A Recipe for Food Literacy: Designing and Evaluating Technologies for Informed Food Choices

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

Association for Computing Machinery (ACM) Publications

This dissertation includes first-authored peer-reviewed material that has appeared in conference and journal proceedings published by the Association for Computing Machinery (ACM). The ACM's policy on reuse of published materials in a dissertation is as follows[1]:

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In listing the type(s) of contribution made by the authors and other contributors, I use CRediT (Contributors Roles Taxonomy). CRediT *"was introduced with the intention of recognizing individual author contributions, reducing authorship disputes and facilitating collaboration. The idea came about following a 2012 collaborative workshop led by Harvard University and the Wellcome Trust, with input from researchers, the International Committee of Medical Journal Editors (ICMJE) and publishers, including Elsevier, represented by Cell Press."* [2]

This thesis consists in part of two manuscripts that are exceptions to sole authorship and have been published or submitted for publication. Chapter 2 serves as a declaration of the Versions of Record for works included in this dissertation:

- Chapter 2: Bomfim, M., Kirkpatrick, S., Nacke, L., Wallace, J. Food Literacy while Shopping: Making Informed Food Decisions with a Situated Gameful App (2020). ACM Conference on Human Factors in Computing Systems. Honolulu, Hawaii, USA. DOI: https://doi.org/10.1145/3313831.3376801 *(published paper)*

- Chapter 3: Bomfim, M., Wong, E., Liang, P., Wallace, J. Design and Evaluation of Technologies for Informed Food Choices. *(paper submitted for publication)*

As lead author of these two chapters, I was responsible for conceptualizing the study design, planning and executing data collection, conducting the analyses, and drafting and submitting manuscripts. My co-authors provided guidance during each step of the research and provided feedback on draft manuscripts. Dr. James Wallace provided significant direction and editorial assistance throughout. Under Dr. Jim Wallace's supervision, I also prepared the remaining chapters in this thesis, which were not written for publication.

[1]https://authors.acm.org/author-resources/author-rights
[2]https://www.elsevier.com/authors/policies-and-guidelines/credit-author-statement

Another contribution to this thesis, which is not present as a chapter, but preceded the work in Chapter 2, is the following extended abstract published by ACM:

Bomfim, M., Wallace, J. Pirate Bri's Grocery Adventure: Teaching Food Literacy through Shopping. (2018) In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18). Association for Computing Machinery, New York, NY, USA, Paper LBW068, 1–6. DOI: https://doi.org/10.1145/3170427.3188496

This extended abstract contributes an in-depth description of the design process and development of the gameful mobile app we used in Study 1 (Chapter 2).

Abstract

Technology increasingly mediates our everyday interactions with food, ranging from purchasing and handling to preparation and eating. And now – more than ever – technology influences the food we buy and ultimately consume. *Food literacy* – the interconnected combination of awareness, knowledge, skills, and behaviours that empower an individual to make informed food choices – has great potential to be implemented in technology designs and lead to healthy eating patterns. However, current technology designs lack this holistic approach to support reflective and informed food choices. We associate this problem with a lack of guidance for designers, with a solution that encapsulates best practices from the nutrition literature translated into actionable technology designs.

This dissertation examines the following research questions: (1) How can we support the development of food literacy through technology at a physical grocery store?; (2) How can food literacy be used to facilitate the design and evaluation of food-related technologies to promote informed choices?; and (3) How do HCI practitioners use food literacy heuristics to evaluate and design food-related technologies? To address these questions, we first ran a proof-of-concept study (Study 1) at a grocery store. We designed a gameful mobile app to investigate how different technology designs incorporating concepts from food literacy would influence food choices through a situated approach at a grocery store. Then, we devised a set of food literacy heuristics in a study involving nutrition experts (Study 2) to guide the design and evaluation of food-related technology. Finally, we confirmed the utility of our heuristics with HCI experts (Study 3) to assess how they would use them in technology design.

In Study 1, we ran a three-week exploratory field study with 24 young adults comparing our situated and gameful app (PBGA) to a non-situated, non-gameful app (MFG) to understand the strengths and weaknesses of their designs in terms of promoting food literacy and motivating healthy eating behaviour. In Study 2, we applied an iterative, expert-driven process that included reviewing the nutrition and HCI literature, a mixed-methods study with website evaluations and interviews with 12 nutrition experts, and qualitative analysis of those interviews to refine our food literacy heuristics. In Study 3, we then conducted mixed-methods interviews and website evaluations using the heuristics with 12 HCI experts to demonstrate their utility for evaluating and designing food-related technology.

Findings from our first study revealed that our gameful mobile app (PBGA) effectively improved players' nutrition knowledge and motivation for healthier food choices and reduced impulse purchases. We found that the situated approach of providing information

during food purchase, combined with gameful design features like challenges, and other visual features such as traffic light colours, contributed to this success. Other results from this study also revealed the importance of a more significant focus on planning, so consumers can optimize their time in the store since a few participants raised concerns about lack of time.

Findings from our second study, involving nutrition experts, have shown how the heuristics support both summative (i.e., outcome-focused) and formative (i.e., process-focused) design and evaluation by encapsulating best practices to support informed food choices. Finally, findings from our third study, involving HCI practitioners, revealed how the heuristics helped participants reflect on their own challenges around food literacy, and tensions between nutrition best practices and HCI experts' personal opinions. The heuristics also served as inspiration and guidance for generating novel design ideas for various applications to support informed food choices.

Collectively, the findings from our three studies resulted in design guidelines in the form of heuristics that are readily available for HCI practitioners to incorporate support for food literacy in their designs. We also offer a reflection on the importance of involving different research communities such as public health practitioners and dietitians in designing food-related technologies for a holistic approach to Human-Food Interaction. This strategy will ensure these technologies encapsulate the best nutrition practices and support not only individual users but also users as part of a population.

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List of Abbreviations

ANOVA Analysis of Variance

BMI Body-Mass Index

GNKQ General Nutrition Knowledge Questionnaire

HBMS Health Belief Model Survey

HCI Human-Computer Interaction

MFG My Food Guide

PBGA Pirate Bri's Grocery Adventure

Chapter 1

Introduction

There is a growing interest in food within the Human-Computer Interaction (HCI) discipline (Deng et al., 2021), with many emerging technologies exploring how people engage with food, ranging from smart kitchens (e.g., Chi et al., 2007) and interactive food simulators (e.g., Kato et al., 2013), to playful technologies that enhance the experience of eating together (Altarriba Bertran et al., 2020; Arakawa et al., 2007; Mueller et al., 2018; Weber et al., 2021). The COVID-19 pandemic also intensified a sustained shift towards technologies selling food online, like online grocery stores and food delivery apps (RBC Capital Markets, 2020; Blitstein et al., 2020), making technology a strong influence on our food choices.

However, these technologies lack the support for informed food choices that would align with healthy eating. For instance, existing mobile applications like Weight Watchers, MyFitnessPal, and FitBit have limitations in fostering healthy eating patterns. They tend to focus on weight loss and calorie control (Hingle et al., 2016; Hwang et al., 2017; Logel et al., 2015; Torning et al., 2009), which emphasizes quantity instead of quality, leading consumers to optimize caloric intake over a nutritious diet (Wharton et al., 2014). They are also commonly associated with negative body image (Penney et al., 2015) and eating disorders (Eikey et al., 2017a).

In the context of online food shopping, major grocery chains and food delivery apps massively promote ultra-processed foods (Brenda, 2009; Bellini et al., 2017; Dujak et al., 2018) and often misrepresent the quality of the foods they sell with misleading health claims (Schermel et al., 2013). In addition, the lack of guidelines or regulations for selling food online, including information about their nutritional content, provides little support for HCI practitioners to apply the awareness, knowledge, and skills necessary to support a healthy diet (Bomfim et al., 2020; Hollis-Hansen et al., 2019; Pitts et al., 2018), further contributing to unbalanced diets, which are the primary risk factor for many leading causes of death worldwide, such as heart diseases, stroke, and type 2 diabetes(Basu et al., 2013; O'Donnell et al., 2010; WHO, 2019; Yang et al., 2014).

This thesis aims to shed light on the question of 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 (Cullen et al., 2015; Vidgen et al., 2014; Slater, 2017; Ronto et al., 2016; Truman et al., 2017) — can be used to inform the design of technology and promote human health. One primary contribution of this work is to provide guidelines to HCI practitioners to apply evidence-based nutrition content in their designs with a holistic approach to food literacy. In support of this contribution, we present the first set of food literacy heuristics to support informed food choices by technology, with their development involving experts in the field of nutrition (Registered Dietitians and Dietetics Students). Heuristics are guidelines that provide simplified advice or practical instructions regarding a particular subject for accomplishing a specific task (Nielsen, 1994; Kientz et al., 2010; Tondello et al., 2019). We further demonstrate how HCI practitioners use the heuristics and discuss the challenges and opportunities for applying food literacy in technology designs.

1.1 Thesis Statement

This thesis bridges the field of Human-Computer Interaction (HCI) and Nutrition Science. It investigates how technologies can promote food literacy and informed food choices by exploring and combining technology features and nutrition content in their designs. This dissertation aims to defend the following thesis statement:

Food Literacy can provide much-needed guidance to technology designers and practitioners through its interconnected combination of awareness, knowledge, skills, and behaviours that empower individuals to make informed food choices.

Hence, to support this statement, the remainder of this dissertation addresses the following research questions:

RQ1. How can we support the development of food literacy through technology at a physical grocery store?

RQ2. How can food literacy be used to facilitate the design and evaluation of food-related technologies to promote informed choices?

RQ3. How do HCI practitioners use food literacy heuristics to evaluate and design food-related technologies?

The answer to each research question resulted in accomplishing the research contributions made through the work presented in this dissertation.

1.2 Research Contributions

Overall, this dissertation contributes an understanding of how to support the development of food literacy through technology, divided into three main contributions. Figure 1.1 summarizes this thesis research questions (RQs) and contributions.

Overarching RQ	Specific RQs	Research Studies	Answers to RQs	Thesis Contributions
RQ-T: How can we support the development of food literacy through technology?	**RQ1:** How can we support the development of food literacy through technology at a physical grocery store?	**Study 1 - Food Literacy while Shopping:** Motivating informed food purchasing behaviour with a situated gameful app.	Our situated and gameful app increased nutrition knowledge and attitudes towards healthy eating and reduced impulse purchases.	**C1:** Providing empirical evidence for the effectiveness of gameful design to promote food-literate decisions when grocery shopping.
	RQ2: How can food literacy be used to facilitate the design and evaluation of food-related technologies to promote informed choices?	**Study 2 - Nutrition Experts:** Design and evaluation of technologies for informed food choices.	Our heuristics were shown to support a summative and formative design and evaluation by encapsulating best nutrition practices to provide informed food choices.	**C2:** Devising a set of food literacy heuristics to facilitate the design and evaluation of food-related technologies.
	RQ3: How do HCI practitioners use food literacy heuristics to evaluate and design food-related technologies?	**Study 3 - HCI Experts:** Design and evaluation of technologies for informed food choices.	Our heuristics were shown to be valuable design tools, helping participants reflect on food literacy challenges. We also discuss tensions between nutrition and HCI best practices.	**C3:** Demonstrating how the food literacy heuristics can be used by HCI experts to facilitate the design and evaluation of food-related technologies.

Figure 1.1: Thesis research questions (RQs), studies, answers to RQs, and contributions

This thesis contributions are listed below:

C1. Providing empirical evidence for the effectiveness of gameful design to promote food-literate decisions when grocery shopping:

Study 1 (Chapter 2) investigated how mobile devices can help develop young adults' knowledge, awareness, and motivation to make informed food decisions when grocery shopping. We applied a situated intervention – one made at the moment of the behaviour, such as when purchasing foods – to this project because they have been shown to promote desired behaviours effectively (Papies, 2016). Additionally, we explored gameful design due to its motivational aspects to encourage healthy behaviours (e.g., Deterding et al., 2011; Kappen et al., 2017; Orji et al., 2017), and visualizations such as traffic light colours to support more informed food choices on site. This proof-of-concept study, validated with young adults, resulted in three main contributions: (a) We designed and developed a mobile shopping app that promotes healthy eating patterns through food literacy; (b) A 3-week exploratory field study showed that our situated app providing information at the time that decisions are made increased nutrition knowledge and attitudes towards healthy eating and reduced impulse purchases; (c) We report on how the mix of situated and gameful design elements contributed to this success: challenges were often cited as a motivating feature.

Results from Study 1 showed a need for focusing more on *planning* because participants wanted to optimize their time in the store, and a lack of time was a concern raised by some of them. Thus, this more significant focus on planning opened the idea of further exploring online grocery shopping because it offers an opportunity for more strategic planning. Additionally, online grocery shopping has been growing in popularity around the world, and now, more than ever, with the COVID-19 pandemic, we have witnessed a sustained shift towards technologies like online grocery shopping (RBC Capital Markets, 2020). This situation brought a potential design space to investigate more technology designs to help people develop food literacy in a situated approach for buying food online, informing the design of Studies 2 and 3 (Chapter 3).

C2. Devising a set of food literacy heuristics to facilitate the design and evaluation of food-related technologies:

In Study 2 we developed food literacy heuristics with nutrition experts through an evaluation of online grocery stores. We devised a set of 20 food literacy heuristics, starting with an established food literacy framework from nutrition sciences literature (Perry et al., 2017), then performing a series of interviews and website evaluations with 12 nutrition experts (Registered Dietitians and Dietetics Students) and refining that initial set through a qualitative analysis of those interviews. At the end of this study, we refined a list of heuristics that encapsulates best practices to support informed food choices. The heuristics can be used as both a summative (i.e., outcome-focused) and a formative (i.e., process-focused) tool for designing and evaluating food-related technologies (Chapter 3).

C3. Demonstrating how the food literacy heuristics are used by HCI experts to facilitate the design and evaluation of food-related technologies:

In Study 3 we confirmed the utility of our heuristics through a series of interviews and website evaluations with 12 HCI experts (PhD Students, UX Researchers, and Software Engineers). Qualitative analysis of these interviews showed how HCI experts generated novel design ideas and considered different food literacy domains, including strategic planning, decision-making, and understanding the impact of food decisions; how they reflected on their own food literacy knowledge and skill gaps; and how the heuristics revealed tensions between nutrition best practices and HCI experts' personal opinions. Our data analysis demonstrated 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 (Chapter 3).

1.3 Thesis Overview

The next two chapters present the three studies included in this dissertation. Collectively, these studies contribute to our goal of better supporting food literacy to promote informed food choices in the context of food-related technologies. Chapter 2 presents Study 1, which focuses on a proof-of-concept study to explore food literacy in technology to promote informed food choices at a grocery store. Chapter 3 presents Studies 2 and 3, explaining the creation, development, and refinement of food literacy heuristics with Nutrition experts (Study 2) and then involving HCI practitioners using the previously created heuristics to assess their use for food-related technologies (Study 3). Finally, Chapter 4 then synthesizes our findings from the previous two chapters and contextualizes the collective impact of the research on food literacy in technology. We summarize our research's main contributions and takeaways in this space and conclude by providing recommendations for future work while discussing possible limitations of the research in this thesis.

Chapter 2

Food Literacy while Shopping: Motivating Informed Food Purchasing Behaviour with a Situated Gameful App

2.1 Abstract

Establishing healthy eating patterns early in life is critical and has implications for lifelong health. Situated interventions are a promising approach to improve eating patterns. However, HCI research has emphasized calorie control and weight loss, potentially leading consumers to prioritize caloric intake over healthy eating patterns. To support healthy eating more holistically, we designed a gameful app called *Pirate Bri's Grocery Adventure* (PBGA) that seeks to improve food literacy—meaning the interconnected combination of food-related knowledge, skills, and behaviours that empower an individual to make informed food choices—through a situated approach to grocery shopping. Findings from our three-week field study revealed that PBGA was effective for improving players' nutrition knowledge and motivation for healthier food choices and reducing their impulse purchases. Our findings highlight that nutrition apps should promote planning and shopping based on balance, variety, and moderation.

2.2 Introduction

Developing the knowledge and motivation for healthy eating early in life remains a challenge. While eating patterns tend to form before and during young adulthood, individuals may have little opportunity to develop their food literacy until they begin to live independently (Colatruglio et al., 2016; Desjardins et al., 2013). As a consequence, sub-optimal eating patterns may persist into later life, affecting long-term health (Cruz et al., 2018; Christoph et al., 2019; Basu et al., 2013; O'Donnell et al., 2010; Yang et al., 2014). In addition, the ease of access to ultra-processed and ready-to-eat foods provides a challenge to anyone wanting to practice food literacy, which requires time, effort, skills, and confidence to select and prepare healthy meals (Colatruglio et al., 2016; Desjardins et al., 2013). This is specifically the case for young adults transitioning into independent living situations where they often have budgetary and time constraints. Food literacy, defined as the interconnected combination of food-related knowledge, skills, and behaviours that empower an individual to make informed food choices (Cullen et al., 2015; Vidgen et al., 2014), may hold the key to changing people's eating patterns.

Mobile technology has great potential for supporting interventions that encourage healthy eating. However, existing mobile applications like Weight Watchers, MyFitnessPal, and FitBit have limitations in how they foster healthy eating patterns. First, they tend to focus on weight loss and calorie control (Hingle et al., 2016; Hwang et al., 2017; Logel et al., 2015; Torning et al., 2009), which emphasizes quantity instead of quality, leads consumers to optimize caloric intake over a nutritious diet (Wharton et al., 2014), and is associated with negative body image (Penney et al., 2015) and eating disorders (Eikey et al., 2017a), especially among youth (Penney et al., 2015). Indeed, evidence on diet and health increasingly points to the importance of overall diet quality (AICR, 2018), illustrated by recent food-based guidelines such as Canada's Food Guide (Health Canada, 2019). Second, these mobile apps are designed to track consumed foods, instead of supporting planning and/or selecting foods at the grocery store (Bellini et al., 2017), and thus fail to prevent impulse purchases (Terzimehić et al., 2018). Finally, approximately half the people who start using self-tracking apps stop using them because of loss of interest and a high data-entry burden (Krebs et al., 2015). Studies suggest that many young adults do not feel they have the time to participate in food interventions such as nutrition education classes (Colatruglio et al., 2016; Truman et al., 2019).

To address the food literacy gap among young adults, we designed and studied the use of a gameful situated mobile app to promote informed food purchasing (Figure 2.1). Situated interventions are applied at the moment a behaviour occurs, such as when purchasing foods. Mobile technology is an ideal fit for this situation. Our approach has three

Figure 2.1: In *Pirate Bri's Grocery Adventure*, players scan products while grocery shopping to visualize nutrition information, engage with weekly food challenges, and make more informed shopping decisions.

main advantages: 1) we designed our custom app with a focus on promoting healthy eating patterns through food literacy instead of calorie control for weight loss; 2) the app can be used while grocery shopping, reducing the time and effort required to participate, and explicitly linking the information and activities to the target behaviour of food purchasing; and 3) using gameful design elements motivates healthy behaviours effectively (e.g., Deterding et al., 2011; Kappen et al., 2017; Orji et al., 2017). Our gameful app, *Pirate Bri's Grocery Adventure (PBGA)*, incorporates gameful design elements, such as *challenges*, *personalization*, and *meaningful choices* (Deterding et al., 2011; Tondello et al., 2019) to motivate young adults to develop food literacy, increase awareness, and improve choices at the grocery store.

