

Designing Digital Technology to Empower Climate-Sensitive Food Purchases

A thesis presented for the degree of Doctor of Philosophy

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Abstract

A shift towards climate-sustainable diets is essential to achieve climate targets and mitigate disaster risks. Despite many people valuing climate-sensitive behaviours, a lack of knowledge and skill undermines action. Digital technology can aid this transition but faces ethical concerns with persuasive methods that may undermine autonomy. Also, prevalent design decisions may not always align well with actual usage patterns, which may undermine the potential of designs. This thesis examines how to design digital technology that supports climate-sustainable diets while addressing these considerations.

The study includes:

- A systematic literature review on opportunities and challenges of food purchase choice applications.
- Three empirical design chapters detailing participatory input and theory-driven procedures culminating in 'MyFoodprint', an app prototype tested in real-world settings.
- A theoretical debate on protecting individual autonomy with behaviour change design.

Key insights reveal:

- Digital tools should focus on educating users about 'foodprint' tailored to their purchasing behaviour.
- To preserve autonomy, attempts to motivate behaviours directly are best avoided.
- Design should not rely on consistent or long-term use.
- Positive support for the potential of MyFoodprint to empower sustainable choices.
- The use of word clouds visualizing product contributions to one's overall foodprint appeared particularly effective alongside support for finding alternative products.
- Indirect benefits included sparking discussions around foodprint.

Contributions include:

- Design implications from various study designs, including field observations.
- Insights into the practical and ethical feasibility of different design options.
- Theory-backed design artifacts available as resources for researchers.
- Categorization of intervention techniques based on their alignment with autonomy.

This work enhances understanding of how digital technology can empower individuals towards sustainable behaviours without compromising personal autonomy.

Declaration

I declare that this thesis was written by myself and that the work within is my own unless explicitly stated otherwise. The work in this thesis has not been submitted for other degrees or qualifications.

Publications arising from this work

Benthem De Grave, R. *et al.* (2024) “Smartphone Apps for Food Purchase Choices: Scoping Review of Designs, Opportunities, and Challenges,” *Journal of Medical Internet Research*, 26, p. e45904. Available at: <https://doi.org/10.2196/45904>.

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Note About The Program

This thesis is an outcome of the Behaviour Informatics Studentship¹. This program, funded by Leverhulme Trust, aims to further knowledge in the combined fields of behaviour (life sciences, social sciences and economics) or informatics (computing science, engineering and mathematics) by bringing together expertise from both domains. The first year of this PhD program was spent exploring potential PhD project topics through taster projects at different research institutes around Newcastle University. Any potential topic involved supervisors from both a behaviour domain and an informatics domain. My PhD thesis involved a supervisor collaboration from the domain of Human-Computer Interaction (Jan Smeddinck, and later Christopher Bull, from the Open Lab in the School of Computing Science) and the domain of Economics (Diogo de Souza Monteiro, from the School of Natural and Environmental Sciences). The choice of supervisors reflects my interest for behaviour economics (a field that “combines elements of economics and psychology to understand how and why people behave the way they do in the real world” (Witynski 2024)), my interest for the potential of digital technology as powerful tools to help addressing problems in this domain. Work on this thesis allowed me to develop valuable knowledge and skill in designing and developing digital technology, as well as understanding of the application of such systems in applied problems of human decision making (including important ethical—and practical—considerations of human autonomy in its application). I am looking forward to applying this acquired knowledge to facilitate valuable contributions in my future work.

¹<https://www.ncl.ac.uk/press/articles/archive/2018/03/leverhulmephds/>

List of Abbreviations

APEASE: Affordability, Practicability, Effectiveness and cost-effectiveness, Acceptability, Side-effects/safety, Equity

API: application programming interface

AWS: Amazon Web Services

BC: Behaviour Change

BCT: behaviour change technique

BCSS: Behaviour Change Support System

BCTT: Behaviour Change Technique Taxonomy

BCW: Behaviour Change Wheel

BQ: BigQuery (Google Cloud Console)

COM-B: capability, opportunity, motivation, behaviour model

EAI: Environmental Attitudes Inventory

FAQ: Frequently Asked Question

FBM: Fogg Behavior Model

FPC: food purchase choices

HCI: Human-Computer Interaction

IPCC: Intergovernmental Panel on Climate Change

IQR: Inter Quantile Range

JSON: JavaScript Object Notation

LME: Linear Mixed-Effect Model

MERN: Mongo DB, Express, React, Node.js stack

MUI: Material User Interface

NFC: near-field communication

NGO: Non-Governmental Organization

PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews

PSD: Persuasive System Design

PSDT: Persuasive System Design taxonomy

PWA: Progressive Web App

QCA: qualitative content analysis

RFID: radiofrequency identification

RfD: Research for Design

RiD: Research into Design

RtD: Research through Design

SDT: Self-Determination Theory

SHCI: Sustainable Human-Computer Interaction

TA: thematic analysis

UEQ-S: user experience questionnaire, short version

UX: User Experience

Chapter 1

Introduction

1.1 Background and Motivations

1.1.1 The Problem

In recent years there has been increased attention to the dramatic impacts of global warming and the human contribution to global warming through greenhouse gas emissions (GHGE, conventionally described as carbon emissions¹) (Masson-Delmotte et al. 2018; Berners-Lee 2019; Hansson, Cerratto Pargman, and Pargman 2021). Some examples of these dramatic impacts, ascribed to climate change, are increases in devastating wildfires (Fraser-Baxter 2023), increases in heavy rainfall in Europe, that may give rise to flooding such as the deadly German floods of 2021 (Carrington and editor 2021; Wehrmann 2024), devastating droughts in Africa leading to starvation and losses of livelihoods and many climate refugees (Harvey 2023; Kimutai et al. 2023; World Weather Attribution 2023), and the predicted imminent collapse of the Gulf Stream due to the rapid melting of sea ice—interfering with the mechanism that drives this ocean current—predicted to cause a substantial temperature decrease in Europe (Carrington and editor 2023).

It is widely accepted that carbon emissions need to be reduced substantially from current levels (Masson-Delmotte et al. 2018; UNFCCC 2024; United Nations 2024). While most attention has been given to the reduction of fossil fuel consumption, the role of food as a contributor to carbon

¹Various gasses have an important contribution to global warming. For example, besides Carbon Dioxide, Nitrogen Oxide and Methane have an important impact on global warming. These are collectively described as Greenhouse gasses (GHG). Different GHG have different effects on global warming and to quantify their collective effect, the term gram/kg/tons carbon dioxide equivalents (g/kg/tCO₂e) is used.

emissions is often overlooked. Yet, the carbon footprint associated with food (or foodprint (Birney et al. 2017)) is estimated to make up as much as 30% of our collective footprint (Vermeulen, B. M. Campbell, and Ingram 2012; Berners-Lee 2020, p. 304; Rosenzweig et al. 2020)—roughly equal to the carbon footprint of human transportation (Berners-Lee 2020, p. 304)—and originates predominantly from farming practices (particularly fertilizer use, the raising of livestock, deforestation, and heating of greenhouses)². Importantly, at current trends, the emissions from global food systems alone are estimated to eat up all or nearly all the remaining carbon budget for limiting global warming to 1.5°C or 2°C³.

1.1.2 Opportunities and Challenges

Amongst various factors that can be addressed to reduce foodprint (e.g., waste reduction and increasing agricultural efficiency) a change in consumer diets (i.e., practically the food that is purchased) is predicted to have the largest potential and is predicted to be critical in meeting global warming goals (M. A. Clark et al. 2020). Notably, these important reductions to our foodprint can be achieved without compromising healthiness and affordability (W. Willett et al. 2019; M. A. Clark et al. 2020). Yet, policymaking to drive change is slow and tedious and conflicted by other interests—even if some progress is being made, e.g. by efforts to introduce environmental footprint labels (Z. Wood 2021; Gumbau 2022; Figueiras 2023; George 2023).

Benefits can be expected from empowering people to pursue climate-sustainable food purchases. Research finds that many people are climate-sensitive, i.e., they value climate-sustainable behaviour (Nielsen 2016; Vermeir, Weijters, et al. 2020; Cromwell and Perkins 2021; Heard and Bogdan 2021), however these values appear poorly reflected in practical behaviour; there is

²A common misconception is that foodprint is dominated by energy use from transportation and that sourcing food locally is a sure way to reduce foodprint (Adrian K Clear, O’neill, et al. 2016; Berners-Lee 2020, p. 208). While this may be true in some cases (e.g., airfreight can nearly determine the foodprint of a product (Small World Consulting 2015; Berners-Lee 2020, p. 169)), most products are transported by ship (very efficient) or truck (efficient) (Small World Consulting 2015) and, overall, transport only makes up about 6% of foodprint (Small World Consulting 2015; Poore and Nemecek 2018). In contrast, local food products can be inefficient, particularly when heating of greenhouses is required (Berners-Lee 2020, p. 208), and result in a net increase in the foodprint of a product, despite being sourced locally. In general, foodprint is dominated by the emissions related to farming, which involve the use of high quantities of nitro-oxide in fertilizers (with nitro-oxide a very potent greenhouse gas, i.e., contributing much to global warming), and the raising of livestock, which has about 10% efficiency (i.e., for every calorie from animal product, about 10 calories of human-edible energy is required in animal feed) (Poore and Nemecek 2018; Berners-Lee 2020).

³Limit-goals of 1.5°C and 2°C global warming are associated with a tipping point of global warming above which the risk of climate disasters is expected to increase rapidly (Masson-Delmotte et al. 2018; M. A. Clark et al. 2020). For each limit-goal, the Intergovernmental Panel on Climate Change (IPCC) Masson-Delmotte et al. (2018) has established carbon budgets, i.e., the maximal acceptable amount of carbon emissions to meet the climate goals.

a value-behaviour, or value-intention gap (Vermeir and Verbeke 2006), (Vermeir and Verbeke 2008; Grunert, Hieke, and Wills 2014; De Silva, P. Wang, and Kuah 2020). Prior work finds that an important role in this value-behaviour gap is played by a lack of knowledge and awareness (Grunert, Hieke, and Wills 2014; de Boer, de Witt, and Aiking 2016; Macdiarmid, Douglas, and J. Campbell 2016; Lentz et al. 2018) and consequently skill and self-efficacy (Arlinghaus and C. A. Johnston 2018) (collectively, foodprint literacy) and that interventions to increase foodprint literacy may lead to increases in climate-sustainable choices (de Boer, de Witt, and Aiking 2016; Zapico, Katzeff, et al. 2016; Luca A Panzone et al. 2018; Katzeff et al. 2020). Also, indirect benefits may result from increases in foodprint literacy. If people feel capable, they are more likely to engage in a behaviour (Deci and Flaste 1996; Ryan and Deci 2000; Ryan and Deci 2020) and such engagement may translate to climate-sustainable behaviour in other domains (Truelove et al. 2014; Lauren et al. 2016). For one, individuals can have an important impact through their vote (Berners-Lee 2020, p. 388). In contrast, a lack of perceived personal effectiveness may lead people to dissociate from environmental problems (Shakeri, Jung, et al. 2023) and potentially engage in environmentally irresponsible and disruptive behaviour. It is thus important to empower people to engage in climate-sustainable behaviour⁴.

Promising opportunities may be found in the use of digital technology to support behavioural change (see e.g., Taj, Klein, and Van Halteren 2019; Crutzen 2021), not in the least because of the potential to provide tailored information at large scale at relatively low cost (König et al. 2021). Such systems are referred to as Persuasive Technology, Behaviour Change Support Systems (BCSS), or Digital Behaviour Change Interventions (Van Delden, De Vries, and Heylen 2019). Applied to the domain of environmental sustainability as eco-feedback technology (J. Froehlich, Findlater, and Landay 2010), digital can improve transparency and support reflection on individual and household practices as well as nudge people towards sustainable behaviours (Adrian K. Clear, Comber, et al. 2013; Comber and Thieme 2013; Herbig, Kahl, and Krüger 2018; Katzeff et al. 2020; Luca A. Panzone, Larcom, and She 2021; Shakeri and McCallum 2021; Hedin, Grönborg, and Johansson 2022), and recent years have seen substantial rise in such systems being developed (Hansson, Cerratto Pargman, and Pargman 2021).

Despite the potential of Behaviour Change Support Systems, ethical concerns have been raised about the application of behaviour change interventions and the use of digital technology to

⁴I acknowledge the view presented in a recent review of sustainable HCI (SHCI) literature (Bremer, Knowles, and A. Friday 2022), concluding that a shift is needed towards Decision Support Systems to inform governmental decision making, and away from technologies that target individual behaviour. Here I have made a case why I believe that continued attention for individual behaviour remains important.

support their cause. Behaviour change interventions are traditionally outcome centred, rather than person-centred (Tengland 2012), and can quickly become manipulative and coercive⁵ (J. Davis 2009; Brynjarsdottir et al. 2012; Tengland 2012; Botes 2023), thus infringing with individual autonomy or self-determination (Ryan and Deci 2000; Ryan and Deci 2017; Ryan and Deci 2020; Tengland 2012). Persuasive designs can (intentionally or not) emphasize individual responsibility for sustainable behaviour, which has been condemned in critical literature (Brynjarsdottir et al. 2012), not in the least because it can draw attention away from the responsibility of corporations and governments whose actions are generally much more influential than those of individuals. These ethical issues can also have very practical consequences as perceived pressure and manipulation can backfire as people may become avoidant or defiant to the perceived influence (Stibe and Cugelman 2016; Irmak, Murdock, and Kanuri 2020; van der Laan and Orcholska 2022). Perceived external control or incentive can also erode intrinsic motivation for a behaviour, and behaviour may become dependent on the continued effective delivery of incentives and control (which may be difficult or expensive) and otherwise dwindle (Ryan and Deci 2000; Ryan and Deci 2020). Instead of prescriptive solutions, an empowering approach focuses on supporting individuals to build their capacity for effective action; helping them prioritise meaningful changes, develop practical competence, and sustain behaviour over time.

1.1.3 State of the Art and Gaps

Digital technology, particularly persuasive technology, plays an increasingly prominent role in promoting sustainable behaviours. Recent years have seen a handful of prototypes and studies exploring digital eco-feedback for food purchasing—ranging from traffic-light ratings in shopping-list apps (A. Clear and F. Friday 2012; Shakeri and McCallum 2021) to data sculptures (Sauvé, Bakker, and Houben 2020) and personalized dashboards (Katzeff et al. 2020; Hedin, Grönborg, and Johansson 2022). These systems show success in raise awareness of carbon footprints, yet a review (see Section 2.7.1) reveals five critical gaps that my thesis seeks to address. A complete description of the gaps is provided in Section 2.7.2, but I summarise them here:

⁵While Persuasive Technology is in principle assumed not to be coercive (Fogg, Danielson, and Cuellar 2009), this notion is challenges in critical literature (J. Davis 2009; Brynjarsdottir et al. 2012). According to this literature, the assumption that Persuasive Technology is not coercive follows from the assumption that people are rational and engage in conscious decision making. However, most decisions are unconscious (Kahneman 2003). Much of our behaviour is driven by habits and heuristics (Thaler and Sunstein 2008; Kahneman 2012). As a result, people are often poorly defended against the persuasiveness of Persuasive Technology, which then can be effectively perceived as coercive (J. Davis 2009; Brynjarsdottir et al. 2012).

1. **Awareness–Action Disconnect:** Designs raise knowledge but rarely focus on practical know-how and skill-building.
2. **Misaligned Metrics & Context:** Per-100 g measures and isolated snapshots obscure low-impact-high-volume purchases and offer little longitudinal perspective.
3. **Autonomy & Empowerment Overlooked:** Few studies probe user agency, while some designs risk feeling judgmental. Participatory methods remain rare.
4. **Unrealistic Engagement Assumptions:** Prototypes presume sustained use, despite evidence of early abandonment; they lack designs optimized for short-burst interactions.
5. **Scalability & Data Quality Limits:** Physical installations and bespoke dashboards fail to scale; real-time carbon databases remain incomplete, undermining trust.

1.2 Research Questions and Thesis Structure

This thesis addresses these gaps by exploring how persuasive technology can be designed to foster foodprint literacy while respecting user autonomy. By examining existing interventions and developing new design approaches, this research aims to bridge the gap between climate-conscious intentions and everyday food choices. Through a human-centred, empowerment-focused perspective, it seeks to advance the design of digital tools that not only raise awareness but also build users' confidence, skills, and motivation to reduce their footprint.

Building on this foundation, the central aim of this thesis is to investigate how foodprint eco-feedback technologies can be designed to empower consumers in making climate-sensitive food choices, rather than merely nudging them toward pre-determined behaviours. Specifically, the research explores how these tools can foster foodprint literacy—combining knowledge with practical skill—while maintaining respect for user autonomy. Recognising the challenges of technology abandonment and the realities of sporadic engagement, this thesis pays particular attention to how interventions can maximise impact even in brief user encounters, and how they can support users in prioritising actions that align with their personal values and contexts.

As such, the overarching research question guiding this work is (**Core RQ**):

How can digital eco-feedback technologies be designed to empower consumers to make environmentally sustainable food choices, while respecting user autonomy and supporting the development of practical decision-making capabilities?

To answer this, the thesis follows a staged, cumulative research structure, moving from conceptual groundwork to applied design and empirical evaluation (Figure 1.1). In this endeavour, each of the core chapter addresses a distinct set of sub-questions.

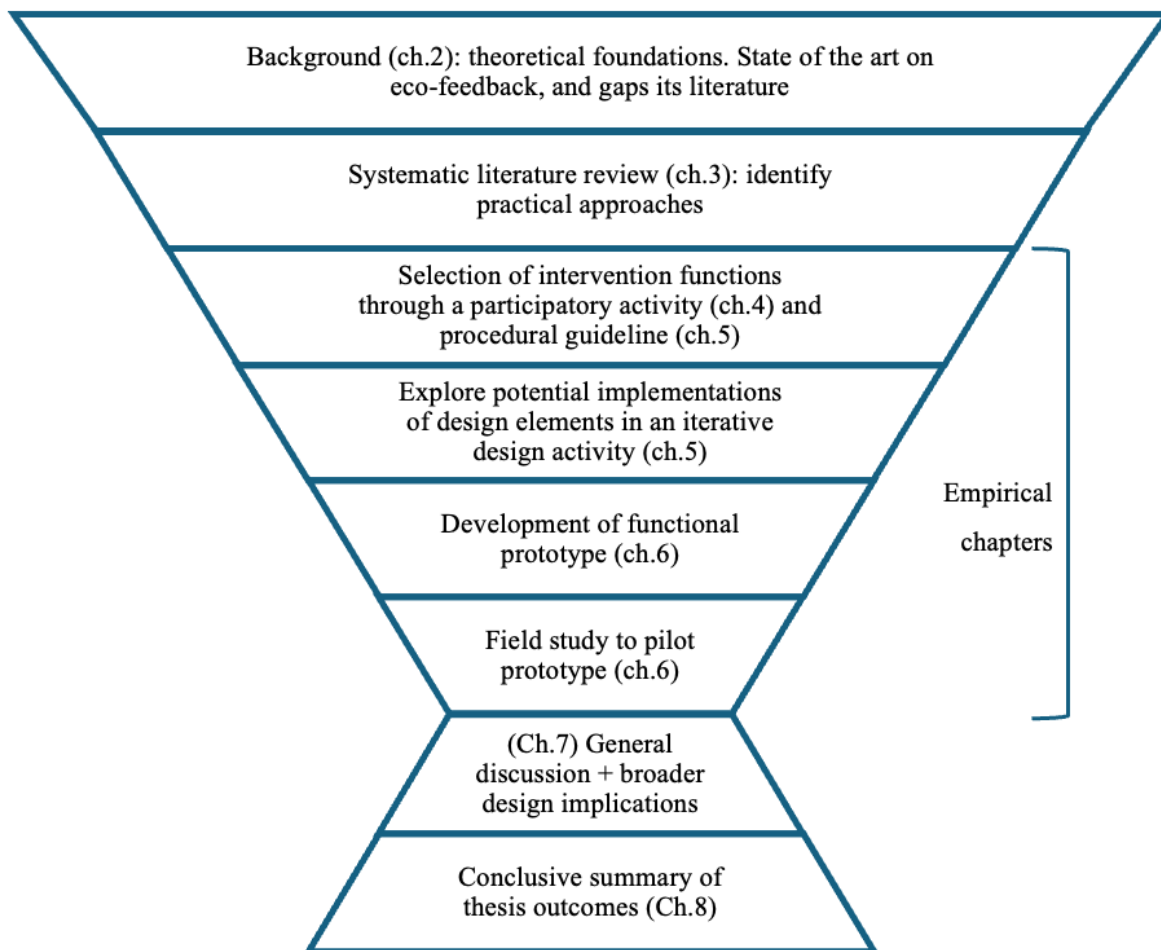


Figure 1.1: Schematic of the thesis structure. The chapters inform one another and initially the focus narrows as designs are specified in increasing detail, after which a wider reflective angle is taken in the last two chapters.

Chapter 1 — Introduction

No specific research questions, but this chapter will:

- Outline the climate impact of food systems.
- Introduce the gap between consumer values and behaviour.
- Highlight the need for tools that go beyond nudging to empower informed choice.
- Present the thesis structure and research questions.

Chapter 2 - Background chapter

- Provides an overview of theoretical foundations, including persuasive technology, behaviour change theories, autonomy, empowerment, foodprint literacy, and ethical design considerations.
- Reviews the state of the art in digital eco-feedback systems, and identifies gaps in current literature.

Chapter 3 - Smartphone Apps for Food Purchase Choices: Scoping Review of Designs, Opportunities, and Challenges

This chapter surveys existing persuasive technologies for support food purchase choices (specifically, smartphone applications). It focuses on the potential and challenges of current systems to impact effective changes in food purchase choices. This survey covers applications beyond those that support climate-sustainable choices, thus benefiting the richness of features and moments of intervention that are categorized.

- Establishes the landscape of existing food purchase apps.
- Identifies design patterns, strengths, and limitations across.
- Helps shape subsequent focus on environmentally sustainable choices.
- Provides a foundation for the design of a digital foodprint tool.

Research Questions:

- RQ3.1: What design approaches have been used in smartphone applications to support consumers' food purchase choices?
- RQ3.2: What opportunities and challenges to impacting changes in food purchase choices are identified in this literature?

Chapter 4 - Attitudes towards design features

This chapter focuses on evaluating how climate-sensitive individuals perceive various design features of a self-monitoring application intended to support sustainable grocery shopping, framed around a first conceptual design for a digital foodprint tool. By contextualizing the findings from the participant interaction with related literature, recommendations are made for the support function of an application, i.e., how an application should provide support (e.g., education, motivation, etc., comparable to the definition of intervention functions in behaviour change literature (Michie, van Stralen, and West 2011)).

Research Question:

- RQ4: How can user-involved design with target users inform the development of an app to support climate-sensitive grocery shopping? Specifically, what features do users approve-off or propose for an app that provides feedback on grocery purchases to encourage climate-sustainable choices and how can this knowledge be used to inform design recommendations

Chapter 5 — Tracing Foodprints: Iterative Design to Explore Design Elements for a Digital Tool for Fostering Carbon-Aware Diet Choices

This chapter focuses on iterative prototyping, UX evaluation, and applying theory-informed design elements. This chapter presents the design and development of a prototype foodprint eco-feedback tool. Informed by the findings of the previous chapters, it explores design strategies to support foodprint literacy, prioritisation, and empowerment in practice.

Research Questions:

- RQ5.1: How can a theory-informed, iterative design process be used to develop a smartphone application that empowers people to reduce their “foodprint”?
- RQ5.2: What design improvements and user feedback emerge across multiple prototype iterations, and how do they inform the final climate-sensitive food purchase support tool? In particular, how can data be visualised to enhance users’ confidence and self-efficacy in making climate-conscious food choices?

Chapter 6 — Evaluating Empowering Foodprint Eco-Feedback

This chapter evaluates the developed prototype in the wild, examining its impact on user experience, self-efficacy, and behavioural intention. It also reflects on how users perceive autonomy within the intervention.

Research questions:

- RQ6.1: What is the user experience and potential impact of the developed MyFoodPrint prototype on encouraging climate-sustainable food purchases in a real-world context?
- RQ6.2: In what ways does using the app influence users’ foodprint literacy, decision-making, and engagement with sustainable food choices during a field deployment?

Chapter 7 — Discussion

Synthesis of findings from empirical chapters 4 to 6

- Broader implications for autonomy-respecting digital intervention design.
- Reflects on contributions to research and practice.
- Proposes an Autonomy-Respectful Design Guide.

Chapter 7 — Conclusion

- Summarises findings.
- Outlines future research directions.

1.3 Overview of Approach and Study Methodology

This study takes a pragmatic philosophical approach and abductive reasoning to address the research question (Glasgow 2013). Unlike the approach of positivism, the pragmatic philosophical approach does not pose that science should only concern itself with the pursuit of knowledge through quantifiable observations, nor denies all existence of shared truths and that science should restrict itself to studying people’s experiences (interpretivism). Instead, the pragmatic approach acknowledges that different scientific approaches can lead to gaining knowledge about the world and that the combination of approaches may be valuable to gain a broader understanding of a subject under study (abductive reasoning). The pragmatic approach embraces the use of a combination of approaches that work best to address the specific problem at hand and commonly applies mixed-method approaches. The pragmatic approach is considered particularly suitable for finding solutions to real-world problems (Glasgow 2013), which is how I view the problem that I am to address and why I choose to use this approach in my thesis. As such, I do not rigorously hold to specific methods or frameworks, but rather select from the frameworks that best appear to fit my research aim. Following the pragmatic approach, I use mixed methods in my empirical works, combining qualitative and quantitative results to mutually support nuance in the interpretation of findings (e.g., embedded mixed methods design) (Johnson, Anthony J. Onwuegbuzie, and Turner 2007).

Also, per the pragmatic approach, this research applies neither uniquely participatory design, nor uniquely expert-led design as an approach to design, but rather aims to bring in values of both approaches. However, as a whole the design approach may be considered to lean towards expert-led design, following an approach that has much in common with Value Sensitive Design⁶

⁶Value Sensitive Design is a design methodology proposed by Friedman and colleagues (Friedman et al. 2013) that centres around a systematic investigation and analysis of stakeholder values for the design of digital systems. The approach includes a thorough review of relevant philosophical and theoretical literature around stakeholder

(Friedman et al. 2013). Participant engagements are used to understand values and perceptions of various elements of a possible design and to steer the general direction. For the practical design and development of prototypes, the thesis integrates the procedure of the BCW (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014) to select intervention techniques for the design (i.e., the active ingredients (Silva, Hay-Smith, and Graham 2023) in a design that support or promote a behaviour response). Practically, the design starts with visual prototypes that are turned into interactive prototypes in Figma and eventually proceeds to the development of a functional prototype using the MERN⁷ (MongoDB, Express, React, and Node.js) framework with D3.js for data visualizations.

The work in this thesis fits under the umbrella of Design Research. As a whole, I consider the thesis as Research through Design (RtD), improving the world and understanding the world through making (Frayling 1993, p. 5; Olson and Kellogg 2014, p. 167), while on a chapter basis the work may be predominantly characterized as Research for Design (RfD) or Research into Design (RiD) (Frayling 1993, p. 5; Olson and Kellogg 2014, p. 167). Through investigating existing designs to inform future design, RiD is predominantly present in Chapter 3 (a systematic scoping literature review of digital technology to support food purchase choices) and in considerable portions of Chapter 5 (involving the review of related works to inform the practical implementation of theory-informed design paths). Chapter 7, where a guiding principle is proposed for designing (paradoxical⁸) behaviour change technology that aims to empower, can be understood as RfD. The application of the Behaviour Change Wheel (BCW)—a framework to guide theory-informed intervention design (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014)—in Chapter 5, can also be understood as RfD. On a chapter basis, Research through Design (RtD) is presented in a creative and exploratory design activity with participants as co-designers to identify design elements for a potential prototype and to study the attitudes of potential users to various design elements (Chapter 4), and in the design and evaluation of design prototypes (Chapter 5 and Chapter 6).

values as well as the involvement of potential users early in the design stage to capture important values that may have been missed in the literature review and analytical mapping of values. This approach does however not put emphasis on the potential user as an active participant in the design. The design approach in the thesis reflects many facets of VSD, but also engages potential users as participants in the design (see Chapter 4).

⁷The MERN Stack is a web-based JavaScript centred framework, using for the front-end (user-interface) the JavaScript based React platform react.dev—optimized for interactive content and characterized by and the JavaScript based Node.js nodejs.org platform for the backend, which communicates with a MongoDB www.mongodb.com data platform. Express expressjs.com is framework that is integrated within the Node.js backend to support structuring the communication between front and backend.

⁸Paradoxical as empowerment and behaviour change may be seen as contrasting approaches (Tengland 2012), where Behaviour Change reflects a prioritization of the outcome, whereas empowerment reflects a prioritization of personal autonomy (see, Section 2.6).

1.4 Terminology of Important Concepts

Below I list some important concepts that the reader is recommended to review to benefit comprehension of the thesis chapters, particularly as some terms may receive a different connotation in other literatures. This list is not intended to be a conclusive overview of terms used in this thesis, but rather a reduced list of concepts that I wish the reader to consider at this point.

Autonomy	Also, Self-determination. This concept relates to the voluntary, pursuit of behaviour, and is considered a general human right (United Nations 1948). Autonomous behaviour contrasts with pressured, manipulated, and coerced behaviour (Tengland 2012; A. W. Wood 2014; Botes 2023), including the behaviour resulting from pressuring oneself due to internalizing of internalized external pressure (Ryan and Deci 2000; Ryan and Deci 2020).
BCSS	Behaviour Change Support System (Oinas-Kukkonen 2010), is a term to describe digital technology to support or promote people in their pursuit of behaviour change; also Persuasive Technology, or Digital Behaviour Change Intervention (Van Delden, De Vries, and Heylen 2019). In this thesis I sometimes prefer BCSS over Persuasive Technology, due to the connotation associated with Persuasive Technology as “more akin to coercion than rhetoric” (Brynjarsdottir et al. 2012) and ethically problematic (J. Davis 2009; J. Davis 2012; Brynjarsdottir et al. 2012), even if this connotation is not always warranted (Bremer, Knowles, and A. Friday 2022) as designs can predominantly support ability (or capability) and as such be considered as empowering (Johnstone 2007; Kleine 2010).
BCTT	Behaviour Change Technique Taxonomy (Michie, Richardson, et al. 2013), a taxonomy of theory-informed intervention techniques.
Carbon budget	The maximal acceptable amount of carbon emissions to meet the climate goals, specifically used in the context of the limit-goals of 1.5°C and 2°C global warming (Masson-Delmotte et al. 2018).

Climate-sensitive people	People who hold values of climate sustainability and wish to consider such values in their behaviour. The term is chosen not to insinuate that climate-sustainable values exist in a vacuum and fully determine a behaviour. On the contrary, it is acknowledged that autonomous, self-induced behaviour results from a balance of competing values (Rosenstock 1974; Tengland 2012) and that people may sometimes choose to prioritise other values and behave inconsistent with climate-sustainable values, while still acting within their overall set of values. However, given a situation of little internal value conflict, climate-sensitive people are expected to choose in favour of climate-sustainable characteristics.
Empowerment	Here defined as <i>“The process in which a person or a unified group of people gains in ability to pursue their values or is therein supported without being controlled or otherwise restricted in their autonomy.”</i> For this thesis, I modified definitions of Zimmerman (Zimmerman 1995) and Rappaport (Rappaport 1985) to reflect the potential of digital technology as an active agent in the process, while stressing the importance of the person or group’s autonomy as in Tengland (Tengland 2012) and Schneider et al. (Schneider et al. 2018).
Foodprint	The carbon footprint (greenhouse gas emissions, GHGE) associated with food
Foodprint literacy	The combination of knowledge and skills (including practical knowledge) to acquire climate-sustainable food.
Intervention techniques	Also, active mechanisms, i the active ingredients (Silva, Hay-Smith, and Graham 2023) in a design that support or promote a behaviour response, such as those listed in the BCTT or PSDT
PSDT	A taxonomy of intervention techniques as published in the Persuasive System Design Model (Oinas-Kukkonen and Harjuma 2009), specific to the design of digital technology to support or promote behaviour change.

Chapter 2

Background

2.1 Introduction

This chapter provides an overview of the foundational concepts and literature relevant to this thesis. The background section can conceptually be divided into two sections. A higher-level background section that sets the stage for an in-depth state of the art review of foodprint eco-feedback technology.

A higher-level background section begins by exploring the role of food in carbon emissions and the concept of foodprint, followed by a discussion on strategies for reducing foodprint, with a focus on behaviour change and foodprint literacy. The chapter then delves into the discipline of behaviour change, its frameworks, and ethical considerations. Next, it examines persuasive technology, its applications, and its intersection with behaviour change interventions. The chapter also highlights the domains of Sustainable HCI and Food HCI, emphasizing their relevance to this research. I then take a dive into the individual autonomy, a topic of frequent concern in Behaviour Change and Persuasive Technology.

Finally, the chapter concludes with a review of the state of the art in foodprint eco-feedback technology and identifies critical gaps in the literature.

2.2 Foodprint and Foodprint Literacy

2.2.1 The Role of Food in Carbon Emissions

It is widely accepted that carbon emissions need to be reduced substantially from current levels (Masson-Delmotte et al. 2018; UNFCCC 2024; United Nations 2024). While most attention has been given to the reduction of fossil fuel consumption, the role of food as a contributor to carbon emissions is often overlooked. Yet, the carbon footprint associated with food (or foodprint (Birney et al. 2017)) is estimated to make up as much as 30% of our collective footprint (Vermeulen, B. M. Campbell, and Ingram 2012; Berners-Lee 2020, p. 304; Rosenzweig et al. 2020)—roughly equal to the carbon footprint of human transportation (Berners-Lee 2020, p. 304).

2.2.2 Carbon Budgets and Foodprint Impact

Limit-goals of 1.5°C and 2°C global warming are associated with a tipping point of global warming above which the risk of climate disasters is expected to increase rapidly (Masson-Delmotte et al. 2018; M. A. Clark et al. 2020). For each limit-goal, the Intergovernmental Panel on Climate Change, Masson-Delmotte et al. (2018), has established carbon budgets, i.e., the maximal acceptable amount of carbon emissions to meet the climate goals. Importantly, at current trends, the emissions from global food systems alone are estimated to eat up all or nearly all the remaining carbon budget for limiting global warming to 1.5°C or 2°C.

2.2.3 Misconceptions About Foodprint

A common misconception is that foodprint is dominated by energy use from transportation and that sourcing food locally is a sure way to reduce foodprint (Adrian K Clear, O’neill, et al. 2016; Berners-Lee 2020, p. 208). While this may be true in some cases (e.g., airfreight can nearly determine the foodprint of a product (Small World Consulting 2015; Berners-Lee 2020, p. 169)), most products are transported by ship (very efficient) or truck (efficient) (Small World Consulting 2015) and, overall, transport only makes up about 6% of foodprint (Small World Consulting 2015; Poore and Nemecek 2018). In contrast, local food products can be inefficient, particularly when heating of greenhouses is required (Berners-Lee 2020, p. 208), and result in a net increase in the foodprint of a product, despite being sourced locally. In general, foodprint is dominated by the emissions related to farming, which involves the use of high quantities of

nitro-oxide in fertilizers (with nitro-oxide a very potent greenhouse gas, i.e., contributing much to global warming), and the raising of livestock, which has about 10% efficiency (i.e., for every calorie from animal product, about 10 calories of human-edible energy is required in animal feed) (Poore and Nemecek 2018; Berners-Lee 2020).

2.2.4 Strategies for Reducing Foodprint

2.2.4.1 The Role of Behaviour Change in Foodprint Reduction

Amongst various factors that can be addressed to reduce foodprint (e.g., waste reduction and increasing agricultural efficiency) a change in consumer diets (i.e., practically the food that is purchased) is predicted to have the largest potential and is predicted to be critical in meeting global warming goals (M. A. Clark et al. 2020). Notably, these important reductions to our foodprint can be achieved without compromising healthiness and affordability (W. Willett et al. 2019; M. A. Clark et al. 2020). Yet, policymaking to drive change is slow and tedious and conflicted by other interests—even if some progress is being made, e.g. by efforts to introduce environmental footprint labels (Z. Wood 2021; Gumbau 2022; Figueiras 2023; George 2023).

2.2.5 Foodprint Literacy and Its Importance

2.2.5.1 Addressing the Value-Behaviour Gap Through Foodprint Literacy

Rather than relying solely on policy measures to drive behaviour change, an alternative approach to supporting climate-sensitive food choices may be found in education and empowerment. By enhancing people's knowledge and skills regarding foodprint, individuals can make informed decisions that align with their values and contribute to a more sustainable food system. This approach is particularly relevant given the well-documented value-behaviour gap, which often impedes climate-sensitive choices (Vermeir and Verbeke 2006; Grunert, Hieke, and Wills 2014; De Silva, P. Wang, and Kuah 2020).

