act of eating itself [6, 73]. Even for those projects, we have captured some applicable knowledge from the food literacy literature, such as 'visualize portion sizes' (H8). However, we can envision that in the future, heuristics that elaborate on food literacy for preparation (e.g., [31, 59]) and eating (e.g., [6, 73]) might also be valuable additions.

Finally, adoption of our heuristics in practice may be a challenge. When we set out to develop our heuristics, we expected that the retail food industry may be the largest barrier to adoption; many

Food Literacy Heuristics

Awareness	
H1. Promote Sustainable Foods	Sustainable food choices are promoted in places such as search results, banners, and advertisements (e.g., In-season produce, local foods)
H2. Interpret Nutrition Content	Help customers interpret a product's nutrition content using symbols, stamps, or colours (e.g., Traffic light colours, Guiding Stars, "High in" symbols).
H3. Highlight Ingredients	Highlight important ingredients like added sugar, saturated fats, artificial ingredients.
H4. Sort by Nutrition Values	Enable customers to sort products according to their nutritional values (e.g., Sodium: Low to High; Sugar: Low to High).
H5. Filter by Nutrition Content	Enable customers to filter products based on specific dietary needs or lifestyles (e.g., low sodium, sugar, gluten-free).
H6. Moderate Ultra-Processed Foods	Ultra-processed foods (e.g., sugary drinks, cookies, ice cream) should not be prominent in search results, banners, and advertisements because they are a high-risk factor for many leading causes of death (e.g., heart disease, stroke, and type 2 diabetes).
H7. Provide Healthy Suggestions	Suggested items should have similar nutritional content or be healthier than the current product being visualized (e.g., Suggest low sodium options when viewing potato chips).
H8. Visualize Portion Sizes	Help customers to visualize appropriate portion sizes on a product's details (e.g., Use images of everyday objects like dice, golf ball, a deck of cards).
Knowledge	
H9. Show Ingredients	The product's list of ingredients is easy to find on a product's description page. A good place is right below the product's picture or price.
H10. Show Nutrition Facts	Customers can easily locate a product's nutrition information. A good place is right below the product's picture or price.
H11. Follow Food Guidelines	Incorporate information from food guidelines. For instance, promoting balanced meals, whole foods, water as a beverage of choice, cooking more often, and limiting the intake of ultra-processed foods.
H12. Educate about Nutrients	Educate customers about how individual nutrients affect their health, with clear statements displayed prominently. (e.g., "Too much sodium increases the risk of developing heart disease."; "A high fibre diet reduces the risk of different cancer types").
H13. Enable Comparisons	Enable customers to compare the nutrition value of two or more products side-by-side.
H14. Summarize Nutrition Info	Offer a visualization of nutrition information for all items in the shopping cart.
H15. Highlight Dietary Needs	Symbols are used and easy to find on the product's description to highlight specific dietary needs (e.g., vegetarian, no milk, halal, gluten-free).
Skills	
H16. Support Strategic Planning	Enable customers to plan ahead (e.g., Enable meal plan or creating a shopping list).
H17. Develop Cooking Abilities	Help customers develop cooking abilities by providing access to recipes either in-site or through external links.
H18. Teach Food Storage	Teach customers how to properly store a product (e.g., fridge, frozen).
H19. Teach Food Preparation	Teach customers how to prepare a product safely and how to integrate a product into a recipe (e.g., how to combine bell peppers).

in the food industry already spend considerable resources promoting less healthy yet profitable foods [60], and are known to mislead consumers to increase profits [89]. However, the nutrition literature shows that promotion of healthier foods can increase profit [20, 68], and our study instead pointed to HCI experts' misconceptions and differences in perspective as a barrier to adoption in practice. Thus, there is a need to advocate within the HCI community for stronger consideration of individual and public health considerations when designing technology, and for cross-pollination between the HCI and nutrition communities of practice.

10 CONCLUSION

Our work is the first to develop and validate a set of food literacy heuristics for technology design. Our iterative design process enabled us to devise heuristics that can effectively and efficiently identify a range of food literacy issues falling under the umbrella of knowledge, awareness, and skills. Further, we have shown that the same heuristics can help designers as formative design tools. They can help designers identify food literacy concerns within different technologies and applications, to consider how those technologies might impact the planning and purchasing decisions of others, and to self-reflect on their own challenges.

This work satisfies a rapidly developing need in HCI research to ground our interactions with food in nutrition science. We believe that technology provides a unique and unexplored means of promoting food literacy — the awareness, knowledge, and skills required to sustain healthy eating patterns — and that these heuristics can be used in myriad technologies to create meaningful learning experiences, help people self-reflect on their food choices, internalize the skills as they develop, and improve their confidence and self-efficacy around food. They can also help to raise awareness of food insecurity, food safety, and how our food choices contribute to climate change within the HCI community, and to consider how our technology may be contributing to those concerns. By developing these heuristics we hope to make this literature more broadly and readily available to HCI researchers and designers, and to foster greater collaboration between the HCI and Nutrition research communities.

11 ACKNOWLEDGEMENTS

We thank the University of Waterloo Games Institute and its members for their constructive feedback. This work was made possible by the Natural Sciences and Engineering Research Council of Canada and in particular NSERC Discovery Grant 2015-06585 and the Saskatchewan-Waterloo Games User Research (SWaGUR) CREATE grant.

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