To investigate the effectiveness of our gameful situated app (PBGA) to promote food literacy in young adults, we conducted a three-week exploratory field study with PBGA compared to an existing nutrition planning app, My Food Guide (Health Canada, 2018). Our results suggest that while both apps increased participants' general nutrition knowledge and attitude towards healthy eating, those who played PBGA made fewer impulse purchases. Our findings contribute four important insights: 1) the importance of promoting healthy eating patterns in an app's design, 2) the effectiveness of situated interventions which can help individuals better understand the nutrition information on product labels, 3) how interventions relate to people's needs when they shop, and 4) the strength of gameful design in motivating healthy food purchases.

2.3 Related Work

A problematic feature of popular mobile applications like MyFitnessPal and FitBit is that they focus on calorie control rather than promoting a nutritious diet (Hingle et al., 2016). This focus can lead to poor nutritional choices and consumers prioritizing caloric intake instead of a healthy diet (Wharton et al., 2014). It can also have negative effects on people with disordered eating behaviours (Eikey et al., 2017a) or negative body image, especially among young adults (Penney et al., 2015).

These interventions also fall short because they concentrate on logging meals after consumption instead of promoting healthier food choices through planning days in advance (Terzimehić et al., 2018). Choices made at the grocery store have a direct and crucial impact on those made at home—you cannot eat those impulse purchases if they never come home from the store. Further, a recent survey by Rahman et al. (2016) shows the general public's interest in food planning apps. Although having a plan before going shopping can help consumers avoid impulse purchases (Bellini et al., 2017), grocery stores design their layouts to influence consumers' decisions and stimulate impulse purchases (Dujak et al., 2018). Thus, situated interventions are needed to counteract the negative influences of retail food environments.

2.3.1 Food Literacy

In response to these needs, the nutrition community has called for technologies that promote *food literacy* instead of short-term weight loss and calorie control (Hingle et al., 2016). Food literacy (Perry et al., 2017) comprises the knowledge and awareness of foods within the different food groups, of nutrients and their relevance to our health and wellbeing, the ability or self-efficacy to choose healthy foods, and the desire or motivation to engage with food to achieve a nutritious diet. food literacy skills have been shown to enable individuals to make informed food choices and facilitate healthier dietary behaviours (Cullen et al., 2015; Vaitkeviciute et al., 2015; Vidgen et al., 2014).

A lack of time to participate in educational classes (Cullerton et al., 2012; Colatruglio et al., 2016; Truman et al., 2019) and the effort required to understand nutritional labels on packages (Campos et al., 2011) are common barriers to motivating young adults to develop their food literacy. Human-Computer Interaction (HCI) research has explored different technologies to help consumers overcome these barriers, like Augmented Reality to reduce the time required to find healthy items (Ahn et al., 2015), scanning devices to quickly identify suitable items for a specific diet (e.g., Mulrooney et al., 2006), interactive displays to calculate serving sizes and compare products (e.g., Bedi et al., 2010), and games played in store to promote healthy snack choices (e.g., Park et al., 2015). These approaches lower barriers to healthy eating through automation of tasks that require time and effort at the grocery store, but fall short of developing food literacy, and the knowledge and motivation to continue healthy eating behaviours for the long-term.

In this work, we approach food literacy through Sizer et al. (2017)'s key factors of a nutritious diet: consuming a *balance* of foods from all four food groups (Fruits & Vegetables, Grains, Milk & Alternatives, Meat & Alternatives); consuming a *variety* of different foods from within each group; and *moderating* consumption of foods to sustain your body—while not exceeding recommended amounts of nutrients like sugar, fat, and sodium. Building on these factors, we investigated how mobile devices can help develop the knowledge, awareness, and motivation young adults require to make informed food decisions when grocery shopping. We were particularly interested in the opportunity to explore situated and gameful design to promote internal motivation and self-efficacy.

2.3.2 Gameful Situated Design for Nutrition

Gameful design has been shown to be an effective way to change overall health attitudes or behaviours (e.g., Deterding et al., 2011; Kappen et al., 2017; Orji et al., 2017), particularly when applied in the field of nutrition (Johnson et al., 2016). For instance, gameful design elements such as progress feedback and incremental challenges have helped people achieve their health goals (Johnson et al., 2016). Games are a potentially effective way to motivate young adults (18-37 years-old) to improve their food literacy because this population represents the biggest portion of video game players (40%) (Statista, 2019).

The use of simulation, where players develop food knowledge and self-efficacy without real-life consequences, has been found to be a promising approach to gameful design by the research community. Games that simulate real-world decisions have been found to increase players' nutrition knowledge and/or self-efficacy (e.g., Grimes et al., 2010; Orji et al., 2017; Orji et al., 2013; Peng, 2009; Kyfonidis et al., 2019). However, simulations also have drawbacks. For instance, Silk et al. (2008) found that participants preferred and acquired more knowledge from an educational website instead of their game. Further, simulations do not account for many factors that impact real-life food choices, such as taste, availability, affordability, level of hunger, or cravings. That is, one might know the healthier food choice when shopping, but decide to buy an alternative based on impulse, availability, affordability, or emotional factors (e.g. selecting “comfort foods”).

To address this shortcoming, researchers have begun to explore how integrating virtual worlds with real life can help players take these factors into account when selecting foods. For example, SpaPlay (Shiyko et al., 2016) differs from the previous games by integrating a simulated resort with real-life activities (e.g., eating a salad, taking the stairs) that need to be developed and maintained to make players progress in the game. Shiyko et al. (2016) found that players experienced an increase in nutrition knowledge and decrease in body mass index (BMI) after three months. However, the game focused on weight loss rather than food literacy, and lacked a control group to determine whether the outcomes were caused by the game or selecting a population already committed to weight loss. We address these limitations in our work.

Based on the potential of simulations, but a lack of research that examines their use in real-life, we explore how gameful design can be used to promote food literate purchasing behaviour while shopping. Situated interventions are an effective way to promote healthy behaviour (Papies, 2016), also overcoming the challenge of lack of time because they can be incorporated in daily routines. We developed our app, PBGA, from the perspective of *meaningful gamification* (Nicholson, 2015; Richards et al., 2014), which posits that gameful design should add game elements with meaning and purpose, that educate the player, help them understand their actions, and internalize content. The gameful app combines elements from the above research, is played at the store, and was developed with a focus on food literacy.

2.4 Pirate Bri’s Grocery Adventure

We developed a gameful app to be played at home and in the grocery store over a series of shopping trips to help players learn, internalize, and maintain healthy shopping behaviour (Nicholson, 2015). We designed the gameful app to be played over a three week period for three different shopping trips. This design applies the concept of slow technology (Hallnäs et al., 2001), by giving players time to reflect upon new content, apply the knowledge, and to discover the consequences of their actions.

Our gameful app was developed using Android Studio, and is compatible with Android versions 4.0 or above. We now provide a walkthrough, with a particular focus on how its design supports the development of food literacy. An in-depth description of the gameful app and its development is provided by Bomfim and Wallace (Bomfim et al., 2018).

2.4.1 Planning for Shopping

When starting PBGA for the first time, players create a character based on their personal information (i.e., gender and age), to assess their nutritional needs (Health Canada, 2019), and food preferences (e.g., salty or sweet). After creating their character, the player is introduced to Brigitte the Pirate Nutritionist (Figure 2.2, a), who serves as a guide for the remainder of the gameful app. Brigitte then asks for how many days they will be buying groceries, and encourages the player to plan and create a grocery list before going to the store. Creating a grocery list has been shown to be the most effective means of minimizing waste and maintaining a budget (Health Canada, 2019). Maintaining a budget is particularly important, as financial constraints are common among young people, including post-secondary students (Canadian Council on Learning, 2010).

To develop a player's sense of competence and progress over the three week period, Brigitte then presents players with three challenges (goals) per shopping trip, with increasing difficulty each week (Figure 2.2, b). For instance, a player with a preference for sweet foods would be challenged to choose products with less sugar (Jayasinghe et al., 2017), whereas one with a preference for salty food would be challenged to keep their sodium intake within daily recommended limits (Zhang et al., 2011).

2.4.2 At the Grocery Store

After creating a grocery list, players head to the store for the next phase (*It's time to go shopping!*). While in the store, players navigate using a map that shows a top-down view of a common supermarket layout. The player then manually chooses the sections they want to go to, depending on their shopping list. When the player enters each section, Brigitte presents an important tip related to the types of foods found there (Figure 2.2, d). For instance, when entering the bread section, she explains the importance of selecting whole wheat options and dietary fibre. When entering the centre aisles, she explains common issues with ultra-processed foods, such as misconceptions about the nutritional value of fruit juice.

Figure 2.2: (a) Brigitte, the Pirate Dog Nutritionist, presents the 3 food literacy *challenges* to be completed in the current shopping trip. (b) As players put food in their cart, they visualize the *progress feedback* towards each goal (challenge). (c) Players can make meaningful choices of which products to buy, by visualizing each item's nutrients using colours that highlight low, moderate, or high amount. (d) As players enter each section, they *learn* from Brigitte about the types of food they will encounter there. (e) Pirate's Cart-Boat shows a summary of *personalized* nutrients and servings for each food group in the cart versus how much is needed for the total trip. (f) Players view an achievements screen to visualize their acquired *skills* around food Literacy.

As the player selects foods from the grocery store shelf, they have two options to add it to their virtual shopping cart: scan the barcode, or manually input the product's name, as not all products have barcodes. This screen also shows the player's progress towards each of their current challenges, so they can keep track of their progress (Figure 2.2, b). After finding a specific product, the app visualizes the product's nutrients using traffic light colours, which highlights whether each nutrient is in low, moderate or high amounts (Figure 2.2, c). If the product has fibre, the bar is always green, but the length of the line changes to reflect high/med/low levels. This visual information helps the player reflect on the implications of adding a product to their cart, particularly within the context of their current challenges. This feature offers the player the opportunity to learn about the products and think about their decisions, developing their own understanding of what is healthy (Gao et al., 2012).

As products are added to the player's cart, they must also indicate the product's number of servings to encourage players to select products that will fulfill the distribution of a balanced diet. For instance, it is possible to visualize how many servings of fruits and vegetables the player should aim to meet a healthy intake for the next days. After each item is added to the cart, a summary screen (Figure 2.2, e) helps players learn about their daily needs. That is, if the player is shopping for 5 days of groceries, and 2 servings of meat and alternatives per day are recommended to the player, their cart requires 10 servings for this food group. The player can also switch to this view for a single day, to aid with comparisons for a specific product.

We intentionally do not include the recommended number of calories, because they can be a poor predictor of healthy foods (Wharton et al., 2014). Instead, we encourage the consumption of more fibre, fruits, and vegetables and the careful monitoring of nutrients such as added sugars, sodium, and trans fats. As the consumer adds products while shopping, the app helps to visualize how much of each nutrient and servings of each food group is in the cart and how much is still needed (or exceeded).

2.4.3 Checking Out

Finally, when a player checks out of the grocery store, Brigitte presents a summary of completed and uncompleted challenges, and gives the player an opportunity to reflect on their goals and return to the aisles to complete a challenge. For example, if they did not meet the required servings of fruits and vegetables, they can return to this section to buy more produce before checking out. If a player completed all three challenges, they are rewarded by unlocking a new member of their crew. Each crew member is a different type of animal, serving as an achievement/goal and as an incentive to foster their curiosity for the next shopping trip.

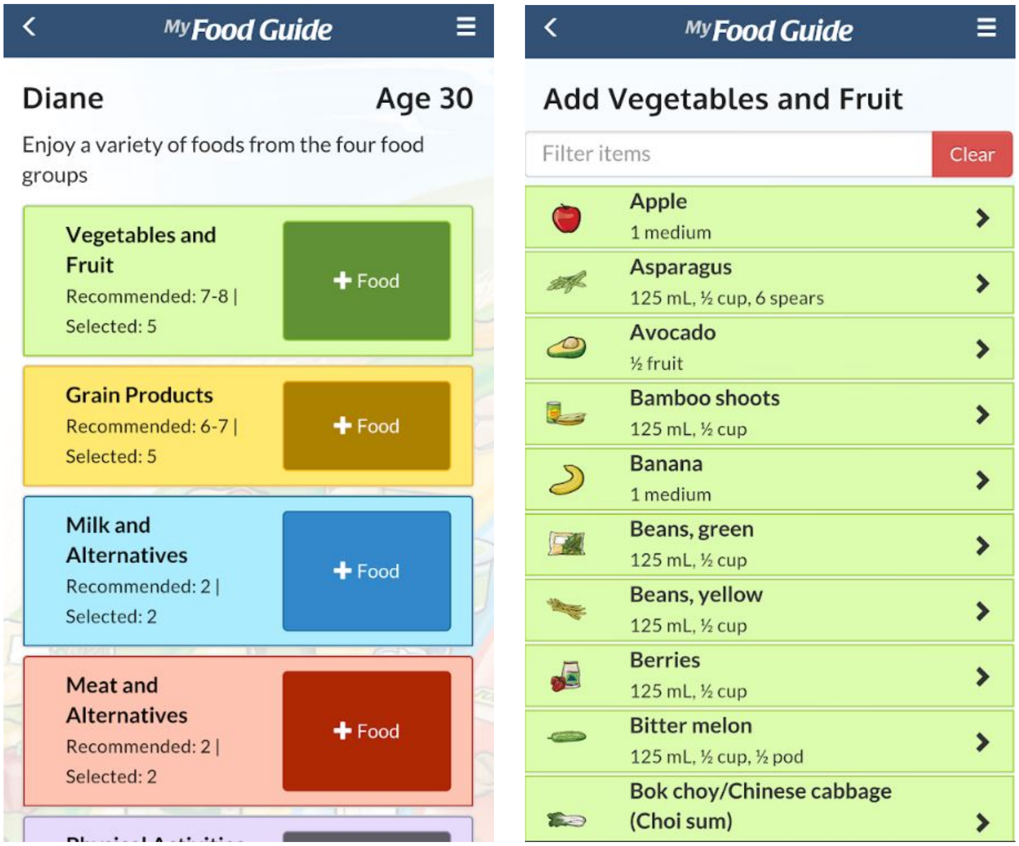
2.5 Exploratory Field Study

Having designed PBGA to promote food literacy, we sought to understand the strengths and weaknesses of its design through an empirical study. In particular, we wanted to understand how it promotes skills like food planning and selection, provides nutrition knowledge, and motivates healthy eating behaviour. To answer these questions, we conducted an exploratory field study in which participants used either PBGA or a commercially-available, non-gameful nutrition app over a 3-week period. The 3-week study period provided participants an opportunity to use their assigned app during multiple shopping trips to their preferred grocery store, and is consistent with other recent studies of technologies to support healthy behaviour promotion (e.g., Grimes et al., 2010; Orji et al., 2013).

We compared PBGA to a non-situated, non-gameful nutrition app called My Food Guide (MFG) (Figure 2.3), which was developed by Public Health Canada, endorsed by Registered Dietitians, and is available for free on the Google Play Store. We considered comparisons to other popular commercial mobile apps, such as MyFitnessPal, but our review found that they primarily focus on calories and are designed to input foods by meals, serving as food diaries of consumed foods. Instead, MFG was designed to create food plans based on food groups instead of meals, that can serve as guides for grocery shopping. Thus, the MFG app targets much of the same food literacy content as PBGA, without placing an emphasis on situated learning (Health Canada, 2018). MFG organizes food plans along the four food groups, and shoppers add foods to a grocery list using a comprehensive set of suggested items (Figure 2.3). For the purpose of this study, each food plan was created as a grocery list, serving as a reference for a shopping trip.

2.5.1 Participants & Recruitment

We recruited 24 participants (M=11; F=13) from a local university, aged 18 to 31. Of these, 16 participants identified as Asian, 4 as Middle Eastern, and 4 as Caucasian. Most (21/24) participants rated their health as 'good', 'very good', or 'excellent', with 9/24 having a BMI greater than 25 based on reported heights and weights. Participants were randomly assigned to use each app over the 3 week period, with 12 participants in each group. To be eligible for the study, participants had to own a mobile phone with Android 4.0 or higher. All 24 participants completed the study, but one participant from MFG did not submit the information of foods planned and bought. They all received a $30 CAD honorarium.



(a) (b)

Figure 2.3: My Food Guide: (a) Shopping list is separated into food groups. (b) As shoppers add food items, a list of foods under the chosen food group is displayed for selection.

2.5.2 Study Design & Procedure

Our 2 × 2 study design included the app used (either MFG or PBGA) as a between-participants independent variable, and time (pre-/post-intervention) as a within-participants independent variable. At the beginning of the study, each participant was randomly assigned to use either the MFG or PBGA app. Participants had two interview sessions, one at the beginning of the study, and one after using the app for a 3-week period.

During the first session, participants completed a background survey to collect demographic information as well as preferences regarding use of mobile games, shopping and cooking habits, and confidence in selecting and preparing foods. Participants also completed the General Nutrition Knowledge Questionnaire (GNKQ) (Kliemann et al., 2016), an extensively validated nutrition knowledge instrument that captures an individual's general knowledge in the area of nutrition, and the Health Belief Model Survey (HBMS) (Rosenstock, 1974), that captures beliefs around healthy eating. The GNKQ is separated into four sections: 1) Dietary Recommendations given by experts, such as the number of recommended servings for different food groups and what types of nutrients we should include in our daily diet; 2) Food Groups, which includes the different food groups and the nutrients they contain; 3) Healthy Food choices covers shopping at the supermarket, choosing meals in restaurants, and food preparation; and 4) Diet and disease management covers health problems or diseases related to diet. The GNKQ and HBMS questionnaires are provided in Appendix D.

The HBMS (Rosenstock, 1974) is frequently used in the design and evaluation of health behaviour interventions (e.g., Orji et al., 2013; Orji et al., 2014; Peng, 2009). The model posits that an individual's likelihood of engaging in a healthy behaviour is defined by their perception of perceived susceptibility, perceived severity, perceived benefit, perceived barrier, cue to action, self-efficacy and intention. Examples of questions from the Health Belief Model Survey (HBMS) are: "Selecting healthy products most of the time would be beneficial to me" (perceived benefit); "It is hard to find a snack that is tasty and healthy" (perceived barrier); "If I do not eat healthily, I will be at high risk of some dietary-related diseases" (perceived susceptibility); "The thought of ending up in the hospital due to dietary-related diseases scares me" (perceived severity); "I would make healthier food choices if I had a better knowledge of the healthier options" (cue to action); "I am confident that I can eat healthily during the next three weeks" (self-efficacy); "I intend to eat more fruits and vegetables during the next two weeks" (intention).

After all surveys were completed, the MFG or PBGA app was installed on the participant's mobile phone and they were asked to use the app to both plan (at home) and select foods (in the grocery store) for the following 3-week period, on at least three different days for their regular grocery shopping.