Research indicates that many individuals are climate-sensitive, meaning they value climate-sustainable behaviour (Nielsen 2016; Vermeir, Weijters, et al. 2020; Cromwell and Perkins 2021; Heard and Bogdan 2021). However, these values are not always reflected in their practical behaviours, highlighting a disconnect known as the value-behaviour, or value-intention gap (Vermeir and Verbeke 2006; Vermeir and Verbeke 2008; Grunert, Hieke, and Wills 2014; De Silva,

P. Wang, and Kuah 2020). Prior studies suggest that a key factor contributing to this gap is a lack of knowledge and awareness (Grunert, Hieke, and Wills 2014; de Boer, de Witt, and Aiking 2016; Macdiarmid, Douglas, and J. Campbell 2016; Lentz et al. 2018). This, in turn, affects individuals' skills and self-efficacy, limiting their ability to translate values into meaningful action (Arlinghaus and C. A. Johnston 2018).

2.2.5.2 Defining Foodprint Literacy

I introduce the term *Foodprint literacy* to describe the combined knowledge and skills—both theoretical and practical—needed to acquire climate-sustainable food. This concept draws from an analogy with *food literacy*, which refers to the knowledge and skills required to acquire and prepare healthy food (Palumbo 2016; Truman, Lane, and Elliott 2017). *Foodprint literacy* extends the idea of *food carbon literacy*, as introduced by Hedin et al. Hedin, Grönborg, and Johansson (2022), by explicitly incorporating the role of practical skills in making climate-conscious food choices. In contrast, Hedin et al.'s definition appears to focus primarily on knowledge without an apparent emphasis on practical application.

It is important to note that Hedin et al. provide a far more detailed framework for *food carbon literacy*, dividing it into three distinct components: *food product carbon literacy*, which refers to knowledge of greenhouse gas emissions associated with different food products relative to one another and to non-food-related emissions; *food handling carbon literacy*, which concerns knowledge of emissions related to food handling practices; and *financial food carbon literacy*, which involves the ability to assess the financial implications of selecting foods that meet both nutritional needs and have low greenhouse gas emissions, as well as the ability to identify cost-effective low-emission food options. This thesis does not adopt such a detailed subdivision but instead presents *Foodprint literacy* as a broader, more encompassing concept that integrates both knowledge and skill in pursuing climate-sustainable food choices.

2.2.6 How Foodprint Literacy Can Drive Climate-Sensitive Choices

Enhancing foodprint literacy has the potential to drive more climate-sustainable choices (de Boer, de Witt, and Aiking 2016; Zapico, Katzeff, et al. 2016; Luca A Panzone et al. 2018; Katzeff et al. 2020). Beyond its direct influence on food-related decisions, increasing foodprint literacy can also yield significant indirect benefits. When individuals feel capable and confident in their

ability to act, they are more likely to engage in sustainable behaviours (Deci and Flaste 1996; Ryan and Deci 2000; Ryan and Deci 2020). Moreover, this engagement can extend beyond food choices, fostering climate-conscious behaviour in other domains (Truelove et al. 2014; Lauren et al. 2016).

For instance, individuals who develop a strong sense of environmental agency may leverage their influence through voting, advocating for policies that support sustainability (Berners-Lee 2020, p. 388). Conversely, when people perceive their actions as ineffective, they may disengage from environmental issues altogether (Shakeri, Jung, et al. 2023). This sense of disempowerment can not only reduce their willingness to adopt sustainable behaviours but may also lead to environmentally harmful or counterproductive actions. Thus, fostering foodprint literacy is not only critical for individual decision-making but also plays a broader role in shaping collective efforts toward climate sustainability.

2.3 Behaviour Change

2.3.1 Understanding Behaviour Change and Its Discipline

The term *behaviour change* can refer broadly to the modification of individual actions, whether intentional or incidental. However, *Behaviour Change (BC) as a discipline* refers to the structured, research-driven approach to modifying behaviour through systematic interventions, often with a clear instrumental focus (Ajzen 1991; Prochaska and DiClemente 1983; Michie, van Stralen, and West 2011). The distinction is important because while BC as a discipline typically follows a top-down approach, focusing on designing interventions to drive specific, measurable outcomes, behaviour change in practice can also occur bottom-up, where individuals or communities modify their behaviours through self-determined or emergent processes, often facilitated rather than directed.

This thesis acknowledges both perspectives. While BC as a discipline provides valuable frameworks and tools for designing interventions, it often prioritizes predefined outcomes, which may sometimes overlook individual autonomy and contextual variability. In contrast, behaviour change as a process can be participatory and emergent, allowing individuals greater agency in defining how and why they change their behaviour. Recognizing this duality is crucial when

considering interventions designed to support climate-sensitive behaviours without being prescriptive or coercive.

2.3.2 Advances in Behaviour Change Research

Over the past decade, the study of Behaviour Change has expanded significantly, driven by the pressing need to address complex societal challenges such as climate change, obesity, and mental health (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014). Early models, such as the Transtheoretical Model (Prochaska and DiClemente 1983) and the Health Belief Model (Rosenstock 1974), provided foundational insights into behaviour change processes but were often criticized for their narrow focus and limited adaptability across diverse populations and contexts (Michie, van Stralen, and West 2011). Additionally, many early behaviour change interventions lacked theoretical grounding, leading to inconsistent outcomes (Michie, van Stralen, and West 2011).

This has led to the development of more comprehensive, theory-driven frameworks that systematically analyze behaviour and guide intervention design. These frameworks aim to provide more effective, scalable, and context-sensitive approaches to influencing human behaviour.

2.3.3 Behaviour Change Interventions: Frameworks and Models

2.3.3.1 Key Models and Frameworks in Behaviour Change

In response to these challenges, researchers have developed Behaviour Change Interventions (BCIs), structured approaches aimed at influencing individuals' actions to achieve positive health, environmental, and social outcomes (Michie, van Stralen, and West 2011; Bartholomew Eldredge et al. 2016). BCIs are based on psychological and sociological theories that provide structured methodologies for designing and implementing effective interventions (Michie, Atkins, and West 2014).

Several key models and taxonomies underpin the field of Behaviour Change and inform intervention design:

- **The COM-B Model (Michie, van Stralen, and West 2011):** This foundational model posits that behaviour is driven by three essential components—Capability (C), Opportunity (O), and Motivation (M)—which together determine Behaviour (B). Capability refers

to an individual's physical and psychological ability to engage in an activity, Opportunity encompasses external factors that facilitate behaviour, and Motivation includes both automatic and reflective processes that drive action.

- The Behaviour Change Wheel (BCW) (Michie, Atkins, and West 2014): Built upon the COM-B Model, the BCW categorizes interventions into nine functions, including education, persuasion, incentivization, coercion, training, enablement, modeling, environmental restructuring, and restriction. Additionally, it identifies seven policy categories—such as guidelines, legislation, and service provision—to support the design and evaluation of interventions. It follows a 6-step approach to identify the target behaviour, need for behaviour change, intervention options, and policy options.
- The Behaviour Change Techniques Taxonomy (BCTT) (Michie, Richardson, et al. 2013): This taxonomy provides a comprehensive list of 93 behaviour change techniques (e.g., goal setting, feedback, self-monitoring, and social support) that can be applied within interventions to promote sustainable behaviours. The BCTT ties in with the BCW as a 7th step for selecting intervention implementation options.
- Intervention Mapping (Bartholomew Eldredge et al. 2016; Ruiters and Crutzen 2020): This structured approach focuses on identifying behavioural determinants, selecting appropriate intervention strategies, and evaluating their effectiveness.

2.3.3.2 Comparing the Behaviour Change Wheel and Intervention Mapping

While both the BCW and Intervention Mapping offer systematic frameworks for designing interventions, they differ in their theoretical underpinnings and practical applications. Intervention Mapping follows a highly structured, step-by-step approach that prioritizes theoretical foundations, stakeholder involvement, and iterative development. In contrast, the BCW takes a broader approach by mapping behaviour determinants onto intervention functions and policy categories, offering a more flexible and scalable method for designing interventions in diverse contexts (Michie, Atkins, and West 2014; Bartholomew Eldredge et al. 2016).

2.3.4 Applications and Facilitation in Behaviour Change

BCIs employ various techniques or mechanisms—also referred to as *active ingredients* (Silva, Hay-Smith, and Graham 2023)—to influence behaviour. Common techniques include goal setting, feedback, self-monitoring, and social support (Edwards et al. 2016; Hedin, Katzeff, et al.

2019; Van Rhoon et al. 2020; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) (for a comprehensive listing see Michie, Richardson, et al. (2013)). Applications of BCIs extend across multiple domains, including food purchases, fostering self-efficacy, and leveraging social and environmental support.

This thesis argues that while traditional BCIs often focus on achieving externally defined goals, an alternative facilitative approach can empower individuals to develop their own strategies for change. This shift from directed interventions to facilitated experiences aligns with ethical considerations of autonomy and self-determination, fostering behaviour change that is more likely to be sustainable over the long term.

2.3.5 Ethical Challenges in Behaviour Change Interventions

Despite their utility, BCIs raise ethical concerns, particularly regarding manipulation (Da Rocha and Hunziker 2020; Busch et al. 2021; Kuyer and Gordijn 2023), autonomy (Tengland 2012), and long-term behavioural sustainability (Knowles, Blair, et al. 2014). Traditional Behaviour Change approaches often prioritize instrumental outcomes, which may lead to coercion or external control over individual decision-making (Tengland 2012). Ensuring that interventions respect autonomy, foster empowerment, and promote *intrinsic motivation* rather than *extrinsic compliance* is essential for designing ethical and effective interventions (Ryan and Deci 2000; Ryan and Deci 2020), (Tengland 2012).

This thesis returns to these concerns in later sections of this background chapter.

2.4 Persuasive Technology

2.4.1 Overview of Persuasive Technology and Its Applications

Persuasive technology—also referred to as Behaviour Change Support Systems (BCSS)—refers to digital tools and interactive systems intentionally designed to influence people’s attitudes or behaviours in a predetermined way (Fogg 2003). It has been widely applied in domains such as health, sustainability, and finance, where digital interventions aim to encourage users toward beneficial actions. For example, fitness tracking apps employ gamification techniques—such as goal setting, feedback, and social reinforcement—to promote physical activity (Consolvo et

al. 2009; Fritz et al. 2014). Similarly, eco-feedback systems provide real-time or aggregated insights into an individual's environmental impact, helping users make more informed choices regarding their energy consumption and carbon footprint (J. Froehlich, Findlater, and Landay 2010; Luca A. Panzone, Larcom, and She 2021). Financial applications also leverage persuasive strategies, such as commitment devices and automated nudges, to encourage saving habits and reduce impulsive spending (Thaler and Sunstein 2008).

2.4.2 The Persuasive System Design Taxonomy (PSDT)

A key contribution to the study of persuasive technology is the Persuasive System Design Taxonomy (PSDT) proposed by Oinas-Kukkonen and Harjumaa (2009). This taxonomy categorizes persuasive techniques into several design strategies that are commonly used in digital interventions:

- Reduction: Simplifying tasks to lower the effort required for desired behaviours.
- Tunneling: Guiding users through a structured process to encourage specific actions.
- Tailoring and Personalization: Adapting interventions based on user preferences and past behaviours.
- Self-Monitoring: Allowing individuals to track their progress and receive feedback.
- Simulation: Demonstrating the impact of behaviour through interactive models.
- Social Influence: Encouraging behavioural change through peer engagement, social norms, and competition.

The PSDT builds on the Fogg Behavior Model (FBM), which posits that behaviour change occurs when motivation, ability, and a prompt (or trigger) align (Fogg 2009). The taxonomy provides structured design principles that guide the development of digital interventions aimed at shaping behaviour in a user-centered manner.

2.4.3 Intersection of Persuasive Technology and Behaviour Change Interventions

While persuasive technology and Behaviour Change Interventions (BCIs) share a common goal—facilitating behavioural change—their foundations differ. BCIs originate in the social sciences and are primarily grounded in psychological theories (Michie, Atkins, and West

2014). In contrast, persuasive technology is rooted in human-computer interaction (HCI) (Fogg, Danielson, and Cuellar 2009), focusing on the design of digital systems that influence behaviour. However, these distinctions are not rigid, and the two fields often intersect. Notably, some researchers consider persuasive technology and Behaviour Change Support Systems (BCSS) synonymous to Digital Behaviour Change Interventions (DBCI) (Van Delden, De Vries, and Heylen 2019).

One area where this intersection is evident is in publications on artifacts of persuasive technology, which appears more likely to reference behaviour change techniques (BCTs) rather than the PSDT (Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023). This trend is apparent in studies such as those by Hedin, Grönborg, and Johansson (2022), Shakeri and McCallum (2021), and Möller (2021), which apply BCTs in designing persuasive interventions for food purchases. The preference for BCTs over PSDT may be attributed to the strong psychological grounding of the Behaviour Change Techniques Taxonomy (BCTT) (Michie, Richardson, et al. 2013; Michie, Atkins, and West 2014). BCTs explicitly describe mechanisms of action, making them particularly useful for hypothesis-driven research (Klasnja, Consovo, and Pratt 2011). In contrast, the PSDT includes elements that describe design principles or patterns, which may not always correspond to clear mechanisms of behavioural influence.

Despite this preference for BCTs, the PSDT remains valuable as a complementary framework. While BCTs provide a rigorous theoretical foundation for defining intervention techniques, PSDT aligns more closely with common design elements in HCI, offering practical insights for implementation (Oinas-Kukkonen and Harjumaa 2009). Some studies have explored the integration of these two frameworks (e.g., Silva, Hay-Smith, and Graham 2023), demonstrating the potential benefits of combining behavioural science with digital design strategies to create more effective interventions.

2.4.4 Ethical Considerations in Persuasive Technology

Persuasive technology, like BCIs, has been subject to ethical scrutiny. In their review of persuasive technology in environmental sustainability, Brynjarsdottir et al. (2012) argue that it often is “more akin to coercion than rhetoric”, raising concerns about manipulation and autonomy (J. Davis 2009; J. Davis 2012). Critics contend that persuasive systems can subtly or overtly pressure users into behaviours they may not have chosen independently.

However, others challenge this perspective, arguing that these ethical concerns may be overstated. In their review of sustainable HCI, Bremer, Knowles, and A. Friday (2022) highlight that many digital interventions categorized as persuasive technology actually lack active persuasion mechanisms, focusing instead on user facilitation and guidance rather than direct influence.

Despite these two sides of the debate, ethical concerns remain a central issue in the design and implementation of persuasive technology. Designers must balance the need to influence behaviour with the imperative to respect user autonomy and agency.

2.5 Sustainable HCI and Food HCI

2.5.1 Exploring Human-Food Interaction (HFI)

The research discussed in this thesis is placed in the intersection of Sustainable HCI and Food HCI. As the approach of the thesis is more aligned with the majority of work in sustainable HCI, I will focus here predominantly on the domain of SHCI, but will provide a brief overview of food HCI before I do.

Human-food interaction (HFI) studies how technology intersects with food-related practices, encompassing aspects such as nutrition, sustainability, and social engagement (Altarriba Bertran et al. 2019). HFI technologies aim to enhance decision-making, improve food literacy, and support dietary transitions toward climate-sensitive food choices.

2.5.1.1 Trends in Human-Food Interaction Research

In their overview of HFI, Altarriba Bertran et al. (2019) reveal a dominance of technology-centric approaches, particularly in sourcing, producing, and tracking food. While 52% of contributions attribute agency to technology (e.g., automation), 48% focus on empowering users to act independently. Functionality-oriented research (66%) outweighs experience-related studies (34%), and individual-focused works (22%) are more prevalent than those addressing social aspects (12%).

- **Source:** Research often emphasizes functionality, such as automation (e.g., meal recommendation systems), but some works empower users (e.g., urban foraging tools).

- **Store:** Contributions balance automation and user empowerment, such as systems combining color-coding and camera tracking to reduce food waste.
- **Produce:** The most researched domain, with diverse foci. Functionality-oriented studies dominate, though experiential and social approaches tend to adopt more human-centric perspectives.
- **Eat:** This domain is relatively balanced in focus but leans toward individual experiences, driven by multisensory HFI studies exploring taste perception.
- **Track:** Research in this domain often clusters around technology-centric approaches, reflecting a dense focus on functionality.
- **Speculate and Store:** These remain underexplored, representing only a small fraction of contributions.

These trends highlight opportunities to balance functionality with user empowerment and to expand research into social and experiential aspects of food practices.

2.5.2 Sustainable HCI and Eco-Feedback Technology

Sustainable HCI is the study of how digital technologies can support environmental sustainability by promoting more sustainable behaviours and lifestyles (Blevis 2007). It encompasses a wide range of topics, including eco-feedback systems, energy-efficient computing, and sustainable design practices. Within sustainable HCI, most works concern persuasive technology (also known as Persuasive Sustainability). In their literature reviews of the domain, both DiSalvo, Sengers, and Brynjarsdóttir (2010) and Hansson, Cerratto Pargman, and Pargman (2021) conclude that the majority of works concern persuasive technology (45% and 35% of all included papers, respectively).

Eco-feedback technology focuses on providing users with real-time or aggregated information about their environmental impact to encourage more sustainable behaviours (J. Froehlich, Findlater, and Landay 2010). It covers nearly all artifacts of Persuasive Sustainability (Brynjarsdottir et al. 2012; Hansson, Cerratto Pargman, and Pargman 2021). Applications of eco-feedback technology include energy monitoring systems, carbon footprint calculators, and food waste tracking apps, among others (J. Froehlich, Findlater, and Landay 2010; Hedin, Katzeff, et al. 2019; Hansson, Cerratto Pargman, and Pargman 2021). Examples of eco-feedback include a visualization of carbon footprint impacts of different ride-share options (Mohanty et al. 2023), see Figure 2.1, or the *Shower Calendar*, which involves a visualization of water usage projected on the shower

door and provides ambient feedback about water consumption of individual family members on various days (Laschke et al. 2011), see Figure 2.2.

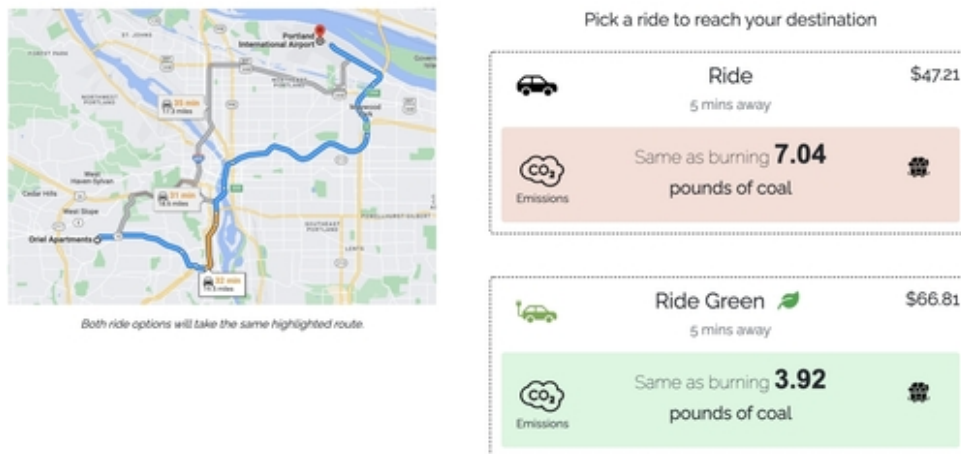


Figure 2.1: Visualization of carbon footprint impacts of different ride-share options. Reproduced from Mohanty et al. (2023).

2.5.2.1 Challenges and Opportunities in Eco-Feedback Technology

Persuasive Sustainability and Eco-feedback are commonly critiqued (Brynjarsdottir et al. 2012; Hansson, Cerratto Pargman, and Pargman 2021). Two prominent critical reviews are those by Brynjarsdottir et al. (2012) and (Knowles, Blair, et al. 2014), whose points are summarized below.

Brynjarsdottir et al. (2012) critique key assumptions underlying sustainability-focused persuasive technology, arguing that these approaches are shaped by a modernist worldview that assumes individuals are rational actors who will change their behavior when provided with sufficient information. This perspective, they contend, leads to several problematic tendencies: an overemphasis on individual responsibility, which disregards the structural roles of corporations and governments; a focus on incremental behavior change, which risks creating the illusion that minor adjustments are sufficient to address pressing environmental challenges; and a top-down design approach, where designers define and prescribe the ‘right’ behaviors for users to adopt.

To move beyond the limitations of this modernist perspective, the authors propose alternative pathways for designing sustainable HCI. Rather than isolating individual behaviors, they argue for approaches that account for the social and cultural contexts in which sustainability-related decisions occur—for instance, recognizing that heating choices are shaped not just by energy efficiency concerns but also by social norms and personal comfort. Instead of rigid, prescriptive

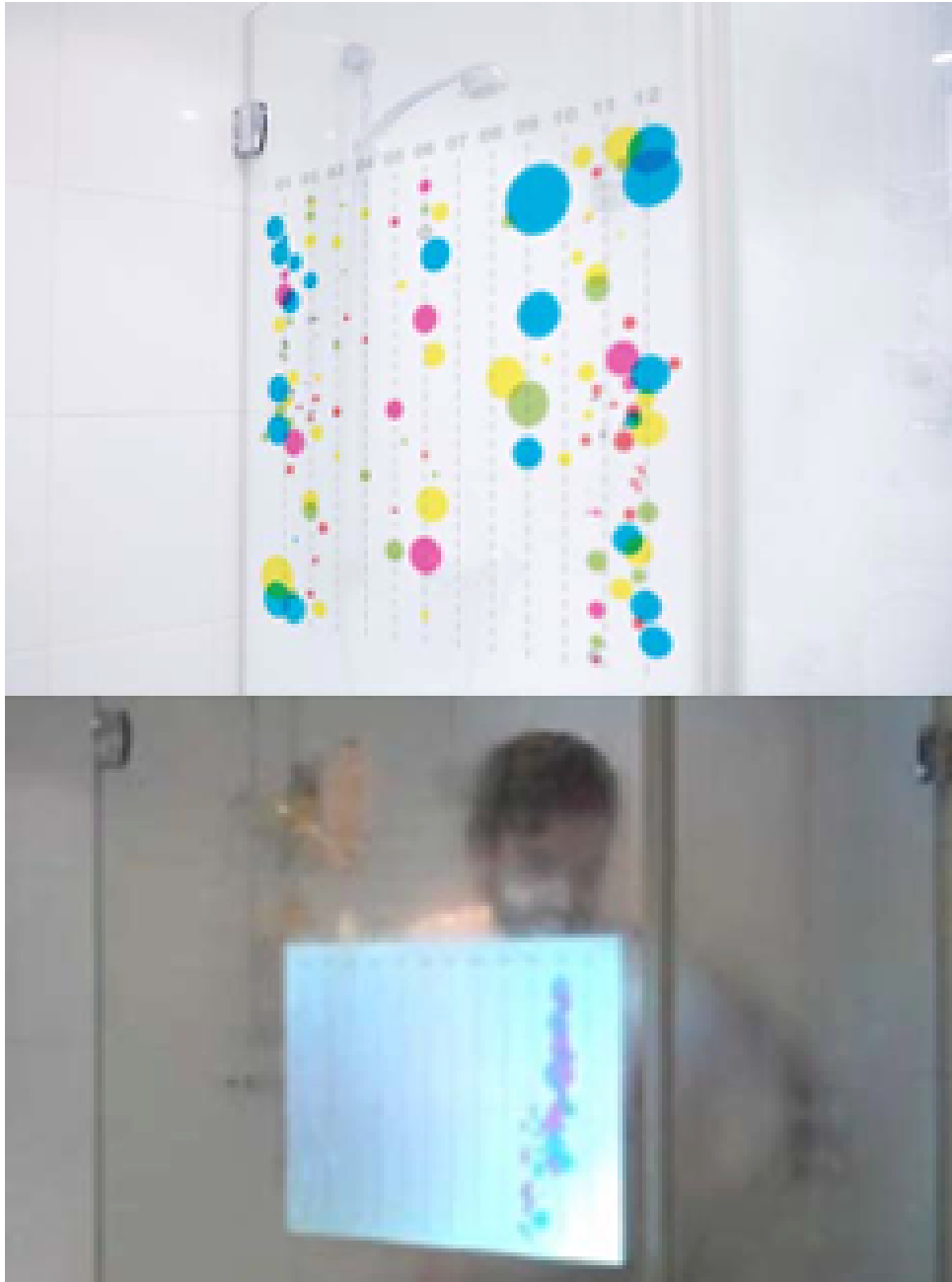


Figure 2.2: The *Shower Calendar* provides ambient feedback about water consumption of individual family members on various days. Reproduced from Laschke et al. (2011).

interventions, they suggest designs that encourage open-ended reflection, allowing users to explore and define sustainability in their own terms. Persuasion, they argue, should be viewed as a rhetorical process rather than a coercive or directive mechanism. Additionally, they advocate for more participatory and context-sensitive approaches that move beyond narrow, technocratic solutions. Through these alternative perspectives, the paper calls for a broader, more nuanced engagement with sustainability in HCI, one that does not reduce change to simplistic behaviorist models but instead acknowledges the complexity of environmental action.

Knowles, Blair, et al. (2014) highlight the complexity of sustainability, emphasizing that meaningful change requires long-term behavioral shifts that often conflict with immediate personal convenience or economic incentives. However, they critique persuasive sustainability approaches for their limited success in fostering lasting change. They attribute this failure to an overreliance on nudging techniques that emphasize short-term personal gains rather than deeper engagement with sustainability.

A key concern they raise is the risk of negative spillover, where improvements in one sustainable behavior are offset by unsustainable actions elsewhere. They argue that this problem arises from the narrow focus on behavior modification rather than addressing the underlying values that drive long-term commitment to sustainability. In their view, eco-feedback technologies should not merely encourage specific sustainable actions but should instead cultivate pro-environmental values that persist even after the technology is no longer in use.

To achieve this, they propose shifting the design of eco-feedback tools from simple nudging mechanisms to approaches that foster reflection and meaningful learning experiences. By encouraging users to critically engage with sustainability on a deeper level, these tools can promote more enduring behavioral change and facilitate positive spillover, where sustainable practices in one domain reinforce sustainability in others.

2.6 Empowerment, Autonomy, and Capability

2.6.1 Autonomy and Manipulation: Key Dimensions

As emphasized previously when discussing behaviour change and persuasive technology, their application frequently raises concerns with manipulation and infringement of autonomy. To understand these concerns better, I will now turn to literature on manipulation.

The consequences of infringement on autonomy are various. On a plain level, an infringement on autonomy is an infringement on people's dignity to self-determine their actions (Tengland 2012) and an infringement on their human right (United Nations 1948). Infringement on autonomy can also lead to a person's loss of internalized (self-initiated) motivation for a task (Ryan and Deci 2000). The behaviour becomes dependent on extrinsic incentives, which makes pursuit of the task beyond the intervention less likely than it was before the intervention started. A diminished ability of people to make rational decisions based on unbiased information weakens their ability to prevent unintended harms that may result from the use of the technology (Tengland 2012; Stibe and Cugelman 2016). In response to perceived manipulation or coercion, interventions may backfire with people defying against (well-meant) manipulative intent and harm their own or others health and well-being (Stibe and Cugelman 2016). Manipulation may also improve one's health (quality of life from a specific perspective) through reducing overall quality of life (Tengland 2012).

2.6.2 Autonomy and Manipulation: Three Dimensions

A person behaves autonomously when making free, conscious, decisions in consideration of their intrinsic values and beliefs (Deci and Flaste 1996; Tengland 2012). In contrast, when people are manipulated, their decisions are guided by extrinsic values and their ability to make autonomous decisions is compromised (Hansen and Jespersen 2013; A. W. Wood 2014; Kim and Werbach 2016; Botes 2023). Three forms of manipulation that can be found in literature—under various names—are (1) deception, (2) playing on emotions, and (3) pressure to acquiesce (A. W. Wood 2014) that impact the various prerequisites for making autonomous decisions, respectively (1) transparency of influence, (2) ability for rational, critical reflection (Hansen and Jespersen 2013; Botes 2023), and (3) locus of control (Ryan and Deci 2000) or freedom of choice (Botes 2023). I will describe each of these dimensions below.

2.6.2.1 Transparency: Disclosure of Persuasive Intent

Seemingly the most intuitive and widely agreed requirement for ethical forms of influence, transparency in the intentions of the influencer (contrary to deception) is generally agreed upon as a requirement for ethical influencing (see e.g., Hansen and Jespersen 2013; Kim and Werbach 2016; Aylsworth 2022; Botes 2023). Transparency relates to the visibility of the influence (Hansen and Jespersen 2013). When the influence is invisible, the influenced is severely hindered in their

ability to resist the influence. The problem of deception also relates to supposed reason behind its use. Deception is used when the assumption is that if the influence was revealed, the choice of the influenced would be different. As stated by Bovens (Bovens 2009) “the psychological mechanisms that are exploited [...] work best in the dark”. With that, a lack of transparency, or deception, in the influence, constitutes a clear infringement on the potential of the influenced to reflect on the influence in consideration of their values and beliefs and make an autonomous decision.

2.6.2.2 Rationality: Ability for Critical Reflection

The second dimension refers to the type of thinking that is likely to be used in decision making. Contrary to the modernistic worldview that portrays individuals as rational agents (Brynjarsdottir et al. 2012), most decisions in daily life occur automatically and unconsciously (Kahneman 2003), (Kahneman 2012; Thaler and Sunstein 2008; Brynjarsdottir et al. 2012). Bounded rationality theory (Kahneman 2003) distinguishes between two types of thinking: Type 1, which is unconscious and automatic, and Type 2, which is conscious, reflective, and rational (Kahneman 2003; Hansen and Jespersen 2013; Faraoni 2023). Decision-making often involves a blend of both automatic and reflective processes (Hansen and Jespersen 2013).

The presentation of information plays a pivotal role in triggering these cognitive processes. For individuals to make autonomous decisions, reflective thinking is essential. However, influences that predominantly activate automatic thinking can hinder autonomy by limiting the consideration of values and beliefs (Hansen and Jespersen 2013). In cases of automatic thinking, “snap decisions” are made based on salient information, rendering individuals susceptible to cognitive biases—those inaccurate or irrational judgments resulting from selective and subjective information processing (Kahneman 2003; Thaler and Sunstein 2008).

Designers can strategically target cognitive biases by shaping information presentation (Thaler and Sunstein 2008; Hansen and Jespersen 2013; Caraban et al. 2019). For instance, emphasizing decisions made by others (social norms) can sway observers toward certain choices. Importantly, when emotions come into play, reflective thinking diminishes, leaving individuals increasingly vulnerable to biases (Botes 2023; Deci and Flaste 1996; Kahneman 2003; A. W. Wood 2014).

2.6.2.3 Control: Freedom of Choice

The third dimension of autonomous decision-making centres on the ability to make unconstrained, free choices. However, this autonomy is often challenged by various forms of external influence (Tengland 2012; A. W. Wood 2014; Ryan and Deci 2020; Botes 2023).

At its extreme, coercion emerges when choices are externally dictated, leaving individuals with limited agency. Considerable motivation, akin to heroism, becomes necessary to resist such pressure (A. W. Wood 2014; Botes 2023). An example of this are persistent email subscription pop-ups on websites. These obstruct navigation unless users comply with the subscription request (Botes 2023).

External pressures need not always be extreme and tangible. A compelling emotional influence can be manipulative (Strudler 2005) and restrict the perceived freedom of choice (Deci and Flaste 1996; Strudler 2005; Ryan and Deci 2020; Botes 2023). Vulnerability to such emotional influence varies from person to person and even fluctuates over time (Botes 2023).

In their seminal work on self-determination, Ryan and Deci (Ryan and Deci 2000) classify different levels of external and internal control that motivate behaviour. From more external to more internal we have (a) external regulation, e.g., through incentives of reward and punishment, (b) introjection: focus on approval of self and others based on introjected (i.e., ‘I should’) values—for our purpose we refer to this as socio-emotional incentives—, (c) identification and integration with goals, and (d) inherent interest or satisfaction. Only in the case of the latter two can speak of an autonomous, free, choice (Ryan and Deci 2000; Ryan and Deci 2020; Tengland 2012), whereas the prior two are external causes of motivation that introduce pressure that interferes with autonomous decision making.

Notably, external pressure or control appears to be most overlooked as a form of manipulation, particular in the case of socio-emotional incentives. We can see this in the proposals of socio-emotional incentives in some nudges (that by definition should not restrict choice (Thaler and Sunstein 2008; Hansen and Jespersen 2013)), e.g., in the case of using posters of human faces to increase norm compliance (Hansen and Jespersen 2013). It also appears overlooked when coining interactions as persuasive (i.e., free from external influence (Botes 2023)) even while the use of socio-emotional incentives does not seem uncommon where the term ‘persuasion’ is used (see e.g., persuasive techniques in (Oinas-Kukkonen and Harjumaa 2009) and discussion of persuasion in (Tengland 2012)). Similarly, Bogost (2010) criticizes common applications of persuasive technology as for being more akin to coercion than persuasion.

2.6.3 Empowerment as a Path to Autonomy

To mitigate the risk of infringing on autonomy, inspiration can be found in empowerment literature. Zimmerman (Zimmerman 1995), who introduced the concept of psychological empowerment, defines it as ‘a process in which people gain understanding and control over personal, social, economic, or political forces in order to take action to better their lives’. The concept can also be understood from its distinction to the instrumental, outcome focussed, characteristic of traditional Behaviour Change Interventions (BCIs). In contrast to the outcome focus of traditional BCIs, empowerment approaches are person-centred. Empowerment literature emphasizes the existence of an internal motivation to change in a positive direction (see eg, Ryan and Deci 2000; Ryan and Deci 2020; Tengland 2012). As Tengland (2012) puts it: “No persuading, rewarding, punishing, coercing or manipulating is needed.” (Tengland 2012, p. 6). The focus is on the ability (or capability (Nussbaum and Sen 1993; Sen 1993; Johnstone 2007))—e.g., their knowledge, skills, perceived self-efficacy and opportunities—to act in accordance with their values and beliefs, and much less on influencing values and beliefs based on a pursuit if a top-down definition of values (Tengland 2012).

Empowerment is tightly connected with autonomy. Higher levels of empowerment imply greater ability to exercise autonomy. We could say that, to mitigate the risk of infringing on autonomy, an envisioned digital behaviour change intervention should not aim to change behaviour, but rather empower people to change their behaviour.

2.6.4 Designing for Empowerment

2.6.4.1 Participatory Design as a Method for Empowerment

Participatory design incorporates various valuable characteristic for empowering people and is put forth as the method for designing for empowerment in various theoretical works on the topic (see e.g., Kleine 2010; Simonsen and Robertson 2012; Tengland 2012; Baumer and Brubaker 2017).

“It fully respects the participating individuals’ right to self-determination, since they are completely involved in the problem formulation, the decision process, and the actions undertaken. Moreover, the approach also develops or increases the ability for autonomy, as well as other forms of control, since active participation

requires taking or sharing responsibility for what is to be achieved, and for how it is to be achieved. This in turn leads to the development of various kinds of knowledge, skills, and 'well-being' (Laverack 2009; Powers, Faden, and Saghai 2012, p. 9). Groups that participate develop their 'collective autonomy', in that they develop deliberating, reasoning, and negotiating skills, and therefore acquire tools for making democratic decisions (Laverack 2009)." (Tengland 2012, p. 10)

Some authors are eminent that participatory design is a prerequisite for empowerment (Schneider et al. 2018). Baumer and Brubaker Baumer and Brubaker (2017) conclude that participatory design provides empowerment by design. And Tengland even goes as far as defining empowerment synonymous to a stringent form of participatory design (Tengland 2012).

2.6.4.1.1 Challenges in Applying Participatory Design

However, applying participatory design as an approach to empowerment also faces some challenges. First, participatory design is particularly suited to local interventions, where participants of the participatory design exercise are direct recipients of the intervention and no further scaling to recipients beyond these immediate recipients is intended (Simonsen and Robertson 2012; Tengland 2012). The approach is less suited to interventions that are intended that have a wide reach as most recipients are no longer involved in the design process and behaviour theory is needed to determine the conditions under which the design can generalize to the larger population (Klasnja, Consolvo, and Pratt 2011; Knowles and J. Davis 2017).

Second, participatory design is not optimal for the more complex issues that require extensive subject matter expertise, like interventions to benefit climate sustainability (Knowles and J. Davis 2017). Extensive expert involvement is needed to identify effective behaviours, advocating for a more expert-centred design approach.

Third, the value of participatory design as an approach to benefit autonomy may be undermined in social dilemma topics such as climate sustainability. Improvements towards environmental sustainability depend on collective action. As such, it's in the individuals interest that others change their behaviour and thus participants to a participatory design process are incentivised to manipulate others to behave sustainably. An example of this dynamic can be seen in a publication by Davis J. Davis (2012) where dominant participants are observed to promote coercive solutions.

Fourth, participatory design faces practical challenges. Participatory design trajectories are lengthy. This conflicts with the time-restricted nature of many research projects and it can be difficult to keep participants engaged (R. E. Gray et al. 2000; Glick and Crivellaro 2023). These limitations may explain why the majority of HCI design artifacts to promote empowerment do not adopt participatory design for the development approach (Schneider et al. 2018).

There is value in alternative approaches to participatory design to design for empowerment, or, as put by Schneider et al. (2018), approaches that balance the values of expert-led and participant-led approaches. This notion inspired the research methods chosen for this thesis. I will now consider what this middle ground could mean in practical terms.

2.6.4.2 Hybrid Approaches to Empowerment Design

In line with the limitations of participatory design that were outline above, prior works have argued for alternatives to participatory design for empowerment that form a sort of hybrid approach between participatory design and expert-led design (Knowles and J. Davis 2017; Schneider et al. 2018). However, there appears to be little published work to clearly outline what defines this hybrid approach and how it should be executed as a research methodology. Many design approaches could be considered to combine elements of participatory design and expert led design. For example, Human Centred Design (Norman 2013; International Organization for Standardization 2019) argues for user involvement at every design stage and could be considered as such a hybrid approach. Also Intervention Mapping (Bartholomew Eldredge et al. 2016; Fernandez et al. 2019; Ruitter and Crutzen 2020) and the Behaviour Change Wheel (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014) consider involving recipients of the intervention. However, it is not clear if—or to what extend—these design approaches align with what Schneider et al. (2018) would consider the ‘best of both worlds’. Importantly, it is not clear how user autonomy is to be preserved or protected when applying such a hybrid approach.

Since users are no longer fully involved in the design process, relevant theory may be needed to protect user autonomy—notably, in the case of social dilemma topics, even if users are fully involved in the design process, user autonomy may still be jeopardized as participants are incentivized to manipulate each other (see, previous section and J. Davis (2012)). I will therefore now look at existing frameworks that can provide theoretical guidelines to respecting user autonomy in the design of behaviour change interventions and persuasive technology.

2.6.4.3 Guidelines to Aid Autonomy-Respectful Design

Various frameworks can provide theoretical guidelines to respecting user autonomy in the design of behaviour change interventions and persuasive technology. Both Hansen and Jespersen (2013) and Caraban et al. (2019) propose frameworks to classify nudges along the dimensions of transparency and rationality. Caraban et al. do this specifically for digital nudges. These works provide practical support for design decisions by mapping various types of nudges in four quadrants (Figure 2.3, Figure 2.4). Through the visual mappings, designers can create an understanding how different design choices reflect nudges that are either respectful of autonomy (i.e., those that are transparent and support reflective thinking) and those that are not; it can guide designers towards design decisions that favour autonomy respect.

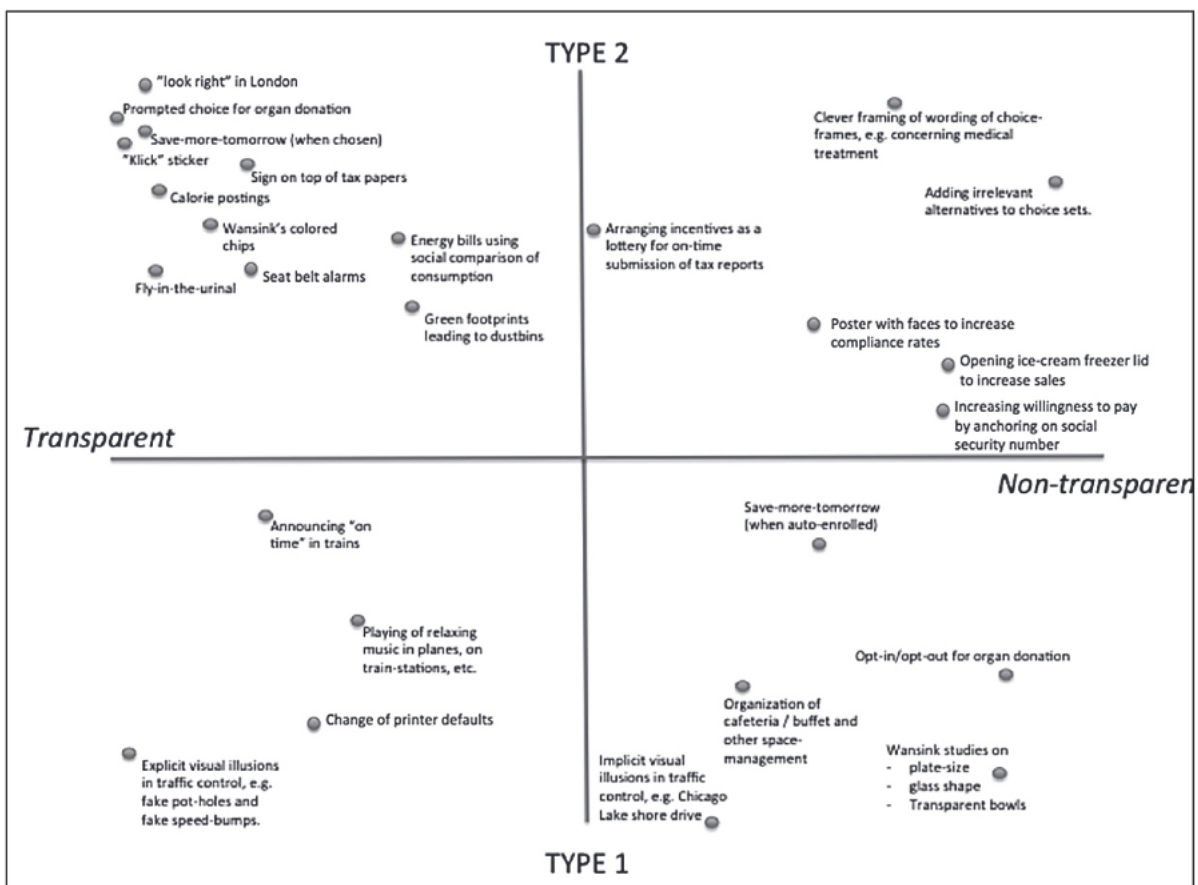


Figure 2.3: Framework by Hansen and Jespersen (2013) to assess the ethical acceptability of four types of nudges. Reproduced from Hansen and Jespersen (2013). Type 2 equals reflexive thinking. Type 1 equals automatic thinking.

Botes (2023) provides five elements to support in the ethical evaluation of digital technology on the ground of autonomy respectfulness. These elements cover the three dimensions of autonomy (1) intention disclosure (or, transparency), (2) option consideration (or, rationality), (3) control (freedom of choice). The elements also cover (4) resource vs. person, a reflection on the

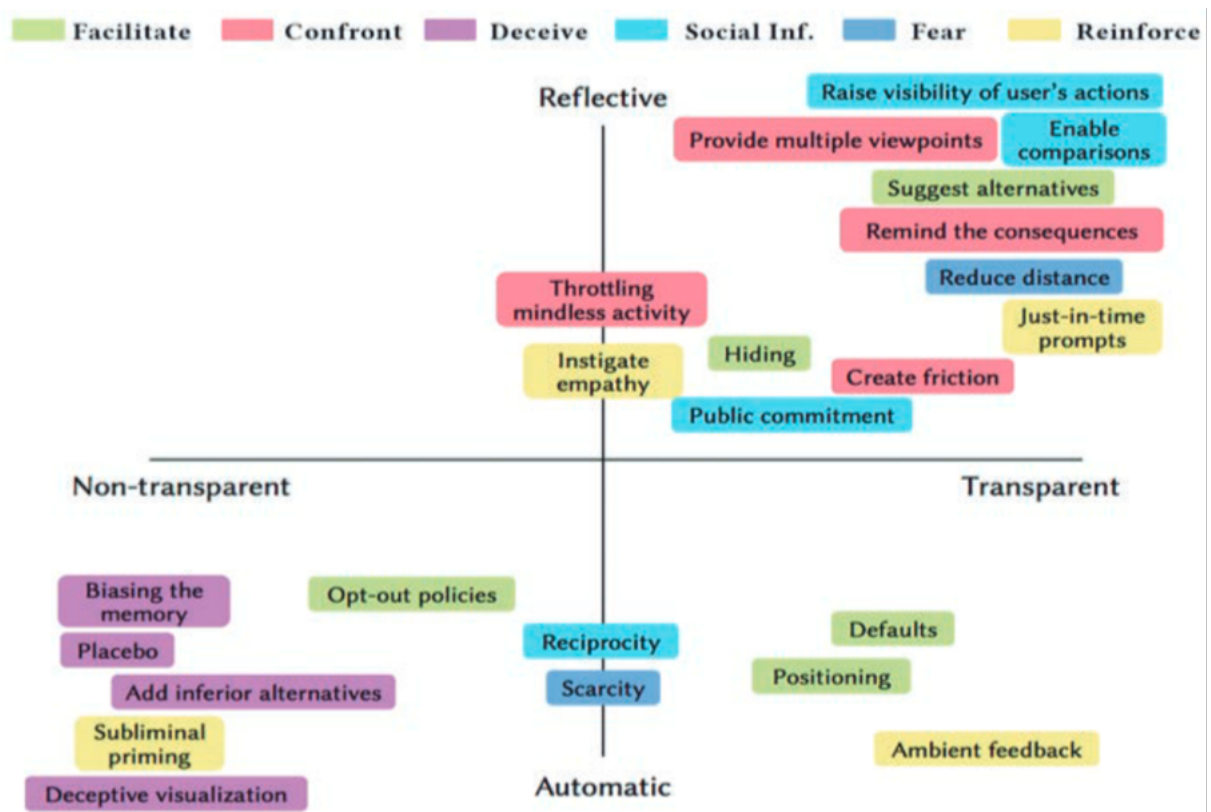


Figure 2.4: Digital nudges organised by dimensions of transparency and rationality. Reproduced from (Caraban et al. 2019). Readers can learn more about the six categories of digital nudges in the respective article.

underlying intent of taking a person-centred (empowering) standpoint or a outcome oriented (behaviour change) focus, and invite the researcher to evaluate against the use of non-transparency in the service of (5) exploitation, so called ‘dark patterns’ (Nyström and Stibe 2020), in which the user is manipulated in a ways that serve a purpose that are not likely to agree with.

Kim and Werbach (2016) reflect on the use of gamification elements from the perspective of autonomy and manipulation and suggest that an organisation should adopt a set of motivational principles that consider transparency, consent, autonomous decision making, and adequate rationale to promote ethical practice in the adoption of gamification techniques.

2.6.4.3.1 Limitations of Existing Guidelines

Unfortunately, there are some difficulties with applying the covered frameworks on a design process. A difficulty with the guideline by Botes is that it supports the evaluation, rather than the design phase. This is potentially problematic because as people are inclined to perceive themselves as more ethical than they really are (*Blind Spots Why We Fail to Do What's Right and What to Do about It* 2013) and later rationalize design choices in an (unconscious) attempt

to prevent cognitive dissonance (i.e., inconsistency in self-image) (Festinger 1962; Kim and Werbach 2016).

Moreover, both the works by Botes (2023) and Kim and Werbach (2016) are lacking in specificity for application in design decisions (Arora and Razavian 2021).

While the works by Hansen and Jespersen (2013) and Caraban et al. (2019) provide such specificity, these frameworks do not consider the third dimension of autonomy (i.e., control, or freedom of choice). By formal definition, nudges do not involve coercion, incentives or other forms of restricting choice (Thaler and Sunstein 2008; Hansen and Jespersen 2013). However, we can observe that this definition leaves room for interpretation, e.g., when we consider nudging approaches that apply social pressure which can still be understood as ethically acceptable along the framework of Hansen and Jespersen (2013), but would be considered manipulative and limiting freedom of choice along other works (Ryan and Deci 2000; Ryan and Deci 2020; A. W. Wood 2014; Botes 2023). Also, the use of incentives is acknowledged in taxonomies of persuasive design (Oinas-Kukkonen and Harjumaa 2009) and behaviour change interventions (Michie, van Stralen, and West 2011; Michie, Richardson, et al. 2013; Michie, Atkins, and West 2014; Bartholomew Eldredge et al. 2016; Fernandez et al. 2019; Ruiters and Crutzen 2020).

There is need for a guideline that can help designers in decision making in the early stages of design, that is specific, and that considers the dimension of control. Without such a guideline, designers are required to take a reflective attitude to consider whether a design is sufficiently respectful of autonomy—which is notably difficult and requires a good understanding of the concepts of manipulation and autonomy. In the empirical works that follow in this thesis I will take such a reflective stance. When reflecting on these studies in the thesis discussion, I will attempt to contribute to a framework to support future autonomy respectful design, in way that is less demanding on thorough understanding of concepts of manipulation and autonomy at the outset of the design process.

2.7 State of the Art of Foodprint Eco-Feedback Technology and Literature Gaps

2.7.1 Reviewing Foodprint Eco-Feedback Technology

Now that I have discussed the theoretical background of the thesis, I will now turn to the state of the art of foodprint eco-feedback technology. I will first discuss the literature on foodprint eco-feedback technology and then I will discuss the literature gaps that are relevant for this thesis.

In my systematic survey of application (Chapter 3, Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. (2024)) I found that very few publications cover artifacts of persuasive technology for reducing foodprint. An example of the few works that provide feedback on the foodprint of food purchases are the works of A. Clear and F. Friday (2012), Herbig, Kahl, and Krüger (2018), Shakeri and McCallum (2021), and Hedin, Grönborg, and Johansson (2022), which I will introduce below.

In their contribution for the ‘Food for Thought’ workshop at Designing Interactive Systems (DIS) 2012, A. Clear and F. Friday (2012) propose a conceptual design for an application that integrates sustainability awareness into everyday shopping practices through a shopping list app (Figure 2.5). The app features a shopping list where each product is assigned a traffic-light color rating to indicate its carbon footprint per 100g, offering users a quick and intuitive way to assess the environmental impact of their choices. The app is designed to raise awareness and offer educational resources rather than imposing drastic behavioral changes. They frame this as a nudging strategy, subtly guiding users toward more sustainable choices while still allowing them to make informed decisions within their usual shopping routines. To cater to varying levels of motivation, the app also allows users to click on items for additional insights (Figure 2.5b), including a deeper breakdown of carbon footprint data and practical tips on reducing food waste. The authors emphasize that for digital assistant technologies to be effective, they should be embedded within existing shopping habits rather than requiring fundamental changes to user behavior.

Herbig, Kahl, and Krüger (2018) present a prototype of a mobile application that allows users to scan the barcode on products to retrieve feedback on the sustainability of the product and receive information on the fit of the product with their personal profile of five sustainability elements.



(a)

(b)

Figure 2.5: Shopping list app by A. Clear and F. Friday (2012). (a) The app features a shopping list where each product is assigned a traffic-light color rating to indicate its carbon footprint per 100g. (b) Clicking on an item provides additional insights, including practical tips on reducing food waste. Reproduced from A. Clear and F. Friday (2012).

After scanning a product, a traffic-light coloured thumbs-up icon was presented at an angle that reflected the aggregated sustainability rating of the scanned product (Figure 2.6a). Participants could also request a breakdown of the sustainability rating on each of the five elements (Figure 2.6b). To develop the prototype, the authors first conducted a workshop with experts from which they formulated guidelines that led to a mockup prototype of a mobile app. This prototype was then put forth in a focus group with lay people, after which the authors adjusted the design and presented their final prototype. To test their prototype, they established artificial data for 12 products and conducted an experiment where 16 participants would go into a store to scan these products. In their qualitative evaluation of the study, they observed that participants saw the app as a tool that they could sporadically use to inform themselves of the sustainability of unknown product categories, but did not see themselves use the app on a regular basis. Participants believed that they would be able to generalize the data to other products quickly and wouldn't need to use the app regularly. Participants highlighted the importance of simple visualizations, but simultaneously highlighted the importance of transparency and trustworthy data. They appreciated how the current design was shaped around these needs. Participants requested ways to compare between products in a future design. The authors pointed out that due to the unavailability of data, a practical implementation of the app was not possible at the time of the study.

Econondrum (Sauvé, Bakker, and Houben 2020) is a physical data sculpture, intended to increase people's awareness of their diet choices. The sculpture (Figure 2.7) consists of ceiling suspended disks with icons of ten common product categories and a subdivision of the meat category to highlight important variations in foodprint of choices from that food group. The size of the icons is proportional to their relative footprint. When consumption of one of these products is logged in an accompanying app, the related icons are lit up and the disk is lowered to reflect the carbon footprint of the meal. The authors mounted the sculpture in an office environment and conducted a three-week field study with eight participants. A qualitative analysis suggests that the device encouraged reflection on foodprint behaviour and contributed to increased foodprint awareness.

Shakeri and McCallum (2021) present the design of Envirofy, a browser plugin that adds information about the carbon footprint of products to online grocery stores (Figure 2.8), designed along the procedure of the Behaviour Change Wheel (Michie, Atkins, and West 2014), and aimed at addressing a value-behaviour gap between shopper's values of environment sustainability and their purchasing behaviour. For each of the products in the active browsing window,

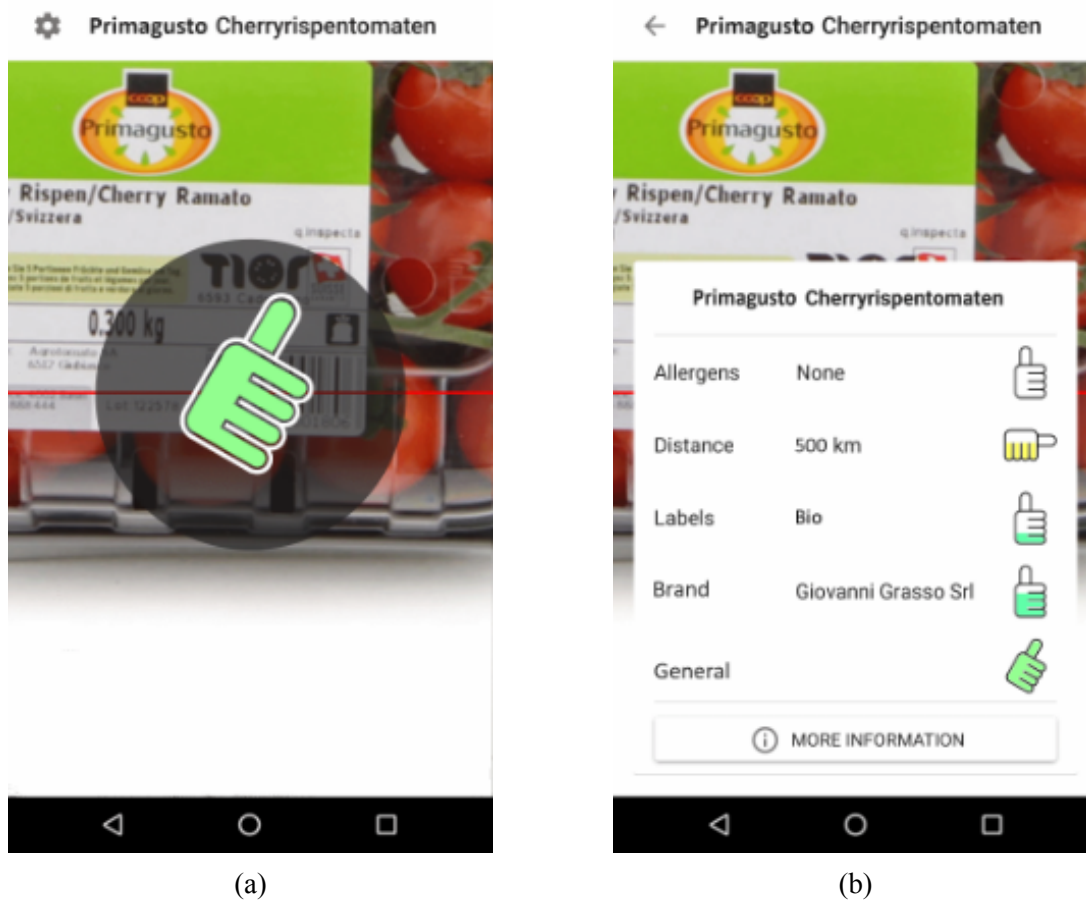


Figure 2.6: Barcode scanning app by Herbig, Kahl, and Krüger (2018). (a) The app features a traffic-light coloured thumbs-up icon at an angle that reflects the aggregated sustainability rating of the scanned product. (b) Users can also request a breakdown of the sustainability rating on each of the five elements. Reproduced from Herbig, Kahl, and Krüger (2018).

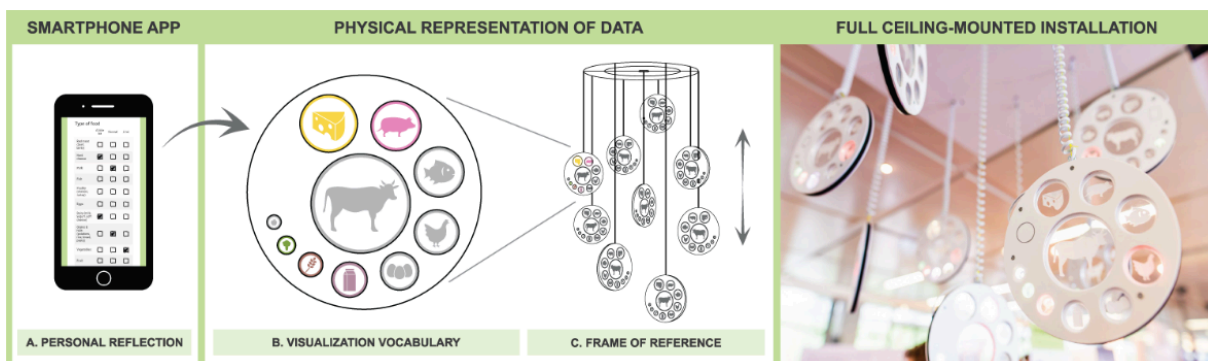


Figure 2.7: Econodrum eco-feedback sculpture. Reproduced from Sauvé, Bakker, and Houben (2020)

the plugin searches its database for information about the production foodprint, transportation mode, and packaging from which the product's carbon footprint is then calculated. Traffic-light coloured icons below the product image indicate the carbon footprint impact from each of the three elements, as well as the total carbon footprint. The shopping basket overview is complemented with traffic-light-colour-highlighted information on foodprint of each of the chosen products. The total basket foodprint is also provided.

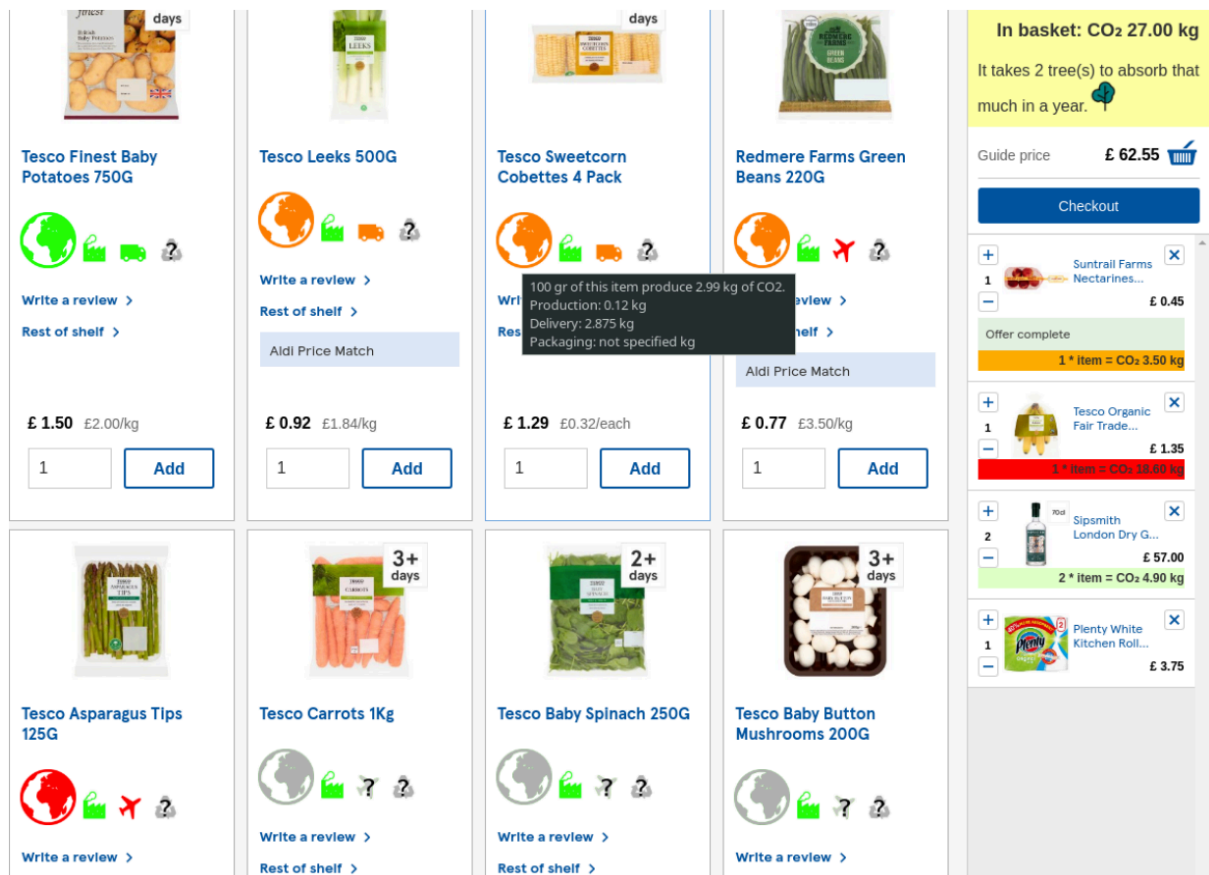


Figure 2.8: Envirofy browser plugin by Shakeri and McCallum (2021). The plugin adds information about the carbon footprint of products to online grocery stores. Reproduced from Shakeri and McCallum (2021)

Normark and Tholander (2014) presented 'Ecofriends', a mobile application that provides users with information about seasonality of fruits and vegetables based on their mention in media sources. With this application, the authors aimed to induce reflection and dialogue by purposefully drawing in data from various sources that often presented mutually incompatible information. One view would show the products that are considered in season (ie, mentioned in the media sources), in which the size of the product icon reflected how much a product was in season (ie, relative the number of media mentions) (Figure 2.9a). A second screen provided an overview of various perspectives from the media sources that could inform a judgement about the seasonality of a product (Figure 2.9b). To explore the application's use in everyday social

contexts, it was evaluated across three field studies, each framed as a dinner gathering among friends. These gatherings involved groups of four to eight people, including two participating researchers. Each group was invited to collaboratively use the application to plan a three-course meal, purchase the required ingredients, and cook together. The dinners also served as a setting for open-ended conversations, through which participants reflected on their experiences with both the joint activity and the application itself. The researchers observed that the participants were looking for practical usefulness of the app, but were often disappointed in their search. They were often frustrated with the ambiguity in the data and the lack of authoritative, stable, knowledge around seasonality that communicated some kind of ‘truth’. The authors conclude that responsibility for interpretation of data is seen as a shared responsibility between designer and user.



(a)



(b)

Figure 2.9: Ecofriends application by Normark and Tholander (2014). (a) The application shows the products that are considered in season, with the size of the product icon reflecting how much a product was in season. (b) A second screen provides an overview of various perspectives from media sources that can inform a judgement about the seasonality of a product. Reproduced from Normark and Tholander (2014).

Bohné, Zapico, and Katzeff (2015), Zapico, Katzeff, et al. (2016) and Katzeff et al. (2020) present work on a dashboard to provide feedback on customers’ share of organic products using loyalty card data (Figure 2.10). The dashboard visualizes provides visualizations of organic shares in the total of all purchases, as well as visualizations that break down the shares in six product categories, and shares for five products of concern (ie, product for which the authors

rated the choice for organic version as particularly important). During a five-month study with 65 users—most of whom reported to value ethical grocery purchasing—the authors found that the visualizations help to increase the purchase of organic products by 23% on average (Katzeff et al. 2020). The authors found that particularly the first visit of the dashboard was important for guiding change, but that frequency of use did not correlate with increased organic purchases (Zapico, Katzeff, et al. 2016). Participants were involved in the design process (Bohné, Zapico, and Katzeff 2015).

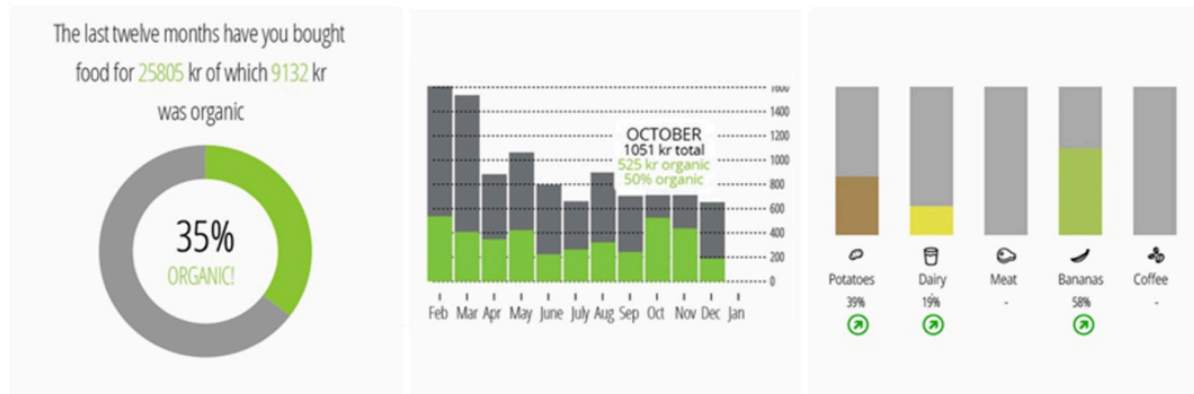


Figure 2.10: EcoPanel dashboard by Bohné, Zapico, and Katzeff (2015), Zapico, Katzeff, et al. (2016), and Katzeff et al. (2020). The dashboard visualizes customers' share of organic products using loyalty card data. Reproduced from Katzeff et al. (2020)

Hedin, Grönborg, and Johansson (2022) present a shopping list application that informs the food-print per 1000g of the listed products (Figure 2.11). To aid the interpretation of the foodprint data, there is also an option to compare the foodprint of the products in the shopping list to the carbon footprint of other household and transportation activities. The application was intended to help users with environmentally sustainability values to reduce their foodprint by increasing their foodprint knowledge and was designed along the procedure of the Behaviour Change Wheel (Michie, Atkins, and West 2014). In their 2 week field study with 38 participants they found that participation resulted in a large increase in foodprint knowledge that generalized to other products. However, the authors also observed that just six participants reported substituting an item on their shopping list because of its high foodprint. Various reasons were observed to complicate the translation from knowledge into action. Participants mentioned that the application provided insufficient support to help them prioritize which products to substitute, and that they struggled to think of practical alternatives for high-footprint products.

Lawo et al. (2021) present a shopping list application for critical consumers to help them in their search for more sustainable and ethical products in local stores (Figure 2.12). Core of the application is a recommendation algorithm that draws on a personal profile of 20 settings of ethical,

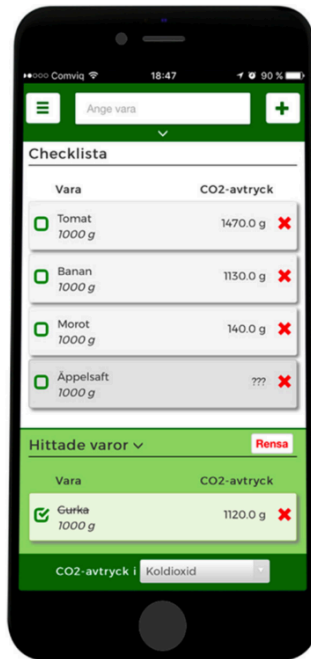


Figure 2.11: Foodprint shopping list application by Hedin, Grönborg, and Johansson (2022). The application informs the foodprint per 1000g of the listed products. Reproduced from Hedin, Grönborg, and Johansson (2022)

environmental, nutritional, and practical preferences and a database of product data from 19 participating local retailers, complemented by data from openfoodfacts.org to provide users. From an ranked list of products based on their match with the user’s profile, users can could search products by name and category and select products to transfer to their shopping list. Items in the list were accompanied by information of the foodprint per kg, nutritional composition, selling retailer, and—depending on the profile setting—other product classification labels (eg, ‘vegan’). Inspiration for the application was based on a co-creation workshop with ten participants. The final prototype was qualitatively evaluated based on a thematic analysis of interviews with ten participants after a two-month field study. Although the application was well received, the authors found that, in contrast to the intended use of the application, the participants didn’t not use the application to prepare their shopping lists. The intended sequence of searching and adding products was perceived to conflict with habitual approaches to planning groceries, which was generally described as fast and coarse, with high-level specification of intended purchases and listing of frequented purchases of products that were known to match the users preferences. In contrast, the application encouraged detailed planning of purchases that was relative demanding on cognitive and time resources. Instead of the intended use, participants used the application to sporadically explore new products that might match their interest. Participants were sometimes disappointed when recommendations appeared to be based on faulty data. Although the modularity of the personal profile was appreciated, participants also reported that setting the profile

posed an entry barrier as it was time-consuming and that they would have appreciated preset profiles for trusted non-profit organizations.

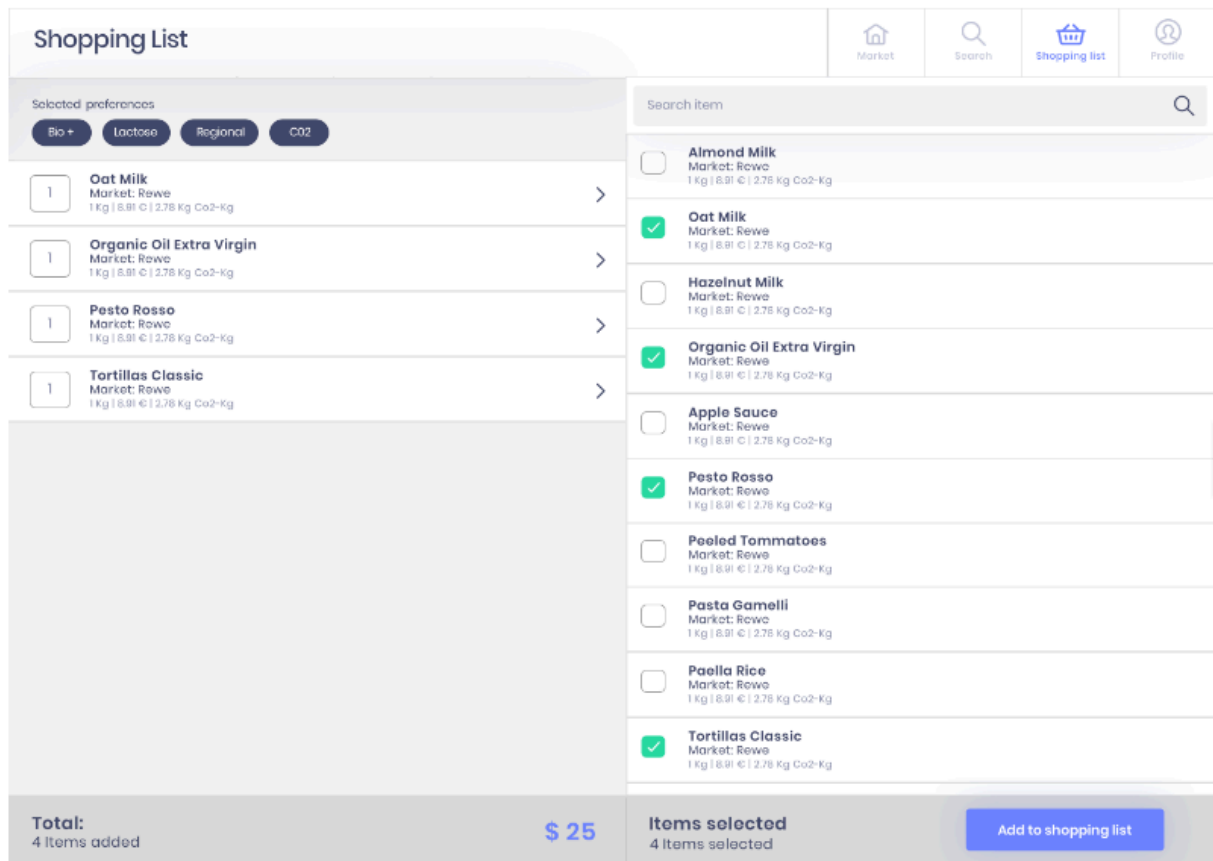


Figure 2.12: Shopping list application by Lawo et al. (2021). The application helps critical consumers to search for more sustainable and ethical products in local stores. Reproduced from Lawo et al. (2021)

2.7.2 Gaps in Foodprint Eco-Feedback Technology

Although a growing body of work explores how digital tools might support sustainable food behaviours, several critical gaps emerge from a review of the existing artefacts and studies.