After three weeks, participants were contacted by email to schedule the second session, which also included a semi-structured interview to gather information about their experience using the app focusing on their perceptions of the app and its features. For the second session, the order of questions on the GNKQ and the HBMS were changed to avoid memorability. During the interview, participants were asked to reflect on how they used the app during the past three weeks and explain how the app affected their understanding and behaviour in planning and purchasing foods.

2.5.3 Data Collection & Analysis

All interactions with PBGA were recorded directly to app logs. Because we did not have access to usage data for MFG, we asked participants assigned to MFG to send screen shots of their shopping lists and receipts for the foods they bought. We collected the following information for each participant: age, gender, food preferences, name of products added to the shopping list, name of products added to purchase, number of times they used the app and days for each shopping trip, values of nutrients for each shopping trip, number of servings for each food group for each shopping trip and the names of completed challenges.

We performed a mixed Analysis of Variance (ANOVA) to compare the mean differences between participants that played PBGA and the control group that used MFG, and their scores of the pre- and post- GNKQ and HBMS to investigate differences in nutrition knowledge and health beliefs ($\alpha < 0.05$).

To compare how participants changed their shopping behaviour, we compared the items from the "Fruits and Vegetables" food group as well as the "Ultra-Processed" foods not included in the four food groups, such as pastries, chocolate and candies, ice cream, and potato chips. Ultra-processed products are made from processed substances extracted or refined from whole foods. They are typically energy-dense, with a high content in total, saturated and trans-fats, added sugars and sodium, and little or no fibre or micronutrients (Moubarac et al., 2013). There is no recommendation for those foods and they should be eaten sparingly, with moderation, due to the high values of sugar, sodium, and fats.

Audio files from the interview in the second session were transcribed, and then analyzed using thematic analysis (Braun et al., 2006). We grouped discussions according to participants' descriptions of how they used each app and what features they would like to better plan and select foods while grocery shopping. We then developed initial codes, searched for themes, and reviewed and grouped them together, which led to the final themes (discussed in section 2.7).

2.6 Quantitative Results

Over the three-week study period, logged data indicated that participants used PBGA as expected for planning meals before shopping, scanning groceries as they shopped, and checking goals before they paid. We now present results related to nutrition knowledge, health beliefs, and purchasing behaviour. After, we present and discuss the main themes that were formed from our qualitative analysis of participant responses during the post-study interviews.

2.6.1 General Nutrition Knowledge

Our mixed-factorial ANOVA revealed no significant difference between apps for pre scores on the General Nutrition Knowledge Questionnaire, ($F_{1,21} = .000, p = 1.000, \eta_p^2 = .00$). The general nutrition knowledge of participants increased for both groups between the pre- and post-scores. Our mixed-factorial ANOVA revealed a main effect for pre- and post-intervention scores on the GNKQ ($F_{1,22} = 15.93, p = .001, \eta_p^2 = .42$), with participants scoring on average 55.17/88 before the study, and 59.38/88 after the study. We found no significant mean difference for app ($F_{1,22} = 0.26, p = .613, \eta_p^2 = .01$): PBGA (Pre M = 55.17, SD = 7.21; Post M = 58.83, SD = 8.41) and MFG (Pre M = 55.17, SD = 12.58; Post M = 59.92, SD = 9.58).

We also examined each section of the GNKQ separately, to discern differences in the types of content that participants learned (Figure 2.4). Section 1 (Dietary Recommendations) had a significant increase with MFG, ($F_{1,11} = 8.69, p = .013, \eta_p^2 = .44$), but had no significant increase with PBGA ($F_{1,11} =, p = .060, \eta_p^2 = .29$). Section 2 (Food Groups) had a significant main effect, ($F_{1,22} = 5.25, p = .032, \eta_p^2 = .17$), but no significant differences between apps. Section 3 (Healthy Food Choices) had no significant main effects ($F_{1,22} = 3.00, p = .097, \eta_p^2 = .12$). Finally, Section 4 (Diet and Disease Management) had a significant increase with PBGA, ($F_{1,11} = 5.21, p = .043, \eta_p^2 = .32$), but we found no significant increase with MFG ($F_{1,11} = .00, p = 1.00, \eta_p^2 = .00$).

2.6.2 Health Belief Model

Our analysis of the HBMS revealed significant differences pre and post scores for Self-Efficacy, ($F_{1,22} = 10.28, p = .004, \eta_p^2 = .32$) for PBGA (Pre M = 3.28; Pre SD = 0.82; Post M = 3.86; Post SD = 0.94) and for MFG (Pre M = 3.64; Pre SD = 0.48; Post M = 3.86; Post SD = 0.66) with no significant mean differences between apps. We also found a significant difference pre and post intervention for Perceived Susceptibility, ($F_{1,22} = 7.04, p = .015, \eta_p^2 = .24$) for PBGA (Pre M = 4.04; Pre SD = 0.83; Post M = 4.54; Post SD = 0.45) and for MFG (Pre M = 3.87; Pre SD = 1.11; Post M = 4.33; Post SD = 0.65), with no significant mean differences between apps. There was no significant difference between apps for pre scores on Self-Efficacy, ($F_{1,21} = .171, p = .204, \eta_p^2 = .07$), or Perceived Susceptibility, ($F_{1,21} = .172, p = .682, \eta_p^2 = .01$). We found no significant increase for either app for the Determinants of Likelihood of Healthy Behaviour, Cue to Action, Perceived Severity, Perceived Benefit, and Perceived Barrier.

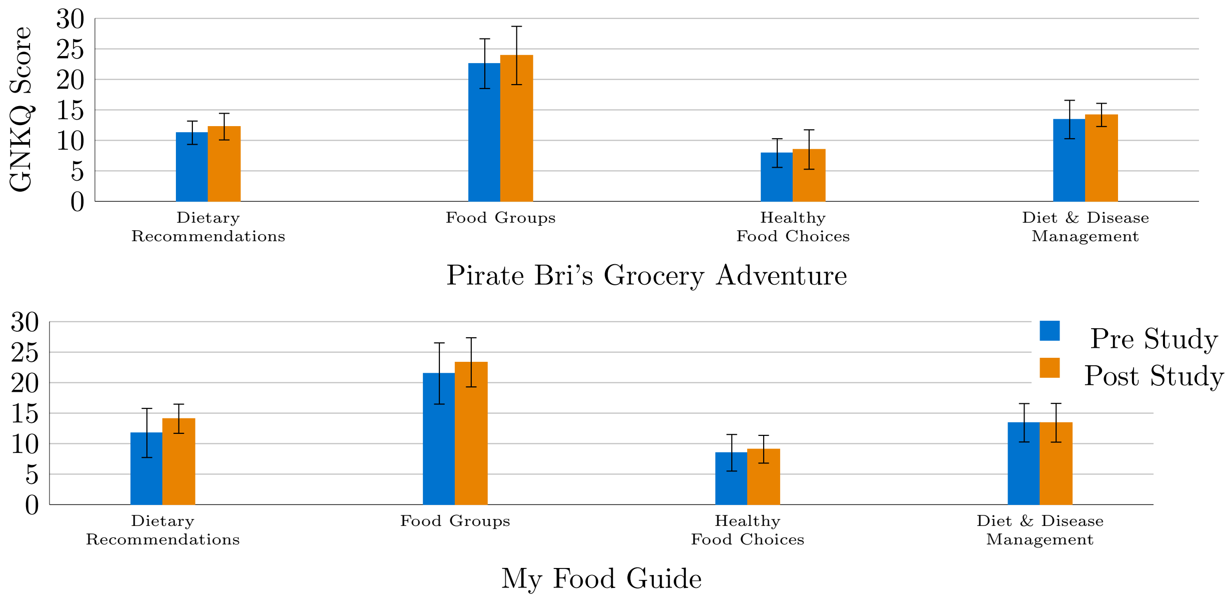


Figure 2.4: General Nutrition Knowledge Questionnaire scores increased for both PBGA (left) and MFG (right) over the course of the study.

2.6.3 Food Purchases

Fruits and Vegetables

We found that across all participants, there was a trend of purchasing more fruits and vegetables (Bought: M = 15.83, SD = 8.82) than they had planned on before going to the store (Planned M = 11.17, SD = 7.38) ($F_{1,21} = 12.34, p = .002, \eta_p^2 = .37$). However, our mixed-factorial ANOVA revealed no significant differences between apps ($F_{1,21} = 2.72, p = .114, \eta_p^2 = .12$) (Figure 2.5). A simple effect for each app showed a significant increase in the amount of fruits and vegetables purchased compared to what was planned for PBGA, (Planned M = 8.83, SD = 5.67; Bought M = 15.42, SD = 7.65), ($F_{1,11} = 13.46, p = .004, \eta_p^2 = .55$), but no significant increase for MFG, (Planned M = 13.73, SD = 8.40; Bought M = 16.27, SD = 10.31), ($F_{1,10} = 1.83, p = .206, \eta_p^2 = .16$).

Ultra-Processed Foods

Our analysis also found a significant difference between the amount of ultra-processed foods that participants planned to buy (M = 1.17, SD = 1.78) and those that they ultimately

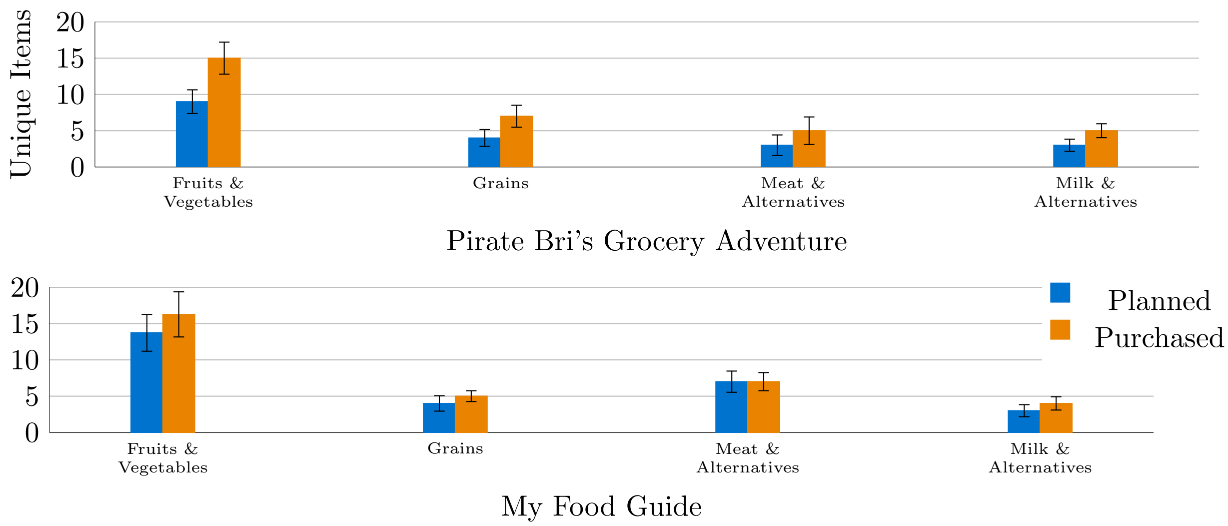


Figure 2.5: Number of items planned and purchased for each food group. Participants using both PBGA and MFG purchased more fruits and vegetables than they had planned to before going to the store.

bought (M = 2.74, SD = 2.78), ($F_{1,21} = 8.65, p = .008, \eta_p^2 = .29$). There was a significant interaction of interval by app, ($F_{1,21} = 7.79, p = .011, \eta_p^2 = .27$). A simple effect for each app showed a significant increase in ultra-processed foods bought compared to planned for MFG, ($F_{1,10} = 9.00, p = .013, \eta_p^2 = .47$), but no significant increase for PBGA ($F_{1,11} = .037, p = .851, \eta_p^2 = .00$).

A one-way ANOVA showed a significant difference ($F_{1,13} = 6.377, p = .025, \eta_p^2 = .33$) between total servings of ultra-processed items bought between PBGA (M = 6.13, SD = 4.91) and MFG (M = 18.86, SD = 13.32) (Figure 2.6). Levene's test revealed that the homogeneity of variances was not assumed, ($F_{1,13} = 5.46, p = .036$); however, the differences in means remain significant with a Welch correction applied, ($W_{1,7.422} = 5.714, p = .046, est.\omega^2 = 0.24$). Four participants from PBGA and four participants from MFG did not add ultra-processed foods to their carts. One participant from MFG did not submit the information of foods planned and bought.

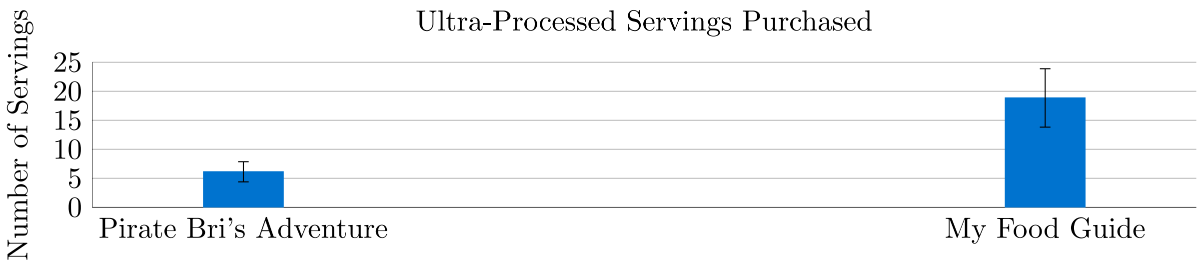


Figure 2.6: Participants who used PBGA purchased a lower number of servings of ultra-processed foods than those who used MFG.

2.7 Qualitative Results

Our results show that both PBGA and MFG improved participants' food literacy over the 3-week study period, as demonstrated through GNKQ responses, as well as participant planning and shopping behaviours, which is consistent with their focus on nutrition content and advice. Overall, these results demonstrate the potential for apps to motivate in-depth healthy behaviour promotion based on food literacy, beyond the calorie approach demonstrated in previous research (e.g., Hwang et al., 2017; Pavey et al., 2014; Peng, 2009; Wharton et al., 2014).

Further, participants who used PBGA for the 3-week study period demonstrated healthier shopping behaviour, compared to those who used MFG. Specifically, participants who used MFG bought nearly three times as much ultra-processed food than those who used PBGA (Figure 2.6). We now explore reasons for these differences based on our thematic analysis of participant responses during post-study interviews. In particular, we discuss how gameful design choices influenced participants' decisions to purchase a balanced diet, and to moderate consumption of less healthy foods.

2.7.1 Balance and Variety

A core component of food literacy is ensuring that an individual's dietary needs are met, that they purchase a variety of foods, and that those foods cover all food groups in a balanced way. Participants reported that both PBGA and MFG ultimately promoted balance and variety in food purchases, but that different features of each app were responsible for this behaviour. Figure 2.5 shows that both PBGA and MFG promoted purchases of foods with balance and variety, as different items within each food group were added to participants' carts.

Many participants indicated that they particularly liked MFG's planning feature, and how it highlighted alternative food choices for more variety, with an emphasis on purchasing foods from all food groups for better balance. Participants frequently mentioned MFG's visualization of all products from a specific food group, with pictures for each food. This visualization served to suggest items to include in their lists, and at times provided inspiration and motivation to try foods that might not be included regularly, or that they may never have tried before. For example, P25 (MFG) described one such experience as: "Quinoa, I didn't know what was that, but I saw on the app and then saw on Wikipedia that it was good for you then I bought to try ... like many things in the list I don't have in my home country, so seeing in the app I see the name of the products and I could understand and it gives me ideas of what to buy." She also tried to buy a larger variety of fruits and vegetables: "Squash was something that I never had before, but I looked at what kind of meal could be made by that and it gave me ideas." Over the 3-week period she was inspired to purchase many new foods like cabbage, eggplant, and figs. This knowledge was also reflected in increased GNKQ scores on dietary recommendations for participants who used MFG.

On the other hand, PBGA encouraged balance and variety through its in-store features: its food balance visualization (Figure 2.2, e) provided feedback on the recommended number of servings of each food group. Participants frequently mentioned discovering that they needed to purchase more fruits and vegetables, and that PBGA nudged them towards making those purchases before leaving the store. For instance, P13 described their experience as "I know I have less fruits and vegetables than I need and it was just nice to see how much I needed and that encouraged me to buy more." P10 described how PBGA served as a reminder at the end of his trip, "As soon as I finished my shopping for the first time, I used to see that screen and remember like 'Oh, shi*, this is not complete!' like for fruits and vegetables, so I wasn't able to complete that, so I just go and buy one more." He was also encouraged to have more salads and look for recipes: "In three weeks I ate more fruits than I previously [ate]. I used to have more snacks, but now I started having more fruits, basically. I also had more vegetables, salads, I watched some videos of recipes as well."

2.7.2 Moderation

Moderation of nutrients, such as sugar, fat, and sodium, is also a core component of food literacy. Three features from PBGA were mentioned by participants as being particularly effective in moderating purchases of foods high in those nutrients: the visualization of nutrition facts, the summary of the nutrients in their shopping cart, and weekly challenges. Participants who used PBGA also demonstrated higher scores for knowledge about Diet, and Disease Management from GNKQ, which might also have influenced the moderation of ultra-processed foods. These topics were primarily featured in Bri's in-game tips, and the increased scores indicate that this feature was effective, despite participants not specifically mentioning it during interviews.

Visualization of Nutrition Facts

All 12 participants who used PBGA reported that the visualization of nutrition facts (Figure 2.2, c) was easier to understand than the food's physical packaging, and helped them understand the healthiness of the products as they shopped. For instance, P15 explained that "I don't usually read [nutrition facts on packages], because I look at the label and I don't really understand, so that's why I liked this screen, because it says this is low, this is high, and then I have a sense. Because the numbers don't mean anything to me, but with this screen I can see." P21 (PBGA) felt that the visualization provided a straightforward way to understand healthiness of a product even if you are a non-specialist: "You don't need to know about food and nutrition, you just have to see that this is high (in the visualization), and you see sodium, sugar high, you don't need [prior] knowledge to understand."

Visualizing the amounts of nutrients in products sometimes surprised participants, raised awareness about foods that they were buying, and identified products they should have in moderation: "Like people always tell me that cheese is really bad and then I scanned and then I saw the high values and I was like 'Oh my God, it really is really bad.' So I really liked that screen, I think it was the best part." (P15). Cereal was also mentioned with surprise by participants, "I thought cereals to be healthier, but it said that cereal had added sugar." (P12).

Notably, participants also reported that the visualization helped them to moderate *consumption* of processed foods: "It was easy to understand and helpful to determine how many servings I should eat. When you look for a product and see how much sodium is there in the things I had to buy, like soy sauce, it had too much sodium. I always knew that soy sauce was high in sodium, but now I can use it a little bit less" (P5, PBGA); "Seeing how much fat you have in a milk made me think oh God, I should drink more water instead of milk all the time ... Seeing that a certain product has 35g of sugar might make you think that's a lot, but when you see a red, it makes you sad (laughs)" (P13, PBGA). Another participant mentioned that this feature did not discourage buying a product that he already intended to buy, but visualizing high values made him buy fewer units and eat less of it afterwards: “It didn’t change what I bought but certainly made me more aware ... I bought the cheese, but I thought to myself, I should eat less of those. And that’s what I’ve been doing.” (P15, PBGA).