1. Narrow Emphasis on Awareness Over Actionable Support

Many existing designs focus primarily on raising awareness of the environmental impact of food choices, often by presenting carbon footprint data per 100g of product (e.g., A. Clear and F. Friday 2012; Shakeri and McCallum 2021; Hedin, Grönborg, and Johansson 2022). While such approaches can increase foodprint knowledge, they often lack the scaffolding needed to transform awareness into meaningful behavioural change. For example, Hedin, Grönborg, and Johansson (2022) report large increases in knowledge but only limited behavioural change, with

participants struggling to identify practical alternatives. This pattern highlights a recurring issue: knowledge alone may not translate into skill, self-efficacy, or sustained behavioural change (Arlinghaus and C. A. Johnston 2018). Design efforts rarely focus on guidance or decision-making support that might help users prioritise impactful substitutions, develop practical competence, or build confidence in their ability to act on their values. In other words, there is general lack of attention to self-efficacy, skill acquisition, and the broader capacity for effective action.

2. Misaligned Metrics and Context

Most foodprint eco-feedback tools present impact data using per-100 g metrics, which poorly reflect actual shopping behaviour. These standardised units obscure the cumulative impact of frequently purchased, high-volume staples (e.g. dairy or bread) while potentially overstating the significance of rarely consumed, high-impact items (e.g. beef or lamb) for people that rarely eat meat (Scarborough et al. 2014; Berners-Lee 2020). As a result, users may struggle to assess which of their purchases are most important to change. Furthermore, nearly all systems provide only momentary snapshots of feedback—typically tied to a single item or shopping session—without aggregating data over time to support reflection on behavioural trends (Zapico, Katzeff, et al. 2016). This limits users’ ability to develop an informed sense of progress or to identify long-term patterns in their consumption. Addressing this gap requires metrics and visualisations that better align with real-world shopping routines and that support reflection across time, not just at isolated moments of choice.

3. Underdeveloped Consideration of Autonomy and Empowerment

Although many systems appear to respect user autonomy superficially (e.g., by avoiding coercion), few explicitly consider autonomy or empowerment as design priorities. Participatory design processes are rarely reported (exceptions include Herbig, Kahl, and Krüger 2018; Lawo et al. 2021; and Zapico, Katzeff, et al. 2016), and no study systematically examines whether users feel supported or pressured by the systems. In contrast, some designs take a more top-down approach that may unintentionally undermine autonomy. For example, Envirofy (Shakeri and McCallum 2021) prominently displays traffic-light icons in shopping baskets, which may be perceived as judgemental or pressuring (see also Chapter 4). Overall, there is limited discussion of how foodprint feedback systems can balance persuasive influence with respect for individual agency—a tension noted in prior critiques of persuasive technology (Brynjarsdottir et al. 2012; Knowles, Blair, et al. 2014).

4. Unrealistic Assumptions About Long-Term Use and Technology Abandonment

Several studies report infrequent use or abandonment of foodprint feedback technologies (e.g., Herbig, Kahl, and Krüger 2018; Hedin, Grönborg, and Johansson 2022; Lawo et al. 2021). This aligns with broader patterns in the literature on self-tracking and persuasive systems, where long-term engagement is the exception rather than the norm (Daniel A. Epstein, Eslambolchilar, et al. 2021). Yet, many systems appear to be designed with the assumption of sustained use. This may be a critical oversight. If engagement is typically brief, systems must be optimised to maximise impact from short-term use (Bentham De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024). Designs focused on behavioural nudging may be particularly vulnerable, as these often depend on repeated exposures (Knowles, Blair, et al. 2014). To account for technology abandonment, clear pathways to long-term impact need to be established that do not rely on continued use of the technology (Bentham De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024; Knowles, Blair, et al. 2014).

5. Scalability and Data Limitations

Finally, several systems face limitations in scalability and data reliability. Physical artefacts like Econodrum (Sauvé, Bakker, and Houben 2020) offer engaging, embodied experiences but are difficult to deploy at scale and lack granularity—e.g., they cannot highlight product-specific concerns such as high foodprint items like coffee or air-freighted goods (Berners-Lee 2020). Other systems, such as Envirofy, depend on real-time product matching and carbon data, which may be incomplete or inaccurate, especially in in-person retail contexts. This can be limiting both to trust and adaptability (Mauch, Laws, et al. 2021; Mönninghoff et al. 2022; Eyles, Grey, et al. 2023).

In summary, the literature on persuasive technology for reducing foodprint shows promising early progress, but critical gaps remain. These include an overemphasis on awareness rather than action, limited support for self-efficacy and prioritisation, underdeveloped approaches to autonomy and empowerment, unrealistic assumptions about long-term engagement, and persistent challenges in scalability and data quality. Addressing these issues will require a shift toward empowering, human-centred, and context-sensitive design strategies that build users' capacity for effective action in everyday food practices.

2.8 Conclusion

This chapter has presented a broad overview of how foodprint relates to global carbon budgets, emphasizing the importance of both knowledge and practical skills in achieving climate-sensitive food choices. We introduced key behaviour change theories and examined their relevance to designing effective interventions, while also addressing ethical considerations regarding autonomy and manipulation. The role of persuasive technology and its intersection with Behaviour Change Interventions were explored, illustrating both its potential and inherent risks. We then saw how Sustainable HCI and Food HCI offer insights into technology's capacity to influence sustainability practices, culminating in a discussion of eco-feedback systems and their critiques. Taken together, these perspectives shape the foundation for understanding how digital tools might be designed to bridge the gap between climate-sustainable intentions and actual behaviour, which sets the stage for the subsequent chapters of this thesis.

Chapter 3

Smartphone Apps For Food Purchase Choices: Scoping Review Of Designs, Opportunities, And Challenges

3.1 Preliminary Notes

3.1.1 Publication Note

The content of this chapter is identical to its publication in the Journal of Medical Internet Review (JMIR) (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. [2024](#)). Only style modifications have been made to align the content with the overall style of the thesis, e.g., the spelling has been changed from American English to the British English, and multimedia appendices replaced by appendices. As such, this chapter also uses the pronoun *we* rather than *I*. This chapter reflects my own thinking and writing. Author contributions were as follows: As the main author, I, Remco Benthem de Grave (RBG), designed the scoping review and took the lead in data collection and analysis. Gareth McMurchy (GM) and Joseph William Hutchinson (JH) contributed to article selection, data charting, and data analysis. These contributions by GM and JH are explicitly stated in the main text. Christopher N. Bull (CNB), Diogo Monjardino de Souza Monteiro (DMSM), Jan David Smeddinck (JDS), and Eleni Margariti (EM) contributed by editing the manuscript. Furthermore, Irina Pavlovskaya (IP), JDS, and EM contributed to the screening of the initial records that led to a preliminary version of the scoping

systematic literature review (ScSLR) (Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) that inspired the current version.

3.1.2 Original Motivation and Change of Focus

This chapter surveys the landscape of smartphone applications designed to support food purchase decisions. Rather than restricting the scope to environmentally sustainable food choices, this chapter takes a broader perspective, including applications aimed at health-conscious, ethical, and sustainability-oriented purchasing goals. This wider framing serves several important purposes within the overall thesis.

First, at the outset of this research, the focus of the thesis had not yet converged specifically on environmental sustainability. An initial broad lens allowed for a comprehensive understanding of the wider design space, helping to identify transferable insights and design strategies from adjacent domains such as health promotion and ethical consumption. These domains face parallel challenges, such as the value-behaviour gap, habit formation, and the balance between autonomy and guidance, which can usefully inform the design of eco-feedback systems.

Second, reviewing a broader set of applications enabled a richer analysis of design diversity. Given the relatively small number of existing tools that explicitly focus on sustainable food choices, a narrowly scoped review might have yielded a limited variety of design patterns. By including health- and ethics-focused apps, this chapter surfaces a more expansive range of strategies and challenges, some of which may offer promising avenues for addressing the specific needs of environmentally sustainable consumption.

Third, this choice reflects a research philosophy grounded in openness to cross-pollination between domains. Innovative design solutions often emerge when lessons from one application area are translated to another. For example, mechanisms for building self-efficacy in health behaviour change might offer valuable insights for enhancing users' capacity to make climate-sensitive food choices.

Finally, this broader approach aligns with the evolution of public discourse. During the early phases of this research, environmental sustainability was gaining momentum as a societal priority. Insights gained through this chapter helped inform the decision to focus the remainder of the thesis specifically on technologies that empower environmentally sustainable food choices.

Accordingly, this chapter addresses the following research questions:

- RQ3.1: What design strategies have been employed in existing smartphone applications to support food purchase choices?
- RQ3.2: What opportunities and challenges to impacting changes in food purchase choices are identified in this literature?

Through these questions, the chapter establishes a foundational understanding of the current landscape of smartphone-based food decision support tools. It highlights patterns, gaps, and lessons learned across various domains of consumer intention, providing critical insights that will inform the more focused exploration of eco-feedback and environmentally sustainable choices in the following chapters.

3.2 Abstract

Background: Smartphone apps can aid consumers in making healthier and more sustainable food purchases. However, there is still a limited understanding of the different app design approaches and their impact on food purchase choices. An overview of existing food purchase choice apps and an understanding of common challenges can help speed up effective future developments.

Objective: We examined the academic literature on food purchase choice apps and provided an overview of design characteristics, opportunities, and challenges for effective implementation. Thus, we contribute to an understanding of how technologies can effectively improve food purchase choice behaviour and provide recommendations for future design efforts.

Methods: Following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines, we considered peer-reviewed literature on food purchase choice apps within IEEE Xplore, PubMed, Scopus, and ScienceDirect. We inductively coded and summarized design characteristics. Opportunities and challenges were addressed from both quantitative and qualitative perspectives. From the quantitative perspective, we coded and summarized outcomes of comparative evaluation trials. From the qualitative perspective, we performed a qualitative content analysis of commonly discussed opportunities and challenges.

Results: We retrieved 55 articles, identified 46 unique apps, and grouped them into 5 distinct app types. Each app type supports a specific purchase choice stage and shares a common functional design. Most apps support the product selection stage (selection apps; 27/46, 59%), commonly

by scanning the barcode and displaying a nutritional rating. In total, 73% (8/11) of the evaluation trials reported significant findings and indicated the potential of food purchase choice apps to support behaviour change. However, relatively few evaluations covered the selection app type, and these studies showed mixed results. We found a common opportunity in apps contributing to learning (knowledge gain), whereas infrequent engagement presents a common challenge. The latter was associated with perceived burden of use, trust, and performance as well as with learning. In addition, there were technical challenges in establishing comprehensive product information databases or achieving performance accuracy with advanced identification methods such as image recognition.

Conclusions: Our findings suggest that designs of food purchase choice apps do not encourage repeated use or long-term adoption, compromising the effectiveness of behaviour change through nudging. However, we found that smartphone apps can enhance learning, which plays an important role in behaviour change. Compared with nudging as a mechanism for behaviour change, this mechanism is less dependent on continued use. We argue that designs that optimize for learning within each interaction have a better chance of achieving behaviour change. This review concludes with design recommendations, suggesting that food purchase choice app designers anticipate the possibility of early abandonment as part of their design process and design apps that optimize the learning experience.

3.3 Introduction

3.3.1 Background

Recent reports suggest that current consumer patterns, particularly in Western societies, have a significant impact on health and pose a considerable burden on the natural environment (W. Willett et al. 2019; M. A. Clark et al. 2020). There is increasing evidence that the food production systems and processes enabling current diets contribute to biodiversity losses, water scarcity, and climate change (Vermeulen, B. M. Campbell, and Ingram 2012; M. A. Clark et al. 2020). In addition, obesity and food-related diseases affect a significant proportion of the global population (World Health Organization 2016), leading to an increasing economic and social burden at both the individual and aggregate levels (Leonard et al. 2014; S.-J. Flaherty et al. 2018; Althoff et al. 2022).

Although many people claim to have values that align with healthy and environmentally sustainable diets (Nielsen 2016), actual consumption patterns are often inconsistent with such stated preferences (Yamoah and Acquaye 2019; Katzeff et al. 2020). Research has found that people often struggle to select suitable products to support a healthy or sustainable diet (O'Brien et al. 2015). Diet choices are affected by factors such as broader values, preferences, prices, availability, social pressure, and socioeconomic constraints (Bellisle 2006; O'Brien et al. 2015). This frequently leads to inconsistencies and compromises between competing priorities (Lawo et al. 2021). Moreover, bounded rationality (i.e., the limited capacity for rational decision-making) and heuristic biases (i.e., rational errors in the way we make quick decisions) often lead to sub-optimal choices.

Digital technology—particularly smartphone technology—can support people in making suitable food purchases (S.-J. Flaherty et al. 2018; J. Chan, McMahon, and Brimblecombe 2021) that align with their values. Smartphone technology (hereafter referred to as apps but not excluding any smartphone technology that is not strictly considered an app) can provide rapid access to information, summarize large amounts of data, and present these in personally meaningful ways. With smartphones being omnipresent, these capabilities are available at nearly any time and place, alleviating the need for retailers to make financial investments that could hold back the implementation of alternative systems (Narasimhan, Gandhi, and Rossi 2009; Bird et al. 2013). In the last decade, several software and hardware mobile technologies have emerged to support consumers in making better (i.e., healthier, and sustainable) diet choices. This is particularly the case for healthy diet support apps, which have received much interest in recent years, particularly in the form of diet-tracking technologies (S.-J. Flaherty et al. 2018; Maringer, Van'T Veer, et al. 2018; Ferrara et al. 2019; Holzmann and Holzapfel 2019).

Although a large body of research has examined digital technology for consumption tracking of different products (Maringer, Van'T Veer, et al. 2018; Ferrara et al. 2019; Holzmann and Holzapfel 2019), research on smartphone apps that support food purchase choices is still limited (S.-J. Flaherty et al. 2018; J. Chan, McMahon, and Brimblecombe 2021). Responding to S.-J. Flaherty et al. (2018) and J. Chan, McMahon, and Brimblecombe (2021), who call for further research on the development of food purchase choice apps and to support the development of effective food purchase choice app designs, we conducted a comprehensive review of the research on such developments to date.

3.3.2 Related Reviews

Our scoping review complements previous reviews. Mauch, Wycherley, et al. (2018) reviewed popular apps for healthy food provision available on the Android and iOS app stores. They downloaded 51 apps, assessed the app quality (following the Mobile App Rating Scale (Stoyanov et al. 2015)), and identified the behaviour change techniques (BCTs) present in the design. They classified most apps as recipe, meal-planning, or shopping list apps. In total, 2 were classified as food choice apps. They found that the apps covered relatively few BCTs and that, although the apps generally scored well on functionality, they scored poorly on engagement. They recommended that future developments use a range of features to simplify healthy food shopping and maximize the use of BCTs.

J. Chan, McMahon, and Brimblecombe (2021) conducted a systematic review to assess the efficacy of point-of-sale nutritional information interventions. They included 26 papers that reported comparative evaluations, 5 of which used digital technology as an intervention medium. In total, 3 of the 5 digital technology intervention studies showed a positive health impact, and the authors concluded that digital point-of-sale information interventions could improve healthy food purchasing. However, they noted that, compared with shelf labels, the requirement to scan products to retrieve information may have posed a barrier that led to inconsistency in the results. They found no relationship between intervention effectiveness and the number of identified BCTs.

3.3.3 Objectives

To the best of our knowledge, the reviews by Mauch, Wycherley, et al. (2018) and J. Chan, McMahon, and Brimblecombe (2021) are the only ones of food purchase choice apps to date. However, they are incomplete. Mauch, Wycherley, et al. (2018) provided a catalogue of publicly available health and diet apps without much appraisal of their use. J. Chan, McMahon, and Brimblecombe (2021) surveyed evaluations of food purchase choice apps but limited the scope of their review to 5 studies that followed a comparative evaluation design. Thus, our review aimed to complement their work by compiling a comprehensive overview of the academic literature on apps for food purchase choice published to date. Specifically, we aimed to (1) describe common design characteristics of the retrieved apps and (2) describe opportunities and challenges to effective implementation as they are observed in the literature.

To address these objectives, we chose to conduct a scoping review. Like meta-analyses, scoping reviews are systematic, yet they are less restrictive in scope. They are suitable for mapping the knowledge on a topic and the characteristics of the evidence (Tricco et al. 2018), which makes them well suited for our aims.

This work provides an overview of existing food purchase choice app characteristics, unpacking how different design approaches might affect food purchase choices. Moreover, it frames common challenges in the implementation of these apps. Finally, it frames design considerations that could support future effective food purchase choice app developments.

3.4 Methods

3.4.1 Overview

We conducted a scoping review of published literature on smartphone-compatible digital technologies for food purchase choices (food purchase choice apps). The review followed the guidelines covered by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews, see Appendix A).

3.4.2 Information Sources

We searched for peer-reviewed articles in 4 libraries that were selected to provide coverage of digital health and well-being technologies from an empirical as well as technical perspective: IEEE Xplore, PubMed, Scopus—which covers the ACM Digital Library—and ScienceDirect. The most recent database search was conducted on July 10, 2023. Together, these libraries cover a broad range of literature, with research on mature as well as emerging technologies and publications from the fields of behavioural science, economics, and computer science. We further scanned the included studies for references to articles that would meet our inclusion criteria.

3.4.3 Search

We searched the 4 libraries using the following keyword combination: “(mobile OR smartphone OR app) AND (purchase OR shopping) AND (food OR grocery OR supermarket).” We limited

our search to articles published from 2008 onward. We chose this date limit in consideration of the introduction of the iPhone—the first widely adopted consumer smartphone with a noteworthy ecosystem of apps—in January 2007 and the time required for app development to pick up.

3.4.4 Selection

For selecting the articles, we applied a stepwise process that involved 3 reviewers (RBG, JH, and GM). RBG exported the search results from the individual database searches, imported them into the article selection tool Rayyan (Rayyan Systems Inc) ([Rayyan 2023](#)), and removed duplicates. We then proceeded with the selection of articles according to the eligibility criteria as described in Table 3.1. First, we filtered articles based on title and—if the title left uncertainty about inclusion or exclusion—abstract. RBG scanned the full set of articles. JH and GM scanned approximately half of the set each. This way, each article was scanned independently by at least 2 authors. We then compared the results and discussed any differences until we reached a mutual agreement. RBG then read the full texts of all the articles that remained for another round of filtering. JH and GM together read 17 full-text articles so that a subset of full-text articles was read and selected by multiple researchers. Any differences in selection were discussed until a mutual agreement was reached.

3.4.5 Data Charting

The data charting process (also referred to as *data extraction*) was iterative, and the coding of several items was inductive.

3.4.5.1 Step 1: Open Coding

Open coding was performed by following an instruction manual and the codes were inserted into a Microsoft Excel (Microsoft Corp) spreadsheet that served as the charting form. The instruction manual was drafted by RBG and subsequently verified for comprehensiveness and clarity of instruction through duplicate coding of a test set of 7 articles by RBG, JH, and GM. For verification, the 3 coders met to compare and discuss differences in coding, and minor adjustments to the instruction manual were made. The 3 coders then continued to code the remaining articles. JH and GM each coded another 5 articles each, and RBG coded the remaining articles.

Table 3.1: Eligibility criteria for article selection.

<p>Inclusion Criteria (all must apply)</p> <ul style="list-style-type: none">• App design characteristics:<ul style="list-style-type: none">– Designed for or compatible with smartphones (such as smartphone apps, web applications, or SMS text messaging).– Designed to support grocery choices by considering non-commercial product information types such as nutritional value and social or environmental impact.• Article characteristics:<ul style="list-style-type: none">– Primary works in peer-reviewed journals. <p>Exclusion Criteria (any of these resulted in exclusion)</p> <ul style="list-style-type: none">• App design characteristics:<ul style="list-style-type: none">– Does not address diet choices.– Does not have an apparent influence on the decision process (e.g., if the technology focuses on automatic billing).– Is exclusively designed for web-based grocery purchases (most purchases are still made in bricks-and-mortar grocery stores, and interventions for bricks-and-mortar and web stores involve rather different interaction challenges; designs for purchases in bricks-and-mortar stores need to address transitions between the physical and digital spaces, whereas designs for web-based purchases do not need to address this transition).– Recipe recommenders (that recommend recipes rather than products).– Diet-tracking apps (unless specifically tracking purchases rather than consumption).– Designed specifically to provide support regarding physical disabilities (e.g., mobility and eyesight disabilities).– Designed around exclusive programs (e.g., exclusive voucher programs available only in restricted areas).– Technology purely designed and intended as a study support tool.• Article characteristics:<ul style="list-style-type: none">– Literature reviews (in case relevant reviews were retrieved through the literature search, they were covered as related work in the Introduction section of this paper).– Not in English.
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Open coding at this stage aimed to cover relevant information at a high level of detail such that this could facilitate the inductive process. Variables that were coded at this stage were app variables (description of the app, including the user interaction, functions, required technical infrastructure, and considered product information), evaluation variables (study design, participants, findings, and reported challenges and opportunities), and article variables (publisher and publication year). In case the same app was discussed in multiple articles, the information for the app variables was combined.

3.4.5.2 Step 2: Collaborative Identification Of Patterns

After completion of open coding, the coders held a workshop meeting to identify patterns in several of the data items from step 1 (description of the app, functions, findings, and reported challenges and opportunities) to determine app types, a harmonized collection of functions, and topics of opportunities and challenges. Miro (RealtimeBoard, Inc) ([Miro 2023](#)), a digital whiteboard for collaborative note taking, was used for this workshop. Post-It notes with the initial codes for several of the data items (excluding the article items) were added to the whiteboard. A complete set of these notes was copied for each of the 3 coders, which they could reorganize to aid in the process of exploring and identifying patterns. Workshop participants also had access to a Microsoft PowerPoint (Microsoft Corp) slide deck with images and descriptions of each app and the spreadsheet with the complete coding from step 1. Pattern exploration was performed in 6 rounds. In each round, a subset of step 1 items was explored, first independently by each of the participants and then collectively.

3.4.5.3 Step 3: Final Coding

RBG updated the charting form with the outcomes of the workshop. Several data items were replaced such that the new data items aligned with the patterns from the workshop. In addition, the full texts of the articles were scanned for references to the patterns of opportunities and challenges that were identified in the workshop (also known as indirect opportunities and challenges).

3.4.6 Data Items

3.4.6.1 Article Characteristics

We charted publication year and publisher. Classification of study types was coded according to the classification adapted from the study by Bardus et al. (2015). We classified article types as (1) design and development (articles that described the design of an app), (2) feasibility (articles reporting procedural outcomes such as use, acceptance, and retention, as well as articles reporting outcomes of experiments that were performed under restrictive conditions [e.g., laboratory setting or a predetermined selection of products to choose from]), (3) evaluation (reporting the effectiveness of a technology intervention trial on food purchase choice), and (4) process evaluations and causal-comparative studies (process evaluations in short; reporting effects on socio-cognitive factors that are related to food purchase choice or reporting on comparisons with alternative interventions). A fifth type was reserved for app store reviews. Combination types were also possible (e.g., an article could cover both a feasibility and an evaluation study and would then be assigned both codes).

3.4.6.2 Design Characteristics

We recorded the app name. The variables app type and functions were charted in correspondence with the patterns that evolved from the workshop (cf. the Data Charting section, step 2). Product information represents the type of information that the app uses to support product choice. This covers nutritional information (e.g., calories, allergens, and macro- and micronutrients), diet balance (or food group; information on food groups of purchases concerning recommendations for a balanced diet, such as MyPlate (*MyPlate | U.S. Department of Agriculture 2023*) or the Eatwell Guide (*The Eatwell Guide 23 Feb 2022, 7:55 p.m.*)), environmental impact (e.g., carbon footprint and food miles), and societal impact. Retailer dependency was classified as “dependent” in case the article mentioned the use of data infrastructure that is controlled by the retailer (e.g., the retailer product database, loyalty card data, or beacons for indoor navigation), “independent” in case the article stated that only crowdsourced or open-access data were used, or “unknown” when this information was unavailable.

3.4.6.3 Study Characteristics (For Evaluation Studies Only)

We recorded the *study design* (i.e., cohort or control group design), evaluation period (*duration*), number of participants in each study group (*participants*), and primary findings (*findings*). The topics of *opportunities* and *challenges* were coded in correspondence to the patterns from the workshop. Here, we distinguished between *direct* (reported as a challenge or opportunity in the article) and *indirect* (not reported as a challenge to the design and identified in the second pass of the article).

3.4.7 Synthesis Of Results

We counted the frequencies at which the values were observed and provided narrative summaries of the findings. Specifically, to synthesize the findings on apps, we grouped observations (i.e., apps) by app type and summarized the design characteristics for each group. We supplemented this with a narrative summary in which we focused on common patterns and salient exceptions to those patterns. Furthermore, we visualized the frequency of functions per app type using a bar chart.

Next, we investigated the opportunities and challenges from a quantitative and qualitative perspective. From the quantitative perspective, we counted significant and insignificant primary evaluation outcomes and provided a narrative summary of dominant patterns in the results. From the qualitative perspective, we provided a content analysis of the charted opportunities and challenges, meaning that we tabulated an overview of counted topics of opportunities and challenges and elaborated on these topics using a narrative summary that was supported by specific observations in the articles.

3.5 Results

3.5.1 Overview Of The Included Articles

The database searches returned a total of 1353 articles. Another 11 articles were included from references. After screening, we retained 4.03% (55/1364) of the articles for this review. Figure 3.1 provides an overview of the number of articles excluded at each step of the selection process and the reasons.

Among the 55 articles that remained after filtering, we identified 41 (75%) design and development studies, 32 (58%) feasibility studies, 13 (24%) evaluations, and 3 (5%) process evaluations. In total, 4% (2/55) of the articles were classified as app store reviews. These counts do not add up to 55 as articles often covered a combination of classifications. The dominant publication venues were IEEE (engineering; 13/55, 24%), ACM (computer science; 13/55, 24%), Elsevier (7/55, 13%), JMIR (5/55, 9%), and Springer (5/55, 9%). A complete overview of the included publications is available in Appendix B.

3.5.2 Summary Of Apps

3.5.2.1 Overview

We charted the characteristics of 46 unique food purchase choice apps (overview available in Appendix C). A total of 5% (3/55) of the articles (S.-J. Flaherty et al. 2018; Mauch, Wycherley, et al. 2018; Mauch, Laws, et al. 2021) provided insufficient information on their covered apps for us to chart them. We identified 9 main functions. For 3 of these, we distinguished different implementations of the functions, creating a total of 21 different function labels (overview with descriptions available in Appendix D). Most apps provided health-relevant information (37/46, 80%), with 70% (32/46) of the apps returning nutritional content and 13% (6/46) of the apps providing information on diet balance (1/46, 2% provided information on both). A total of 26% (12/46) of the apps provided information on environmental impact. Other product qualities included societal impact (3/46, 7%), product freshness (1/46, 2%), and product authenticity (whether the provided origin and product type were genuine; 1/46, 2%). Approximately one-quarter (12/46, 26%) of the apps were found to be dependent on the retailer.

We categorized the apps into 6 app types. We observed that all—except one (Bomfim and Wallace 2018)—of the covered apps (45/46, 98%) provided support for a distinct moment or stage regarding product choice. Therefore, we named each app type according to the stage that it addressed. We found apps that addressed (in chronological order) structured purchase *planning* (7/46, 15%), *contemplation* (2/46, 4%), *approaching the product* (6/46, 13%), physically *selecting the product* (27/46, 59%), and *reflecting* on the purchases (7/46, 15%). A total of 2% (1/46) of the apps addressed a combination of these stages (the planning, contemplation, selection, and reflection types. For calculations and graphical mappings, we did not count this toward the individual app types. In those cases, we included a separate multistage app type). In the

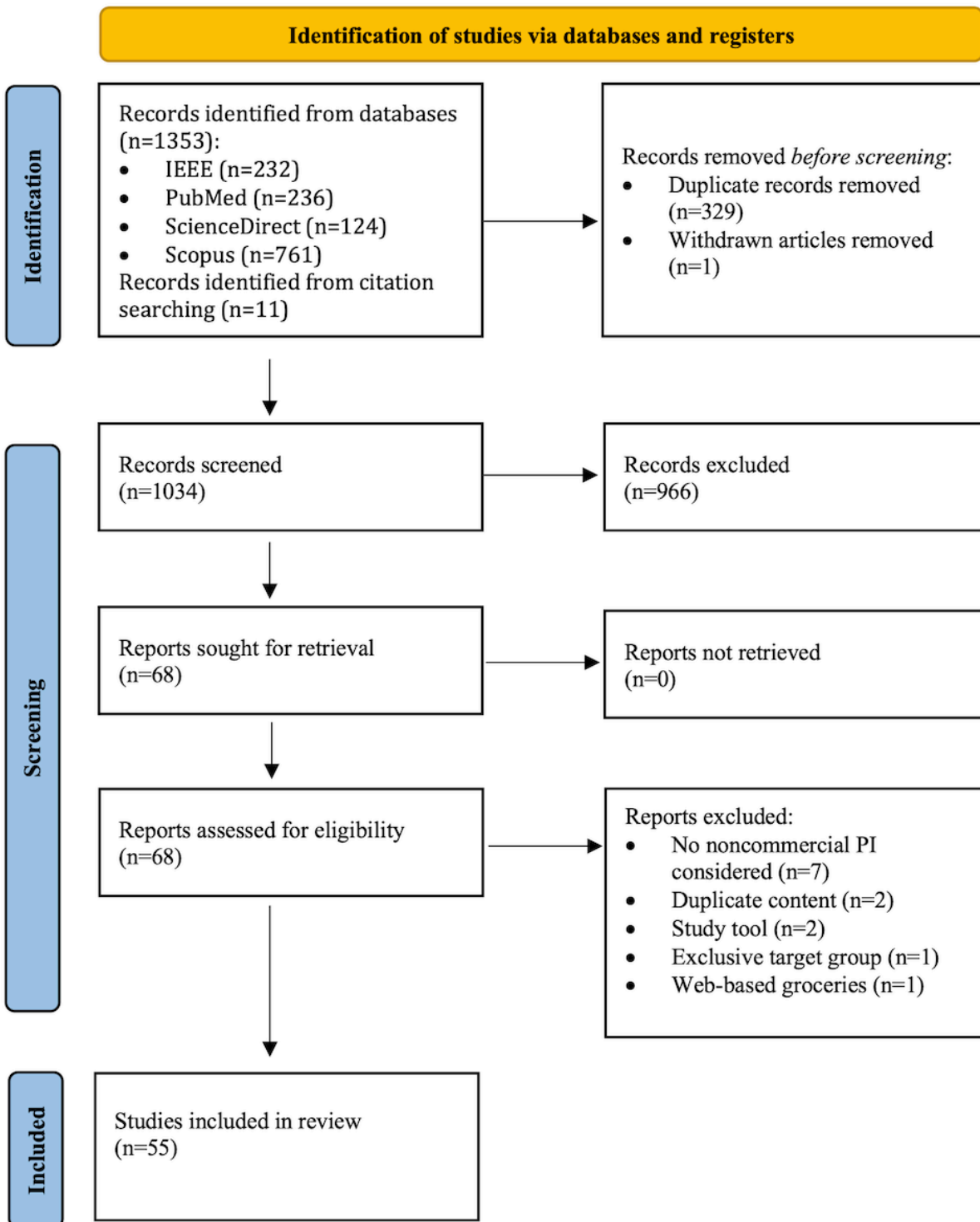


Figure 3.1: Results of article search and screening. PI: product information.

following sections, we describe these app types along with common functions (Figure 3.2) and examples.

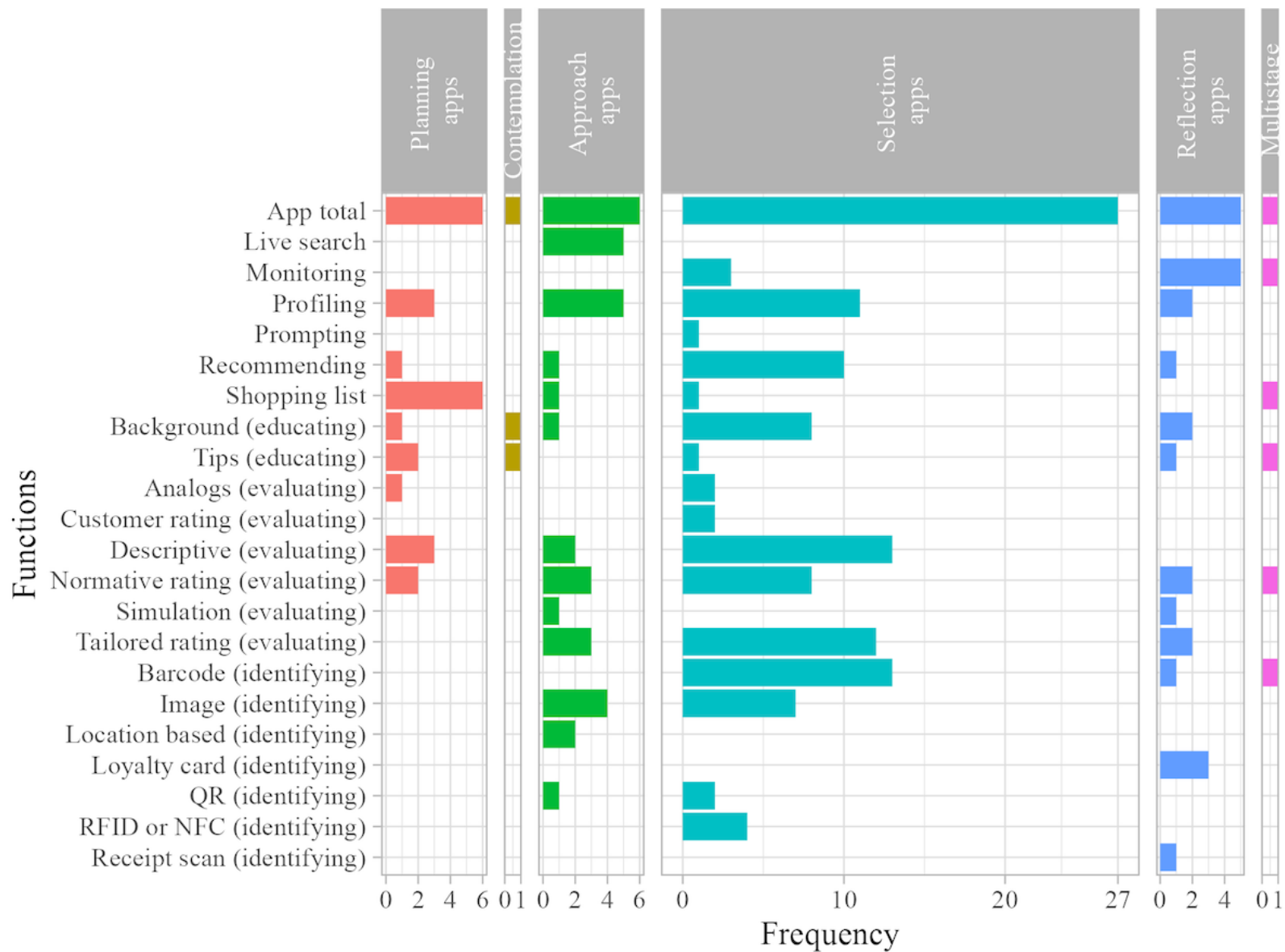


Figure 3.2: Frequency of functions by app type. Separate panels for each app type are scaled to the total number of apps within the app type. An overview of function descriptions is available in Appendix D. NFC: near-field communication; RFID: radiofrequency identification

3.5.2.2 Purchase Planning Apps

These apps support the planning for the use of a shopping list. This can be done by automatically generating a shopping list (Díaz-Hellín et al. 2015), suggesting a goal for the shopping list content (Bomfim and Wallace 2018; Bomfim, Kirkpatrick, et al. 2020), or providing feedback about product characteristics within the shopping list (A. Clear and F. Friday 2012; Hedin, Grönborg, and Johansson 2022). For example, Hedin, Grönborg, and Johansson (2022) used an autocomplete algorithm that lists food items from a carbon footprint database while the user types. The carbon footprint value per 100 g is then presented next to the list item.

3.5.2.3 Contemplation Apps

The contemplation apps have a mostly practical educational function and provide knowledge and tips that help the user make decisions about food purchases while shopping. For example, Bangia, Shaffner, and Palmer-Keenan (2017) introduced a podcast series that informs the listener about the benefits of omega-3, the types of products in which it is found, and practical considerations such as the affordability of different forms of omega-3. The podcast series has short episodes, one each covering products that are typically found in the same shopping aisle so that it can be played when visiting the specific aisle.

3.5.2.4 Approach Apps

Product approach apps use the live search function to provide information about nearby products. Options are visualized on the device screen together with suitability ratings for each product. These apps were found to provide nutritional and environmental but not diet balance information. For example, the app described by Isley, Ketcham, and Arent (2017) uses augmented reality to project semi-transparent traffic-light colour frames and A-to-F tailored ratings over breakfast cereal boxes as the user views the respective shelf section through the phone camera. Special cases were 4% (2/46) of the apps, which used indoor position data to provide the user with information about nearby products but relied on the retailer for these data.

3.5.2.5 Selection Apps

Selection apps provide the user with an evaluation of the product after it has been identified. Barcode scanning (13/46, 28%) is the most common type of identification. Normative ratings (8/46, 17%) and tailored ratings (12/46, 26%) are the most common types of evaluations. Many of these apps also recommend alternative products from the same product category (10/46, 22%; e.g., the category of milk and dairy-free milk alternatives).

For example, upon barcode scanning, App 30 (FoodSwitch) (Dunford et al. 2014) shows the product name and traffic-light nutrition label for the identified product and lists same-category alternatives ordered from more to less healthy below the identified product.

The following were special cases. Although selection apps rely on the active pursuit of product information, one of the identified selection apps makes an exception and allows the user to be passive in the information pursuit. Customers use the retailer-dependent App 22 (Dirk app) (van der Laan and Orcholska 2022) to scan articles as they go around the store as part of a checkout-free automated payment process. In case the user scans an unhealthy item, the app provides a pop-up with information and an alternative.

In addition, one selection app, App 41 (Nutriflect Mobile) (Reitberger, Spreicer, and Fitzpatrick 2014), is designed to be used in combination with a reflection app, App 40 (Nutriflect Home), that records the diet balance in food purchases. This is the only selection app that provides feedback on diet balance (see also the visual in Appendix E).

3.5.2.6 Reflection Apps

These apps rely on monitoring purchases to provide the user with feedback on an aggregated data visualization. Some of these apps are intended to be used in the store (Bird et al. 2013; Bomfim and Wallace 2018; Bomfim, Kirkpatrick, et al. 2020), tracking items as they are added to the shopping basket and providing the user with the opportunity to make adjustments before leaving the store. Other apps provide feedback based on a record of purchases (e.g., from loyalty card data) and support intention formation for the next purchase.

For example, Bird et al. (2013) let the user scan the barcodes of products as they were added to the shopping basket to receive diet balance information. The app interface provided visual feedback on the content of the basket according to 5 food groups (grains, meat, dairy, fruits and vegetables, and treats) through a pie chart. The size of each slice of the pie chart was

proportional to the recommended number of purchases for that food group, and each slice could be partly filled using, for example, light green to represent the remaining amount to be added to the basket and dark green to represent the amount already added.

3.5.2.7 Multistage Apps

One app was found to address multiple stages of the purchase process. Bomfim and Wallace (2018) and Bomfim, Kirkpatrick, et al. (2020) proposed an app, App 44 (PBGA), that covers the planning, contemplation, selection, and reflection stages to support users in achieving a balanced diet. App 44 (PBGA) supports users in creating a shopping list in line with a healthy diet balance (planning), provides users with tips for identifying healthy options in various aisles (contemplation), provides nutrient information upon scanning the barcode of a product (selection), and monitors the scanned items to recommend purchases in each of 5 food groups.

3.5.3 Challenges And Opportunities

3.5.3.1 Study Outcomes

Table 3.2 provides an overview of the 11 evaluation studies. These evaluation studies cover 22% (10/46) of the apps: 7% (2/27) of the selection apps (lowest) and all the reflection apps (7/7, 100%; highest). In total, 72% (8/11) of the studies reported a significant behavioural impact. However, mixed results were observed for the 2 evaluated selection apps. Otherwise, no clear patterns between app type and study outcome could be observed. A total of 27% (3/11) of the studies reported outcomes (findings) toward a diet balance, all showing significant results (see also Appendix F for a grouping of evaluations by product information).

Table 3.3 provides an overview of the 6 process evaluations and causal-comparative studies. Knowledge gain was the most reported socio-cognitive outcome factor (4/6, 67%). All these studies reported significant knowledge gain.

Table 3.2: Summary of evaluation studies organized by app type.

App type and name	Design	Duration	Participants	Findings
Planning apps				
App 39 (MyNutriCart) (Palacios et al. 2018)	Cohort	8 wks.	27 participants	Significant healthier diet balance of purchases
Contemplation apps				
App 5 (Bangia, Shaffner, and Palmer-Keenan 2017)	Cohort	6 mos.	251 participants	Significant increase in omega-3-rich purchases
Approach apps				
App 8 (Asikis et al. 2021)	Cohort	7 mos.	69 participants in the intervention group and 323 participants in the control group	Significant increase in higher-rated purchases
Selection apps				

Table 3.2: Summary of evaluation studies organized by app type.

App type and name	Design	Duration	Participants	Findings
App (22) Dirk app (van der Laan and Orcholska 2022)	3 user interface variations (1 × presenting the alternative without information about its healthiness and 2 × with variations of information that indicate that the presented item concerns a healthier alternative) vs control	5 wks.	1783 scans ¹	Significantly healthier purchases when presenting alternatives without health information and nonsignificantly healthier when adding health information
App (30) FoodSwitch (Eyles, McLean, et al. 2017)	App vs no app	4 wks.	33 participants in the intervention group and 33 participants in the control group	Significant reduction in sodium concentration in purchases
App (30) FoodSwitch (Eyles, Grey, et al. 2023)	App+reduced-sodium salt vs no app	12 wks.	84 participants in the intervention group and 84 participants in the control group	Nonsignificant change in sodium intake

Reflection apps

¹Participant counts are unknown. Only the number of scans that triggered information prompts was available.

Table 3.2: Summary of evaluation studies organized by app type.

App type and name	Design	Duration	Participants	Findings
App 13 (Lurz et al. 2023)	Cohort	2 wks.	31 participants	Nonsignificant change in the healthiness of purchases
App 25 (EcoPanel) (Zapico, Katzeff, et al. 2016)	App vs no app	5 mos.	65 participants in the intervention group and 2587 participants in the control group	Significant increase in organic purchases
App 32 (FutureMe) (Mönninghoff et al. 2022)	App+future-self simulation vs app without	12 wks.	42 participants in the intervention group and 53 participants in the control group	Nonsignificant difference in the healthiness of purchases
App 35 (Healthy Shopping App) (Bird et al. 2013)	Cohort	4 wks.	7 participants	Significantly healthier diet balance of purchases
App 40 (Nutriflect Home) (Reitberger, Spreicer, and Fitzpatrick 2014)	Cohort	4 wks.	21 participants	Significantly healthier diet balance of purchases

Table 3.3: Summary of process evaluations and causal-comparative studies.

App type and name	Design	Duration	Participants	Findings
Planning apps				
App 33 (GreenCobra) (Hedin, Grönborg, and Johansson 2022)	Cohort	2 wks.	30 participants	Significant knowledge gain
App 37 (MFG ²) (Bomfim, Kirkpatrick, et al. 2020)	Cohort	3 wks.	12 participants in the control group	Significant knowledge gain
App 39 (MyNutriCart) (Palacios et al. 2018)	App vs education	8 wks.	27 participants in the intervention group and 24 participants in the control group	Nonsignificant difference in healthiness of purchases vs education
Selection apps				
App 26 (EDO app) (Samoggia and Riedel 2020)	Cohort	12 wks.	143 participants	Significant knowledge gain and significant gain in self-efficacy
Multistage apps				

²MyFoodGuide

Table 3.3: Summary of process evaluations and causal-comparative studies.

App type and name	Design	Duration	Participants	Findings
App 44 (PBGA) (Bomfim, Kirkpatrick, et al. 2020)	Cohort ³	3 wks.	12 participants in the intervention group and 12 participants in the control group	Significant knowledge gain
App 44 (PBGA) (Bomfim, Kirkpatrick, et al. 2020)	App 44 (PBGA) vs App 37 (MFG ⁴)	3 wks.	12 participants in the intervention group and 12 participants in the control group	Significant reduction in ultra-processed food purchases

³Knowledge gain was assessed using a pre- and post-test design, whereas behaviour change was assessed by comparing the effects of different apps. Therefore, we list the results in separate table rows even though the 2 evaluations were performed in the same study.

⁴MyFoodGuide

3.5.3.2 Qualitative Content Analysis Of Challenges And Opportunities

3.5.3.2.1 Overview

Table 3.4 provides the counts of common topics regarding challenges and opportunities as they were identified through a qualitative content analysis (an overview of challenges and opportunities is in Appendix G). We elaborate on these topics in the following sections.

Table 3.4: Common challenge topics found in the studies.

Topic	Direct ⁵	Indirect ⁶	Total
Behaviour change	8	10	18
Barriers to change	5	4	9
Scope of impact	3	6	9
Interaction	23	20	43
Engagement	12	2	14
Trust	5	7	12
Burden of use	5	4	9
Learning	1	7	8
Technical feasibility	13	7	20
Source data ⁷	8	3	11
Performance	5	4	9

3.5.3.2.2 Behaviour Change Challenges

3.5.3.2.2.1 Barriers To Change

Behaviour change is hard, and participants struggle to achieve diet goals (Bird et al. 2013; Bomfim, Kirkpatrick, et al. 2020). Conflicting priorities complicate adoption of changes (López et al. 2017; Lawo et al. 2021; Hedin, Grönborg, and Johansson 2022). The user may not like the suggested products (López et al. 2017) or perceive the pursuit of adopting changes as too

⁷The data that underlie the information that is viewed on the app. This is typically a database of product information.

⁵The authors of the publication recorded the topic as a challenge to the implementation of the app.

⁶The authors addressed the topic but not directly as a challenge to the implementation of the app.

time-consuming (Lawo et al. 2021; Hedin, Grönborg, and Johansson 2022). Participants look for ways to prioritize their efforts but may find support for this lacking (Hedin, Grönborg, and Johansson 2022). Zapico, Katzeff, et al. (2016) argued that reflection on previous behaviour helps people prioritize behaviour change, and they developed a reflection app (Bohné, Zapico, and Katzeff 2015; Zapico, Katzeff, et al. 2016). Apps can also support prioritization by providing salient reminders of past behaviour as memories of past behaviour may not be accurate (Reitberger, Spreicer, and Fitzpatrick 2014). Reitberger, Spreicer, and Fitzpatrick (2014) supported this by linking a selection app with behaviour-monitoring data from a reflection app. This allowed the selection app to assess the suitability of products from the perspective of past behaviour.

3.5.3.2.2 Scope Of Impact

Although a benefit of mobile apps lies in their scalability (S.-J. Flaherty et al. 2018), the impact is limited to the users who choose to adopt the technology (Dunford et al. 2014; Katzeff et al. 2020). This is often only a small proportion of the population (Dunford et al. 2014). However, Reitberger, Spreicer, and Fitzpatrick (2014) noted that this impact can be extended to household members by monitoring household purchases using a reflection app. Reflection on household behaviour can spark conversation and lead to social facilitation.

Retailer dependency can also restrict the scope of impact. Information about purchases is available only at specific stores (Bohné, Zapico, and Katzeff 2015). The app may have little value for people who purchase much of their food from other retailers (Mönninghoff et al. 2022). The commercial interest of retailers may also lead them to restrict the information that is provided. For example, retailers may be interested in providing data that encourage the purchase of organic products but may be less inclined to provide data on other indicators of sustainability (Bohné, Zapico, and Katzeff 2015). Retailers may also choose to withhold negative information or withhold information altogether as negative information was found to have a stronger impact on rejecting a product than that of positive information on choosing a product (Hegen 2016).

3.5.3.2.3 Interaction Challenges

3.5.3.2.3.1 Engagement

Engagement issues (limited use and abandonment) were frequently reported (Tomlinson 2008; Vintsarevich et al. 2011; Eyles, McLean, et al. 2017; López et al. 2017; S.-J. Flaherty et al. 2018; Mauch, Wycherley, et al. 2018; Fuchs et al. 2019; Mauch, Laws, et al. 2021; Lawo et al. 2021; Mahdi, Chilcott, and Buckland 2022; Mönninghoff et al. 2022; Eyles, Grey, et al. 2023). Engagement issues are seen as a barrier to behavioural impact (Mauch, Wycherley, et al. 2018; Fuchs et al. 2019; Mauch, Laws, et al. 2021; Mönninghoff et al. 2022; Eyles, Grey, et al. 2023), and 4% (2/55) of the studies attributed insignificant findings to this issue (Mönninghoff et al. 2022; Eyles, Grey, et al. 2023). However, Zapico, Katzeff, et al. (2016) did not observe a correlation between frequency of engagement and behavioural impact. They reported significant behavioural impact despite a low engagement frequency with their App 25 (EcoPanel) reflection app. Engagement issues may result from knowledge gain (learning) (Herbig, Kahl, and Krüger 2018; Samoggia and Riedel 2020), a perceived burden of app use (Tomlinson 2008; Herbig, Kahl, and Krüger 2018; Eyles, Grey, et al. 2023), performance (S.-J. Flaherty et al. 2018; Mönninghoff et al. 2022), and trust issues (Mönninghoff et al. 2022), whereas tailored or personalized feedback can increase engagement (Fuchs et al. 2019; Mönninghoff et al. 2022)—although personalized feedback can negatively affect engagement when the data are not trusted (Mönninghoff et al. 2022). Normark and Tholander (2014) found that, when technology does not perform as expected, this leads to frustration and rejection of the technology.

3.5.3.2.3.2 Burden Of Use

The use of the technology may be found effortful and disruptive to the shopping routine (Broll et al. 2013; Reitberger, Spreicer, and Fitzpatrick 2014; Asikis et al. 2021) or shopping list creation (Lawo et al. 2021) and, therefore, less acceptable for frequent use (Normark and Tholander 2014; Herbig, Kahl, and Krüger 2018). Instead, studies indicated that technology is used as an infrequent lookup and to explore new products (Herbig, Kahl, and Krüger 2018; Asikis et al. 2021; Lawo et al. 2021), which may not have been the intended use (Lawo et al. 2021). However, one study (Herbig, Kahl, and Krüger 2018) was found to consider the likelihood of infrequent use as part of their design process.

3.5.3.2.3.3 Learning

Learning (knowledge gain) was framed as a challenge from the viewpoint of some authors as they perceived that it might hinder repeated use of the app and contribute toward its abandonment. Indeed, as people gain knowledge about products through the use of the app, they

may perceive less need to use it again (Herbig, Kahl, and Krüger 2018; Samoggia and Riedel 2020). However, knowledge gain (i.e., increasing food literacy) through digital interaction was frequently highlighted as an important mediator of behaviour change (Bangia, Shaffner, and Palmer-Keenan 2017; Bomfim and Wallace 2018; Bomfim, Kirkpatrick, et al. 2020; Samoggia and Riedel 2020; Hedin, Grönborg, and Johansson 2022). This means that learning was viewed as a challenge for food purchase choice app adoption but not necessarily for achieving behaviour change. Moreover, knowledge gain was generalized beyond the products that were evaluated using the app (Herbig, Kahl, and Krüger 2018) and even the food group (Samoggia and Riedel 2020). Some authors suggested that, because of rapid learning, initial app interactions may be the most important for guiding change (Zapico, Katzeff, et al. 2016; Herbig, Kahl, and Krüger 2018), and in some cases, further engagements may have little incremental impact on further behaviour change (Zapico, Katzeff, et al. 2016). In addition, Bangia, Shaffner, and Palmer-Keenan (2017) observed a significant behavioural impact from a one-off intervention with their app 6 months after the intervention had taken place, pointing out that repetition is not an essential mechanism to achieve knowledge gain and mediate behavioural impact.

3.5.3.2.3.4 Trust

Issues with trust were also flagged as negatively affecting engagement with technology. Involvement of the retailer in the app source data was noted as a potential source of distrust (Bird et al. 2013; Herbig, Kahl, and Krüger 2018; Lawo et al. 2021), leading to efforts to develop technology that can work independently from the retailer (Bird et al. 2013). Commercial interests may restrict transparency (Bohné, Zapico, and Katzeff 2015), involve advertisements in the form of recommendations to influence purchases (Jayananda et al. 2018), or restrict product information unfavorably (Hegen 2016). Even when the motives of influence are genuine, external influence may result in reactance (the resistance against a persuasive intent that is nonetheless perceived as manipulation). van der Laan and Orcholska (2022) showed how a persuasion attempt to choose a healthier alternative can be nullified when external motives are exposed. Commercial interests may also make demands on privacy protection, particularly when personal data are shared (Asikis et al. 2021). As many of the apps are designed to be used in nonprivate environments, privacy concerns are also relevant for the mode of feedback, particularly when the feedback is not well concealed (e.g., when using audio feedback (Broll et al. 2013)) or when the phone camera is used for recognition of products and personal identifiable features may be exposed (Hedin, Grönborg, and Johansson 2022).

3.5.3.2.4 Technical Feasibility Challenges

3.5.3.2.4.1 Source Data

Acquiring and maintaining (accurate) source data may also present feasibility issues, for example, when using location information for recognizing products (Ahn et al. 2015; Hormann et al. 2019; Asikis et al. 2021). Acquiring and updating source data to achieve the required performance was found to be very challenging (Hormann et al. 2019; Tsai et al. 2021). In addition, some data, such as data on environmental sustainability and social impact, may be difficult to acquire (Head et al. 2014; Herbig, Kahl, and Krüger 2018; Asikis et al. 2021; Hedin, Grönborg, and Johansson 2022). This can pose significant implementation challenges.

3.5.3.2.4.2 Performance

Technical challenges may stand in the way of the practical implementation of an app. For example, performance issues may limit the app regarding approaches using image recognition. Studies that reported on recognition performance found that not all products could be identified (Waltner, Schwarz, Ladstätter, Weber, Luley, Bischof, et al. 2015; Röddiger, Doerner, and Beigl 2018), and no evaluation studies were found for apps that use image recognition to identify products. Indeed, Isley, Ketcham, and Arent (2017) noted that water bottles could not be detected by a camera, and QR labels on shelves were needed to assist their study. They also reported that cereal boxes were not always accurately detected or were not detected at all.

Field trials using near-field communication (NFC) or radiofrequency identification (RFID) as a detection method were not found. Although no performance issues were reported, it was noted that NFC or RFID labels were not (yet) provided for the grocery products in the study supermarket (Reitberger, Spreicer, and Fitzpatrick 2014), which made practical implementation of this strategy unfeasible at the time of the study.

Even when a product is correctly scanned, product data may not be returned. We found various studies that noted issues with missing or faulty data for products, particularly in the case of retailer-independent designs (Vintsarevich et al. 2011; Fuchs et al. 2019; Eyles, Grey, et al. 2023; Lurz et al. 2023), although faulty data could also be observed for retailer-dependent designs (Lawo et al. 2021).

3.6 Discussion

3.6.1 Principal Findings

We systematically reviewed the academic literature on food purchase choice apps and inductively charted common design characteristics as well as opportunities and challenges for their effective implementation. We identified 5 distinct app types, each supporting a specific stage of food purchase choice. The most common app type (almost 60%; 27/46, 59%) was selection apps. Most selection apps identify products through barcode scanning and evaluate the product by returning a (tailored or norm-based) rating of nutritional content without any dependence on a specific retailer. Other types of apps and product information were less frequent.

We investigated opportunities and challenges by charting quantitative results from evaluation trials and qualitatively exploring patterns in the authors' observations. Similarly to J. Chan, McMahon, and Brimblecombe (2021), we observed that the results from 11 comparative evaluation trials indicate the potential for food purchase choice apps to support behaviour change. However, the proportion of evaluated selection apps is notably small (2/26, 8% vs 9/20, 45% for other types); moreover, the results for this app type are mixed, suggesting potential efficacy challenges with this approach (Franco, Malhotra, and Simonovits 2014; A.-W. Chan et al. 2017). Notably, all comparative evaluations that provided diet balance information (3/11, 27%) showed a positive impact. Evaluation trials also indicated the potential of food purchase choice apps to contribute to knowledge gain, with all 4 evaluations reporting significant findings.

Qualitative findings based on content analysis of the authors' observations highlighted opportunities and challenges surrounding food purchase choice apps. In food purchase choice apps, engagement issues such as repeated use and long-term adoption present a common challenge. The findings indicate that engagement challenges frequently result from a perceived burden of use. These results are in line with those of the research on the abandonment of behaviour change technology (Cordeiro, Daniel A. Epstein, et al. 2015; Lazar et al. 2015). We also observed broader challenges relevant to the pursuit of behaviour change (e.g., people may struggle to identify which efforts to prioritize), trust in retailer motives, and technical feasibility. Learning was observed as a common opportunity derived from the use of food purchase choice apps. Opportunities for addressing various challenges were repeatedly found in apps that apply behaviour monitoring (reflection apps).

3.6.2 Implications

3.6.2.1 Consideration Of Mechanism Of Technology-Mediated Change In Design Thinking

Selection apps address the moment of product selection and appeared particularly popular for supporting food purchase choices. Selection apps provide support just-in-time (at “exactly the right moment”) (Fuchs et al. 2019) (see the “just-in-time” intervention literature (Nahum-Shani, Hekler, and Spruijt-Metz 2015; Goldstein et al. 2017); i.e., the moment a choice is translated into action in-store and a product is either added or not added to the shopping basket). There is no need to rely on—potentially inaccurate—memory (Reitberger, Spreicer, and Fitzpatrick 2014). Rather than relying on rational thinking, this approach allows the user to be guided by a gentle push (nudge) in the direction of healthy or sustainable choices on the spot (Fuchs et al. 2019; van der Laan and Orcholska 2022; Fagerstrøm et al. 2023 Apr-Jun) (see the works by Caraban et al. (2019), Thaler and Sunstein (2008), and Sunstein (2014) for frameworks of nudging). As such, the approach aligns with a growing acknowledgment that most decisions during in-store grocery shopping are not made through deliberate, rational decision-making processes but rather through heuristics (S. J. Flaherty et al. 2020) (“mental shortcuts,” or “snap decisions” based on less conscious evaluations of the available information (Thaler and Sunstein 2008; Kalnikaite et al. 2011)). It can be argued that conscious decision-making is not the design aim of a nudge-driven system, but it can be a side outcome. Along these lines, behaviour change beyond a single purchase relies on the repeated exposure to these nudges and on the repeated use of the food purchase choice app that uses nudges to achieve impact.

Despite their claimed benefits, we observed frequent reporting of engagement challenges with selection apps and food purchase choice apps in general. Users perceive the use of selection apps as interruptive or burdensome (Ni Mhurchu et al. 2017; Herbig, Kahl, and Krüger 2018; Eyles, Grey, et al. 2023), leading them to slowly abandon their use over time, which jeopardizes the intended behaviour change goal of such apps. These findings align with those of Vhaduri and Prioleau (2021), highlighting that infrequent engagement with digital health technology jeopardizes the potential health benefits. Similarly, Ni Mhurchu et al. (2017) found that the healthiness of food purchases only increased for people who frequently used the selection apps.

Various researchers have attempted to characterize the causes that underlie these engagement issues with digital health applications (Cordeiro, Daniel A. Epstein, et al. 2015; Lazar et al.

2015; Daniel A. Epstein, Caraway, et al. 2016; Vhaduri and Prioleau 2021) and proposed design modifications that may improve long-term engagement. Kalnikaitė et al. (2011; 2013) and Todd, Rogers, and Payne (2010) highlighted the importance of causing minimal disruption to the shopping routine and providing “just enough information, in the right form.” A variety of product identification and evaluation approaches may be driven by the premise of minimal disruption in the selection of apps that we found through our literature search. However, these approaches sustain the focus on nudge-based systems. The questions remain open regarding improving nudge-based systems enough to accomplish long-term use to achieve behavioural impact.

Related to this, we observed 2 important shortcomings in the attempt to improve behaviour change impact by designing food purchase choice apps with the premise of repeated use. First, we found that engagement challenges are common across various domains of digital technology (e.g., for just-in-time digital health interventions (T. Greenhalgh et al. 2017; Joonyoung Park and Lee 2023), web-based diet interventions (C. Young et al. 2019), self-tracking apps (Cordeiro, Daniel A. Epstein, et al. 2015; Daniel A. Epstein, Caraway, et al. 2016), wearables (Attig and Franke 2020), and IoT (Melo, Andrade, and Darin 2022)). The widespread presence of engagement issues suggests that they are hard to solve, and the results of efforts to achieve engagement for extended periods are likely to be modest at best. Short periods of engagement may be better understood as the rule rather than the exception (Cordeiro, Daniel A. Epstein, et al. 2015; Daniel A. Epstein, Caraway, et al. 2016).

Second, the proposal to improve nudge-based systems for improved engagement reflects the prioritization of quantity over quality of engagement. A focus on engagement quantity aligns with a nudge-mediated mechanism of behaviour change (i.e., the app redirects automatic behaviour by changing the choice environment without significant involvement of conscious decision-making (Thaler and Sunstein 2008; Kalnikaite et al. 2011)). However, the findings of our study challenge this prioritization of quantity over quality and suggest that other important mechanisms are at play.

Our findings suggest that learning (knowledge gain) plays an important mediating role in the impact of food purchase choice apps on food purchase choice behaviour. In their study with a reflection app, S. J. Flaherty et al. (2020) found that behavioural feedback can spark learning through critical reflection on products and one’s beliefs about products and influence future purchases. Reitberger, Spreicer, and Fitzpatrick (2014) and Zapico, Katzeff, et al. (2016) observed that the use of a reflection app contributed to a positive change in food purchase choice. Also in-

dicative of learning, Bangia, Shaffner, and Palmer-Keenan (2017) observed a positive change in food purchase choice 6 months after using an information-rich food purchase choice app during one shopping trip.

The mechanism of learning-mediated changes appears to depend more on the quality than on the quantity of food purchase choice app engagements. Few interactions may suffice for learning to happen (Zapico, Katzeff, et al. 2016; Bangia, Shaffner, and Palmer-Keenan 2017; Herbig, Kahl, and Krüger 2018). A single interaction may even suffice for a significant impact on behaviour (Zapico, Katzeff, et al. 2016; Bangia, Shaffner, and Palmer-Keenan 2017). In their research with selection apps, Samoggia and Riedel (2020) and Herbig, Kahl, and Krüger (2018) noted that learning can even reduce the likelihood of future use as the perceived value of the information diminishes, findings that align with those of Daniel A. Epstein, Caraway, et al. (2016), who found that internalization of the learnings from the use of diet trackers can be a cause of abandonment of the technology as such a mechanism of learning-mediated change can intervene with a mechanism of nudge-mediated change.

Although the described mechanism of learning involves conscious reflection, it does not conflict with an appreciation for the role of heuristics in grocery shopping. S. J. Flaherty et al. (2020) observed that conscious reflection serves to update beliefs that drive heuristics-based food purchase choice. After a period of conscious reflection on purchases, routinized, heuristics-based shopping is continued.

In summary, we observed that there is an important role for learning in behaviour change supported by food purchase choice apps and that—contrary to a mechanism that relies on nudging—learning is relatively robust against disengagement as it does not necessarily rely on continued engagement with the app. This has important implications for the design of food purchase choice apps. There are opportunities to design apps that can be effective despite potential abandonment that designers may want to pursue. In the next section, we provide some practical suggestions for designing with learning in mind, along with other suggestions for the future design of food purchase choice apps.

3.6.2.2 Suggestions For Future Design

The purpose of this section is to formulate briefly some practical suggestions for the design of food purchase choice apps that follow from the contents of this review.

3.6.2.2.1 Optimize For Learning

As discussed in the previous section, learning appears to play a key role in the potential behavioural impact of food purchase choice apps. We propose that the key elements of learning-oriented food purchase choice app design include information clarity, information contextualization (i.e., providing informative context to support decisions), and an emphasis on rich information—elements that we observed in the use of functions such as tips and tricks and background information. Key elements also include design with a view for minimal interactions as opposed to repeated use, design to support reflection on information and rational thinking that extends beyond the app's use, and design to support user autonomy and gradual abandonment of the app.

This proposal aligns with our observations that behaviour monitoring can benefit learning (Zapico, Katzeff, et al. 2016; S. J. Flaherty et al. 2020; Lurz et al. 2023) and that the use of knowledge tips and background information is also associated with knowledge gain (Bangia, Shaffner, and Palmer-Keenan 2017; Herbig, Kahl, and Krüger 2018). Importantly, the optimization of designs for a nudging effect (Todd, Rogers, and Payne 2010; Kalnikaitė, Bird, and Yvonne Rogers 2013) may conflict with efforts to optimize designs for learning.

3.6.2.2.2 Formalize Assumptions Of App Use Over Time

Many food purchase choice app designs seem to be developed on the unspoken premise of continued engagement to achieve behavioural impact, although this is not a given. We observed that it is uncommon for designers to articulate expectations regarding the regularity and nature of engagement within the design process (an exception is the study by Herbig, Kahl, and Krüger (2018)). However, our findings suggest that early abandonment appears to be common and can have a detrimental impact on the potential of an app to affect behaviour. To mitigate unforeseen impact, we suggest that designers view abandonment as a key element of their design strategy and formulate engagement expectations early in the design process. It is recommended that designers include considerations about engagement over time and possible abandonment in design thinking. By bringing transparency into the matter, designers can then develop diverse mechanisms to address abandonment.

3.6.2.2.3 Overcome Biases And Norms When Selecting Design Characteristics

Although we observed a wide range of design characteristics (app types, functions, and product information), food purchase choice app designers seem biased toward selecting a set of characteristics (see, for instance, selection apps and the use of barcode scanning and normative or tailored ratings of nutritional information). We found that other app types and product information may have more potential. Therefore, we encourage designers to explore other options for the design of selection apps and, broadly, of food purchase choice apps. Some suggestions include the use of diet balance as product information and reflection apps as an app type, which are further addressed in the following sections.

3.6.2.2.4 Use Diet Balance As Product Information

This product information was commonly associated with significant behavioural impact (cf. the Study Outcomes section). Achieving a balanced diet can be framed as goal setting, which is considered an effective BCT (Lyons et al. 2014; Humphreys et al. 2021; Aguiar et al. 2022). In addition, the simplicity of classifying choices into 5 categories may be beneficial for facilitating behaviour change. Goal setting requires a form of monitoring and is, therefore, suitable for reflection apps—for which monitoring is a key function. Goal setting is also compatible with planning apps (Bomfim, Kirkpatrick, et al. 2020) based on purchase intention monitoring. However, the need to define quantities for the intended purchases may present a barrier (Kulpy and Bekaroo 2017; Lawo et al. 2021; Hedin, Grönborg, and Johansson 2022), which may make this a less suitable option.

3.6.2.2.5 Consider Behaviour Monitoring (Reflection Apps)

We observed that various opportunities for addressing common challenges with food purchase choice apps are found in reflection apps framed around behaviour monitoring. Behaviour monitoring is considered one of the more impactful BCTs (Humphreys et al. 2021; Aguiar et al. 2022). Behaviour monitoring can help prioritize actions (Zapico, Katzeff, et al. 2016), which is a common barrier to achieving behaviour change. Behaviour monitoring can be resistant to engagement issues (Zapico, Katzeff, et al. 2016), particularly those related to missing product data (Lurz et al. 2023), as it does not depend on the information of a single product (as opposed to many selection apps and nudging approaches). It also provides opportunities for feedback on diet balance, a type of product information that was commonly associated with significant behavioural impact. Moreover, as reflection is independent of the point of purchase (usually happens after the purchase), the interaction with reflection apps is likely to be less time-pressured

than the interaction with those designed to be used during shopping (e.g., selection apps and nudging systems), which can provide better learning opportunities.

3.6.2.2.6 Practical Limitations And Future Opportunities For Reflection Apps

Relevant to the aforementioned, it must be noted that most reflection apps included in this study used loyalty card data or receipt scanning, approaches that facilitated easy data recording (Reitberger, Spreicer, and Fitzpatrick 2014; Bohné, Zapico, and Katzeff 2015; Mönninghoff et al. 2022; Lurz et al. 2023). However, practical implementation of these approaches can present difficulties. The applicability of loyalty card data is limited to the people who use loyalty cards, and the availability depends on the retailers that make these data available. Although Swiss law seems to require retailers to make these data available through an application programming interface (API) (Mönninghoff et al. 2022), such regulations may not apply in other countries, which can pose constraints to designers who want to pursue such approaches. Moreover, receipt scanning requires trained machine learning algorithms and may not work optimally (Bohné, Zapico, and Katzeff 2015; Lurz et al. 2023); however, given that alternatives such as barcode scanning are often perceived as too effortful (Cordeiro, Daniel A. Epstein, et al. 2015), receipt scanning seems to be a promising avenue for future designs. These limitations can be framed as opportunities for further research for developing effective food purchase choice apps.

3.6.3 Limitations

We acknowledge several limitations in our decisions for executing and reporting this review. We report these in no specific order.

The use of digital technology for behaviour change can raise important ethical concerns (Da Rocha and Hunziker 2020; Busch et al. 2021; Kuyer and Gordijn 2023) as these technologies have the potential to be manipulative. This review did not systematically assess the ethical concerns that might be associated with the app designs or the approaches that were taken to mitigate manipulative potential (i.e., design approaches that respect individual needs and priorities, such as participatory design (J. Davis 2012; Simonsen and Robertson 2012; Tengland 2012) or human-centred design (Norman 2013)). Such an assessment was beyond the scope of this study. However, designers of technology must be respectful of individual needs and priorities and follow user-centred approaches.

We did not calculate a meta-statistic estimate of the effects of food purchase choice apps. Appropriate reporting of this statistic relies on the stringent review procedure of a meta-analysis. We provided a simple summary analysis of study findings that provided context for the opportunities and challenges that were reported in the literature. Calculating a meta-statistic would be beyond this means and not our objective, and following the requirements for a meta-analysis would have compromised our ability to report on the objectives that we did formulate. Moreover, with the current body of literature, we see little justification for conducting a meta-analysis to calculate the impact of food purchase choice apps. The variety in reported outcome measures, together with a modest number of studies reporting evaluation results, complicates the calculation of a meta-statistic and restricts the conclusions that can be drawn.

The final charting was performed by only one person. This limited the rigor of establishing exact counts of the observed codes. However, the main function of observation counts was to indicate the magnitude of common patterns in designs, opportunities, and challenges. Establishing exact counts for each observation was less important. Importantly, the identification of the common patterns themselves played a superior role in addressing the study objectives. Multiple reviewers were involved in the identification of patterns in the literature.

We acknowledge that the apps could have been described along with additional characteristics. We listed the characteristics that appeared most salient in describing the variations in apps without much interpretation. The apps could have been characterized by mapping techniques from the BCT Taxonomy (BCTT) (Michie, Richardson, et al. 2013). However, we had several reasons not to characterize apps using BCTs. First, mapping along the BCTT requires a firm understanding of the various techniques as well as a firm understanding of the intervention that applies the techniques (C. E. Wood et al. 2015). The comprehensiveness and clarity of app descriptions in the articles varied considerably, and it was not feasible to download and investigate the apps as most were not deployed on app stores. This limited our ability to perform accurate mapping of BCTs, with the potential for misleading interpretations drawn from this mapping. Second, the value of mapping BCTs is expected to be moderate. BCTs have been associated with the efficacy of behavioural intervention (Lyons et al. 2014; Humphreys et al. 2021; Aguiar et al. 2022), and counting BCTs in apps is used as a practice to estimate the potential of an app to affect behaviour (Mauch, Wycherley, et al. 2018; J. Chan, McMahon, and Brimblecombe 2021). However, several studies failed to find a relationship between the number of applied BCTs and behavioural outcomes (Dombrowski et al. 2012; Pesseau et al. 2015; J. Chan, McMahon, and Brimblecombe 2021). As a binary mapping approach, mapping along the BCTT does not con-

sider the quality of the BCT implementation or its prominence in the app. For these reasons, we decided not to prioritize the mapping of BCTs.

3.6.4 Conclusions

This scoping review examined the design characteristics, opportunities, and challenges of food purchase choice apps. Most food purchase choice apps are designed to help users select healthier products by scanning the barcode and displaying a nutritional rating. The value of this design comes from its potential to influence (nudge) users' decisions at the point of purchase (just in time), with little demand for conscious decision-making. However, our findings suggest that this design approach does not encourage repeated use and long-term adoption, which limits opportunities for behaviour change through nudging. Instead, our results indicate that learning plays an important role in behaviour change and that this mechanism is less dependent on continued use. We argue that designs that optimize learning within each interaction will have a better chance of achieving behaviour change. This review concludes with design recommendations, suggesting that food purchase choice app designers (1) anticipate the possibility of early abandonment as part of their design process and (2) design apps that optimize the learning experience.