Visualizing the Pirate’s Cart-Boat

The summary of nutrients (Figure 2.2, e) was also reported by participants to be helpful when shopping, and in particular helped moderate consumption of sugar, fats, and salt. For example, P21 described their use of this visualization: “I think having your daily nutrients versus just counting calories is pretty interesting because I know a lot of people that just do this thing that they got to eat whatever they want as long as they’re under their calories limit, like you’re eating McDonald’s or you’re eating things like processed foods. But this screen is like, you’re getting all the actual nutrients that you need to have a healthy lifestyle” (P21, PBGA).

Another participant highlighted how focusing on monitoring calories can be an unhealthy approach in nutrition apps: “Before, when I used to count calories I was more obsessed with checking labels, but I found that, for me, it leads you to unhealthy eating behaviour, so I just didn’t want to look at nutrition label in packages anymore. I think a lot of people who are concerned about weight checks just for calories, which was what I was doing, but it’s also important to check for sodium and fat contents and other things besides calories. So now I check for those other things besides calories” (P17, PBGA). When asked why she changed that habit, she added: “Because I had a negative perception of how I looked, so I wanted to keep my calories for 1100 calories a day, but I think I had a lot of unrealistic goals for myself that were not healthy. So afterwards I was like ‘I don’t wanna look at that anymore’.” (P17, PBGA). This quote from P17 shows how tracking calories can lead to unrealistic goals and how tracking nutrients are perceived as more meaningful for creating healthy habits.

Challenges

Challenges were frequently mentioned by participants as a strong motivator while shopping, particularly for moderating purchases of items high in sodium, fat, and sugar. We also noticed that challenges aimed at promoting balance and variety tended to be more difficult for participants than those targeted at moderating consumption of nutrients. For example, fewer participants completed the challenges for purchasing recommended amounts of fruits and vegetables (33%) or fibre (42%) than those for reducing intake of sugar (83%), saturated fat (92%), or sodium (92%).

Participants' success in meeting these challenges was varied, ranging from balancing constraints of an individual's lifestyle, to lack of awareness of their importance in a healthy diet. For example, participants described a variety of difficulties when trying to meet the sodium challenge. P10 related this difficulty to their student lifetyle, "Sodium was very difficult, because since I'm a student, generally I cannot cook every day, so sometimes I'm busy with my work and I generally prefer eating chips and processed food" (P10, PBGA). On the other hand, P12 described a tension between lowering sodium and maintaining a vegetarian diet, "I usually choose foods with high protein, because I'm vegetarian and thus cannot have meat. But now I'm looking at sodium as well" (P12, PBGA). Other participants mentioned that sodium was simply something that they did not think about when shopping, "sodium was the most interesting challenge to me. Sodium is something that I don't really think about when I'm planning in general. After that I tried to minimize the canned beans I bought. I paid an extra 50 cents to get the low sodium version." (P19, PBGA).

Despite these obstacles, participants largely met the nutrient-related challenges while in-store. In post-study interviews, they frequently mentioned that they served as a 'nudge' towards the end of a shopping trip to revisit their dietary needs.

2.8 Discussion & Implications

Our study shows that designing for food literacy can improve people's nutrition knowledge, health beliefs, and in-store shopping behaviour. Both PBGA and MFG demonstrate how organizing food items into food groups encourages shoppers to make adjustments and fill their carts with balance and variety. We observed that this behaviour was more prominent in planning with MFG (because of the list of suggestions) compared to being more prominent in selecting foods in stores with PBGA (because of the Challenges, the Visualization of Nutrition Facts, and the Visualization of Pirate's Cart-Boat). On the other hand, participants who used PBGA moderated their intake of ultra-processed foods more successfully than those who used MFG. Participant responses suggest that this success was supported by features that helped them visualize the nutrients in different foods while in the store, and was motivated by gameful design elements like challenges. We now reflect on these aspects of PBGA's design.

2.8.1 More Informed Decisions

Our field study shows that food literacy apps can be used by young adults to increase their nutrition knowledge, motivate themselves towards healthy eating, and to purchase a variety of fruits and vegetables, and fewer ultra-processed foods. Participants who used both PBGA and MFG increased their nutrition knowledge (GNKQ) and motivation towards healthy eating (HBMS), and purchased groceries that were balanced across the four food groups. Together, these results demonstrate the benefits of promoting food literacy, a focus on interventions that take place before consuming foods, and the potential to help individuals make more informed food choices.

We also found that PBGA's design was particularly effective in promoting certain aspects of food literacy. For example, participants' increased knowledge around diet and disease management can be directly linked to content provided by Bri (Figure 2.2, d). Motivation towards healthy eating was increased for both groups (i.e., HBMS), but impulse purchases were significantly lower for those using PBGA. This reduction in impulse purchases is particularly notable, because we found no difference between groups' planned purchases of any food group. That is, participants' initial intention to purchase healthy foods was similar for both groups, but those using PBGA left the store with fewer unhealthy foods. Thus, the gameful situated app motivated participants to follow the key factors of a nutritious diet: balance, variety, and moderation.

Many participants also mentioned that PBGA helped them recognize products with high values of nutrients that they were not aware of before, and that learning that while shopping later influenced how they *consumed* their food. After making purchases high in nutrients, such as soy sauce that is high in sodium or cheese that is high in saturated fats, many of our participants decided to limit their intake to better match daily recommendations. We take this feedback as indicative that participants were internalizing lessons learned in the store, and practising food literacy skills later at home.

2.8.2 Situated Interventions

Situated interventions for groceries are particularly important to counteract the negative influence of the retail food environment on consumers. This is because grocery stores are carefully designed to influence a shopper's behaviour (Wilkinson et al., 1982). Staples like milk and bread are placed in the back, requiring shoppers to walk by other products. Eye-level shelf space is used to promote ultra-processed cereals and snacks, often the most profitable for retailers, that are packaged in bright boxes that draw an individual's attention; and candy and chocolate bars tempt customers at the checkout, where impulse can quickly translate into a sale. These engineered retail environments work against a shopper's balanced diet (Cohen et al., 2012), and in-store supports like nutrition labelling can be difficult to interpret, even for those who are health conscious (Campos et al., 2011).

Our work demonstrates the importance of this situated approach, and how smartphones can help shoppers act in their self-interest in this complex and hostile environment. PBGA's situated features address many barriers to informed shopping: the map feature makes shoppers aware of the grocery store layout, and asks them to consider their needs as they walk between the different areas; the food scanning feature and traffic-light colours visualization helps shoppers understand the nutrients in each food as they consider the purchase; and the cart-boat visualization helps them monitor their overall intake of nutrients and balance of each food group. Critically, these activities take place when purchases are made, with real foods. Participants were enthusiastic about having a tool that helped them make sense of nutrition information in the grocery store, and to avoid impulse purchases of less healthy items.

2.8.3 Motivation from Gameful Design

PBGA's gameful design elements were widely praised by participants as engaging, informative, and motivating. Participants were particularly enthusiastic about the weekly challenges, and reported that they often stopped in the midst of a shopping trip to make sure that their goals were within reach. The impact of challenges is perhaps most apparent by the difference between planned and purchased foods (Figure 2.5); even though participants did not initially create ideal shopping lists with PBGA, they ultimately purchased a balanced group of foods, and moderated purchases of ultra-processed foods. This motivation was often described by participants during interviews, such as: "It is very motivating to see the quests that I completed" (P16, PBGA), and "When I saw the salt quest, I said 'Yeah, I do wanna get less salt, that's cool!"' (P13, PBGA). PBGA's overall design was also reported to be a motivator by participants, e.g., "The design was like a theme of a game, which was helpful in getting motivation" (P12, PBGA), and was reflected in increased Self-Efficacy on the HBMS, where self-efficacy is associated with a higher likelihood of achievement (Schwarzer et al., 1996).

While participants frequently mentioned enjoying the challenges, some were found to be particularly difficult, such as the Fruits & Vegetables challenge, which was only completed by 4/12 participants, and the Fibre challenge, completed by 5/12 participants. A potential improvement to make these challenges more attainable would be to provide increasing levels of difficulty that build a participant's competencies more smoothly, and that encourage smaller changes in their eating patterns. For example, bronze, silver and gold medals could be awarded based on performance. Additionally, showing all challenges at once instead of three each week would give players a more personalized approach and support their autonomy.

It's also important to recognize that gameful elements were not designed in isolation, and that elements like personalization, meaningful choices, and learning (Deterding et al., 2011) also contributed to PBGA's design. While it's difficult to determine the impact of any one of these design elements independent from one another, our research points to their combined effectiveness in motivating informed food purchases.

2.8.4 Planning for the Win

Finally, we learned that MFG's list of suggestions for each food group helps shoppers be prepared at the grocery store, and to purchase foods with balance and variety. However, some participants mentioned that design improvements could be made to help shoppers purchase foods with moderate amounts of saturated fats, sugar, and sodium. To help with these decisions, a nutritious shopping list could highlight and order foods under each food group from the healthier options to the unhealthier option. For example, white bread and whole wheat bread are both considered 'grains', but an app that encourages healthier options could place whole wheat bread higher on the list. Linking with local flyers could also help participants plan within their budget. However, many flyers are loaded with unhealthy options, and thus care would need to be taken to filter out many promotions. Suggestions based on nutritional needs, preferences, and past purchases would also support healthier and personalized planning.

2.9 Limitations and Future Work

Our study identified new opportunities for improving the design of gameful nutrition apps to develop food literacy in the context of shopping. However—like any single study—our results should be interpreted within the context of their limitations. As exploratory work, a limitation of our study design is that we cannot make any conclusions about the clinical effectiveness of PBGA as an intervention for promotion of food literacy. Our intention was to explore the potential of situated and gameful apps from an HCI perspective, and to identify features like narrative, challenges, and meaningful decisions, for motivating people to use such apps. Our decision to study use of the app over 3 weeks, and to compare to My Food Guide were driven by this choice, and the ability to elucidate strengths and weaknesses of our design. A different design, such as a long-term randomized controlled trial, is required to assess the impact of the use of PBGA on long-term behaviour change.

Another limitation was our choice to not address the issue of budgeting. Food insecurity, defined as uncertain or insufficient access to food because of financial limitations, is a widely identified issue for students in the nutrition literature (Gallegos et al., 2014). In our own study, 9 participants mentioned cost as one of the most important factors when shopping for groceries, and two participants declared spending as little as $10–50 CAD in groceries a month. Despite the importance of cost, neither MFG nor PBGA directly address food insecurity.

However, both apps encourage planning as a means of maintaining a budget, and present advice to the shopper to help plan based on cost. The results of our study suggest that this approach can be effective: participants who used PBGA purchased about one third as much ultra-processed food as those who used MFG. We expect that additional features, such as helping students identify items that are in season—and thus less expensive—or that are on sale through links to local flyers, would be beneficial. Gameful design may also be effective, such as providing shoppers an opportunity to 'trade' one expensive, less healthy item in their cart for an in-season fruit or vegetable, in exchange for an in-game reward. For now, we simply acknowledge the importance of designing for food insecurity, and that balancing the cost of a healthy diet is a critical area for future research, particularly for vulnerable populations like students.

2.10 Conclusion

Our work is the first to use gameful design and situated learning to develop the food literacy skills of planning and selecting foods when grocery shopping. We took this approach with the goal of moving beyond counting calories and short-term weight loss, and to place an emphasis on developing long-term food literacy skills. Results from our three-week field study show that our app increased participants' food knowledge and encouraged balanced food purchased across all four food groups. We also found that the app helped shoppers moderate purchases of sugar, fat, and sodium. Practising these skills in the grocery store provides a meaningful learning experience, helps individuals internalize the skills as they develop, and improves confidence and self-efficacy.

This research is a first step towards developing food literacy skills more broadly, which includes skills for planning and selecting foods, but also for preparing meals and enjoying them with friends and family at home. Our app shows how this approach can effectively support food purchasing behaviour, and contributes insights into how gameful design can be used to develop food literacy in the grocery store. We envision that future work will extend this research to develop the full range of food literacy skills.

2.11 Acknowledgements

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Chapter 3

Design and Evaluation of Technologies for Informed Food Choices

3.1 Abstract

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.

3.2 Introduction

Technology is playing a growing role in our everyday interactions with food, ranging from food preparation, via smart kitchens (e.g., Chi et al., 2007) and interactive simulators that foster the development of cooking skills (e.g., Kato et al., 2013), to playful technologies that enhance the experience of eating together (Altarriba Bertran et al., 2020; Arakawa et al., 2007; Mueller et al., 2018; Weber et al., 2021). 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 (Goddard, 2020, RBC Capital Markets, 2020) that offer better availability, variety, and convenience than shopping in person (Blitstein et al., 2020). 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 diet when purchasing food online (Hollis-Hansen et al., 2019; Pitts et al., 2018). Indeed, human-food interaction research has to date focused on creating novel technologies (Altarriba Bertran et al., 2019), rather than social or health-focused improvements, and may promote behaviours that are harmful in practice (e.g., Eikey et al., 2017b; Purpura et al., 2011). 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 (Cruz et al., 2018; Christoph et al., 2019; Basu et al., 2013; O'Donnell et al., 2010; Yang et al., 2014). An unbalanced diet is the primary risk factor for many leading causes of death including heart diseases, stroke, and type 2 diabetes (Basu et al., 2013; O'Donnell et al., 2010; WHO, 2019; Yang et al., 2014), that are preventable if healthy behaviours are established early in life (Statistics Canada, 2013).

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 (Cullen et al., 2015; Vidgen et al., 2014; Slater, 2017; Ronto et al., 2016; Truman et al., 2017) — 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 (Pitts et al., 2018; Au et al., 2013; Ducrot et al., 2017). To date, work has demonstrated the effectiveness of food literacy as a guiding principle through proofs-of-concept (e.g., Bomfim et al., 2020), 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 (Nielsen, 1992; Nielsen, 1994) is widely-used, highly effective in a number of domains (e.g., U.S. Department of Health, 2015; Monkman et al., 2015; Walsh et al., 2017; Väätäjä et al., 2016), and can be used as both a formative (i.e., process-focused) and summative (i.e., outcome-focused) design tool (Mankoff et al., 2003; Kientz et al., 2010). 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 chapter 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.

3.3 Background

Within the nutrition literature, food literacy is broadly defined as the *awareness*, *knowledge*, and *skills* required to achieve a nutritious diet (Perry et al., 2017; Vettori et al., 2019). 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 (Perry et al., 2017). 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 (Cullen et al., 2015; Vaitkeviciute et al., 2015; Vidgen et al., 2014).

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 (Campos et al., 2011) and judging appropriate portion sizes (Talati et al., 2018), which can lead to consumption of the type and amount of foods that are inconsistent with dietary guidelines (Bryant et al., 2005). Product packaging exacerbates these issues, since it is carefully designed to capture shoppers' attention, rather than to inform (Chandon, 2013). 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 (Dujak et al., 2018; Moodie et al., 2021). Consequently, it can be challenging to balance one's food needs, like nutrition, taste, and hunger, with available resources like time, money, and skills (Vidgen et al., 2012). As a consequence, sub-optimal eating patterns are common, and negatively affect the overall health of the global population (Cruz et al., 2018; Christoph et al., 2019; Basu et al., 2013; O'Donnell et al., 2010; Yang et al., 2014).

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 (Olzenak et al., 2020). When it is available, nutrition facts and/or ingredients are presented inconsistently (Lee et al., 2021) 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 (Benn et al., 2015), 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 home page or the first page of a search's result are more likely to be purchased (Breugelmans et al., 2007; Benn et al., 2015). Retailers take advantage of this behaviour to promote impulse purchases over more nutritious options (Pitts et al., 2018; Lee et al., 2021; Blumtritt, 2020). 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 (Benn et al., 2015), 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 profit (Middel et al., 2021; Brimblecombe et al., 2020). For instance, a study involving a co-creative design of a food store was shown to improve the acceptance of changes for a healthier store, with strategies such as 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 (Middel et al., 2021). 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 (Brimblecombe et al., 2020). 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.

3.3.1 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 (Mizrahi et al., 2016; Laursen et al., 2015), 3D printing of food-based rewards for exercise (Khot et al., 2017) and as a means to experience computational data (Mueller et al., 2021), multi-sensory food interactions that enhance or augment the experience of eating (Obrist, 2017; Spence et al., 2017), and the use of virtual reality (e.g., Arnold et al., 2018) and social media (Chung et al., 2017; Choe, 2019) 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. (2019), Altarriba Bertran et al. (2018), and Deng et al. (2021), 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., Park et al., 2015; Orji et al., 2013; Grimes et al., 2010), and scanning devices to help people quickly identify suitable items for a specific diet (Mulrooney et al., 2006). Similarly, researchers have used augmented reality (AR) to help shoppers find healthy items (Ahn et al., 2015), interactive displays to calculate serving sizes and compare products (Bedi et al., 2010), and mobile apps that help shoppers to visualize and interpret the nutritional balance of their shopping cart (Bird et al., 2013; Bomfim et al., 2020).

Further, HCI researchers have examined how online grocery shopping can motivate healthy food choices. For instance, Dillahunt et al. (2019) 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 et al. (2020) explored how nudging shoppers with social comparisons during checkout facilitated healthier food decisions when shopping online. Similarly, Hollis-Hansen et al. (2019) showed that by initiating future thinking, individuals became more goal-oriented, thus tending to make healthier choices and reducing the total calories of their grocery carts. In another study, Epstein et al. (2016) 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' (Ahn et al., 2015). 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. (2019) 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 (Sizer et al., 2017). 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 (Morozov, 2013), the pursuit of technological interventions that unilaterally solve individual or social issues, has been commonly cited as a shortcoming of existing HFI research (Morozov, 2013; Dolejšová et al., 2018; Altarriba Bertran et al., 2019; Cho et al., 2021). In their review, Altarriba Bertran et al. (2019) 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. (2021) 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 meals replacement with a powder mixture (Dolejšová et al., 2017). Similarly, weight loss apps have been shown to contribute to and exacerbate eating disorder behaviours (Eikey et al., 2017b; Purpura et al., 2011), and self-monitoring fitness apps promote over-exercising, leading to injuries and burnout, especially among those who do not exercise regularly (Whelan et al., 2020). 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.

3.3.2 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 (1992) and Nielsen (1994), 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 (Mankoff et al., 2003; Kientz et al., 2010), and is particularly valuable to smaller teams that may not have a nutrition expert. Formative evaluation is a type of evaluation that helps to "form" the design for a product, aiming to improve and refine its design by applying a particular set of recommendations. On the other hand, summative evaluations describe how well a product performs by determining if its design meets specific measurable goals (Joyce, 2019).

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 (Carvalho et al., 2009), social networking websites centred on health (Yeratziotis et al., 2012), persuasive health technologies (Kientz et al., 2010), and health literacy (U.S. Department of Health, 2015; Monkman et al., 2015), to name a few. Notably, the U.S. Department of Health (2015) 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 instance, Monkman et al. (2015) extended the HLO guide to create heuristics for assessing the usability of mobile blood pressure tracking applications. Yeratziotis et al. (2012) developed heuristics to evaluate the security of online health social networking, and Carvalho et al. (2009) created heuristics to reduce medical errors and promote patient safety. Finally, Kientz et al. (2010) 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 (Paddison et al., 2002) 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 on the Codex Alimentarius Commission on Food Labelling (CACFL) agenda of 2019 (Codex Alimentarius Commission, 2019), 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, consolidated findings from HCI research, and 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.

3.4 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., Nielsen, 1992; Nielsen, 1994; Feth et al., 2019).

To ensure our heuristics captured the most applicable food literacy practices, we developed them through a three-phase process (Figure 3.1). 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 then 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.

3.4.1 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 Perry et al. (2017), considered how it might be applied to technology design, and generated an initial set of 24 heuristics (discussed in subsection 3.4.3). 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,

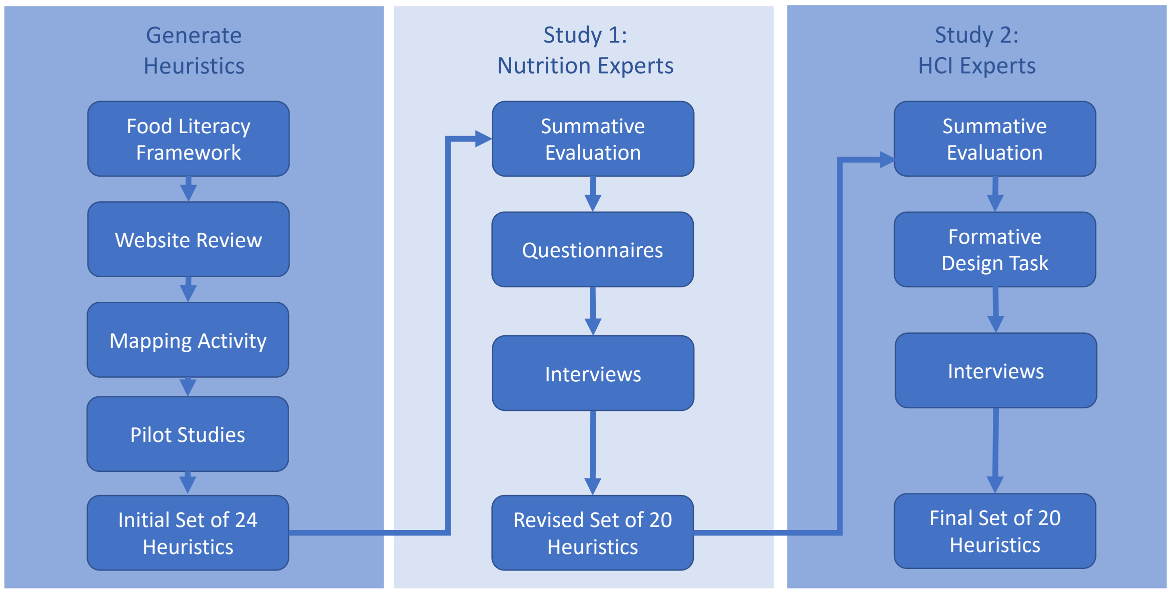

Figure 3.1: We developed our heuristics in three phases: First, we identified the most important aspects of food literacy from Perry et al. (2017) food literacy framework, reviewed current grocery websites, performed a mapping activity to generate the heuristics, and conducted pilot studies to calibrate them; Second, we refined the heuristics through a study involving nutrition experts (Study 1) who ran website evaluations and provided feedback. Finally, we confirmed the heuristics utility through website evaluations and interviews with HCI experts (Study 2), resulting in the final, adjusted heuristics (found in Table 3.8).

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." (2017, p.5).

Notably, their framework integrates advice by Vidgen and Galegos (Vidgen et al., 2012; Vidgen et al., 2014) and we mainly focused on the "plan and manage" and "select" domains of food literacy proposed in their work, but also considered the other domains of "prepare", and "eat". 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%) (Altarriba Bertran et al., 2019). 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.

3.4.2 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 (Vidgen et al., 2014). 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., Bomfim et al., 2020; Buscher et al., 2001; Sonnenberg et al., 2013). 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 (Codex Alimentarius Commission, 2019). And finally, the COVID-19 pandemic caused a sudden and substantial rise in online shopping (RBC Capital Markets, 2020).

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 and second authors 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 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 3.1).

3.4.3 Mapping Food Literacy Attributes to Website Features

Next, the first author mapped the food literacy attributes from Perry et al. (2017) to the grocery shopping website features. The first author reviewed the list of attributes and descriptions from Perry et al. (2017) 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

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 3.1: 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.

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 in 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.

3.4.4 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 3.2.

3.5 Study 1: Evaluation with Nutrition Experts

After devising the original heuristics, our next step was to refine them with food literacy experts. Thus, to evaluate our initial set of heuristics, we conducted a mixed-methods user study with nutrition and food literacy experts. We specifically recruited domain experts

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 3.2: 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 3.8.

in nutrition due to their unique ability to provide insights and knowledge in this domain. Involving domain experts in the development and validation of heuristics is a strategy that has been found effective in other research that develops domain-specific heuristics (e.g., Jacob Nielsen, 1994; Somervell et al., 2005; Mankoff et al., 2003; Väätäjä et al., 2016; Feth et al., 2019). 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 the heuristics 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 the ones they would remove for considering irrelevant. We also asked them to rank the top 10 most important heuristics to support food literacy. This top 10 would make participants 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 analysis plan with Open Science Framework in November 2019 (https://osf.io/5dwnz/).

3.5.1 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 3.3. All 12 participants completed the study, and each received a CAD$30 honorarium. Regarding participant's gender, we did not consider it a confounder, so we did not control for it. Because we were mainly interested in expert feedback, the participant's gender would not affect this information. Moreover, dietitians are predominately female in Canada (95%) (Gheller et al., 2015), 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 3.3: A summary of our participants' demographic information.

3.5.2 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.

3.5.3 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 (Van Someren et al., 1994). 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.

3.5.4 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 (Saunders et al., 2018).

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 (Braun et al., 2019; Braun et al., 2020). 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.

3.5.5 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 Awareness issues, 4.25 Knowledge issues, and 2.33 Skills issues (Figure 3.2). 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.

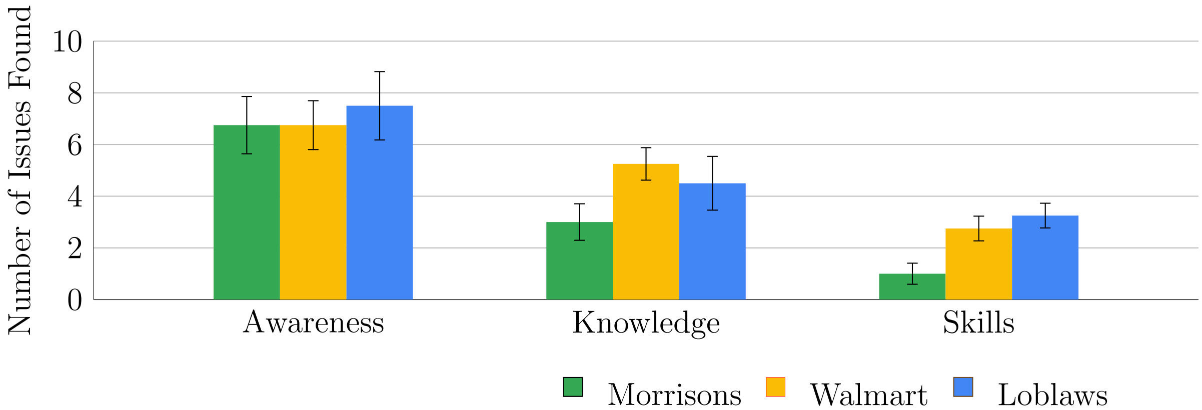

Figure 3.2: Number of issues found in each food literacy category for the three grocery websites included in our study. Error bars attached to each column represent pooled standard error term.

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.

Understandability, Ease of Use, Specificity, and Usefulness

We found that the average score of heuristics quality statements was generally high, with average scores for all heuristics and questions between 3.6 and 5 (Figure 3.3), which showed a high level of agreement on the understandability, ease of use, usefulness, and specificity of the heuristics. 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.

Top 10 Heuristics

When we asked participants to rank the top 10 most important heuristics to support food literacy, the two most commonly voted were "Interpret nutrition content" (H2) and "Support budgeting" (H20), voted by ten (10/12) and nine (9/12) participants, respectively. A summary of the heuristics ranked as being in the Top 10 is provided in Table 3.4.

3.5.6 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 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.

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.

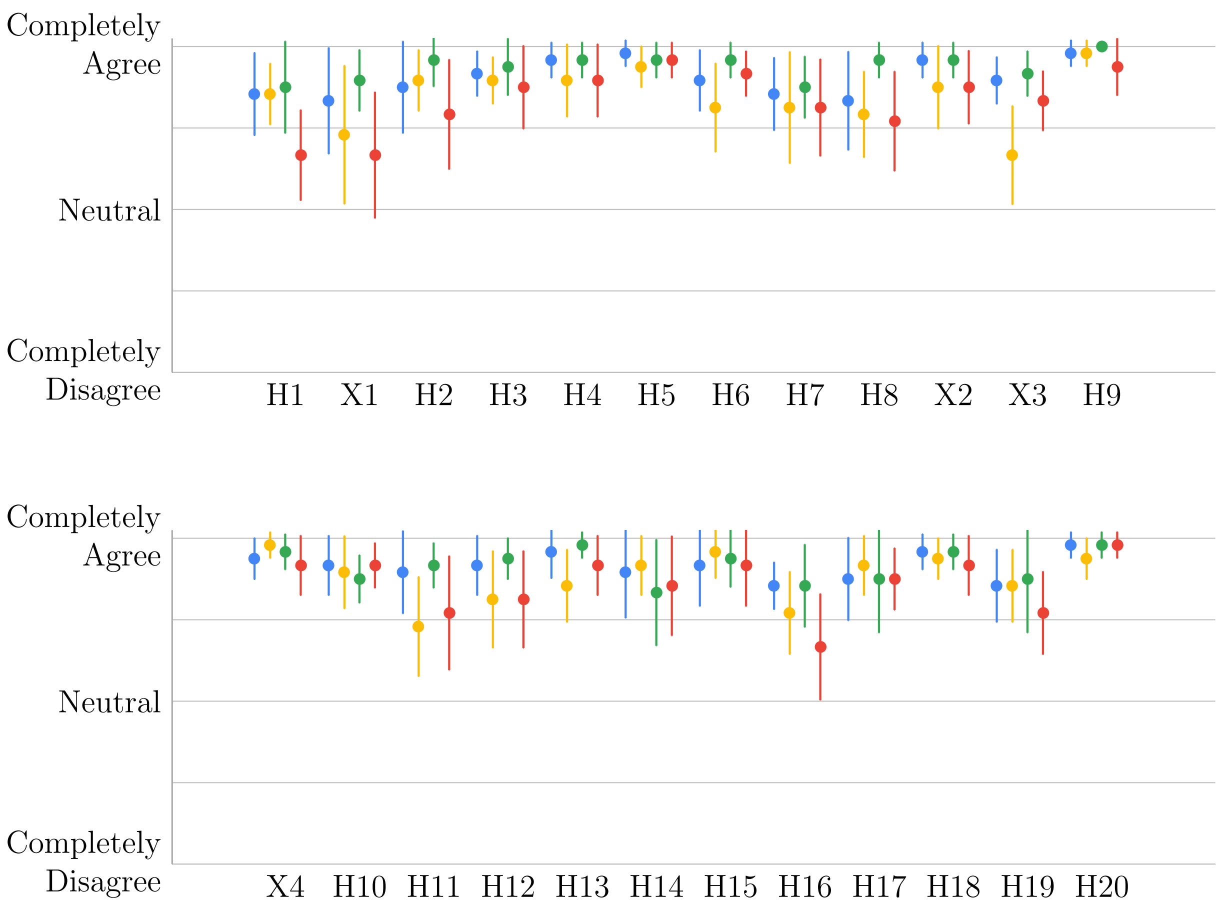

Figure 3.3: Average ratings and 95% confidence intervals for 5-point Likert scale questions "The heuristic was easy to understand" (leftmost, blue), "The heuristic was easy to use (i.e., apply to the website)" (middle left, yellow), "The heuristic was useful" (middle right, green), and. "The heuristic was specific and detailed" (rightmost, red). Heuristics that were removed from our final set are denoted with an 'X'.

	Heuristic	Category	Votes
T1	**Interpret Nutrition Content (H2)** 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
T2	**Support budgeting (H20)** and place emphasis on healthy items. (e.g., highlight healthy items on sale; provide a "Sort by" feature combining lower price and more nutritious items).	Skills	9
T3	**Sort by Nutrition Values (H4)** Enable customers to sort products according to their nutritional values (e.g., Sodium: Low to High; Sugar: Low to High).	Awareness	8
T4	**Filter by Nutrition Content (H5)** Enable customers to filter products based on specific dietary needs or lifestyles (e.g., low sodium, sugar, gluten-free).	Awareness	8
T5	**Follow Food Guides (H11)** 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.	Knowledge	8
T6	**Provide Healthy Suggestions (H7)** 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
T7	**Enable Comparisons (H13)** Enable customers to compare the nutrition value of two or more products side-by-side.	Knowledge	7
T8	**Show Nutrition Facts (H10)** Help customers easily locate a product's nutrition information. A good place is right below the product's picture or price.	Knowledge	6
T9	**Educate about Nutrients (H12)** Educate customers about how individual nutrients affect 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").	Knowledge	6
T10	**Highlight Dietary Needs (H15)** Use symbols to highlight specific dietary needs and make them easy to find in the product's description. (e.g., vegetarian, no milk, halal, gluten-free).	Knowledge	6

Table 3.4: Top 10 heuristics as ranked by participants. Based on our interviews with nutrition experts, 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 (Sonnenberg et al., 2013) and the guiding stars (Sutherland et al., 2010).

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., Sonnenberg et al., 2013; Sutherland et al., 2010), 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 3.4), that can be found in Appendix C.

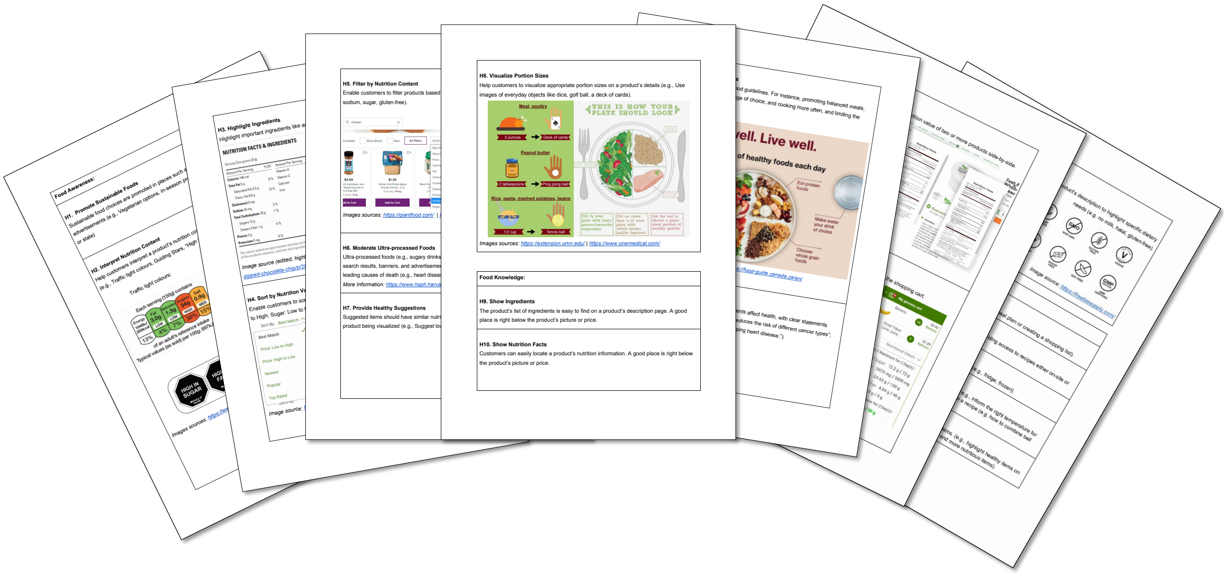

Figure 3.4: The extended version of our heuristics includes additional detail, examples, and images. We developed this seven page resource based on feedback from participants.

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 (P1, P8) 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 (P1, P2, P3, P4) 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 after this study is seen in Table 3.5, and we label them as X1, X2, X3, and X4 throughout the paper.

Heuristic		Category
X1	Promotes foods that are produced locally.	Awareness
X2	Uses nutrition labels to advertise the benefits of products (e.g., high in fibre, fortified with vitamin d).	Awareness
X3	Uses nutrition symbols to advertise poor nutritional values on the products (e.g., high in sugar, high in sodium).	Awareness
X4	Acknowledges where food is produced (e.g., country, place, producer).	Knowledge

Table 3.5: The four heuristics that were developed as part of our initial set of 24, but were later dropped as part of our iterative design process after Study 1.

3.6 Discussion & Revised Heuristics

Our study shows 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, arriving at the final set in Table 3.8. A complete set of heuristics, including additional examples, reference material, and images, is provided in Appendix C.

3.6.1 Use in Retail Food Technology

We intentionally focused on the food literacy domains of 'purchasing' and 'selecting' foods for this study, and our evaluation of grocery shopping websites demonstrated their utility in these applications. However, the heuristics may also be useful when designing or evaluating other retail food technologies like food delivery and meal kit apps (e.g., Prabhu et al., 2020) since they also encompass the same domains. Similarly, our heuristics may also be useful in evaluating technologies such as digital restaurant menus (Lessel et al., 2012) or interactive tables (Chen et al., 2011) to promote more informed choices by consumers.

Importantly, we do not view these heuristics as *necessary* for all food-related technologies, they are simply guidelines that can help identify areas for improvement, and may be applied judiciously. That is, when evaluating a technology, the person performing the evaluation must also consider which heuristics are most relevant for that application, and which may not be appropriate. For instance, one might choose to focus an evaluation on only one of the Awareness, Knowledge, or Skills categories in certain applications, or even within separate stages of an application. Meal kit applications might focus on skills, with consumers creating meal plans for their family on a budget, developing cooking abilities while applying food safety measures for handling and storing, and creatively reusing leftovers afterwards. On the other hand, food delivery apps might focus on knowledge by offering a detailed breakdown of ingredients and nutrients in each dish, enabling comparisons of their nutritional value, and educating consumers about them. Finally, given the large variety of ultra-processed foods marketed by grocery stores, they might choose to focus on awareness by limiting exposure to ultra-processed foods, offering health-oriented filters and sorting features, and using symbols and colours to help shoppers more efficiently select healthier options.

3.6.2 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 3.4) are reflective of current legislation and best practices in non-digital contexts (Health Canada, 2018; Health Canada 2019; Government of Canada, 2021). Since these heuristics are more 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 3.4 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 might currently be in-season, and an individual's geographic region. The nutrition literature has well-established the effectiveness of the awareness, knowledge, and skills required to select and purchase foods (Cullen et al., 2015; Vidgen et al., 2014; Perry et al., 2017; Slater, 2017; Ronto et al., 2016). Our heuristics provide guidance for creating technologies that develop those aspects of food literacy.