3.6.5 Acknowledgments

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Chapter 4

Attitudes Towards Design Features

4.1 Introduction

To support people in their food purchase choices, my survey of food purchase choice apps (see Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. (2024) and Chapter 3) emphasized the potential of behaviour reflection applications (i.e., self-tracking, or self-monitoring technology (Li, Dey, and Forlizzi 2010)). With this chapter I aim to investigate attitudes of climate-sensitive people towards various theory-informed design features for a self-monitoring application to empower people towards making climate-sustainable grocery purchases and make a first step towards a person-centred design of a self-tracking application. My survey of apps lists various design features found in prior works (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024). However, technology for the support of behaviour change has been criticized for its potential to manipulate and undermine individual autonomy (Tengland 2012; Da Rocha and Hunziker 2020; Kuyer and Gordijn 2023) and it is not clear to what extent the various design features align with a person-centred perspective. The current study aims to enhance this understanding through a creative and exploratory design workshop with participants as co-designers. As potential future users, participants evaluate and discuss various design features.

4.2 Conceptual Design

As a starting point for the workshop, I formulated a conceptual design and formulated steps that described how the application could be integrated around the grocery shopping routine

(Figure 4.1). The conceptual design adopts recommendations from the previous chapter (Section 3.6.2.2). Fundamentally, the design is a self-monitoring app (the fifth recommendation), a design that was argued to be favourable for learning (the first recommendation) and also praised for its potential to be effective despite potential technology abandonment (second recommendation). Crucially, it reflects on our prior findings in Chapter 3, rather than defaulting to mainstream solutions (third recommendation). The design considers receipt scanning (rather than product scanning) as the method for collecting data (sixth recommendation) to address data collection challenges around self-monitoring (Cordeiro, Bales, et al. 2015; Daniel A Epstein et al. 2015; Daniel A. Epstein, Caraway, et al. 2016; Devakumar, Modh, and Saket 2021; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024)—which can otherwise spark the issue of technology adoption (Michel and Burbidge 2019). At this high-level conceptual design stage, the design does not yet determine whether it will provide feedback on food group or product level (fourth recommendation), but the design does provide the potential to provide feedback on both food group and product level. Beyond the recommendations from the previous chapter, the conceptual design also aims to address another limitation of self-monitoring technology that are found in literature. Specifically, the formulation of steps aims to bring attention to the frequently overlooked (Daniel A. Epstein, Eslambolchilar, et al. 2021) topic of moving beyond reflection and consider the process of forming and pursuing intentions for change¹.



Figure 4.1: Envisioned integration of the application around the grocery shopping routine.

The conceptual design centres around an approach of scanning grocery receipts as a method of data collection. Challenges around data collection have received considerable attention in self-tracking literature (Devakumar, Modh, and Saket 2021) as efforts related to manual tracking have been associated with early abandonment of self-tracking technology (Cordeiro, Bales, et al. 2015; Daniel A Epstein et al. 2015; Daniel A. Epstein, Caraway, et al. 2016; Devakumar, Modh, and Saket 2021; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024). In response to this challenge, less involved alternatives to manual tracking have been pursued, such as automating data collection, e.g., through integration with loyalty card schemes (Zapico, Katzeff, et al. 2016; Mönninghoff et al. 2022) or allowing people to scan receipts,

¹While conscious, intentional, decision making through intention forming is not necessary to drive a behaviour (Thaler and Sunstein 2008; Falko F. Sniehotta, Pesseau, and Araújo-Soares 2014; Papies 2017), an alternative of influencing behaviour through automatic responses is found to undermine autonomy and is considered ethically problematic (Tengland 2012; Hansen and Jespersen 2013).

rather than manually entering items or scanning individual products (Reitberger, Spreicer, and Fitzpatrick 2014; Sainz-De-Abajo et al. 2020; Möller 2021; Lurz et al. 2023). An important limitation with loyalty card-based data collection is that, to date, this data is often difficult to access (Bowyer et al. 2022), but is also limited to both stores and people that participate in loyalty card schemes (Mönninghoff et al. 2022). Because of its flexibility (receipts are still commonly available), receipt scanning was chosen as a basis for this study.

4.3 Methods

4.3.1 Overview

This study involved three online co-design workshops that involved people evaluating design features—represented by cards—by positioning them on a 3-ring dartboard, followed by a group discussion to reflect on the feature evaluations. The sections below describe the participant recruitment, workshop preparation, procedure, and data analysis.

4.3.2 Participants

A combination of homogenous and convenience sampling (Anthony J Onwuegbuzie and Leech 2007) was used to collect participants for the study. Sampling was homogenous in the sense that all were considered climate-aware individuals (i.e., they verbally confirmed valuing environmentally conscious dietary behaviours). Potential participants were directly approached and, after verbal expression of interest, sent an email with information providing basic information on the purpose and procedure of the workshop. Included with the email, they received an informed consent form², which they were required to complete and return before the workshop. Ethics approval was obtained prior to commencing the workshops (Ref: 12274/2020).

In total, 12 persons (10 male, 2 female) participated over the course of three workshops. Representative of the climate-aware consumer (Vermeir and Verbeke 2006), the average participant in the sample is middle-aged and educated (mean age 40, and 8 out of 12 had a university degree). All participants were situated in the Northeast of England.

²Participant information and consent form are available in Appendix H.

4.3.3 Preparation

The workshops were conducted between 28 April and 15 May 2021 and—taking place in a period of COVID restrictions—took place entirely online, using the video conferencing software Zoom³ and the virtual workshop platform Miro Boards⁴. Miro allows multiple remote participants to interact in a 2D virtual space, supporting interactions akin to adding sticky notes on a whiteboard, making connections between content.

In preparation for the workshops, a Miro board was pre-populated with specific contents to guide the workshop activities. This content was divided over four areas. The first two areas covered an introduction exercise to help people familiarize themselves with Miro; creating content, observing each other’s activity, and moving content around on the board. A third area provided a brief introduction to the conceptual application design and how it was envisioned to be integrated around the grocery shopping routine, with questions written underneath that linked the steps to potential design features (Figure 4.2). The fourth area, which concerned the main activity of the workshop, contained cards with potential application features and a dartboard-inspired frame with three rings in which participants could organize their cards (Figure 4.3). The dartboard was made up of three rings: a ‘Please do!’-labelled inner ring (green), a middle ‘Maybe...’-labelled ring (yellow), and a red ‘Don’t’-labelled outer ring. Participants could drag cards onto the dartboard to express their opinion about a specific feature. The Miro board was prepared so that participants could only drag a copy of a card and the original card was still available for other participants to evaluate.



Figure 4.2: The envisioned integration of the conceptual application around the grocery shopping routine, presented to the participants ahead of the co-design activity.

There were 22 default feature cards, divided over six groups (Figure 4.3), organized around the dartboard. For each group, there were also two empty cards that participants could complete themselves⁵. The groups were characterized by different outline colours and linked to ques-

³zoom.us

⁴miro.com

⁵Extra empty cards could be created on demand.

tions associated with the different steps of integration of the application around the shopping routine (Figure 4.2). The choice for the cards themselves was informed through prior literature (Table 4.1). There were four *data type* cards (grey outline) and three *data unit* cards (yellow outline) linking to the question ‘What footprint data is most meaningful to you?’, five *data presentation* cards (green outline) linking to the question ‘What makes you understand what you can change?’, five *change motivation* cards (red outline) linking to the question ‘What makes you decide to make a change?’, two *remember intention* cards (blue outline) linking to the question ‘What will help you remember your intentions?’ and three *technology adoption* cards (purple outline) linking to the question ‘What will motivate you to use the app?’.

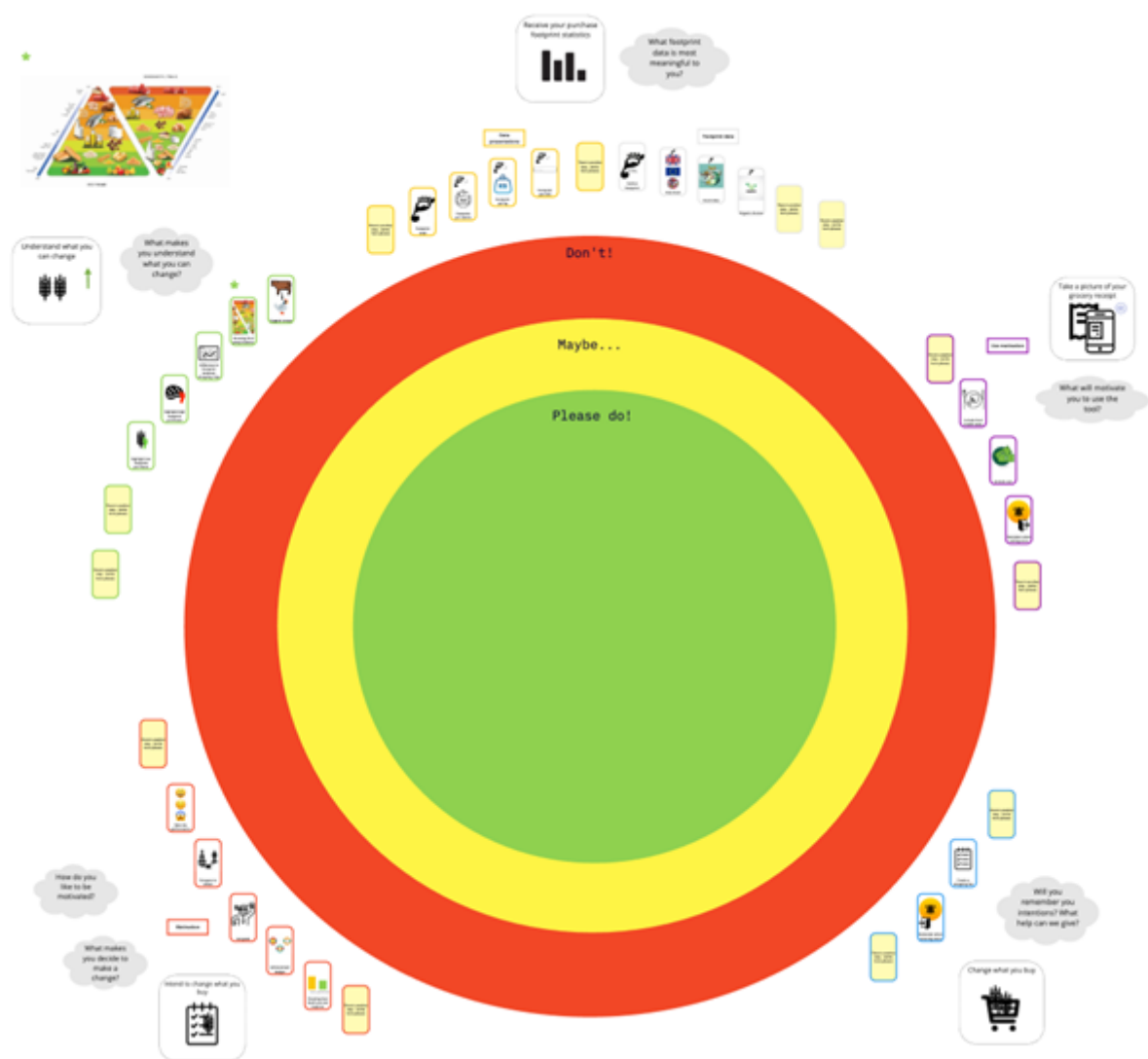


Figure 4.3: A snapshot of the main activity of the workshop.



Figure 4.4: Default feature cards

Table 4.1: Rationale for default feature cards based on prior literature.

Card group	Card label	Rationale
Data type (grey)	Carbon footprint	Carbon footprint data is available for various products (Audsley et al. 2009; Scarborough et al. 2014; Luca A Panzone et al. 2018; Poore and Nemecek 2018) and some research developments have started using this data (Herbig, Kahl, and Krüger 2018; Luca A Panzone et al. 2018; Sauv�, Bakker, and Houben 2020; Shakeri and McCallum 2021).
	Food miles	Transport has a (variable) impact on the foodprint of a product (Small World Consulting 2015; Poore and Nemecek 2018; Berners-Lee 2020), and ‘foodmiles’ a quantification of miles that food has travelled is sometimes used as a shorthand proxy for foodprint (Adrian K Clear, O’neill, et al. 2016; Herbig, Kahl, and Krüger 2018).
	How local	A categorical alternative to foodmiles, with a more interpretational character, that is commonly used as a shorthand proxy for foodprint (Adrian K Clear, O’neill, et al. 2016; Berners-Lee 2020) and attempts have been made to objectify the measure (Herbig, Kahl, and Krüger 2018).
	Organic	Prior research has argued that organic choices are more environmentally sustainable (Grunert 2011; Berners-Lee 2020; Katzeff et al. 2020) (although the link with foodprint less clear (Berners-Lee 2020)) and has been used as shorthand proxy for environmental sustainability and (potentially incorrectly) for foodprint (Bohn�, Zapico, and Katzeff 2015; Adrian K Clear, O’neill, et al. 2016).
Data unit (yellow)	Foodprint per kg	The common way of quantifying foodprint is by describing foodprint as a proportion of its weight gCO ₂ e/kg (Audsley et al. 2009; A. Clear and F. Friday 2012; Scarborough et al. 2014; Small World Consulting 2015; Luca A Panzone et al. 2018; Poore and Nemecek 2018; W. Willett et al. 2019; Berners-Lee 2020; Shakeri and McCallum 2021; Hedin, Gr�nberg, and Johansson 2022).

Card group	Card label	Rationale
	Foodprint per kcal	An alternative functional unit to gCO ₂ e/kg is gCO ₂ e/kcal that can be argued to be more meaningful because people have relative stable caloric intake requirements, but calorie density can vary much from product to product (Hedin, Katzeff, et al. 2019; W. Willett et al. 2019; Aiello et al. 2020).
	Foodprint total	Foodprint can also be expressed as the total of all purchases, or a shopping basket (e.g., Luca A Panzone et al. 2018; Shakeri and McCallum 2021).
Data pre-sentation (green)	Product swaps	Relating to the common PSD methods of comparison and suggestion. Product comparisons have been applied in various applications to inform users of alternative (potentially better) choice options (Dunford et al. 2014; Hegen 2016; Lawo et al. 2021; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024).
	Healthy-sustainable food group	A review has indicated the potential of providing food group feedback to support behaviour change (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024) and several works have described distributions of food groups within sustainable diets (e.g., BCFN 2016; W. Willett et al. 2019).
	Performance statistics	Relating to the common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD methods of self-monitoring and reduction. Prior works have visualised aggregated performance values (Bohné, Zapico, and Katzeff 2015; Zapico, Katzeff, et al. 2016).

Card group	Card label	Rationale
	Highlight high foodprint purchases	As not all products have the same environmental impact, prior work (Bohné, Zapico, and Katzeff 2015) used visualisations to highlight specific products with high impact by visualizing the proportion of high impact purchases (Bohné, Zapico, and Katzeff 2015; Zapico, Katzeff, et al. 2016) or by applying a traffic-light colour scheme (A. Clear and F. Friday 2012; Hegen 2016; Shakeri and McCallum 2021) to facilitate rapid evaluations (Kalnikaitė, Bird, and Yvonne Rogers 2013).
	Difference in foodprint between shopping trip	Relating to the common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD method of self-monitoring. Prior work has used visualisations to present fluctuations in sustainability of shopping trips over time (Bohné, Zapico, and Katzeff 2015; Zapico, Katzeff, et al. 2016).
Motivation (red)	Achievement badges	Relating to the common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD method of reward and a common gamification technique (Koivisto and Hamari 2019). Gamification is increasingly used to motivate people (Koivisto and Hamari 2019).
	Goal setting	Relating to the common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD method and a popular gamification method (Koivisto and Hamari 2019). Gamification is increasingly used to motivate people (Koivisto and Hamari 2019).
	Compare to others	Social comparison is a common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD method and a popular gamification method (Koivisto and Hamari 2019).

Card group	Card label	Rationale
	Knowing how much you can improve	Relating to the common (Adaji and Adisa 2022; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) PSD method of comparison and an important factor in effective action planning (Michie, Richardson, et al. 2013; Michie, Atkins, and West 2014)
	Judge my performance	Relating to the common PSD method of feedback (Adaji and Adisa 2022), or praise (Oinas-Kukkonen and Harjumaa 2009), and used in prior work (Reitberger, Spreicer, and Fitzpatrick 2014) to provide people with a quick interpretation of feedback on their performance.
Remember intentions (blue)	Automate next shopping list	The use of shopping lists plays an important role in shopping habits of some people (Adrian K. Clear, O'Neill, and A. Friday 2015). Prior research has shown potential of automatic generation of shopping lists for changing purchase behaviour (Palacios et al. 2018).
	Reminder when entering store	Grocery shopping is a mostly habitual and little thought involved (Kalnikaitė, Bird, and Yvonne Rogers 2013; Adrian K Clear, A. Friday, et al. 2015; Adrian K. Clear, O'Neill, and A. Friday 2015). Conscious attention is required to intervene with habitual behaviours (Thaler and Sunstein 2008; Kahneman 2012; Hansen and Jespersen 2013). External cues can help a shift to conscious attention (Fogg 2009; Hansen and Jespersen 2013; Michie, Atkins, and West 2014) and remember prior intention (Gollwitzer, Gawrilow, and Oettingen 2010). Reminders is a common PSD method that can provide such an external cue (Oinas-Kukkonen and Harjumaa 2009; Adaji and Adisa 2022) and a prior app store review argued that developments of apps to support behaviour change of food choices would benefit from using this method (Mauch, Wycherley, et al. 2018).

Card group	Card label	Rationale
Technology adoption (purple)	Reminder when exiting store	As above, but relating to the intention of taking, and scanning receipts.
	Include costs	The higher the perceived value of technology, the more likely the technology is adopted (F. D. Davis, Bagozzi, and Warshaw 1989; Venkatesh, Morris, et al. 2003; Venkatesh, Thong, and Xu 2012). Cost has been described as the most influential factor for making purchase decisions (Raskind et al. n.d.).
	Include food health stats	The higher the perceived value of technology, the more likely the technology is adopted (F. D. Davis, Bagozzi, and Warshaw 1989; Venkatesh, Morris, et al. 2003; Venkatesh, Thong, and Xu 2012). Integration of data to serve different data collection goals is suggested to benefit the value of self-tracking technology (Li, Dey, and Forlizzi 2010; Daniel A. Epstein, Eslambolchilar, et al. 2021). The popularity of food tracking apps (Daniel A Epstein et al. 2015; Mauch, Wycherley, et al. 2018; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024) indicate that people care about tracking their diet health. Moreover, healthiness of a product has been described as the second most influential factor for making decisions about food purchases (Raskind et al. n.d.).

4.3.4 Procedure

After the participants joined the video conferencing session and a brief introduction was given, participants were given a link to the collaborative Miro workshop board. Participants then worked on an introduction exercise to get familiar with the board and primed for discussion. After this exercise, participants were briefly introduced to the conceptual design and its envisioned integration in the shopping routine. Participants were then explained the core exercise: evaluating a collection of feature cards—covering both researcher-provided, as well as

participant-created cards—by placing them on the dartboard. Participants spent approximately 45 minutes collaboratively⁶ working on the core exercise: creating and moving cards and reflecting on the contents in a discussion with the workshop organizer and fellow participants. The total workshop took approximately 1-hour. The whole procedure was audio and video recorded for transcription and data analysis purposes (as consented by the participants).

4.3.5 Analysis

Data analysis consisted of a qualitative content analysis (QCA) of card positions on the dartboard and an inductive thematic analysis (TA) of the conversation recordings (main analysis). The aim of the QCA was to support the TA. For the QCA, I counted how often a specific feature card was found in either of the 3 rings and aggregated the results in a table. As the aim of the QCA was to support the TA, the interpretation of the QCA is kept intentionally brief.

For the inductive thematic analysis, I followed the 6-step approach as described by Braun and Clarke (2012) and Braun, Clarke, et al. (2019). Transcripts of the recordings were created by the auto-transcription service provided by Zoom. The auto transcriptions were read (step 1) and—when the recorded text from a participant didn't seem to make sense—manually adjusted by listening to the recording and modifying the respective part of the transcript. Such corrections were not systematically done when participants were talking about technical issues with the platform or video call or when the discussion was off topic (small talk) at the start and end of the recording. This was followed by an initial round of coding and re-coding the data (step 2). Codes were then organized into initial themes and subthemes (step 3), reviewed with the transcripts and codes, and adjusted (step 4), named (step 5), and finally written up (step 6).

4.4 Results

4.4.1 Overview

The result section is divided in a qualitative content analysis (QCA) and thematic analysis (TA). The QCA is intended as an initial, coarse, indication of the sentiment towards various features. It is therefore brief and with limited interpretation. After this, the core of the analysis is found

⁶Meaning that all participants were viewing, and editing, the same workshop board; they could observe the result of each other's activity on the board and see the mouse pointers of other participants moving around.

in the TA which provides a deeper interpretation of the participants' sentiments towards various features. On various occasions are the interpretations in the TA linked back to the results of the QCA.

4.4.2 Content Analysis (QCA)

Table 4.2 provides an overview of the results from a QCA of the card allocation exercise. Three of the card groups show relatively homogenous scoring within the groups (i.e., the grey data type, green data presentation and red motivation groups). Relatively homogenous positive (i.e., mostly *yes*) scores in the grey and green card groups, suggest a preference for being given information (high *yes* counts for the (grey) data type cards and (green) data presentation cards). However, mostly negative (i.e., mostly *no*) scores for foodprint-by-ratio cards of foodprint-per-calorie and foodprint-per-weight within the group of data unit cards (yellow) indicates that quantification of foodprint needs consideration. In contrasts to mostly positive scores for information cards, relatively homogenous negative (i.e., mostly *no*) scores for behaviour change motivation (red), suggests a less favourable opinion towards motivational approaches. No distinct pattern is seen for the technology adoption (purple) cards, indicating that people are divided in what they consider appropriate features to encourage their engagement with the system.

Table 4.2: QCA of feature card positions on the dartboard. D/P: Default/Participant-created. Yes: 'yes please', Maybe: 'Maybe...', No: 'Don't'. Colour saturation is applied to highlight difference in quantity of the count, with a higher colour saturation reflecting a higher count.

		D/P	YES	MAYBE	NO
Data type					
Carbon Footprint	D	7	1	0	
How local	D	7	1	0	
Food miles	D	7	2	0	
Organic choices	D	3	3	0	
Plastic weight	P	1	1	0	
Tell me what's in season, so I can make wiser choices	P	1	0	0	
Habitat loss	P	1	0	0	

educational tips about things that are particularly harmful (links to news)	P	3	1	0
Data unit				
Footprint total	D	6	1	0
Footprint per calorie	D	1	1	3
Footprint per kg	D	1	0	5
Footprint per serving	P	1	0	0
Data presentation				
Suggest swaps	D	7	3	0
Healthy-sustain-able food group	D	2	3	3
Performance statistics high CO2	D	7	2	0
Highlight high footprint purchases	D	7	1	0
Difference in footprint between shopping trips	D	6	0	0
Traffic light visualisation as currently used for recommended intake	D	4	1	0
show me a visual comparison of the items I bought	P	1	0	0
Motivation				
Achievement badges	D	0	0	1
Set goals	D	1	3	1
Compare to others	D	2	0	5
Knowing how much you can improve now potential	D	3	2	0
Judge my performance	D	0	2	6
reward coupons	P	2	0	0
Remember intentions				
Automate next shopping list	D	3	1	1
Reminder when entering store	D	3	1	4
Technology adoption				
Include food health stats	D	4	3	1
Include cost	D	4	1	2
Reminder when exiting store	D	2	0	2

As automated as possible, maybe as I shop online (browser extension?)	P	4	0	0
Show the data visually / give me fun comparisons	P	2	0	0

4.4.3 Thematic Analysis

From the thematic analysis of the transcribed discussions of the three workshops I defined four themes that reflect the participant's sentiment towards various system features. These are:

- Sick of being judged. I want to know why.
- Motivating people is a delicate and personal thing.
- Need for clarity.
- Integrating technology with daily life: searching for the path of least resistance. The first two themes talk about the participants attitudes towards the potential role of the system to motivate behaviour change, while the latter two themes talk about important usability aspects for using the system and integrating it into the daily live.

In the quotes below, participants are referred to by a pseudonym.

4.4.3.1 Sick of Being Judged. I Want to Know Why.

Participants talked about their dislike for being judged in their decisions. Being judged in decisions left a feeling of being lectured that could make people feel bad and insulted.

Julia, reflecting on her choice to put the card 'judge my performance' in the red 'no' circle:

"I don't like things that make me feel bad about what I eat, so I don't want to be told that".

Rather, they wanted technology to help them in making informed decisions. One of the participants expressed the problem well:

Ricardo: "I think [there is value to] a bit of, like, extra education to things, because people might just get sick of being told what you're doing is bad without knowing why."

To help them take an informed decision, participants saw an important role for the application to increase their understanding of how different foods impact the environment (i.e., provide education). The provision of information itself played an important role in this. *Charles: “I mean yeah the more data... the more information I got off that, the more it would be interesting to me”*. This desire for information is also echoed in the high counts of data characteristics in the QCA and custom cards requesting education tips (see, Section 4.4.2).

Rather than through data alone, participants felt that the system could also educate through specific forms of nudges that encourage people reflect on their choices. Such nudges were not perceived as judgmental.

Robert: “I’d suggest things like swaps and like a traffic-light system, so like it’s not judging you and it’s not telling you that you’re bad, but it’s kind of making you think twice...I quite like being made to think a bit about why [to choose something], given an alternative.”

We can see this sentiment (i.e., preferring to be informed rather than judged) echoed in the results of the QCA (see, Section 4.4.2). Here we can see a distinct preference for data and information features (grey and green cards) over motivational features (red cards). One exception of this is an information feature that characterizes products based on their classification within a health-and-sustainable diet, to which I will come back below (see, Section 4.4.3.3).

4.4.3.2 Motivating People Is a Delicate and Personal Thing.

Whereas there appeared to be a general agreement between participants that a system should provide knowledge to help make informed decisions, there was considerable variation in what participants perceived as acceptable motivational nudges to encourage people to follow through and reduce their foodprint (note that making an informed decision does not yet imply that a decision is made in favour of a lower foodprint). While some participants are vividly opposed to artificial approaches to try to motivate them—possibly perceiving these as intrusive and judgmental—several such approaches appeared to be acceptable to other participants. For example, Rick expresses his disapproval for a specific motivational feature of social comparison:

“I put it in the red zone... so [firm tone] I personally am not really bothered about other people because... I want to make sure [that] I do it, not... I don’t care about other people... “

In contrast, Charles acknowledges the practical effectiveness of social comparisons and accepts the approach a means to an end:

“The only reason I put compared to others in the middle, is because I don’t really care about that, but as well you know when like you’re on MyFitnessPal and your friend signs up and you think you’re doing it for yourself but suddenly find yourself looking at their results and then give them crap for eating Éclair the other night... I think that kind of... some kind of subconscious peer pressure is going on.”

Other participants fall in the middle and propose how gamified elements like achievement badges are made less artificial by reflecting the practical (and positive) implications of choices.

Ricardo: “I think that would be better than an achievement badge personally, well, like whether the achievement badge says you planted five more trees by... by as [Charles] says not buying the cucumber wrapped in plastic...”

This variety in what counts as acceptable means of motivating people was perceived as incompatible to some participants, and several participants proposed that motivational features would be best personalized.

James: “it would be interesting if one of the things that people could do is choose their own type of motivation [...] Because obviously [...] [an approach that will work for some] is not going to work for some others...”

4.4.3.3 Need for Clarity

Where people need to make decisions based on information, clarity of information is crucial. Participants pointed out potential difficulties in making sense out of the data and make informed decisions. Particularly, the way in which foodprint was quantified could be a source of confusion.

Charles: “I don’t think my brain would work with footprint per calory... I don’t understand how that compares to other things...I think as a consumer, my brain would freeze...”

This perception also aligns with the results of the QCA that shows unfavourable towards various data unit cards (specifically footprint-per-kcal or footprint-per-kg).

Confusion can also be caused by bringing multiple decision parameters together. Involving multiple decision parameters was thought to dilute the focus and could complicate forming change intentions. For example, one participant expressed her struggle with making decisions based on footprint and health simultaneously.

Jane: “I think I would really struggle to choose for something that’s better for my footprint and then also consider what I should do for my health. For me that goes into a different brain.”

This sentiment may explain the mixed results in the QCA for cards that involved diet health (i.e., ‘Healthy-sustainable food group’ and ‘Include food health stats’).

4.4.3.4 Integrating Technology with Daily Life: Searching for the Path of Least Resistance.

Participants also talked about potential challenges and opportunities to adopting a system in their daily lives. Participants lived busy lives where time, energy and attention are treated as valuable resources. The less time and effort involved in using the system, the more confident participants felt that they would manage to adopt the system. And the less time and effort involved considering what diet changes to make, the more confidence participants felt that they could make those changes. Participants see the ideal system as one that automates data, that is integrated within pre-existing shopping routines, and that presents data such that making informed decisions on alternative purchases becomes a simple and straight-forward task. For example, Charles sketches a potential scenario in which data collection is automated through a loyalty card scheme:

“[imagine that] I paid for something within Tesco, with Tesco pay, and this automatically happened in Tesco... that it told [the footprint of my purchases] to me through the app... that would be great, so I don’t even have to scan everything!”

Alternatively, Gary considers how the system could function within their existing habit of using grocery lists and generate a grocery list for the next shopping trip in which specific items were replaced with lower footprint alternatives.

Gary: “we tend to buy very much the same things, kind of week after week... not exactly the same but pretty much the same... so if you just... once you’d come out and scanned it, and it gave you the suggestions and you’d just make the changes [in the integrated shopping list] and then it’s really there for you when you go in the next time...”

Rick considers how the system could simplify decisions for alternative purchases by pointing the user towards suitable alternatives:

Rick: “that’d be a really good thing, if you can do something else, like [suggesting what an interaction with the system might be like],”so avocados are very bad for the world but they’re great for me well, actually, what can I do instead? Well, actually, we’ve got nuts and peanut butter that’s better for the environment. Only, only a tiny little difference to your health...”

Participants were however divided about the potential of notifications to support integration of the system. Consistent with the varied preferences for notification in the QCA (Section 4.4.2), some participants were sceptical about the potential to present a worthwhile interruption. For example, Charles noted:

“I mean Tesco had a reminder, when you use their app, and I used their app, and I didn’t find it useful getting that alert whenever I walked into Tesco.”

4.5 Discussion

In this study I investigated participants attitudes towards various features for an application to support footprint-aware food purchases. I did this through a participant-involved design activity that involved rating feature cards and performing a thematic analysis of the conversations that followed. Four themes that were formed describe the attitudes that were inferred from the analysis. The themes infer a strong preference for the system to support people in their ability to make informed decisions rather than judging or instructing decisions (theme: *Sick of being judged. I want to know why.*), but variability in the receptiveness towards motivational features to encourage action (theme: *Motivating people is a delicate and personal thing*), needs for clarity in the data (theme: *Need for clarity*), and considerations for integrating a system in the daily life (theme: *Integrating technology with daily life: searching for the path of least resistance*). In

the following sections I will discuss these findings in relation to existing literature and discuss their implications for design.

4.5.1 Design for Learning Experiences

As captured in the theme *Sick of being judged. I want to know why*, I inferred that participants desire support in their ability to make informed decisions, rather than being told how to behave. In other words, participants wanted to be supported in their autonomy, self-determination, to make choices. This observation is in line with literature that expresses autonomy as a basic human need (United Nations 1948) that people strive for (Deci and Flaste 1996; Tengland 2012). In contrast to autonomy, when people feel judged, they feel controlled and diminished in their autonomy (Deci and Flaste 1996).

Notably, participants did not merely ask for a tool to provide the information to make informed decisions: they expressed interest for learning. From an autonomy perspective this makes sense. Gaining knowledge plays an important role in increasing one's autonomy. The more knowledgeable, the more able people are to assess persuasive information in light of their values and self-determine their best course of action (Deci and Flaste 1996; Tengland 2012). In contrast, at low levels of knowledge, behaviour is more likely to be driven by extrinsic influences and values (Deci and Flaste 1996; Tengland 2012; Taalesen 2023).

Technology-mediated feedback on food purchase choices (FPC) may present an attractive opportunity for learning. Feedback can encourage reflection that leads to learning (S. J. Flaherty et al. 2020). The personal relevance of the information—it concerns a product that the person has purchased, or at least considered—as well as the active involvement in information acquisition may benefit effective learning (Priniski, Hecht, and Harackiewicz 2018; Deslauriers et al. 2019; D. J. Skinner and Price 2019). A recent literature review has also highlighted the potential of digital applications for FPC to contribute to learning (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024), and several studies have noted how feedback about FPC can contribute to generalized, transferable, knowledge (Herbig, Kahl, and Krüger 2018; Samoggia and Riedel 2020; Hedin, Grönborg, and Johansson 2022). FPC relevant learning has been observed in the use applications that build on self-tracking (Zapico, Katzeff, et al. 2016), shopping list generation (Hedin, Grönborg, and Johansson 2022), as well as barcode scanning (Herbig, Kahl, and Krüger 2018; Samoggia and Riedel 2020).

This leads to the first design implication (**DI1**): designers may want to pursue systems that target footprint relevant learning and design the systems such as to optimize the potential to reflect on, and learn from, the presented information.

Difficulties in comprehension may however compromise learning. Learning involves the assimilation of knowledge on top of prior knowledge (D. J. Skinner and Price 2019). The study indicated that participants may have difficulty comprehending some of the units in which footprint may be presented (i.e., footprint-per-weight [gCO₂e/kg] and footprint-per-kcal [gCO₂e/kcal]) and the QCA suggested a preference for information on the total footprint (gCO₂e) of a purchase. Prior studies also describe how the choice of unit may lead to comprehension difficulties (Salo, Mattinen-Yuryev, and Nissinen 2019; Hedin, Grönborg, and Johansson 2022). Notably, these studies suggest that footprint-per-weight is the preferable unit for comparison. Further, research is needed to establish what units are most suitable for providing footprint feedback in the proposed system. However, to facilitate comprehension and learning, it is clear that designers should carefully consider which units to use for quantifying footprint (**DI2**).

4.5.2 Motivate People?

The theme Motivating people is a delicate, and personal, thing indicated the variability between people in their acceptance and tolerance of various motivational strategies. Importantly, the theme described that motivation strategies that were acceptable for some participants, were much disliked by other participants.

Prior research provides several explanations for the variability of people's acceptance towards motivational strategies. Dahlstrøm (2017) describes that the content of feedback can be perceived either as informing or as controlling. Format and content of the feedback, as well as individual differences on the end of the receiver, play a large role in the likelihood that feedback is perceived as controlling or informing (Deci and Flaste 1996; Dahlstrøm 2017; Treiblmaier and Putz 2020). Prior experiences, personality traits and fluctuations in emotional state underly such individual differences (Deci and Flaste 1996; Botes 2023).

Alternatively, Tengland (2012) describes that, under certain circumstances, people may willingly allow themselves to be controlled and manipulated and give up autonomy. People may perceive low ability for self-determination in their daily lives and feel controlled, 'lived', by a constant stream of external influences. Under such circumstances, people may lack faith to gain the ability to self-determine their behaviours. They may feel out of options and may have

become conditioned to believe that valued outcomes are achieved only to yet more external control (Deci and Flaste 1996; Tengland 2012). This should however be a clear shout for the need for approaches that increase people's ability, rather than adding more external control (Tengland 2012).

Another reason for the variability between people in their acceptance of motivation techniques may relate to people's different—dopamine⁷ related—levels of reward sensitivity. Particularly motivational approaches that rely on reward and achievement (i.e., gamification (Weiser et al. 2015; Kim and Werbach 2016)) can cause spikes in the amount of the neurotransmitter dopamine that is released into the bloodstream (Dutton 2023). These spikes are associated with feelings of pleasure. Each time a reward is expected, this causes a little dopamine spike. People require a certain base level of dopamine released into their bloodstream to feel good. However, people naturally vary in their resting dopamine levels and in some people the resting dopamine levels are below the feel-good base level. This can make them repeatedly seek out activities that may increase their released dopamine levels to the feel-good base level. This would make them naturally inclined to seek out achievement and reward.

While one may argue that individual differences in acceptance and tolerance for motivational strategies could be accommodated through making related features optional through personalization, there are important risks that are not addressed through personalisation. While motivational approaches such as those involved in gamification can lead to very desirable outcomes like contributing to people's perceived competence that can benefit education (Jones, Blanton, and Williams 2023) and their persistence in healthy behaviours (Edwards et al. 2016; Looyestyn et al. 2017), there are important risks to gamification strategies that need consideration. Particularly, a problem with motivational approaches is that behaviours that cause dopamine release can be highly addictive. This is a known risk in gamification literature (Kim and Werbach 2016). People may opt-in for motivational approaches with little forethought. Once they are caught in a behaviour-reward cycle, people may find it difficult to disengage from a certain behaviour, even after that behaviour has stopped serving its original value or when pursuit of the behaviour is no longer consistent with a person's value priorities (Purpura et al. 2011; Kim and Werbach 2016). Notably, a similar behaviour-reward cycle is known as operant conditioning (B. F. Skinner 2007), an approach that defies individual autonomy (B. F. Skinner 2007; Kim and Werbach 2016) and is highly contested for its ethical appropriateness (Kim and Werbach 2016). While

⁷Dopamine is a neurotransmitter that is (amongst other things) involved in the expectation of a reward. Dopamine is related to feeling pleasure. As such, dopamine is also involved in many addictive behaviours.

problematic in its own right, addiction can also exacerbate other risks of gamification, like its potential to lead to psychological harms (Kim and Werbach 2016; Arora and Razavian 2021; Al-Msallam, Xi, and Hamari 2023), e.g., as people may fail to uphold internalized or perceived performance expectations. While such risks do not necessarily unfold (Kim and Werbach 2016; Arora and Razavian 2021)—gamification approaches often fail to be effective in the first place (Lindahl 2015; Koivisto and Hamari 2019; Sailer and Homner 2020)—special care is needed to ensure ethical implementation of such motivational approaches (Kim and Werbach 2016; Arora and Razavian 2021; Al-Msallam, Xi, and Hamari 2023) and there appear to be no clear cut solutions to ensure that harms are successfully mitigated (Kim and Werbach 2016; Hung 2017; Arora and Razavian 2021; Al-Msallam, Xi, and Hamari 2023).