3.6.3 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. In revising the heuristics based on our interviews, we also found 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 (P2, P5, P6, P7, P8) included this heuristic in their Top 10, but three participants (P1, P3, P11) indicated that we should remove it. Those in favour of the heuristic cited the known difficulty consumers have in visualizing serving sizes (Cowburn et al., 2005), 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 (Faulkner et al., 2017; Byrd-Bredbenner et al., 2004). Other pictorial representations could also be explored, such as the proportion that the food should be placed on a plate (e.g., Canada's food guide eat well plate, 2019). These visualizations would help to avoid over-serving and "portion distortion", where people mistakenly perceive large portion sizes as appropriate (Schwartz et al., 2006).

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 presented in Chapter 2, 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 (DiCosola III et al., 2020); 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.

3.7 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 show their utility for HCI experts without a background in nutrition. To do so, we replicated our mixed-methods study (Study 1) with HCI experts. We specifically recruited participants with at least 1 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/).

3.7.1 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 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 3.6. All 12 participants completed the study, and each received a CAD$30 honorarium.

3.7.2 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 (Table 3.8) 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.

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 3.6: A summary of our participants' demographic information.

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 (Van Someren et al., 1994). 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 a 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.

3.7.3 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 (Saunders et al., 2018).

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 (Braun et al., 2019; Braun et al., 2020). 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". Then, the final themes were developed 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.

3.7.4 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 3.5). 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 not-so-high level of agreement among participants, as half of the participants identified a violation with them. 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 carry out on the website they evaluated. Participant 4 said, "I feel like the example and

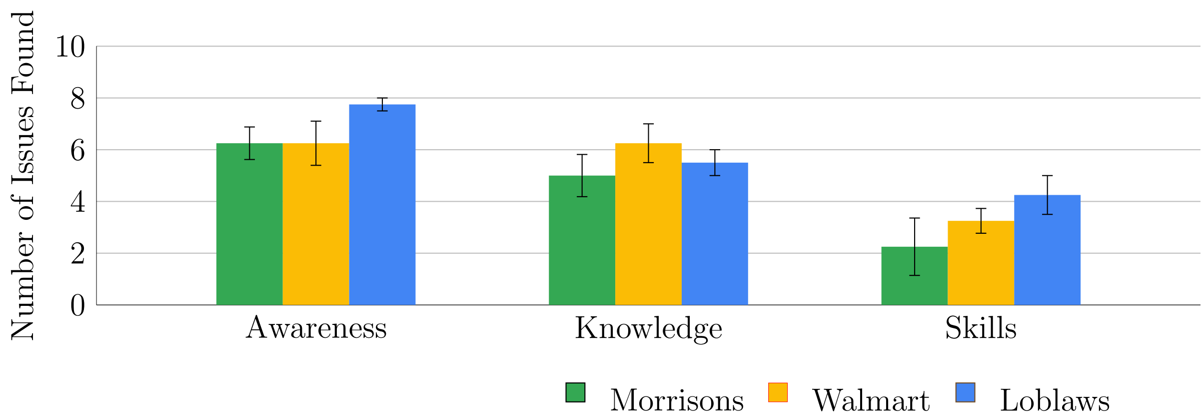

Figure 3.5: Number of issues identified by HCI experts in each food literacy category for the three grocery websites included in the study. Error bars attached to each column represent pooled standard error term.

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."

3.7.5 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 3.7). 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.

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.

Theme 1: Participants generated novel design ideas that considered different stages of food literacy

Participants used the heuristics to explore how design solutions 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

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 3.7: A summary of participants' formative design activities.

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.

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.

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 (Liaukonyte et al., 2013).

The HCI experts felt that designers would interpret specific heuristics and the implication of certain words on user experience. For instance, 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 customers, 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 on creating designs to educate and create awareness among people, 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. For instance, 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.

3.8 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 particularly 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 for both groups. We also note that both groups identified a similar distribution of problems among the websites and categories Figure 3.5.

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 for HCI experts, that might identify with people using these technologies. It might inspire them to put themselves in the users' shoes and propose designs that benefit them as consumers as well.

Moreover, we identified some tensions between nutrition best practices and HCI experts' personal opinions. In addition, we faced 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.

3.8.1 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 from Perry et al. (2017), 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 mentioned they would envision using the heuristics for applications like food trackers, cooking websites, and digital restaurant menus. We expect that given the rapid increase in the amount of research in human-food interaction that these examples are only the beginning (Altarriba Bertran et al., 2019), 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 provides a means of identifying heuristics that may be most relevant to a technology or group of people (Perry et al., 2017). 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 3.4) may be useful for rapid evaluations of 15 or 20 minutes for those working under time constraints. The majority of the heuristics from the top 10 ranked by nutrition experts were used by HCI experts during the 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 used during the formative evaluation, we noticed that some heuristics were used more than others, and we may interpret this result in different ways: (1) The most used heuristics might reflect the biggest 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.

3.8.2 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. (2019), 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 (Afshin et al., 2019). 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 (Story et al., 2004; Robinson et al., 2007). 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 (Ha et al., 2018; Wickham et al., 2018). Moreover, even global food guidelines incorporate awareness about this issue (Health Canada, 2019).

Overall, we interpret these tensions as a real opportunity to improve the design process for food-related technology, and as reinforcing 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.

3.8.3 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 3.8. 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".

3.9 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

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	Display the product's list of ingredients in an easy-to-find location on a product's description page. A good place is right below the product's picture or price.
H10. Show Nutrition Facts	Help customers 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	Help customers visualize nutrition information for all items in the shopping cart.
H15. Highlight Dietary Needs	Use symbols to highlight specific dietary needs and make them easy to find in the product's description. (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).
H20. Support Budgeting	Provide budgeting support for customers with an emphasis on healthy items. (e.g., highlight healthy items on sale; provide a "Sort by" feature combining lower price and more nutritious items).

Table 3.8: Our final set of 20 food literacy heuristics, organized as groups of heuristics for *awareness*, *knowledge*, and *skills*.

and HCI research. However, there are clearly exceptions, such as work in HCI that aims to enhance the act of eating itself (Arakawa et al., 2007; Mueller et al., 2018). 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., Chi et al., 2007; Kato et al., 2013) and eating (e.g., Arakawa et al., 2007; Mueller et al., 2018) 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 in the food industry already spend considerable resources promoting less healthy yet profitable foods (Kelly et al., 2015), and are known to mislead consumers to increase profits (Schermel et al., 2013). However, the nutrition literature shows that promotion of healthier foods can increase profit (Middel et al., 2021; Brimblecombe et al., 2020), 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.

3.10 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 develop 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 sustainability, 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.

3.11 Acknowledgements

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Chapter 4

Conclusion

This thesis began by investigating how we could support food literacy to promote informed food choices through technology at a physical grocery store (RQ1). A three-week exploratory study answered this question (Chapter 2) by investigating how gameful design strategies would influence young adults' knowledge, awareness, motivation, and food purchases at a grocery store. Results from Study 1 showed a need for focusing more on *planning* because participants wanted to optimize their time in the store, and a lack of time was a concern raised by a few participants. Thus, this more significant focus on planning opened the idea of further exploring online grocery shopping because it offers an opportunity for more strategic planning. Moreover, with the COVID-19 pandemic promoting increased use of online grocery purchases and food delivery apps (RBC Capital Markets, 2020), we aimed at focusing on online food purchases for Studies 2 and 3.

We then wanted to investigate more broadly how we could use food literacy to facilitate the design and evaluation of food-related technologies to promote informed choices (RQ2), given the lack of guidance and standards for HCI practitioners to follow best practices and apply food literacy concepts into their designs. Therefore, in Chapter 3, starting with an established food literacy framework from nutrition sciences literature (Perry et al., 2017), we applied an iterative, expert-driven process to derive and refine a novel set of food literacy heuristics for technology design. The first part of this chapter involved a study with Registered Dietitians and Dietetics Students (Study 2). Results from this study showed how the heuristics support both summative (i.e., outcome-focused) and formative (i.e., process-focused) design and evaluation, helping us refine our initial heuristics and answer our RQ2.

Therefore, with a revised version of our heuristics, we conducted Study 3, where we applied mixed-methods interviews and food-related website evaluations with 12 HCI experts to demonstrate our heuristics' utility for evaluating and designing a variety of food-related technologies. This study is presented in the second part of Chapter 3. Results from this study answered how HCI practitioners use food literacy heuristics to evaluate and design food-related technologies, addressing our RQ3.

4.1 Contributions and Impact

This dissertation provides evidence towards supporting the development of food literacy through technology, with three main contributions, summarized in Figure 4.1. Each research study resulted in one main contribution, which served as a connection point to the subsequent study. For instance, design features used in Study 1 were incorporated into the heuristics devised and refined with Nutrition experts in Study 2. Then, those heuristics were used in practice by HCI experts in Study 3. We now discuss the relevance and impact of each contribution, and how they are connected.

4.1.1 C1: Providing empirical evidence for the effectiveness of gameful design to promote food-literate decisions when grocery shopping

In Study 1, we sought to investigate how mobile devices could support the development of food literacy among young adults when grocery shopping. We explored the motivational aspects of gameful design and visualizations such as traffic light colours to support more informed food choices at the store. Results from this study showed that participants who played the gameful app made fewer impulse purchases than the ones who used the non-gameful existing nutrition planning app. Our findings contribute three important insights: 1) promoting food literacy instead of calories and consumption in an app's design is essential, 2) situated mobile apps providing information at the time that decisions are made reduce impulse purchases, 3) gameful design contributes to healthy food purchases.

The impact of this contribution to the field of HCI is that designers should explore a situated approach to shopping by applying food literacy concepts that help users understand the nutritional content of foods as they shop and how they impact their health. This approach is critical since the lack of information while shopping contributes to food selections that are not aligned with healthy dietary patterns (Hollywood et al., 2013; Mhurchu et al., 2018). Further, strategies to foster motivation, such as gameful design elements,

Overarching RQ	Specific RQs	Research Studies	Answers to RQs	Thesis Contributions
RQ-T: How can we support the development of food literacy through technology?	**RQ1:** How can we support the development of food literacy through technology at a physical grocery store?	**Study 1 - Food Literacy while Shopping:** Motivating informed food purchasing behaviour with a situated gameful app.	Our situated and gameful app increased nutrition knowledge and attitudes towards healthy eating and reduced impulse purchases.	**C1:** Providing empirical evidence for the effectiveness of gameful design to promote food-literate decisions when grocery shopping.
	RQ2: How can food literacy be used to facilitate the design and evaluation of food-related technologies to promote informed choices?	**Study 2 - Nutrition Experts:** Design and evaluation of technologies for informed food choices.	Our heuristics were shown to support a summative and formative design and evaluation by encapsulating best nutrition practices to provide informed food choices.	**C2:** Devising a set of food literacy heuristics to facilitate the design and evaluation of food-related technologies.
	RQ3: How do HCI practitioners use food literacy heuristics to evaluate and design food-related technologies?	**Study 3 - HCI Experts:** Design and evaluation of technologies for informed food choices.	Our heuristics were shown to be valuable design tools, helping participants reflect on food literacy challenges. We also discuss tensions between nutrition and HCI best practices.	**C3:** Demonstrating how the food literacy heuristics can be used by HCI experts to facilitate the design and evaluation of food-related technologies.

Figure 4.1: Thesis research questions (RQs), studies, answers to RQs, and contributions, replicated from 1.1

and visuals such as traffic-light colours and summarized information about products, are good designs to encourage healthier dietary patterns. Therefore, we included traffic-light colours and a summary of the shopping cart in the heuristics devised in Study 2 due to their relevance in fostering informed food choices found in Study 1.

4.1.2 C2: Devising a set of food literacy heuristics to facilitate the design and evaluation of food-related technologies

Given the lack of guidance and standards for HCI practitioners in applying the holistic approach to food literacy in technology, we devised, to the best of our knowledge, the first set of food literacy heuristics encapsulating nutrition practices to facilitate the design and evaluation of technologies. We achieved these practices by devising our heuristics from an established food literacy framework from nutrition sciences literature and involving nutrition experts through an iterative design process. Hence, developing our heuristics from the nutrition literature and assessing them with nutrition experts contributed to a set of guidelines that encapsulates the most suitable nutrition approaches to facilitate the design and evaluation of technologies by HCI researchers and designers.

4.1.3 C3: Demonstrating how the food literacy heuristics can be used by HCI experts to facilitate the design and evaluation of food-related technologies

Building on our findings from Study 2, HCI experts used the revised heuristics in Study 3, demonstrating their utility for evaluating and designing a variety of food-related technologies in practice. We showed that the heuristics are valuable formative and summative design tools and that they help HCI practitioners reflect on their challenges around food literacy. This reflection might positively inspire designers to put themselves in the users' shoes and propose designs that benefit them as users too. However, it also indicates the importance of educating HCI practitioners about food literacy. Finally, we also identified tensions between nutrition best practices and HCI experts' thinking about design, demonstrating a need to reconcile differences in perspective between HCI and nutrition practitioners to move technology design towards population-level solutions.

At the end of this study, we contributed a refined and revised heuristics set to be used as guidelines for HCI researchers and practitioners to evaluate and design technologies for informed food choices. Therefore, collectively, our three studies and their contributions provide support for the central claim of our thesis statement:

Claim: *Food Literacy can provide much-needed guidance to technology designers and practitioners through its interconnected combination of awareness, knowledge, skills, and behaviours that empower individuals to make informed food choices*

4.2 Implications for Human-Computer Interaction

We envision our heuristics inspiring HCI designers and researchers to improve HFI designs by enhancing technologies to provide more awareness, knowledge, and skills around food, such as exploring smart kitchens to assist users in acquiring new cooking and preparation skills and learning from the foods they prepare (Mizrahi et al., 2016; Chi et al., 2007). Additionally, systems that sell food online can promote more informed food choices with design features such as filters, sorting, comparisons, and healthy suggestions.

Moreover, there is a need to counteract Techno-solutionism (Morozov, 2013), and we envision the future of HFI exploring more social, playful, and cultural aspects of food practices in technology mentioned in Altarriba Bertran et al. (2019). Thus, designers can then explore our heuristics by including social and cultural strategies that involve family and friends in learning nutrition content and acquiring and sharing food skills. These social and cultural components involving food practices are also part of food literacy, including attitudes such as respecting food traditions and cultures, sharing food skills, and enjoying food socially (Perry et al., 2017).

Our heuristics could also potentially counteract harmful technologies that promote claimed healthy behaviour through weight loss (Eikey et al., 2017b; Purpura et al., 2011) and unbalanced diets (Dolejšová et al., 2017) because food literacy promotes a healthy relationship with food, focused on dietary patterns instead of fad diets. This holistic approach to food literacy is critical to be applied in technology aimed at youth, and young adults, as they are mostly affected by negative body image and eating disorders (Penney et al., 2015; Rounsefell et al., 2020).

Another implication for HCI is to combine food literacy content with gameful design strategies and other visual features, which we successfully found to reduce impulse purchases in Study 1. For instance, participants from this study mentioned that challenges, the traffic-light visualization of nutrition facts, and the summary of the nutrients in their shopping cart were effective in moderating the purchase of ultra-processed foods. Therefore, HCI designers and researchers interested in healthier outcomes can apply these components to their designs to hinder impulse purchases. Moreover, some features used in the mobile app of Study 1 are also present in the heuristics and might have also influenced the reduced impulse purchases. They are: interpreting nutrition content (H2), by using traffic light colours, and summarizing nutrition info (H14), by providing a visualization of the appropriate distribution of a balanced diet. Thus, HCI researchers can investigate if such heuristics applied to their designs can also curb impulse purchases.

Food literacy heuristics can also be applied in various technologies that are not so obvious such as grocery shopping websites, which includes games. For instance, many games incorporate food aspects as part of their story, such as "The Legend of Zelda: Breath of the Wild" (Leack, 2017), where the player needs to gather ingredients, cook recipes and eat them to progress in the game. Although the game is not focused on food, it incorporates this component as a crucial part of the gameplay. Thus, game designers and researchers could further explore examples like this to incorporate more realistic food aspects in games in the future by applying the heuristics and encouraging players to learn food skills and knowledge that they can actually apply in real life.

Finally, we expect that our heuristics will be used and potentially improved by other HCI researchers to align with new technologies that will emerge from future HFI research and be adapted to satisfy the most recent food literacy guidelines as they also evolve. We see this work as the first step in applying food literacy concepts to technology, and we hope that with this thesis being available to the public, our heuristics become a pattern in HFI technology. We also anticipate that as HCI practitioners broadly use our heuristics, they can be enhanced over time by including new heuristics or updating existing ones.

4.3 Implications for Public Health Sciences

Food literacy is seen as a direction for creating policies, novel programs, resources and research to provide educators and policy-makers with guidelines to implement interventions aimed at different food-related areas (Fernandez et al., 2020; Vidgen et al., 2014; Cullen et al., 2015). Moreover, because technology is currently an important influence in food decisions, it is essential to implement interventions in this sector. Therefore, we see our heuristics as an essential component of future interventions to support food literacy at a population level. Heuristics such as promoting sustainable foods (H1), limiting ultra-processed foods (H6), and following food guides (H11) are aligned with current public health interventions (Canada, 2019a; FAO, 2014; Adams et al., 2020), showing the relevance of our heuristics at a population-level.

We envision that our heuristics may represent ideals that need to be considered to influence the creation of policies for selling food online, given the lack of legislation for nutrition labelling and claims for selling food online. There is ongoing work on the development of regulation of digital food retail in discussion at Codex Committee on Food Labelling (2019), which includes providing mandatory nutrition labelling information (e.g., nutrition facts table, list of ingredients), that we highlight in our heuristics H9, and H10. In addition, our heuristics can provide insight into essential elements to include in the regulation of digital food environments to support food literacy through technology. For instance, critical heuristics that align with current public-health practices can be drawn from the Top 10 heuristics ranked by nutrition experts in Study 2. Examples of heuristics that could be applied in a broad range of digital food retail include providing information to support the interpretation of nutrition content (H1) – voted by Nutrition experts in Study 2 as the most important heuristic – and factors that support global and local food guidelines (H11), such as limiting the intake of ultra-processed foods.

Finally, findings from Study 3 inspired us to reflect on the importance of involving different research communities such as public health practitioners and dietitians in designing food-related technologies more holistically. This involvement is crucial due to the tensions we found between nutrition and HCI best practice in this study. Therefore, HCI researchers and designers must ensure these technologies encapsulate the best nutrition practices and support not only individual users but also the whole population. We believe that this involvement has implications for technologists and public health practitioners. Our heuristics can provoke conversations among those communities in an effort to find the best way to implement those heuristics to support individuals at a population level.

4.4 Using the Heuristics in Practice

Many HCI designers and practitioners might wonder how to use the heuristics in practice, so we provide some insights and clarifications on possible questions they might have, with further advice on the use of the heuristics. For instance, the number of heuristics a system should meet to be a good supporter of food literacy will depend on different factors, such as applicability. Therefore, depending on the system's domain, some heuristics might not be considered essential, as we found in participants' feedback from Studies 2 and 3. Thus, developing cooking abilities (H17) should be indispensable in a cooking simulator or a smart kitchen but might not be necessary for a restaurant delivery app, making it challenging to determine the exact number of heuristics a system should support.