Considering the limited perceived acceptance of motivation techniques by the participants of the study, together with the ethical risks involved in implementing such techniques, leads me to conclude that **DI3**: motivation features are better not pursued for the proposed system, or at least, should receive little priority. When such techniques are considered, special scrutiny is required to ensure ethical implementation of the techniques is a system deployment.

Notwithstanding the above, participants did point to a motivational approach that may be relatively well accepted. A participant suggested to reflect behavioural change in trees saved. Literature finds that such positive feedback is less likely than negative feedback to be perceived as controlling (Deci and Flaste 1996; W. Wang et al. 2014). The close link between the feedback and the valued outcome (i.e., both relating to reducing CO₂e, as trees are valuable for capturing CO₂e (Berners-Lee 2020)) may also increase the likelihood that the feedback is perceived as informing, rather than controlling (Dahlstrøm 2017). Moreover, by translating footprint to a tangible format (trees rather than a numeric value), this may contribute to autonomy through benefiting comprehension and the self-efficacy belief that a person can make an impact (Salo, Mattinen-Yuryev, and Nissinen 2019; Berners-Lee 2020).

DI4: when considering a motivational technique, designers may want to consider positive feedback that is meaningful to reducing carbon footprint.

4.5.3 Facilitate Technology Integration

Covered by the theme *Integrating technology with daily life: searching for the path of least resistance*, participants provided various practical pointers to benefit adoption of the conceptual design going forward. These pointers can be structured around the various factors of technology

adoption of the UTAUT2 (Extension of the Unified Theory of Acceptance and Use of Technology) (Venkatesh, Thong, and Xu 2012).

Covered by the theme *Integrating technology with daily life: searching for the path of least resistance* participants drew attention to time and effort as hurdles for integrating a system in their daily lives. These are well known barriers to technology adoption and behaviour change that have been covered well in various strand of research, e.g., as *ease of use* in technology adoption models (F. D. Davis, Bagozzi, and Warshaw 1989; Venkatesh, Morris, et al. 2003; Venkatesh, Thong, and Xu 2012), as *difficulty factors* for behaviour change in the Fogg Behavior Model (FBM) (Fogg 2012). However, the discussion topics also provided various pointers for opportunities to benefit adoption of the conceptual design going forward. The various pointers appear to link well with various factors of technology acceptance in the UTAUT2 (Venkatesh, Thong, and Xu 2012), an influential technology adoption model (Dwivedi et al. 2020). Structured by the UTAUT2, I will now reflect on some of these pointers considering existing literature and, where relevant, formulate recommendations for design considerations going forward (FC's).

Ease of use (Effort expectancy): Similar to prior work on the integration of self-tracking technology in daily life (Daniel A Epstein et al. 2015; Daniel A. Epstein, Caraway, et al. 2016), the discussion pointed to the value of minimizing the effort of tracking to facilitate technology adoption. While the observation highlights the value of automating tracking, it provided no new insights to challenge the rationale for the tracking approach taken for the conceptual design (see, Section 4.2 Conceptual design).

Ease of use was however also discussed in relation to forming change intentions. Participants expressed appreciation for functionality to compare with similar products. This observation is in line with extensive efforts in prior works to provide users with similar alternatives to choose from (e.g., Dunford et al. 2014; Head et al. 2014; Lawo et al. 2021), as well as work by Hedin, Grönborg, and Johansson (2022) who designed and evaluated a shopping list app with product footprint feedback and who observed that a lack of guidance to suitable alternatives may have hindered their participants to alter their choices. **FC1**: In further pursuing the conceptual design, a designer may find value in providing alternative suggestions.

Habit: One way of pursuing these recommendations forward is by integrating the suggestions within the grocery planning habits. As pointed out by one participant, prior research finds that consumption and purchases have clear recurring patterns (Zenun Franco 2017), which facilitates the opportunity to build shopping lists off prior purchases. Some people habitually use shopping

lists (Adrian K. Clear, O’Neill, and A. Friday 2015), and results from the study (QCA and TA) suggest that participants felt positive towards integration of such a feature. **FC2:** As an add-on feature, there appears to be considerable potential for a shopping list feature to benefit integration of the application in existing routines, that a designer may want to consider.

Value: Including health and price data was expected to be perceived as increasing the value of the technology (Table 4.2) and thus benefit technology adoption. However, the results of the study did not clearly confirm this. Some participant statements suggested a potential reason for this. People may struggle to reflect on alternatives by considering multiple parameters at a time and feel paralyzed by the additional information. Indeed, literature suggests that people aim to reduce complexity when considering product information (Beach 1993; Isley, Ketcham, and Arent 2017) and consider only one or two choice parameters at a time. Also, cognitive overload may stifle decision making (Kahneman 2012; Kalnikaitė, Bird, and Yvonne Rogers 2013). However, the result—being split between positive and negative responses to the added information—suggest that the information may be conditionally valuable. The way sustainability and health data are presented (e.g., simultaneously, or as separate statistics) may determine to which extent the added information is perceived as valuable or confusing. Further investigation may be valuable.

Facilitating conditions: Also, notifications were not received as well as expected. Prior research had suggested that notifications should be included more and are a valuable way to remind people in the midst of busy and distracted daily lives (Table 4.1). However, the modest enthusiasm may be explained by poor timing of most notifications (Fischer, C. Greenhalgh, and Benford 2011). Notifications are often provided in non-opportune moments and may be perceived as disruptive, an annoying. People may have lost their trust in notifications to provide a valuable note. This suggests that more research is needed to verify whether notifications are valuable in the system and what are opportune times for notifications.

Hedonic motivation: The participant input also hinted at the opportunity to include fun in the system through playful visualizations (other than through gamification). While playful visualization can enhance the appeal of a visualization, in their review of eco-feedback technology J. Froehlich, Findlater, Ostergren, et al. (2012) emphasize that playful visualizations may hamper opportunities to visualize rich data and suggest that designers search for visualizations that balance playfulness and information richness. **FC3:** In further pursuing the conceptual design, a designer may want to investigate opportunities to combine information richness and playfulness in data visualizations.

4.5.4 Limitations

The sample of participants was small. However, the sample size was deemed adequate, as the last workshop only contributed to 1 additional subtheme (<10%), compared to 14 subthemes that had been identified priorly. Therefore, a sufficient saturation was found to be achieved.

The cards provided abstract descriptions of feature and participants may differed in their interpretations of the features. While this limited interpretations of attitudes towards specific features based on the QCA, it was still possible to form an understanding of attitudes to *types* of features, from the QCA and TA combined.

4.6 Conclusion

This study investigated the attitudes of climate-sensitive people towards various design features for a self-monitoring application to support climate-sustainable food purchases. It did this through a co-design activity in which participants evaluated and discussed potential design features. The findings suggest that climate-sensitive people may value technology that increases their knowledge and understanding of foodprint to make informed decisions, rather than merely guiding their choices. Designers may want to pursue designs that target foodprint relevant learning and design such as to optimize the potential to reflect on, and learn from, the presented information. In pursuit of this, designers should carefully consider the unit for expressing foodprint to facilitate comprehension and learning. The findings also suggested that people may differ considerably in their attitudes towards motivational features. Rather than suggesting personalization of motivational features I suggest that, in the current context, designers not invest in designing such features as their expected value is limited, while effort is needed to ensure ethical implementation of such features. Further practical design recommendations to include the visualization of alternative products and to provide visualization that balance playfulness and information richness are also made.

Chapter 5

Tracing Foodprints: Iterative Design to Explore Design Elements for a Digital Tool for Fostering Carbon-Aware Diet Choices

5.1 Abstract

The current chapter describes the iterative design of a prototype of eco-feedback technology to empower people in the reduction of their foodprint. A framework is used to support the development of theory-informed designs and in each iteration cycle user evaluations are performed and contextualized with related literature to form recommendations for future iterations. Four iterative designs are created and several design implications for future design are formulated.

5.2 Introduction

In the current chapter, I aim to address the thesis research question through an investigation of various design elements of an application for foodprint feedback. I do this by iteratively developing a theory-informed prototype, supported by the insights from the previous chapter and related literature (Research for Design).

Specifically, the recommendations from the previous chapter were addressed as follows:

- Addressing Design Implication 1 of the previous chapter (see, Section 4.5.1), *to pursue systems that target foodprint relevant learning and design the systems such as to optimize*

the potential to reflect on, and learn from, the presented information the iterative process explores how data can be presented—and iteratively improved—to support reflection and learning about foodprint.

- Addressing Design Implication 2 of the previous chapter (see, Section 4.5.1), *carefully consider which units to use for quantifying foodprint*, the iterative design cycles include the reviewing literature on various options for representing foodprint and investigating the experience of study participants with the various options.
- The Design Implication 3 of the previous chapter (see, Section 4.5.2), *to be cautious in the pursuit of motivational feature and carefully consider any such feature for their ethical implications*, shaped the Behaviour Change Wheel (BCW) intervention functions that were selected for the design of the prototype (see, Section 5.3.2.1). Moreover, any remarks from participants about controlling qualities of features led to careful reflection on the ethical implications of the feature and potential removal of the feature in subsequent iterations.
- Addressing Forward Consideration 1 of the previous chapter (see, Section 4.5.3), *to consider providing alternative suggestions*, alternative suggestions were implemented in the second prototype version (see, Section 5.5.1.2.1) and improved in the third prototype version (see, Section 5.6.1.5).
- Addressing Forward Consideration 3, the word cloud visualization of foodprint was implemented as a visualization that could potentially combine information richness with playfulness.
- Forward Consideration 2 of the previous chapter, *to consider a shopping list feature for the benefit of technology adoption* was not implemented in the current study, as it was considered as an add-on feature, separate from the core functionality of the application (to provide actionable feedback on foodprint), that could be explored in future work.

For each iteration, user experience (UX) evaluations are used to inform recommendations for the next iterations (Research through Design). Prior work has emphasized the importance of theory-informed design for advancing research (Michie, M. Johnston, et al. 2008; Klasnja, Consolvo, and Pratt 2011; Hekler, Klasnja, J. E. Froehlich, et al. 2013; Hedin, Katzeff, et al. 2019). When empirically evaluating a design, the use of theoretical underpinning helps in understanding which design elements and which active mechanisms were responsible for the outcomes, which can then inform the implementation of these mechanisms in future designs. Also, user research early in the design phase plays an important role in the design of solutions that can

effectively be used (Norman 2013).

In the design and user evaluation of the prototype, particular attention has been given to the ability of people to identify practical opportunities to act on the feedback and reduce their foodprint. This ability appears to be under-addressed in prior designs of foodprint feedback. For example, most designs of foodprint feedback appear to centre around listing the foodprint of products in units of 100g (A. Clear and F. Friday 2012; Luca A Panzone et al. 2018; Shakeri and McCallum 2021; Hedin, Grönborg, and Johansson 2022). Whereas this is the common unit of presenting foodprint (Poore and Nemecek 2018; Berners-Lee 2020), it allows for little consideration of individual choice context as products are not purchased at equal weight (Scarborough et al. 2014; Sauvé, Bakker, and Houben 2020; Hedin, Grönborg, and Johansson 2022), and users may struggle to prioritise which products are most relevant for change (Hedin, Grönborg, and Johansson 2022). Behaviour change is hard (Klasnja, Consolvo, and Pratt 2011) and insufficient ability to prioritise may undermine continued action. Also, while the information about foodprint of products can increase foodprint knowledge and awareness (de Boer, de Witt, and Aiking 2016; Sauvé, Bakker, and Houben 2020; Hedin, Grönborg, and Johansson 2022), knowledge and awareness may not translate into skill (Arlinghaus and C. A. Johnston 2018; Hedin, Grönborg, and Johansson 2022) and practical knowledge may need to be acquired to gain ability to act on knowledge (Arlinghaus and C. A. Johnston 2018). E.g., Hedin, Grönborg, and Johansson (2022) found that even as participants were aware of the high foodprint of items, an inability to think of practical alternatives for high-foodprint products posed a barrier to making effective changes to choices.

The aim of the study was not to provide a finalized prototype but rather to explore the opportunity of design elements and make recommendations to inform future design. In this sense, it also incorporates design elements in the last prototype version that are subsequently not recommended for further implementation.

This work contributes by formulating design implications for the development of eco-feedback technology for the reduction of foodprint, highlighting the unequal potential of various design elements for future designs. It furthermore contributes with concrete designs, presented in four prototype versions, which can inspire future eco-feedback design. Particularly, the study contributes a novel and promising way of providing feedback on purchases by using a word cloud to empower users to easily identify practical opportunities to reduce their foodprint.

The remainder of the chapter is structured as follows.

1. **Methods:** The method section describes the overarching approach to the iterative design, how Research for Design (RfD) is applied to formulate theory-informed design, and how Research through Design (RtD) is applied through the subsequent analysis of UX evaluations.
2. **Prototype versions (4 sections):** Following the method section are four sections for each prototype version, each subdivided into sections that describe the design and a section that discusses and contextualizes the results of the UX evaluations to inform design iterations.
3. **General discussion:** This is then followed by a general discussion in which the combined contents from the separate result and discussion sections are assembled into design implications.

5.3 Method

5.3.1 Overview

The study applies iterative design and theory-informed design. Figure 5.1 provides a diagram of the cycle of iterative design. Each cycle starts with (1) a reflection on theory and empirical research to inform the design (RfD, including theory-informed design), followed by (2) prototype design, (3) UX interviews (evaluation), (4) an exploration of patterns in the interviews (i.e., content analysis), and completes with (5) a reflection of those patterns with related literature to inform the next version (iteration recommendations). Notably, the act of designing the prototypes enabled a synthesis of the prior empirical and theoretical insights. Cycles followed in relatively rapid succession around pre-planned interviews that were conducted over two weeks. The following sections describe each of the steps of the cycle.

5.3.2 Research For Design (RFD)

In this step intervention mechanisms (aka, techniques) were selected—informed by the Behaviour Change Wheel (BCW), the Behaviour change technique taxonomy (BCTT) and the Persuasive Systems Design Taxonomy (PSDT)—and related work was reviewed to inform options for implementing the intervention mechanisms in design.

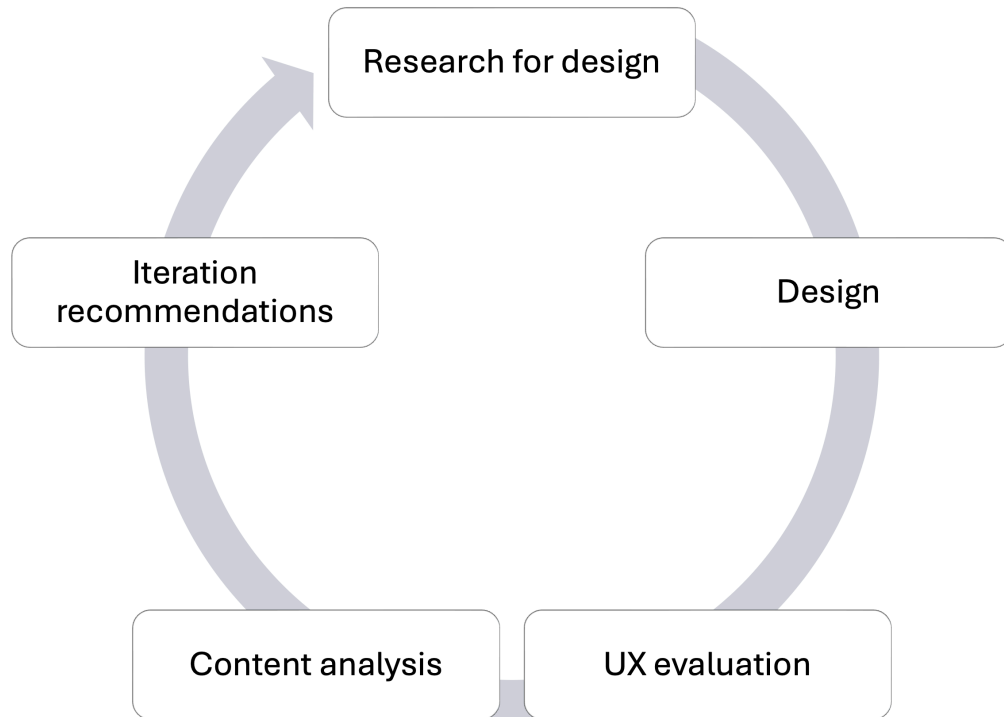


Figure 5.1: The iterative design cycle, applied for the development of the prototype.

5.3.2.1 Behaviour Change Wheel (BCW) And Behaviour Change Technique Taxonomy (BCTT)

The BCW (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014) is a framework for designing and characterizing behavioural change interventions, derived from the synthesis of 19 such frameworks, and (similar to Intervention Mapping¹ (Bartholomew Eldredge et al. 2016; Ruiters and Crutzen 2020)) provides a practical guide for designing theory-informed behavioural change interventions. The BCW builds on the COM-B model that considers capability, opportunity, and motivation as essential building blocks for behaviour. These building blocks are mapped on nine intervention functions (e.g., education, persuasion, training) and seven policy categories (e.g., guidelines, legislation, and service provision). It follows a 6-step approach to identify the target behaviour, need for behaviour change, intervention options, and policy options.

¹As frameworks of behaviour change, Intervention Mapping (Bartholomew Eldredge et al. 2016; Ruiters and Crutzen 2020) and BCW (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014) are both practical guides for the design of behaviour change interventions. A central variation to the two frameworks is that Intervention Mapping approaches opportunities for behaviour change by identifying theoretical determinants of behaviour, whereas BCW acknowledges that behaviour can result from a combination of components of behaviour (i.e., capability, opportunity, and motivation) and seeks to systematically identify all such links (Michie, van Stralen, and West 2011). As such it is considered to have wider applicability than Intervention Mapping (Michie, van Stralen, and West 2011).

The BCTT is a taxonomy of 93 theory-informed behaviour change techniques (intervention mechanisms; e.g., goal setting, problem-solving, and information about social and environmental consequences) (Michie, Richardson, et al. 2013). It is used to characterise behaviour change interventions (e.g., Mauch, Wycherley, et al. 2018; Silva, Hay-Smith, and Graham 2023) and also ties in with the BCW as a 7th step for selecting intervention implementation options. In their practical guide (Michie, Atkins, and West 2014), Michie et al. provide lists of the intervention mechanisms that are commonly used for each of the intervention functions.

In the current study, it was attempted to apply the guide to the design of an empowerment intervention. A key difference between empowerment and behavioural change is the person versus outcome focus. Whereas in behavioural change one prioritizes an instrumental goal (i.e., a practical outcome), in empowerment one prioritizes individual values and autonomous pursuit of those values, embracing the potential that a person may autonomously decide against any behaviour change (Tengland 2012). As such, the use of a framework for designing behaviour change interventions may appear to conflict with the principle of empowerment. However, the BCW can be valuable as a systematic approach to clearly formulate both the problem that the design aims to address, and to systematically identify design opportunities. Moreover, the BCW includes a set of APEASE (Affordability, Practicability, Effectiveness and cost-effectiveness, Acceptability, Side-effects/safety, Equity) criteria that structure the process of selecting intervention functions, and these may allow to structure the intervention design along the BCW to meet the principles of (the state of) empowerment.

In preparation for the study, informed by the insights from Chapter 4, the intervention options were determined by completing the relevant BCW worksheets (see Appendix I). In line with the findings of Chapter 4, *education* through the provision of a service (e.g., mobile app, providing education tailored to the person's context) was found most suitable to address the problem of product purchases inconsistent with a person's values (including values of climate sustainability) and provision-of-a-service was confirmed as a viable policy option. Complementarily, also elements of *enablement*, *training*, and *persuasion* (only in their pure, factual, non-manipulative, non-controlling form²) were identified as suitable intervention functions. This identifies a range of recommended intervention mechanisms, including information about social and environmen-

²The term 'persuasion' has also been coined for cases where social pressure was expected (e.g., through leverage of social authority (Tengland 2012), or emotional appeal (J. Davis 2009; Brynjarsdottir et al. 2012)). In the context of this study, persuasion as a viable intervention function is restricted to the use of factual display of information that may lead the user to motivate themselves to change behaviour (Botes 2023). For example, by bringing attention to inconsistencies between values and behaviour, without intentionally hiding or warping information. Any use of pressure (material or social) or purposeful introduction of biased information is here considered as coercive or manipulative.

tal consequences, feedback on behaviour, and problem-solving for which practical design implementation could be sought.

5.3.2.2 Persuasive Systems Design Taxonomy (PSDT)

In their 2009 article, Oinas-Kukkonen and Harjuma (2009) provide a taxonomy of intervention mechanisms specifically for the design of digital behaviour change interventions. The taxonomy is informed by the Fogg Behavior Model (FBM)(Fogg 2009) and a review of digital interventions and forms an extension of a taxonomy of intervention mechanisms proposed by Fogg (2003; 2009). As such, the taxonomy can be used to complement or further specify intervention implementations derived from the BCW and BCTT. Similarly to the argument with the BCW, the principles of the PSDT may appear to conflict with designing for empowerment—the FBM is noted to target the change of behaviour and attitudes (Fogg 2009). However, persuasion is not necessarily in conflict with autonomy (Tengland 2012), and through reflection of the acceptability of the intervention mechanisms, the taxonomy may provide a valuable tool for identifying opportunities for intervention implementation.

5.3.2.3 RFD By Reflecting On Existing Literature

I investigated related prior literature on designs of diet purchase choices and sustainable behaviour interventions for implementations of the selected intervention mechanism to identify potential design elements (features). Empirical literature relevant to the design elements was then sought to verify the potential of design elements and, when relevant, further literature to support the practical implementation of the design elements (e.g., literature on required data sets) was sought. As specific design elements were identified that appeared promising, they were mapped back onto the BCTT and PSDT. This was done to assess whether other intervention mechanisms were (inadvertently) represented in the design element. This allowed for systematically assessing design elements for acceptability and discarding of elements that were deemed unsuitable.

Various alternative promising designs could be identified through this process and multiple design variations could be included in a prototype to allow a qualitative comparison of more and less suitable design elements (note that the aim was not to propose an optimal design from the start, but rather to explore different design paths).

Whereas RfD is an extensive phase in the earlier cycles, when a basis for all design elements needs to be laid, this phase will become less prominent during later iterations that are mostly characterized by modifications of design elements.

5.3.3 Design And Development

Prototype designs were created in Figma³. Figma is a digital platform that allows the creation of high-fidelity visual prototypes (i.e., a deck of frames with visual content that describes the application). In Figma, the designer can program navigation between the frames by defining areas within the frames that respond to click or scroll interactions, thus creating the feel of a functional application.

Data for the visualizations was based on data from a related study (Luca A Panzone et al. 2018), kindly shared by the first author, Dr. Luca Panzone. This study involved the use of a purpose-built online supermarket with over 600 products, complemented with foodprint labels, in which participants placed two weekly orders up to £25 each. For each participant, the dataset contained information about purchased items, purchase date, item name, product category (3-level hierarchy), foodprint per kg, product weight, macronutrient information, price, and more.

The purchases from one participant were selected as a basis for the data that was shown in the prototype in the current study and enriched with further simulated purchases. This participant purchased a low amount of meat (less than 3 items per purchase) and purchased a variety of other dietary products. To enrich the data of this participant, data simulations were done to extend the data from two to five baskets⁴, using the statistical software R (R Core Team 2023). For the simulations, it was assumed that 60% of purchases are repeat purchases. Prior work indicates that a substantial proportion of products are purchased habitually Adrian K Clear, O'neill, et al. (2016); Zenun Franco (2017). To simulate this, 60% of the simulated basket was populated by randomly selecting purchases from their earlier baskets. For the other 40% of the basket, products were randomly selected from all purchases from all participants with a similar dietary style (i.e., also little meat in their purchases). This approach made sure that the remaining 40% was mostly populated with popular products. The more often a product was purchased by any participant, the more often it would appear in the list of purchases and the more likely that a random selector would select this product. The simulations created a set of purchases with

³figma.com

⁴Basket: the term to define the content of a single shopping trip.

associated product data that could now be aggregated and visualized in various ways (e.g., using various groupings). When the footprint database was replaced in designing version 3 (see Section 5.6.1.5) the simulated purchases were mapped on the new database.

5.3.4 UX Evaluation

5.3.4.1 Procedure

After an explanation of the study procedure and the purpose of the application, participants were given a link through which they could access the prototype on their mobile phones. They were given five tasks in total: (1) to explore the application, (2) to imagine that the purchases presented in the app were their own and formulate two changes they would make in their next grocery trip, (3) to complete a survey on their preferences for visualizations⁵, (4) to write down and, if possible, draw what they would like to change in the application, and (5) to write down when they would use the application (see, Figure 5.2). Tasks were completed in a systematic order, with the researcher calling the start and end of each task and providing brief introductions to each task. Each task was completed with a discussion in which the participant shared their thoughts briefly introduced by the researcher after the previous task was completed. The total time of a session ranged from 40-60 minutes. Interviews were conducted online, using the Zoom⁶ videoconferencing platform, and recorded for processing. A detailed description of the procedure is available in Appendix N.

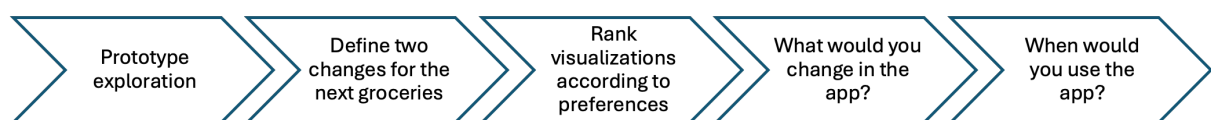


Figure 5.2: The interview session procedure. Each step involved a discussion.

5.3.4.2 Participants

A combination of homogeneous and convenience sampling (Anthony J Onwuegbuzie and Leech 2007) was used to collect participants for the study. The sampling was homogeneous in the sense that all people included expressed that they value climate-sustainable behaviours. Fifteen participants were recruited for the study. Ten participants were female. Ages varied between 23

⁵The surveys are available in Appendix J, Appendix K, Appendix L, and Appendix M.

⁶zoom.us

and 64 years, with a mean of 33 years. All participants had lived in the Northeast of England for at least a year within the two years before the study, but six had a non-English nationality. Twelve people had completed a university degree. All participants provided written consent to participate in the study. Participation was reimbursed with a £15 shopping voucher. Ethical approval for the study was obtained before the study (Ref: 16989/2021) and participants were given information sheets and provided written consent before participation.

5.3.5 Content Analysis And Iteration Recommendations

Interviews were transcribed and inductively coded for Conventional Quantitative Content Analysis (QCA) (Hsieh and Shannon 2005) for the identification of patterns in the interviews. Observed patterns were then discussed in relation to relevant literature and potential recommendations for the next prototype version were formulated. Given the limited time, an initial coarse version of the analysis and reflection was performed during the active phase of the iterative design (i.e., in between the first and last cycle). These initial analyses were later expanded and written up.

After the last cycle, a more thorough approach to the content analysis was taken. Here, coding of three randomly selected scripts was done by two pairs of eyes, after which an initial codebook was established through discussion between the two coders to harmonize and group codes. One coder then coded the remaining scripts. Additional codes that were identified in this process were added to the codebook. The two coders that established the initial codebook met again to discuss and agree on the final structure of the codes, and their harmonization in patterns.

5.4 Prototype Version 1

5.4.1 Design

5.4.1.1 Overview

The first theory-informed prototype consisted of data presentations concentrated in three distinct pages, referred to as the diet share page (Figure 5.3a), the stats page (Figure 5.3b), and the product feedback page (Figure 5.3c), which are introduced in the following sections⁷.

⁷The clickable prototype as viewed by the participants is available at <https://www.figma.com/proto/CxCeRdow5gnaF1MkU56yd/Vegeterian-example-13-12-2021?node-id=206%3A50&scaling=scale-down&page->

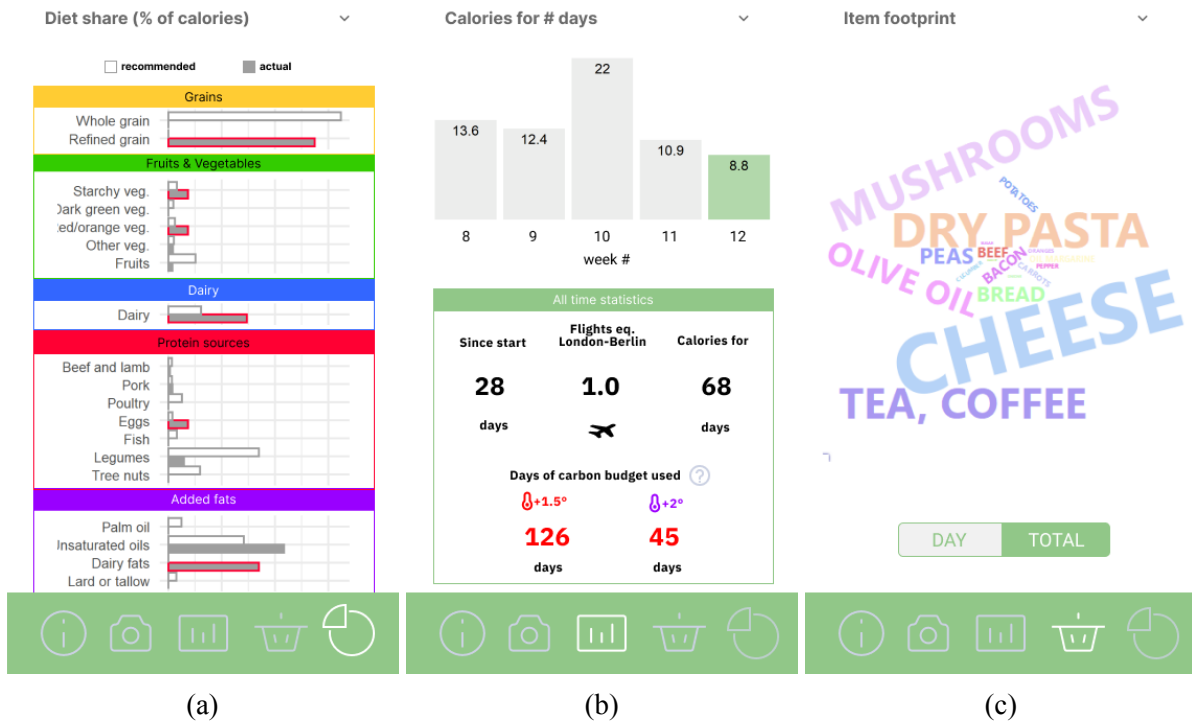


Figure 5.3: Pages of the first prototype version.

5.4.1.2 Recommended Diet Share Visualization (Diet Share Page)

5.4.1.2.1 Related Work

My prior review (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. (2024) and Chapter 3) has emphasized the potential of food group feedback on changing consumption behaviour and the use of recommendations of healthy shares of various food groups is common in many formal guidelines (e.g., W. C. Willett and Stampfer 2003; *The Eatwell Guide* 23 Feb 2022, 7:55 p.m.). By visualizing people’s diet purchases against recommendations of shares from different food groups, people can be made aware of the consequences of their purchasing habits for their diet health and motivated to adjust purchase choices (Bird et al. 2013; Reitberger, Spreicer, and Fitzpatrick 2014; Bomfim and Wallace 2018). Prior works have used pie charts to visualize people’s purchase data against healthy diet share recommendations (Bird et al. 2013; Reitberger, Spreicer, and Fitzpatrick 2014). As an extension to guidelines for a healthy diet, researchers have also proposed guidelines for a healthy-and-sustainable diet (e.g., BCFN 2016; W. Willett et al. 2019). A 2019 Lancet study (W. Willett et al. 2019) puts forth guidelines divided into 5 main, and 18 sub-categories, and provides recommendations for shares in terms of grams as well as calories. To my awareness, this guideline has not yet been used in a visualization to compare or inform people’s purchases.

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5.4.1.2.2 Implementation

The diet share page (Figure 5.3a) represents a visualization of the Lancet study guideline for a healthy-and-sustainable diet (W. Willett et al. 2019). Because of this relatively large number of categories (18), far beyond the recommended number of categories for a pie chart (Holtz n.d.), a stacked chart was used to visualize recommended shares vs. purchased shares. The eighteen sub-categories were grouped by the five main categories of grains, fruits & vegetables, dairy, protein sources and added sugar and fat. For each sub-category, recommended and purchased proportions of each category clustered next to one another. A legend is provided and there is a button to toggle between visualizing the data in the proportion of weight or proportion of calories. A mapping of the design elements of the diet share visualization on related work and associated techniques from the BCTT and the PSDT is presented in Table 5.1.

Table 5.1: diet share implementation, active mechanisms, and rationale.

Implementation (and active mechanisms)	Rationale
<p>Visualizing people’s diet purchases against recommendations of shares from different food groups (BCTT: Feedback on behaviour, PSDT: Normative feedback, Self-monitoring).</p>	<p>Prior research found that providing people with feedback about their purchases against recommended shares from different food groups can benefit alignment between recommendations and purchases (Bird et al. 2013; Reitberger, Spreicer, and Fitzpatrick 2014; Bomfim and Wallace 2018; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024).</p>
<p>As above (BCTT: Incompatible beliefs).</p>	<p>Behaviour feedback can bring awareness to discrepancies between values and behaviour and, through cognitive dissonance, motivate changes to future purchasing behaviour (e.g., Zapico, Katzeff, et al. 2016).</p>
<p>Whenever a recommended share was overshoot by a factor of two or more, a red stripe was shown to draw attention to the impact of purchase behaviour on the sustainability of the user’s diet (BCTT: Saliency of consequences).</p>	<p>Humans have a limited ability to hold different pieces of information in their minds simultaneously and make decisions and an abundance of information can limit a person’s ability to make decisions around this information (Kahneman 2003; Thaler and Sunstein 2008; Kalnikaitė, Bird, and Yvonne Rogers 2013). Visual cues can help focus attention and support a person’s ability to make decisions and memorize information (Kalnikaitė, Bird, and Yvonne Rogers 2013; Knafllic 2015).</p>
<p>The purchases are aggregated into eighteen categories (PSDT: Reduction).</p>	<p>People struggle to hold, and mentally aggregate information. Technology can be valuable in alleviating this cognitive burden (Souza-Monteiro, Lowe, and Fraser 2022).</p>

5.4.1.3 Aggregated Foodprint Visualizations (Stats Page)

5.4.1.3.1 Related Work

Prior work suggests that summary statistics of purchase data can be leveraged to draw awareness of inconsistencies between people's shopping behaviour and their values of environmental sustainability (Zapico, Katzeff, et al. 2016). Zapico, Katzeff, et al. (2016) developed and tested a dashboard that provided users with summary statistics of their share of organic purchases with figures of total shares and trends over time. They recorded people's beliefs about their share of organic purchases before viewing their behaviour data in the dashboard and found that differences between prior beliefs about shares of organic purchases and their share of organic purchases as it was presented by the dashboard correlated with future changes in organic purchases. They reasoned that prior expectations about organic shares reflected the user's values of environmental sustainability explained this finding through the cognitive dissonance theory (Festinger 1962), which poses that people naturally aim for consistency between their self-beliefs (including values) and their behaviour and that when they observe a dissonance between beliefs and behaviour, they will change their behaviour, or their self-beliefs (or both), to return to a sense of consistency between beliefs and behaviour.