Data availability can also be a constraint in determining what heuristics to use. For instance, if the system does not have sufficient data (e.g., nutrition information for produce), it will limit the designer from displaying this information for these products. Therefore, it is crucial to ensure data availability for the application of the heuristics by aligning this issue with the project's team in the early stages of design.

When defining which heuristics to use in evaluating or designing a novel system, the designer should reflect on whether the system needs to comply with a particular heuristic to help people develop food literacy. A good start is considering the top 10 heuristics (Table 3.4) as a quick guide and shortcut to ensure that the most critical heuristics are being considered. Moreover, considering the different food literacy categories (awareness, knowledge, and skills) depending on the system's domain can also be a suitable approach. For instance, HCI experts from Study 3 felt that 'Skills' heuristics are ideal for meal kit systems, as consumers must prepare the foods themselves at home. Thus, designers can provide the creation of meal plans for the consumer's family on a budget (H16, H20), help them develop cooking abilities (H17) while teaching food safety measures for handling and storing (H18, H19), and propose advice on creatively reusing leftovers afterwards (H19). These strategies could be applied, for instance, through short videos.

On the other hand, systems like food delivery apps can focus on the 'Knowledge' heuristics, with designers offering a detailed breakdown of ingredients and nutrients in each dish

(H9, H10, H14), enabling comparisons of their nutritional value (H13) for more informed choices, and educating consumers about them (H12) with additional advice from food guidelines (H11). Displaying dietary needs (H15) will also ensure consumers know they make the most appropriate meal choices according to their nutritional needs.

Finally, given the large variety of ultra-processed foods marketed by grocery stores, designers can mainly focus on the 'Awareness' heuristics within this domain by limiting exposure to ultra-processed foods (H6), offering health-oriented filters (H5) and sorting (H4) features, and using symbols and colours (H1) to help shoppers more efficiently select healthier options.

4.5 Limitations & Opportunities for Future Research

We focused the creation of our heuristics mainly for food literacy's domains of *planning* and *selecting* foods because they were most representative of the current applications of technology and HCI research. However, there are many other types of work in HCI that explore other domains such as *preparing* (e.g., Chi et al., 2007; Kato et al., 2013) and *eating* (e.g., Arakawa et al., 2007; Mueller et al., 2018). Our Skills heuristics such as 'Develop Cooking Abilities' (H17) and 'Teach food preparation' (H19) can clearly be applied in food preparation technology. Similarly, we can apply some heuristics in designs focused on enhancing the act of *eating*, such as exploring the visualization of portion sizes (H8). In addition, we envision that future work could explore social aspects of eating together, adding heuristics that focus on this experience since many technologies are going towards this direction (e.g., Arakawa et al., 2007; Mueller et al., 2018). This social aspect also aligns with the latest advice in global food guidelines, with recommendations such as 'Eat meals with others' (Health Canada, 2019) and 'Eat in company whenever possible' (FAO, 2014).

An essential aspect that HCI researchers should further explore in technology to improve food literacy is to also consider food security, as it is vital for all people as a prerequisite to using food literacy. The reason is that food choices are very limited in cases of food insecurity, and food literacy alone is not enough to help vulnerable populations affected by food insecurity (Gallegos, 2016). This issue is widely identified in the nutrition literature (Gallegos et al., 2014), and we also identified in results from our Study 1, involving students. Thus, it is crucial to acknowledge the importance of designing for food insecurity in future technology. Moreover, we specifically incorporated the heuristic 'Support budgeting' (H20) with food insecurity in mind, but designers can also combine other heuristics to improve this issue. For instance, by supporting strategic planning within a budget (H16) and teaching food storage (H18), people facing food insecurity can be given the opportunity to identify cheaper and healthier options that would fit into their budget while avoiding food waste with proper storage. In addition, developing cooking and preparation skills (H17, H19) can empower this population to select a broader range of food options to cook (Gaines et al., 2014).

Another direction for future work is investigating the impact of using our heuristics in big retail chains and other digital food environments, assessing how specific heuristics could improve their sales by attracting consumers interested in health and how food purchases are affected. Research on this area is essential to address the concern of some participants of Study 3 regarding the retailer's interests in the heuristics. Other studies can also explore the grocery shopping space using our heuristics in different contexts. For instance, involving children in grocery shopping has a positive impact in helping them develop a healthy relationship with food (Srikanth, 2019), which makes it an attractive approach to design technologies using our heuristics that fosters parents to shop together with their children. Designers can explore gameful design to foster motivation among children, as it has been shown to be a positive approach to promote healthy habits among this population (Suleiman-Martos et al., 2021). We also learned from Study 1 that exploring gameful design in the grocery store can teach and improve healthy choices among young adults. Thus, future work can involve children and their parents to assess if they can also promote healthier outcomes among this population.

Finally, as a food literacy measurement tool becomes available, HCI researchers can directly assess the impact of technologies using the heuristics on users' food literacy. This validation will be possible in the near future, as the Locally Driven Collaborative Projects (LDCP) program by Public Health Ontario is currently working on the development of a food literacy assessment tool (Public Health Ontario, 2020).

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APPENDICES

Appendix A

Mapping of Heuristics

Heuristic	Food Literacy Attribute Description	Website Feature
H1. Promote Sustainable Foods	Make sustainable food choices	Search results, Banners
H2. Interpret Nutrition Content	Awareness to prioritize nutrition information in food choices	Information visualization (e.g., Traffic light colours, Guiding Stars, "High in" symbols)
H3. Highlight Ingredients	Capacity to gain nutrition information	Highlight ingredients list
H4. Sort by Nutrition Values	Ability to choose the healthiest food option	Sort
H5. Filter by Nutrition Content	Awareness to prioritize nutrition information in food choices	Filter
H6. Limit Ultra-Processed Foods	Learn to prefer healthy, and nutritious food	Filter in search results
H7. Provide Healthy Suggestions	Learn to prefer healthy, and nutritious food	Product's suggestion
H8. Visualize Portion Sizes	Awareness of appropriate portion size	Information visualization (e.g., illustrative images)

H9. Show Ingredients	Ability to read labels	Ingredient's list
H10. Show Nutrition Facts	Ability to read labels	Nutrition facts table
H11. Follow Local Food Guides	Awareness of the type and/or varieties of foods (e.g., grain, vegetables)	Visualization of the Eat Well Plate, Text information
H12. Educate about Nutrients	Awareness of nutrients and their relevance to health and well-being	Text information
H13. Enable Comparisons	Ability to make informed food choices; Understanding how to select and purchase nutritious foods with a diverse number of choices	Comparison side-by-side
H14. Summarize Nutrition Info	Understanding how foods fit into a balanced diet	Shopping cart visualization
H15. Highlight Dietary Needs	Commonly used words or terms that distinguish nutritional characteristics of food (e.g., high-fibre, low-sodium)	Visualization of symbols
H16. Support Strategic Planning	Ability to planning meals	Shopping list, Meal plan feature
H17. Develop Cooking Abilities	Ability to perform cooking tasks such as reading recipes	Link to recipes, videos of recipes
H18. Teach Food Storage	Know how to properly store food	Text information
H19. Teach Food Preparation	Ability to perform basic kitchen skills like chop/mix/stir/measure ingredients and prepare meals	Text information, videos of preparations

H20. Support Budgeting	Understanding how to select and purchase nutritious foods and meals within a budget in a complex food environment with a diverse number of choices	Highlight healthy items on sale; have a "Sort by" feature combining lower price and more nutritious items

Table A.1: Mapping of Heuristics, Food Literacy Attributes, and Suggested Website Feature

Appendix B

Website Issues Found

Heuristic*	Description*	Category	Votes
H10	Uses nutrition symbols to advertise poor nutritional values on the products (e.g., high in sugar, high in sodium).	Awareness	12
H3	Facilitates the interpretation of nutrition facts (e.g., use of traffic light colours; guiding stars).	Awareness	11
H16	Educates about individual nutrients (e.g., why limiting sodium, why eating more fibre).	Knowledge	11
H2	Promotes foods that are produced locally.	Awareness	10
H15	Incorporates information from Canada's Food Guide (e.g., makes use of the Eat Well Plate).	Knowledge	10
H18	Provides a visualization of the cart's nutrition values (e.g., fibre, sodium, sugar).	Knowledge	10
H5	Allows the user to sort resulted products from a search based on specific nutritional values (e.g., low to high sodium)	Awareness	9
H7	Promotes more fresh foods as opposed to ultra-processed foods (e.g., home page, promotions).	Awareness	9

H17	Helps the user compare the nutritional value of different products.	Knowledge	8
H1	Promotes sustainable food choices (e.g., plant-based protein).	Awareness	7
H4	Facilitates the interpretation of the ingredients list (e.g., highlights added sugar in the ingredients list).	Awareness	7
H11	Helps shoppers visualize an appropriate portion size.	Awareness	7
H20	Supports strategic planning (e.g., meal planning).	Skills	7
H21	Helps the development of cooking self-efficacy (e.g., link to recipe videos).	Skills	7
H8	Suggests similar products as substitutions for a specific product (e.g., if it is out of stock).	Awareness	6
H23	Informs how to prepare the products.	Skills	6
H9	Uses nutrition labels to advertise the benefits of products (e.g., high in fibre, fortified with vitamin d).	Awareness	5
H14	Acknowledges where food is produced (e.g., country, place, producer).	Knowledge	5
H22	Informs how to store the products.	Skills	5
H19	Uses symbols on a product's view to highlight specific dietary needs (e.g., no milk, halal, gluten-free).	Knowledge	4
H24	Supports budgeting (e.g., highlighting healthy items on sale, link to local flyers, facilitates price match).	Skills	3
H13	Provides the nutritional facts of the products.	Knowledge	2
H6	Allows the user to filter products based on specific dietary needs or lifestyle (e.g., vegetarian, halal, organic).	Awareness	1
H12	Makes the products' lists of ingredients visible.	Knowledge	1

Table B.1: Study 2. Website issues found by Nutrition experts. *Heuristic number and description is based on the first version of the heuristics before the revisions.

Heuristic*	Description*	Category	Votes
H3	Highlight Ingredients	Awareness	12
H4	Sort by Nutrition Values	Awareness	12
H13	Enable Comparisons	Knowledge	12
H2	Interpret Nutrition Content	Awareness	11
H6	Limit Ultra-Processed Foods	Awareness	11
H7	Provide Healthy Suggestions	Awareness	11
H11	Follow Local Food Guides	Knowledge	11
H12	Educate about Nutrients	Knowledge	11
H14	Summarize Nutrition Info	Knowledge	11
H8	Visualize Portion Sizes	Awareness	10
H15	Highlight Dietary Needs	Knowledge	10
H19	Teach Food Preparation	Skills	10
H20	Support Budgeting	Skills	8
H1	Promote Sustainable Foods	Awareness	7
H5	Filter by Nutrition Content	Awareness	7
H16	Support Strategic Planning	Skills	7
H17	Develop Cooking Abilities	Skills	7
H18	Teach Food Storage	Skills	7
H9	Show Ingredients	Knowledge	6
H10	Show Nutrition Facts	Knowledge	6

Table B.2: Study 3. Website issues found by HCI experts. *Heuristic number and description is based on the final version after the revisions.

Appendix C

Food Literacy Heuristics – Extended Version

FOOD LITERACY HEURISTICS – EXTENDED VERSION

Food Awareness:

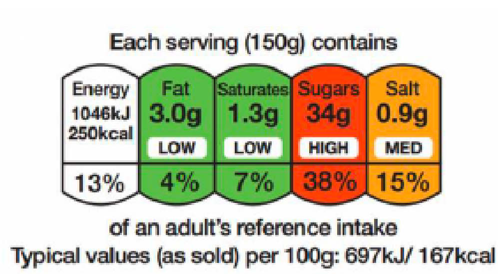
H1. Promote Sustainable Foods

Sustainable food choices are promoted in places such as search results, banners, and advertisements (e.g., Vegetarian options, in-season produce, local foods - same province or state)

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).

Traffic light colours:



Guiding Stars:

"High in" symbols:

Images sources: https://www.food.gov.uk/ | https://guidingstars.ca/ | https://www.paho.org/

H3. Highlight Ingredients

Highlight important ingredients like added sugar, saturated fats, artificial ingredients.

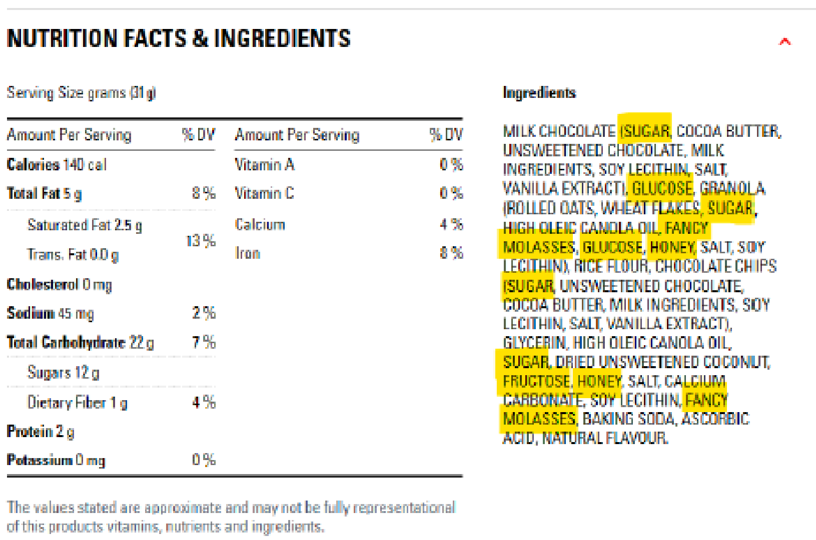


Image source (edited, highlighting added sugars): https://www.loblaws.ca/granola-bars-dipped-chocolate-chip/p/20913606_EA

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).

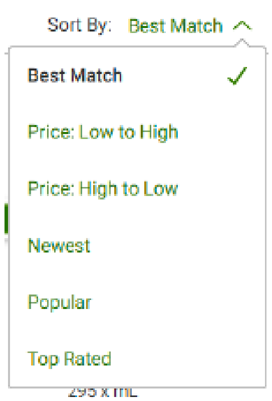
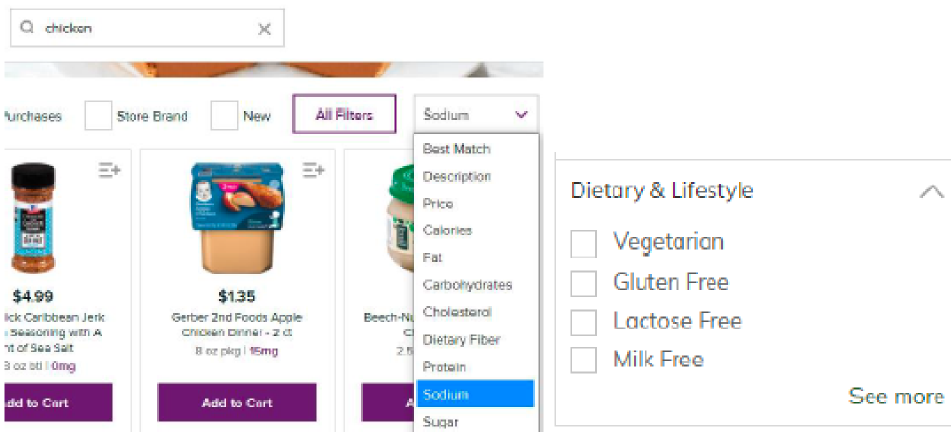


Image source: https://www.walmart.ca/

H5. Filter by Nutrition Content

Enable customers to filter products based on specific dietary needs or lifestyles (e.g. low sodium, sugar, gluten-free).



Images sources: https://giantfood.com/ | *https://groceries.morrisons.com/*

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).

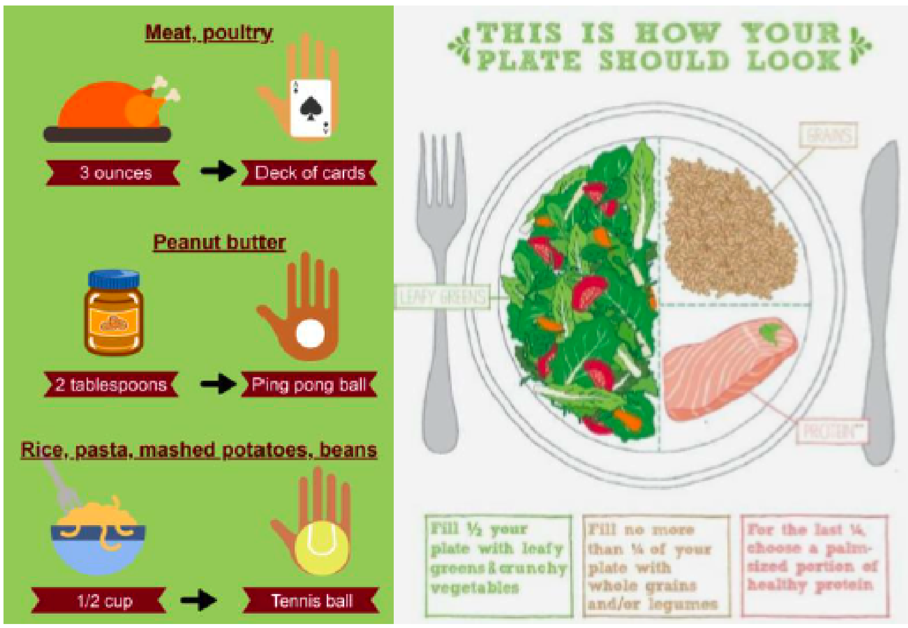
More Information: https://www.hsph.harvard.edu/nutritionsource/processed-foods/

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).



Images sources: https://extension.umn.edu/ | https://www.onemedical.com/

Food 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, and cooking more often, and limiting the intake of ultra-processed foods.

Image source (Canada's Food Guide): https://food-guide.canada.ca/en/

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.").

H13. Enable Comparisons

Enable customers to compare the nutrition value of two or more products side-by-side.

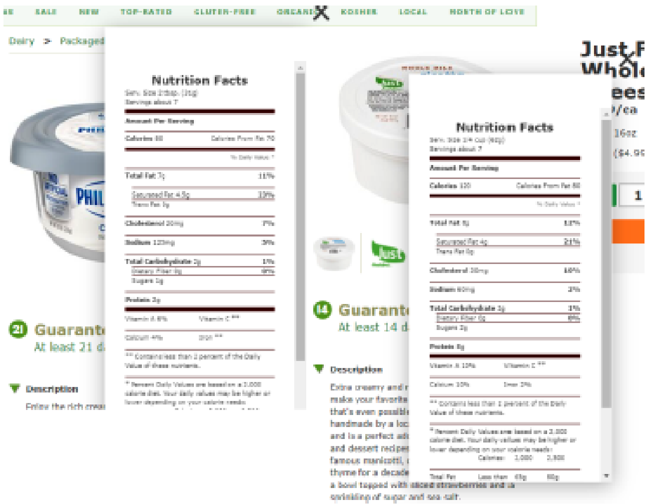


Image source (edited): https://www.freshdirect.com/

H14. Summarize Nutrition Info

Offer a visualization of nutrition information for all items in the shopping cart.

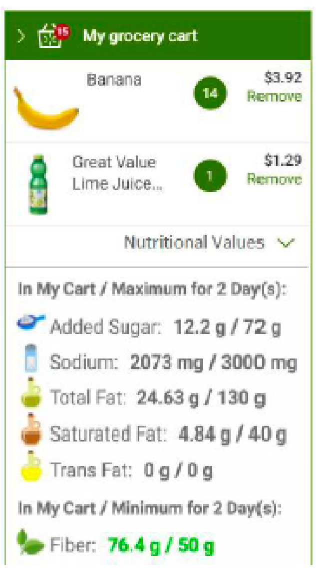


Image source (edited): https://www.walmart.ca/cp/grocery

H15. Highlight Specific 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).

Image source: https://freebiesupply.com/

Food 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 on-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 (e.g., inform the right temperature for cooked chicken) and how to integrate a product into a recipe (e.g. how to combine bell peppers in a preparation).

H20. Support Budgeting
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).

Appendix D

Health Belief Model Survey (HBMS) and General Nutrition Knowledge Questionnaire (GNKQ)

Health Belief Model Survey

This survey determines the influences the health determinants of health behaviour as they apply to decisions around healthy eating behaviour.

Please indicate your agreement for each one of the statements below:

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. Selecting healthy products most of the time would be beneficial to me					
2. What you eat can make a difference in your chance of getting a disease, like heart disease or cancer					
3. I will have more energy during my daily activities if I select and eat healthy food					
4. Controlling the consumption of sugar will help prevent me from some dietary-related diseases					
5. Eating the recommended number of servings of fruits and vegetables a day will help reduce cancer risk					
6. Eating less red meat will be beneficial for my health					
7. It is important to take into consideration a number of nutrients of foods, not only the number of calories, to predict if a product is healthy					
8. Having a healthy diet is costly					
9. Preparing and/or cooking healthy food is difficult					
10. It is hard to find a snack that is tasty and healthy					

11. Trying to find healthy foods will waste too much of my time					
12. Healthy foods are usually tasteless					
13. It is not convenient to have a healthy diet					
14. It is difficult to find healthy products					
15. If I do not eat healthily, I will be at high risk of some dietary-related diseases					
16. If I do not eat healthily, I will have a higher risk to have a weakened immune system, making me more susceptible to some immune-related diseases					
17. The thought of having an undesired weight due to an unhealthy diet concerns me					
18. The thought of ending up in the hospital due to dietary-related diseases scares me					
19. I would pay more attention to the quality of my food choices if I read information in the mass media (news stories, ads, other programs)					
20. I would make healthier food choices if I had someone close who incentivized me					
21. I would make healthier food choices if I had a better knowledge of the healthier options					
22. I would make healthier food choices if I had more time to dedicate					

23. I am confident that I can eat healthily during the next three weeks					
24. I am confident that I can select healthier groceries					
25. I am confident that I know the amount of nutrients and servings of food groups recommended for myself					
26. I intend to make healthy food choices most of the time in the next three weeks					
27. I will be more attentive about the amount of sodium I consume, and try to select foods with appropriate amounts					
28. I will be more attentive about the amount of sugar I consume, and try to select foods with appropriate amounts					
29. I will be more attentive about the amount of saturated fat I consume, and try to select foods with appropriate amounts					
30. I intend to eat the number of servings of fruits and vegetables that meets my daily recommendations					

GENERAL NUTRITION KNOWLEDGE QUESTIONNAIRE (GNKQ)

This is a survey, not a test. Your answers will help identify which dietary advice people find confusing. It is important that you complete it by yourself. Your answers will remain anonymous. If you don't know the answer, mark "not sure" rather than guess. Thank you for your time.

Section 1: The first few items are about what advice you think experts are giving us.

1. Do health experts recommend that people should be eating more, the same amount, or less of the following foods? (tick one box per food)

	More	Same	Less	Not Sure
Fruit	☐	☐	☐	☐
Food and drinks with added sugar	☐	☐	☐	☐
Vegetables	☐	☐	☐	☐
Fatty foods	☐	☐	☐	☐
Processed red meat	☐	☐	☐	☐
Wholegrains	☐	☐	☐	☐
Salty foods	☐	☐	☐	☐
Water	☐	☐	☐	☐

2. How many servings of fruit and vegetables per day do experts advise people to eat as a minimum? (One serving could be, for example, an apple or a handful of chopped carrots) (tick one)

2	☐
3	☐
4	☐
5 or more	☐
Not sure	☐

3. Which of these types of fats do experts recommend that people should eat less of? (tick one box per food)

	Eat less	Not eat less	Not sure
Unsaturated fats	☐	☐	☐
Trans fats	☐	☐	☐
Saturated fats	☐	☐	☐

4. Which type of dairy foods do experts say people should drink? (tick one)

Full fat (e.g. full fat milk)	☐
Reduced fat (e.g. skimmed and semi-skimmed milk)	☐
Mixture of full fat and reduced fat	☐
Neither, dairy foods should be avoided	☐
Not sure	☐

5. How many times per week do experts recommend that people eat oily fish (e.g. salmon and mackerel)? (tick one)

- 1-2 times per week ☐
- 3-4 times per week ☐
- Every day ☐
- Not sure ☐

6. Approximately how many alcoholic drinks is the maximum recommended per day (The exact number depends on the size and strength of the drink)? (tick one)

- 1 drink each for men and women ☐
- 2 drinks each for men and women ☐
- 2 drinks for men and 1 drink for women ☐
- 3 drinks for men and 2 drinks for women ☐
- Not sure ☐

7. How many times per week do experts recommend that people eat breakfast? (tick one)

- 3 times per week ☐
- 4 times per week ☐
- Every day ☐
- Not sure ☐

8. If a person has 1 cup of fruit in a day, how many of their daily fruit and vegetable servings would this count as? (tick one)

- None ☐
- One serving ☐
- Two servings ☐
- Three servings ☐
- Not sure ☐

9. According to the 'Canada's Food Guide' (a guideline showing the servings of food types people should eat to have a balanced and healthy diet), how many servings of Milk and Alternatives should an adult (19-50 years) aim for? (tick one)

- One ☐
- Two ☐
- Three ☐
- Four ☐

Section 2: Experts classify foods into groups. We are interested to see whether people are aware of food groups and the nutrients they contain.

1. Do you think these foods and drinks are typically high or low in added sugar? (tick one box per food)

	High in added sugar	Low in added sugar	Not sure
Diet cola drinks	☐	☐	☐
Natural yoghurt	☐	☐	☐
Ice cream	☐	☐	☐
Tomato ketchup	☐	☐	☐
Melon	☐	☐	☐

2. Do you think these foods are typically high or low in salt? (tick one box per food)

	High in salt	Low in salt	Not Sure
Breakfast cereals	☐	☐	☐
Frozen vegetables	☐	☐	☐
Bread	☐	☐	☐
Baked beans	☐	☐	☐
Red meat	☐	☐	☐
Canned soup	☐	☐	☐

3. Do you think these foods are typically high or low in fibre? (tick one box per food)

	High in fibre	Low in fibre	Not Sure
Oats	☐	☐	☐
Bananas	☐	☐	☐
White rice	☐	☐	☐
Eggs	☐	☐	☐
Potatoes with skin	☐	☐	☐
Pasta	☐	☐	☐

4. Do you think these foods are a good source of protein? (tick one box per food)

	Good source of protein	Not a good source of protein	Not sure
Poultry	☐	☐	☐
Cheese	☐	☐	☐
Fruit	☐	☐	☐
Baked beans	☐	☐	☐
Butter	☐	☐	☐
Nuts	☐	☐	☐

5. Which of the following foods do experts count as starchy foods? (tick one box per food)

	Starchy food	Not a starchy food	Not sure
Cheese	☐	☐	☐
Pasta	☐	☐	☐
Potatoes	☐	☐	☐
Nuts	☐	☐	☐
Plantains	☐	☐	☐

6. Which is the main type of fat present in each of these foods? (tick one box per food)

	Polyunsaturated fat	Monounsat -urated fat	Saturated fat	Cholesterol	Not sure
Olive oil	☐	☐	☐	☐	☐
Butter	☐	☐	☐	☐	☐
Sunflower oil	☐	☐	☐	☐	☐
Eggs	☐	☐	☐	☐	☐

7. Which of these foods has the most trans-fat? (tick one)

Biscuits, cakes and pastries	☐
Fish	☐
Rapeseed oil	☐
Eggs	☐
Not sure	☐

8. The amount of calcium in a glass of whole milk compared to a glass of skimmed milk is: (tick one)

About the same	☐
Much higher	☐
Much lower	☐
Not sure	☐

9. Which one of the following nutrients has the most calories for the same weight of food? (tick one)

Sugar	☐
Starchy	☐
Fibre/roughage	☐
Fat	☐
Not sure	☐

10. Compared to minimally processed foods, processed foods are: (tick one)

Higher in calories	☐
Higher in fibre	☐
Lower in salt	☐
Not sure	☐

Section 3: The next few items are about choosing foods

1. **If a person wanted to buy a yogurt at the supermarket, which would have the least sugar/sweetener? (tick one)**

0% fat cherry yogurt ☐
Natural yogurt ☐
Creamy fruit yogurt ☐
Not sure ☐

2. **If a person wanted soup in a restaurant or cafe, which one would be the lowest fat option? (tick one)**

Mushroom risotto soup (field mushrooms, porcini mushrooms, arborio rice, butter, cream, parsley and cracked black pepper) ☐

Carrot butternut and spice soup (carrot , butternut squash, sweet potato, cumin, red chillies, coriander seeds and lemon) ☐

Cream of chicken soup (British chicken, onions, carrots, celery, potatoes, garlic, sage, wheat flour, double cream) ☐

Not sure ☐

3. **Which would be the healthiest and most balanced choice for a main meal in a restaurant? (tick one)**

Roast turkey, mashed potatoes and vegetables ☐
Beef, Yorkshire pudding and roast potatoes ☐
Fish and chips served with peas and tartar sauce ☐
Not sure ☐

4. **Which would be the healthiest and most balanced sandwich lunch? (tick one)**

Ham sandwich + fruit + blueberry muffin + fruit juice ☐
Tuna salad sandwich + fruit + low fat yogurt + water ☐
Egg salad sandwich + crisps + low fat yogurt + water ☐
Not sure ☐

5. **Which of these foods would be the healthiest choice for a pudding? (tick one)**

Berry sorbet ☐
Apple and blackberry pie ☐
Lemon cheesecake ☐
Carrot cake with cream cheese topping ☐
Not sure ☐

6.	Which of these combinations of vegetables in a salad would give the greatest variety of vitamins and antioxidants? (tick one)
Lettuce, green peppers and cabbage	☐
Broccoli, carrot and tomatoes	☐
Red peppers, tomatoes and lettuce	☐
Not sure	☐

7.	If a person wanted to reduce the amount of fat in their diet, but didn't want to give up chips, which of the following foods would be the best choice? (tick one)
Thick cut chips	☐
Thin cut chips	☐
Crinkle cut chips	☐
Not sure	☐

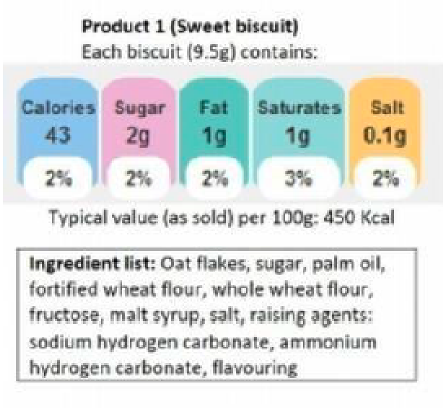
8.	One healthy way to add flavour to food without adding extra fat or salt is to add: (tick one)
Coconut milk	☐
Herbs	☐
Soya sauce	☐
Not sure	☐

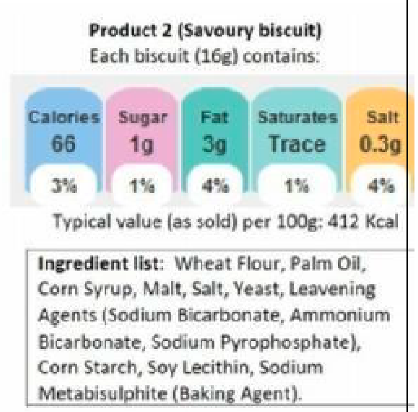
9.	Which of the following cooking methods requires fat to be added? (tick one)
Grilling	☐
Steaming	☐
Baking	☐
Sautéing	☐
Not sure	☐

10.	Traffic lights are often used on nutrition labelling, what would amber mean for the fat content of a food? (tick one)
Low fat	☐
Medium fat	☐
High in fat	☐
Not sure	☐

11.	"Light" foods (or Diet foods) are always good options because they are low in calories. (tick one)
Agree	☐
Disagree	☐
Not sure	☐

The following questions are related to food labels:





12. Looking at products 1 and 2, which one has the most calories (kcal) per 100 grams (tick one)

Product 1	☐
Product 2	☐
Both have the same quantity	☐
Not sure	☐

13. Looking at product 1, what are the sources of sugar in the ingredient list? (tick one)

Sugar and malt syrup	☐
Sugar, fructose and lecithin	☐
Sugar, fructose and malt syrup	☐
Not sure	☐

Section 4: This section is about health problems or diseases related to diet and weight management

1. Which of these diseases is related to a low intake of fibre? (tick one)

- Bowel disorders ☐
- Anaemia ☐
- Tooth decay ☐
- Not sure ☐

2. Which of these diseases is related to how much sugar people eat? (tick one)

- High blood pressure ☐
- Tooth decay ☐
- Anaemia ☐
- Not sure ☐

3. Which of these diseases is related to how much salt (or sodium) people eat? (tick one)

- Hypothyroidism ☐
- Diabetes ☐
- High blood pressure ☐
- Not sure ☐

4. Which of these options do experts recommend to reduce the chances of getting cancer? (tick one)

- Drinking alcohol regularly ☐
- Eating less red meat ☐
- Avoiding additives in food ☐
- Not sure ☐

5. Which of these options do experts recommend to prevent heart disease? (tick one)

- Taking nutritional supplements ☐
- Eating less oily fish ☐
- Eating less trans-fats ☐
- Not sure ☐

6. Which of these options do experts recommend to prevent diabetes? (tick one)

- Eating less refined foods ☐
- Drinking more fruit juice ☐
- Eating more processed meat ☐
- Not sure ☐

7. Which one of these foods is more likely to raise people's blood cholesterol? (tick one)

- Eggs ☐
- Vegetable oils ☐
- Animal fat ☐
- Not sure ☐

8. Which one of these foods is classified as having a high Glycaemic Index (Glycaemic Index is a measure of the impact of a food on blood sugar levels, thus a high Glycaemic Index means a greater rise in blood sugar after eating)? (tick one)

- Wholegrain cereals ☐
- White bread ☐
- Fruit and vegetables ☐
- Not sure ☐

9. To maintain a healthy weight people should cut fat out completely. (tick one)

- Agree ☐
- Disagree ☐
- Not sure ☐

10. To maintain a healthy weight people should eat a high protein diet. (tick one)

- Agree ☐
- Disagree ☐
- Not sure ☐

11. Eating bread always causes weight gain. (tick one)

- Agree ☐
- Disagree ☐
- Not Sure ☐

12. Fibre can decrease the chances of gaining weight. (tick one)

- Agree ☐
- Disagree ☐
- Not sure ☐

13. Which of these options can help people to maintain a healthy weight? (answer each one)

	Yes	No	Not sure
Not eating while watching TV	☐	☐	☐
Reading food labels	☐	☐	☐
Taking nutritional supplements	☐	☐	☐
Monitoring their eating	☐	☐	☐
Monitoring their weight	☐	☐	☐
Grazing throughout the day	☐	☐	☐

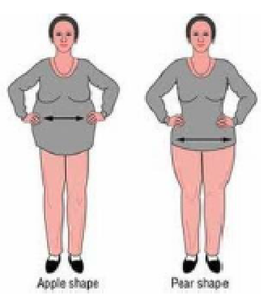
14. If someone has a Body Mass Index (BMI) of 23kg/m^2, what would their weight status be? (tick one)

Underweight	☐
Normal weight	☐
Overweight	☐
Obese	☐
Not sure	☐

15. If someone has a Body Mass Index (BMI) of 31kg/m^2, what would their weight status be? (tick one)

Underweight	☐
Normal weight	☐
Overweight	☐
Obese	☐
Not sure	☐

Look at the body shapes below:



16. Which of these body shapes increases the risk of cardiovascular disease (Cardiovascular disease is a general term that describes a disease of the heart of blood vessels, for example, angina, heart attack, heart failure, congenital heart disease and stroke)? (tick one)

Apple shape	☐
Pear shape	☐
Not sure	☐

Glossary

Eat well plate The Canada's food guide illustrative plate that shows the proportions of foods on a plate for healthy meals or snacks (Canada, 2019a).

Food balance Consuming foods from all four food groups (fruits & vegetables, grains, milk & alternatives, meat & alternatives) (Sizer et al., 2017).

Food insecurity Uncertain or insufficient access to food because of financial limitations (Gallegos et al., 2014).

Food literacy The interconnected combination of awareness, knowledge, skills, and behaviours that empower an individual to make informed food choices (Cullen et al., 2015; Vidgen et al., 2014; Slater, 2017; Ronto et al., 2016; Truman et al., 2017).

Food moderation Consuming enough food to sustain your body (neither too much nor too little) while not exceeding recommended amounts of food components like sugar, fat, and sodium (Sizer et al., 2017).

Food-related technologies Technologies within the context of food that deals with production, selection, management, tracking, and eating practices (Altarriba Bertran et al., 2019).

Food variety Consuming various types of different foods from within each food group (Sizer et al., 2017).

Formative evaluation A type of evaluation that helps to "form" the design for a product, aiming to improve and refine its design by applying a particular set of recommendations (Joyce, 2019).

Gameful design Designing non-game applications with game elements (Tondello et al., 2019).

Guiding stars A food rating system that rates food based on nutrient density using a scientific algorithm to assign a 0, 1, 2 or 3 star rating. Three stars is the highest rating a product can receive (Sutherland et al., 2010).

Human-Food Interaction Sub-field of Human-Computer Interaction that investigate how people interact with food through technology (Altarriba Bertran et al., 2019).

Summative evaluation A type of evaluation that describes how well a product performs by determining if its design meets specific measurable goals (Joyce, 2019).

Sustainable foods Foods with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations (FAO, 2010).

Techno-solutionism The attempt of using technological interventions to unilaterally solve individual or social issues through shortcuts and quick-fixes (Morozov, 2013).

Traffic-light colours A visual scheme that offers a quick glance nutritional content of a product or meal representing the amount of food components, categorized as low (green), medium (yellow) or high (red) (Sonnenberg et al., 2013).

Ultra-processed foods Foods made from processed substances extracted or refined from whole foods. They are typically high in calories, saturated and trans-fats, added sugars and sodium, and have little or no fibre or micro-nutrients (Moubarac et al., 2013).