However, whereas the number of organic purchases can be contextualized against the number of non-organic purchases with relative ease (Zapico, Katzeff, et al. 2016), most people perceive carbon footprint as a very abstract measure (Zapico, Turpeinen, and Brandt 2009; Hedin, Claesson, and Odqvist 2017; Hedin and Luis Zapico 2018; Salo, Mattinen-Yuryev, and Nissinen 2019), which makes it difficult for people to interpret a footprint value and assess whether it is following their climate sustainable values. Authors of prior works therefore advise to convert absolute carbon footprint values in different dimensions, that people find easier to interpret, such as flight distances (Hedin and Luis Zapico 2018; Salo, Mattinen-Yuryev, and Nissinen 2019). An alternative is to contextualize footprint in relative terms against a benchmark. The IPCC provides such a benchmark with their published annual carbon budgets for global warming (Masson-Delmotte et al. 2018). The report lists climate budgets to limit global warming to 1.5°C as well as 2°C global warming; with the higher degree goal representing a higher calculated risk of climate disaster, but less stringent requirements on emission reductions (albeit still requiring considerable compromises to 'business as usual')(Masson-Delmotte et al. 2018; M. A. Clark et al. 2020). These budgets can be recalculated to a daily footprint budget per person (Berners-Lee 2019; Berners-Lee 2020; Wilson 2022).

A reflection on foodprint can also be approached by considering food waste (Ganglbauer, Fitzpatrick, and Molzer 2012; Adrian K. Clear, Comber, et al. 2013; Comber and Thieme 2013; M. A. Clark et al. 2020). With people in high-income countries wasting about 20-30% of the food that they purchase (Gustavsson et al. 2011; Waste Managed 2024), food waste has a non-neglectable impact on a person's foodprint (M. A. Clark et al. 2020). One (crude) way of approximating a measure for potential food waste is through estimating the difference between a person's caloric needs and the calories present in the purchased food. A common practice is to estimate a person's caloric needs from a small set of personal descriptives (sex, age, activity level) and rely on the resulting measure as a relatively accurate estimation (e.g., National Heart, Lung, and Blood Institute 2013; Fuchs et al. 2019). With a strong institutional and marketing focus on calories in the global west in the last decennia (Credence Research 2024), it can be assumed that most potential users of the proposed system will be familiar with the concept of daily energy needs in terms of calories.

5.4.1.3.2 Implementation

Similar to the work by Zapico, Katzeff, et al. (2016), the stats page provides all-time summary statistics and measures of aggregated foodprint over time. To assist contextualization, the foodprint is presented in three different ways: in *London-Berlin flight equivalents*, the foodprint is expressed as the carbon footprint equivalent from N flights between London and Berlin (1), in *days of carbon budget*, the number of daily carbon budgets covered by the aggregated purchase foodprint, separate for both 1.5°C and 2°C global warming (2), and implicitly through *days of caloric needs*, a value that approximates the number of days that the purchased food could last, given no waste and meeting caloric needs. A counter for the number of days since the start of tracking is provided to allow the user to compare with their *days of carbon budget* and *days of caloric needs* and evaluate their behaviour. A mapping of the design elements of the stats page on related work and associated techniques from the BCTT and the PSDT is presented in Table 5.2.

Table 5.2: stats page implementation, active mechanisms, and rationale.

Implementation (and active mechanisms)	Rationale
<p>The stats page provides feedback on tracked purchase behaviour with all-time summary statistics and measures of aggregated foodprint over time (BCTT: Feedback on outcomes of behaviour, Incompatible beliefs). As above (BCTT: Problem-solving).</p>	<p>Behaviour feedback can bring awareness to discrepancies between values and behaviour and, through cognitive dissonance, motivate changes to future purchasing behaviour (e.g., Zapico, Katzeff, et al. 2016). The provision of behaviour feedback can be effective in prompting a phase of critical reflection in which habitual purchases are critically evaluated and reconsidered in line with desired outcomes (S. J. Flaherty et al. 2020).</p>
<p>Presenting aggregated foodprint from various purchases and shopping trips (PSDT: Reduction).</p>	<p>People struggle to hold, and mentally aggregate information. Technology can be valuable to alleviate this cognitive burden and facilitate accurate aggregation to support decision-making (Souza-Monteiro, Lowe, and Fraser 2022).</p>
<p>Presenting foodprint in terms of foodprint budgets, calculated from IPCC global warming budgets (BCTT: Salience of consequences, Information about social and environmental consequences).</p>	<p>People struggle to understand carbon footprint values as they are found to be very abstract (Zapico, Turpeinen, and Brandt 2009; Hedin, Claesson, and Odqvist 2017; Hedin and Luis Zapico 2018; Salo, Mattinen-Yuryev, and Nissinen 2019). By expressing the values in terms of flights, or against climate budgets, this can become more concrete.</p>
<p>Presenting purchases in terms of daily calorie needs (BCTT: Salience of consequences Information about social and environmental consequences).</p>	<p>Food waste is an important contributor to foodprint (M. A. Clark et al. 2020). When purchase quantities exceed energy needs, this can be an indicator of food waste (C. W. Young et al. 2018).</p>

Implementation (and active mechanisms)	Rationale
<p>Presenting foodprint in terms of foodprint budgets based on the IPCC report (BCTT: Credible source, PSDT: Trustworthiness, Authority, Expertise).</p>	<p>Prior work indicates that climate-sensitive put weight on reliable sources to provide guidelines for foodprint-related behaviour (Herbig, Kahl, and Krüger 2018; Lawo et al. 2021).</p>
<p>Whenever foodprint from purchases exceeded climate budgets by more than 10%, the figure representing the days of climate budget was coloured red in the summary statistics. (BCTT: Saliency of consequences).</p>	<p>Humans have a limited ability to hold different pieces of information in their minds simultaneously and make decisions and an abundance of information can limit a person's ability to make decisions around this information (Kahneman 2012; Kalnikaitė, Bird, and Yvonne Rogers 2013). Visual cues can help focus attention and support a person's ability to make decisions and memorize information (Kalnikaitė, Bird, and Yvonne Rogers 2013; Knafllic 2015).</p>
<p>The stats page provides feedback on tracked purchase behaviour with all-time summary statistics and measures of aggregated foodprint over time. (BCTT: Feedback on outcomes of behaviour, Incompatible beliefs).</p>	<p>Behaviour feedback can bring awareness to discrepancies between values and behaviour and, through cognitive dissonance, motivate changes to future purchasing behaviour (e.g., Zapico, Katzeff, et al. 2016).</p>

5.4.1.4 Product Feedback

5.4.1.4.1 Related Work

Some products (e.g., beef, lamb, coffee, and certain cheeses) have foodprints that are many times higher than those of other products (Scarborough et al. 2014; Poore and Nemecek 2018; Berners-Lee 2020; M. Clark et al. 2022), and data visualizations can emphasize those differences (Knafllic 2015; Poore and Nemecek 2018; Sauvé, Bakker, and Houben 2020). The use of such visualizations of purchase feedback can draw awareness to past choices that had disproportionately high foodprints (Sauvé, Bakker, and Houben 2020) and signal inconsistencies between climate-sustainable values and past purchase behaviour (Zapico, Katzeff, et al. 2016) and motivate future changes (Festinger 1962).

Not all visualizations may be equally suitable for engaging people with their foodprint data.

The use of dry and factual data presentation, commonly seen in eco-feedback, can be a hindrance to user engagement (J. Froehlich, Findlater, and Landay 2010; Venkatesh, Thong, and Xu 2012). Yet, playful animations are relatively hard to produce and found to often compromise too much data richness (J. Froehlich, Findlater, and Landay 2010; Venkatesh, Thong, and Xu 2012). In their review of eco-feedback applications, J. Froehlich, Findlater, and Landay (2010) therefore recommend the use of playful characteristics in common data visualizations. Word clouds are recognised for their popularity in informal data presentations (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015). Although formally criticised for its limitations in providing accurate comparisons of data values (Holtz 2018), the graph is said to be easy to understand and to have a high visual appeal (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015). A reason for its appeal may be explained by word clouds minimizing the visual distance between the label and the data point. Reducing this visual distance is recommended as it reduces effort in reading the data and benefits interpretation (Knafllic 2015) while effort is mostly perceived as unpleasant (Holland et al. 2012).

Prior work has also discussed the suitability of various units for comparing the foodprint of products (Salo, Mattinen-Yuryev, and Nissinen 2019; Hedin, Grönborg, and Johansson 2022). By convention, foodprint is expressed in terms of the weight of the product (Audsley et al. 2009; Poore and Nemecek 2018; Berners-Lee 2020; Hedin, Grönborg, and Johansson 2022) and as nutrition labels present nutrition per 100g, people are expected to be familiar with expressing food properties per 100g. However, considering that the amount of food that is consumed is driven by the energy (calories) that a person requires, and calories per 100g can vary substantially between

products, a measure of foodprint per 100kcal can be more meaningful (W. Willett et al. 2019; Hedin, Grönborg, and Johansson 2022). More efficient energy sources would thus mean a lower carbon footprint. However, people may struggle to comprehend foodprint expressed in units of calories (Salo, Mattinen-Yuryev, and Nissinen 2019; Hedin, Grönborg, and Johansson 2022) (see also Chapter 4). Also, products can have zero calories, meaning an infinite foodprint per 100kcal, which limits the data that can be visualised (Hedin, Grönborg, and Johansson 2022).

Products are however not purchased or consumed in equal amounts (Scarborough et al. 2014; Sauv , Bakker, and Houben 2020; Hedin, Gr nborg, and Johansson 2022) and prior work found that people may struggle to determine whether a product should be considered for replacement based on a high foodprint per 100g alone, without considering how much of a product they would purchase (Hedin, Gr nborg, and Johansson 2022). By recording past product choices, feedback can be provided that considers both the foodprint per 100g, as well as quantities (Sauv , Bakker, and Houben 2020) and informs which products have a dominant impact on their foodprint, relevant to their specific purchasing behaviour.

5.4.1.4.2 Implementation

The product feedback page features a word cloud that visualises the foodprint for different products, identified from the user's grocery receipts. Participants could toggle between three different representations of the word cloud of purchase feedback in which the size of the word reflected either (a) the total foodprint of purchases from a specific product, (b) the foodprint of a product in foodprint per 100g, and (c) the foodprint of a product per 100kcal. Using buttons at the bottom of the page, participants could choose different time frames for the visualisation, meaning that they could choose to visualise the content from a single grocery receipt, or that of multiple groceries. A mapping of the design elements of the product feedback page on related work and associated techniques from the BCTT and the PSDT is presented in Table 5.3.

Table 5.3: product feedback page implementation, active mechanisms, and rationale.

Implementation (and active mechanisms)	Rationale
The product feedback page provides a visualization of foodprint for different product types (BCTT: Information about social and environmental consequences).	Most people have limited knowledge of the foodprint of different products. Providing information about the foodprint of items has been found to increase awareness (de Boer, de Witt, and Aiking 2016; Hedin, Grönborg, and Johansson 2022) and influence purchase choices (Luca A Panzone et al. 2018)
The product feedback page informs the user of the relative impact of their purchase choices on their foodprint (BCTT: Feedback on outcomes of behaviour, Problem-solving).	The provision of behaviour feedback can be effective in prompting a phase of critical reflection in which habitual purchases are critically evaluated and reconsidered in line with desired outcomes (S. J. Flaherty et al. 2020).
As above (PSDT: Liking).	People are generally interested in learning about their behaviour (Li, Dey, and Forlizzi 2010; Daniel A. Epstein, Eslambolchilar, et al. 2021).

Implementation (and active mechanisms)

Rationale

Visualizing product feedback using a word cloud visualization (PSDT: Liking).

The use of dry and factual data presentation, commonly seen in eco-feedback, can be a hindrance to user engagement (J. Froehlich, Findlater, and Landay 2010; Venkatesh, Thong, and Xu 2012). Yet, playful animations are relatively hard to produce and found to often compromise too much data richness (J. Froehlich, Findlater, and Landay 2010; Venkatesh, Thong, and Xu 2012). In their review of eco-feedback applications, Froehlich et al. (J. Froehlich, Findlater, and Landay 2010; Venkatesh, Thong, and Xu 2012) therefore recommend the use of playful characteristics in common data visualizations. Word clouds are recognised for their popularity in informal data presentations (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015). Although formally criticised for its limitations in providing accurate comparisons of data values (Holtz 2018), the graph is said to be easy to understand and to have a high visual appeal (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015). A reason for its appeal may be explained by word clouds minimizing the visual distance between the label and the data point. Reducing this visual distance is recommended as it reduces effort in reading the data and benefits interpretation (Knafllic 2015) while effort is mostly perceived as unpleasant (Holland et al. 2012).

Implementation (and active mechanisms)	Rationale
<p>Participants could toggle between three different representations of the word cloud of purchase feedback in which the size of the word reflected either (a) the total foodprint of purchases from a specific product, (b) the foodprint of a product in foodprint per 100g, and (c) the foodprint of a product per 100kcal. This way users could choose which information felt more relevant to them to reflect on their choices (PSDT: Tailoring).</p>	<p>By convention, foodprint is expressed in terms of the weight of the product (Audsley et al. 2009; Poore and Nemecek 2018; Berners-Lee 2020; Hedin, Grönborg, and Johansson 2022) and as nutrition labels represent nutrition per 100g, people are expected to be familiar with expressing food properties per 100g. However, considering that the amount of food that is consumed is driven by the energy (calories) that a person requires, and calories per 100g can vary substantially between products, a measure of foodprint per 100kcal can be more meaningful [Hedin, Willett]. More efficient energy sources would thus mean a lower carbon footprint. However, products can have zero calories, which means an infinite foodprint per 100kcal. Products are however not consumed in equal amounts (Scarborough et al. 2014; Sauvé, Bakker, and Houben 2020; Hedin, Grönborg, and Johansson 2022) and contrasting product foodprint based on the actual amounts purchased may be more relevant to people to provide people a sense as to where their foodprint comes from.</p>

Implementation (and active mechanisms)	Rationale
<p>Products with a higher foodprint appear larger in the word cloud. Some products may appear much larger than others, emphasizing a person’s past choices with a relatively high foodprint (BCTT: Saliency of consequences, Incompatible beliefs).</p>	<p>Some products (e.g., beef, lamb, coffee, and certain cheeses) have foodprints that are many times higher than those of other products (Scarborough et al. 2014; Poore and Nemecek 2018; Berners-Lee 2020; M. Clark et al. 2022), and data visualizations can emphasize those differences (Knafllic 2015; Poore and Nemecek 2018; Sauv�, Bakker, and Houben 2020). The use of such visualizations of purchase feedback can draw awareness to past choices that had disproportionately high foodprints (Sauv�, Bakker, and Houben 2020) and signal inconsistencies between climate-sustainable values and past purchase behaviour (Zapico, Katzeff, et al. 2016) and motivate future changes (Festinger 1962).</p>
<p>A word cloud visualization that projects the foodprint of products based on a person’s usage of a product (i.e., foodprint per 100g x weight purchased). Rather than providing information on the foodprint of any product, the purchase feedback visualization only lists products that people have purchased in the past (PSDT: Personalization).</p>	<p>Products are however not consumed in equal amounts (Scarborough et al. 2014; Sauv�, Bakker, and Houben 2020; Hedin, Gr�nberg, and Johansson 2022) and prior work found that people may struggle to determine whether a product should be considered for replacement based on a high foodprint per 100g alone, without considering how much of a product they would purchase (Hedin, Gr�nberg, and Johansson 2022).</p>

5.4.2 Results And Discussion

In the evaluation of the first prototype, two patterns were distinctly present.

5.4.2.1 Difficulty In Searching Alternatives

Participants gravitated to the word clouds to consider future changes that they would want to make to their shopping. They identified products that they wanted to (partly) replace. However, they struggled to think of products to replace them with. Participants expressed a desire for the app to help them find suitable replacements, e.g., they mentioned they would like to click on the words to see alternatives, or to see alternatives that other people had found.

The observation highlights the practical difference between awareness (e.g., Sauv , Bakker, and Houben 2020) and perceived self-efficacy to change behaviour and it aligns with findings in prior work (Hedin, Gr nberg, and Johansson 2022). Hedin, Gr nberg, and Johansson (2022) developed and evaluated a digital grocery list that provided foodprint for each of the items on the shopping list. They observed that several participants struggled to think of alternatives for the high foodprint items in the list and that this held them back from adjusting their choices to reduce their foodprint.

The provision of alternative products is a common feature in grocery shopping assistants (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024). After scanning the barcode of an item, information about the scanned product is provided alongside a list of similar alternatives, with nutritional (Dunford et al. 2014) or environmental information (Head et al. 2014) provided for each of the products to assist the user to make an informed decision about the product to choose. In the development of these shopping assistants, efforts were made to provide the users only with products with high similarity (e.g., comparing a marmalade with other marmalades). *Iteration recommendation 1.1*: It is recommended to incorporate alternative suggestions in a future prototype (Hedin, Gr nberg, and Johansson 2022).

5.4.2.2 Difficulties In Comprehension

At various points, participants struggled to understand the various metrics that were presented. Difficulties with comprehension were most profound for the various measures on the stats page, but they were also observed for the other data visualisations (i.e., the diet share and shopping

basket). Participants expressed the need for a tutorial to understand what they were looking at.

These findings can be understood by considering learning theory. Theories of learning suggest that people learn by assimilating new knowledge into existing knowledge. Limited existing knowledge may hinder the uptake of new information (D. J. Skinner and Price 2019). Prior work highlights that carbon footprint is perceived as an abstract concept and people are unfamiliar with considering foodprint values (de Boer, de Witt, and Aiking 2016; Salo, Mattinen-Yuryev, and Nissinen 2019) and people may thus have a hard time understanding various measures of foodprint information. Tutorials can play an important role in understanding unfamiliar concepts and facilitate engagement in new material presented in digital technology (Venkatesh, Thong, and Xu 2012). *Iteration recommendation 1.2*: For the next version, it is advisable to incorporate a tutorial.

5.5 Prototype Version 2

5.5.1 Design Changes

5.5.1.1 Overview

In prototype version 2, small adjustments are incorporated, based on the reflection on findings from the evaluation of version 1. Adjustments involve the inclusion of a page of product alternatives (Figure 5.4a) and the provision of a tutorial (Figure 5.4b), which are further described below⁸.

5.5.1.2 Product Alternatives Page

5.5.1.2.1 Related Work

Prior works (Head et al. 2014; Hedin, Grönborg, and Johansson 2022) and the evaluation of prototype version 1 suggested that the provision of product alternatives is an important feature for helping people in their ability to form intentions for changing their future purchases. Such intentions are an important predictor of behaviour (F. D. Davis, Bagozzi, and Warshaw 1989;

⁸The clickable prototype as viewed by the participants is available at <https://www.figma.com/proto/2Wfbjf8EPYZVILDHouK5Dj/Little-meat-eater-prototype-15-12-2021?node-id=206%3A50&scaling=scale-down&page-id=0%3A1&starting-point-node-id=206%3A50>

Cheese

[back](#)

Summary: 26/02/2017 - 26/03/2017
Quantity: 15
Weight (kg, total): 2.775
gCO₂ (total): 21813
gCO₂/100g (average): 786
gCO₂/kcal (average): 2.05

Details

QTY	Description	gCO ₂ /100g	gCO ₂
11	Tesco British Mature Cheddar 450g	815	3667
3	Tesco Value Mozzarella 125g	662	828
1	Tesco Mozzarella 150g	662	993

Dairy alternatives (recorded before)

Type	Description	gCO ₂ /100g	gCO ₂
Block butter	Tesco English Unsalted Butter	950	8075

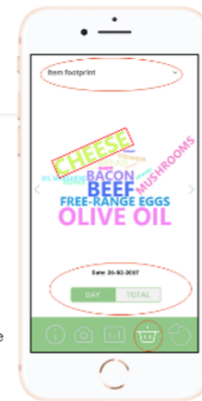
Dairy alternatives (not yet recorded)

Type	Description	gCO ₂ /100g	gCO ₂
Fresh milk	Organic Skimmed Milk 1 Pint	90	511
Fresh milk	Organic Skimmed Milk 2 Pints	90	990
Fresh milk	Organic Semi Skimmed Milk 1 Pint	110	625
Fresh milk	Organic Semi Skimmed Milk 2 Pints	110	1210
Fresh milk	Organic Semi Skimmed Milk	110	2530

(a)

Your basket

- In your basket you'll find an overview of your purchases.
- Your purchases are presented in a wordcloud where the size of the word represents the total carbon footprint of that product type.
- Purchases of one product type are combined in one word. For example, if you bought 2 cheese items, this will mean that the word 'cheese' would still only appear once, but the size of the word cheese would become twice as large.
- By clicking the drop-down at the top, you can change this so the size of the word to represents the footprint per 100g or per calorie, which can be useful when searching for substitute products.
- The cloud covers a specified period. That can be one day (for example the day you scanned your receipt) or a longer period.
- If you click on the word...



(b)

Figure 5.4: The product alternatives page (a) and tutorial (b), introduced in prototype version 2. The complete tutorial is available at [Appendix O](#).

Venkatesh, Morris, et al. 2003; Venkatesh, Thong, and Xu 2012) and a critical element in autonomous, self-determined, goal pursuit (Deci and Flaste 1996; Tengland 2012).

Prior works describe applications that suggest product alternatives with high similarity (e.g., other marmalades, or other milk alternatives) (Dunford et al. 2014; Head et al. 2014). However, such a focus on small incremental changes to reducing foodprint has been criticized for providing a false impression that valuable contributions to sustainability can be made through minimal changes (Brynjarsdottir et al. 2012). Instead, the quest for more sustainable diets requires people to make substantial changes to their diet choices (M. A. Clark et al. 2020) and changes between types of products are often more substantial than changes within product types (Poore and Nemecek 2018; Berners-Lee 2020).

When products with lower similarity are proposed, extra effort may be important to help people find acceptable alternatives. Prior research finds modest acceptance rates in food swap recommendations (C. E. Wood et al. 2015; Buntun et al. 2021; Lawo et al. 2021; Taalesen 2023). One reason for this is that people don't like the suggested alternatives (Black, Clemmensen, and Skov 2009; Lawo et al. 2021) and considering prior purchase behaviour may benefit the suitability of suggested alternatives (Lawo et al. 2021).

5.5.1.2.2 Implementation

To accommodate the request for alternative suggestions (see Section 5.4.2.1, recommendation 1.1), participants can now view alternatives (Figure 5.4a) by selecting a product on the product feedback (Figure 5.3c). This action will take the user to an alternatives page that lists the food-print of the selected product and various product alternatives within the food group (e.g., dairy, or vegetables). To benefit the potential acceptability of alternatives, the page first lists food group alternatives that the user has recorded before, before listing other alternatives. The page also provides details about the selected product (product data and information about logged purchases of this item) and is provided at the top of the page, to follow convention (Shneiderman et al. 2017; Herbig, Kahl, and Krüger 2018; Shakeri and McCallum 2021) and benefiting engagement by meeting user expectations (Holland et al. 2012; Venkatesh, Thong, and Xu 2012). A mapping of the design elements of the stats page on related work and associated techniques from the BCTT and the PSDT is presented in Table 5.4.

Table 5.4: alternatives page implementation, active mechanisms, and rationale.

Implementation (and active mechanisms)	Rationale
<p>Participants can click on products on the product feedback page to search for alternatives (BCTT: Problem-solving, PSDT: Suggestion).</p>	<p>1. Prior works (Head et al. 2014; Hedin, Grönborg, and Johansson 2022) suggest that the provision of product alternatives is an important feature for helping people in their ability to form intentions for changing their future purchases and reduce their foodprint. Intentions are an important predictor of behaviour (F. D. Davis, Bagozzi, and Warshaw 1989; Venkatesh, Morris, et al. 2003; Venkatesh, Thong, and Xu 2012) and a critical element in autonomous, self-determined, goal pursuit (Deci and Flaste 1996; Tengland 2012). 2. Active engagement in information search has been found to benefit problem-solving skills and long-term retention of information (Priniski, Hecht, and Harackiewicz 2018; Deslauriers et al. 2019; D. J. Skinner and Price 2019).</p>

Implementation (and active mechanisms)	Rationale
<p>The alternatives pages list the foodprint of the selected product and various product alternatives within the food group (e.g., dairy, or vegetables) (BCTT: Information about social and environmental consequences, PSDT: Comparison).</p>	<p>Providing people with foodprint values has been shown to contribute to people’s foodprint knowledge (de Boer, de Witt, and Aiking 2016; Shakeri and McCallum 2021; Hedin, Grönborg, and Johansson 2022) and can benefit their ability to make more sustainable purchases (Tengland 2012; Arlinghaus and C. A. Johnston 2018). While prior works describe applications that provide alternatives with high similarity (e.g., other marmalades, or other milk alternatives) (Dunford et al. 2014; Head et al. 2014), such a focus on small incremental changes to reducing foodprint has been criticized to provide a false impression that valuable contributions to sustainability can be made through minimal changes (Brynjarsdottir et al. 2012). However, the quest for more sustainable diets requires people to make substantial changes to their diet choices (M. A. Clark et al. 2020) and changes between types of products are often more substantial than changes within product types (Poore and Nemecek 2018; Berners-Lee 2020).</p>
<p>As alternatives to the selected product, the application looks for products that the user has recorded before and lists those as alternatives, before listing other alternatives (PSDT: Personalization).</p>	<p>Prior research finds modest acceptance rates in food swap recommendations (C. E. Wood et al. 2015; Bunten et al. 2021; Lawo et al. 2021; Taalesen 2023). One reason for this is that people don’t like the suggested alternatives (Black, Clemmensen, and Skov 2009; Lawo et al. 2021) and considering prior purchase behaviour may benefit the suitability of suggested alternatives (Lawo et al. 2021).</p>

Implementation (and active mechanisms)**Rationale**

Details about the selected product (product data and information about logged purchases of this item) are provided at the top of the page (PSDT: Liking).

It is a common approach to provide data details upon clicking a data item (Shneiderman et al. [2017](#); Herbig, Kahl, and Krüger [2018](#); Shakeri and McCallum [2021](#)) and people may expect this behaviour. Familiarity is generally associated with positive affect (Holland et al. [2012](#)).

5.5.1.3 Tutorial

5.5.1.3.1 Related Work

See Section [5.4.2.2](#) Difficulties in comprehension, recommendation 1.2.

5.5.1.3.2 Implementation

A tutorial⁹ was created that explained the various concepts, visualization, and possible interactions in the prototype. Study participants were taken through the contents of the tutorial, before engaging with the prototype.

5.5.2 Results And Discussion

5.5.2.1 Overview

There were no stark differences noted in the evaluations of version 1 and version 2. However, as more interviews were conducted more patterns in the observations from the evaluations could be discovered. Some of these are refinements of the patterns discussed for version 1 and some are newly formulated (even when they already occurred in the evaluation of version 1). The patterns are discussed in the following text.

5.5.2.2 The Appeal Of The Word Cloud Visualisation

Throughout the various evaluations (of both version 1 and 2) responses to the word cloud are overwhelmingly positive. Participants perceive the word cloud as intuitive to understand, attractive and fun in its appearance, and efficient in drawing attention to ‘pain points’ and in displaying a large amount of content. Moreover, they perceive the displayed information as actionable and concrete.

A few limitations with the word cloud visualization could also be observed. Some participants noted that they might occasionally want to investigate the small words—their purchases with a relatively low footprint—which was difficult with the word cloud. The use of three different visualizations of the word cloud with different units also appeared inefficient as participants toggled back and forth between the different word clouds to decide which products to swap.

⁹The tutorial is available at [Appendix O](#).

The positive reception of the word cloud aligns with prior literature pointing out its popularity in non-scientific venues (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015). Observations from interviews suggest that, whilst being a standard graph type that is easily created, the word cloud visualization also incorporates an element of fun. It is conceivable that the experience of fun is aided by the intuitive ease of using the visualization, helped by removing the distance between value and label (Knafllic 2015). Effort is mostly perceived as unpleasant (Holland et al. 2012). By reducing the effort to process the visualization, the visualization choice may thus have helped to create a pleasurable, fun, experience. As such, the graph type appears to find the pragmatic balance between being engaging and simple to create (J. Froehlich, Findlater, Ostergren, et al. 2012). For its current purpose, its limitations in providing perceptual accuracy (Holtz 2018) did not appear to pose a practical hindrance.

However, word clouds are not optimal for providing a structured and comprehensive data overview, for which some alternative visualizations like the bar chart are better suited. *Iteration recommendation 2.1:* In line with proposed guidelines for visualizing foodprint data (Herbig, Kahl, and Krüger 2018) incorporation of a bar chart as an alternative visualization to the word cloud is recommended to facilitate optional in-depth investigations of the product feedback content.

Formal logic following probability theory explains why participants investigate multiple word clouds to make decisions about products to swap. Both the share of a specific product on a person's total foodprint (in prototype versions 1 and 2 displayed in one of the three word clouds) and the potential of finding a lower foodprint alternative—characterized by a relatively high foodprint per unit of substitution (e.g., weight [100g] or energy [100kcal], visualized in the other two word clouds in prototype version 1 and 2)—determine the potential for reducing a person's foodprint from swapping a specific product in the product feedback. *Iteration recommendation 2.2:* Instead of providing multiple word clouds with providing product feedback in different units, it is recommended to capture multiple dimensions in one word cloud visualization.

5.5.2.3 Value Of Various Time Frames

For the product feedback visualization, participants consistently perceive the all-time aggregation of their purchases as most relevant. However, participants also expressed a preference for the opportunity to explore product feedback for different periods (e.g., months, and individual receipts).

These findings are in line with prior research. Many food products that people buy are recurring purchases (Adrian K Clear, O’neill, et al. 2016; Zenun Franco 2017). Aggregation of purchases over long periods will allow us to capture such recurring patterns and identify those products with the best opportunities for replacement. However, certain life changes may cause considerable shifts in diet patterns (Adrian K Clear, O’neill, et al. 2016) and, in these cases, aggregations over shorter periods may be more suitable to highlight new recurring purchase patterns. Also, people are naturally curious to learn about their behaviour (Li, Dey, and Forlizzi 2010) and the addition of aggregations over short periods may provide them with additional opportunities to satisfy their curiosity through a detailed investigation of their behaviour. Guidelines from prior literature recommend presenting high-level aggregated information by default and allowing the user to actively explore details upon interest (Herbig, Kahl, and Krüger 2018), thus shaping the recommendation for the next version: *Iteration recommendation 2.3*: Present users with long-term aggregated data on first encounter and allow the user to explore their data over various periods.

5.5.2.4 Difficulty In Searching For Alternatives

The evaluation of prototype version 2 shows that finding alternatives remains challenging. Participants struggled to find suitable alternatives amongst a list of irrelevant duplicates (different packing sizes of the same alternative, or many versions of the same product type with similar or identical foodprint), while other relevant products appeared to be missing from the list. Moreover, the display of the foodprint per package size (besides the foodprint per 100g) was perceived as irrelevant. Also, the personalized list of previously purchased alternatives was found to be limited in content and participants focussed on the larger list of other alternatives to search for alternatives.

Some of the described challenges appear to result from limited consideration of people’s information processing ability. People are limited in their ability to process large amounts of information (J. A. Deutsch and D. Deutsch 1963; Kalnikaitė, Bird, and Yvonne Rogers 2013). Aggregation and visual indicators can help people process information (Kalnikaitė, Bird, and Yvonne Rogers 2013; Knafllic 2015).

The challenges also appear to relate to the choice of the underlying data for the visualizations. The foodprint database used for prototypes 1 and 2 includes various products of the same product type but has a limited range of product types (Tesco 2012), while swaps between different

product types are considered more important for reducing one's foodprint (Poore and Nemecek 2018; Berners-Lee 2020) (see, Section 5.5.1.2.1 and Table 5.4). Also, the personalized list of previously purchased alternatives was based on a small number of shopping trips and little information was therefore available to present here. Literature on recommender systems informs that where little data on past behaviour is available, recommendations of popular choices can be more suitable.

Iteration recommendation 2.4: Improve the presentation of the alternative view by removing alternatives with high similarity, removing package foodprint, and including graphical indicators.

Iteration recommendation 2.5: Consider alternative foodprint databases with a larger range of product types.

5.5.2.5 Difficulties In Comprehension

As in the evaluation of the previous prototype, difficulties in comprehending the various concepts and metrics remained a prominent pattern. In its current form, the tutorial appeared to do little to prevent such difficulties. Participants perceived that the up-front presentation of the information was too much to remember, while interactive clarifications of content were missing in the prototype.

Iteration recommendation 2.6: Integrate the tutorial within the interaction with the prototype and include information references through the prototype to clarify concepts.

Challenges with comprehension were observed in the contextualization of foodprint in the form of the carbon budgets and days of calories (for the latter measure, see also Section 5.5.2.6). Participants appeared confused with the approach of quantifying impact in days and one participant recommended that budgets be better expressed in credits. Even as participants struggled with comprehension, several participants saw potential value in the contextualization of foodprint in carbon budgets as it provided a concrete and meaningful goal.

Iteration recommendation 2.7: Explore other units to express the impact of the user's purchases against climate budgets.

5.5.2.6 Difficult Relationship With Calories

Throughout the interviews repeated negative responses to the use of the calorie unit were observed. Responses could be rather sharp, e.g., 'I don't care about calories' [P6], and participants

could frame the use of the calorie unit as off-putting. After some consideration, some participants reflected that they mistook the foodprint per 100kcal unit as a form of calorie counting and expressed interest in the value, albeit with reservations about its practical use for replacing items as they were used to thinking of products in weight quantities rather than calories. The use of ‘days of calories’ was given no such positive response. Several participants perceived it as either an overweight or food scarcity measure.

The poor reception could be explained by the connotation of the calorie measure. Calories are commonly associated with weight loss and body image, are seen as ‘to be avoided’, and can be a source of stress (Harvard Health Publishing 2024). Other people may have been exposed to food scarcity (not unknown to the global West (Francis-Devine, Danechi, and Malik 2024)) and connect the measure with hunger. Conflicting prior associations can hinder the assimilation of new knowledge (D. J. Skinner and Price 2019), particularly when prior associations have an emotional load (Kahneman 2003), and the common connotation of calories may thus interfere with the uses of calories in the presented prototype (i.e., as measures of foodprint-energy-efficiency, recommended intake, or calorie budgets as a proxy of potential food waste).

These observations also align with prior work arguing for quantification of foodprint in weight (per 100g), rather than calories (per 100kcal) (Salo, Mattinen-Yuryev, and Nissinen 2019; Hedin, Grönborg, and Johansson 2022) (see also Table 5.3), but equally note the potential relevance of considering foodprint in terms of calories. *Iteration recommendation 2.8*: Use foodprint per 100g as the default unit, while presenting foodprint per 100kcal as an optional alternative.

More than other measures the use of ‘days of calories’ appears to combine various challenges. As an indirect proxy of foodprint from food waste, the measure is conceptually rather different from the other measures in the prototype. As such it may significantly add to difficulties in comprehension. Also, the results indicated that potentially stressful associations were triggered by the measure, and the use of the measure could be considered unethical. *Iteration recommendation 2.9*: abandon the use of days of calories going forward.

5.5.2.7 Restrictions Of The Diet Share Visualization

Participants pointed out various restrictions to the use of the diet share visualization. Participants felt confused by the large quantity of information. This confusion was amplified by perceived inconsistencies between information when recommended and recorded amounts were quantified

per 100g or 100kcal; recorded amounts were found to overshoot recommendations in one quantification, while not in the other. Participants also noted that the detailed guidelines felt ridged and intrusive. Several participants had diet restrictions that were perceived to conflict with the guideline, and it was unclear if, and how, overshoot in one category could be compensated in another. Some participants did note that, as additional information.

When information is perceived as personally relevant, it is perceived as more valuable (Balcombe et al. 2016), and more likely to be engaged with (F. D. Davis, Bagozzi, and Warshaw 1989; Venkatesh, Thong, and Xu 2012). Moreover, guidelines may be perceived as less intrusive when they are personalized.

Notably, the authors of the guideline (W. Willett et al. 2019) do not claim that, in its current form, the guideline is suitable to inform individual behaviour. Highlighting the complexity of the guideline: the report that provides the guideline brought together more than twenty experts and consists of 96 pages and 474 references. The diet guideline itself is summarized in a table of nearly 100 values and various notes of conditional cases (W. Willett et al. 2019). The extent of information may attest to the challenges involved in translating the guideline into a presentation that responds to personal diet restrictions and communicates the information in a sufficiently clear and easy-to-understand manner such that individuals can use it to form intentions for behaviour change.

While findings from the current study don't deny the potential value of developing such presentations, a project to do so is likely to be of considerable effort and will need to involve various experts including dietitians (Maringer, Wisse-Voorwinden, et al. 2019) as well as experts on foodprint. As such, the pursuit of the diet share visualizations may be best considered as a separate project and not pursued as part of the current design path.

5.5.2.8 Inconsistencies In Receipt Scanning

The evaluations also exposed difficulties with a reliance on consistent receipt scanning. Several participants noted that they were likely to forget taking or losing some of their grocery receipts. Other participants expressed their dislike for dutiful, consistent, receipt scanning.

The observations align with prior research highlighting common issues with diet-tracking applications. Research on diet tracking finds that, despite dedicated design efforts to simplify tracking, users frequently fail to record consumption (Osadchiy 2020). Diet tracking is frequently

considered effortful, and people commonly abandon regular tracking after short periods of no more than a few weeks (Cordeiro, Daniel A. Epstein, et al. 2015; Daniel A. Epstein, Caraway, et al. 2016).

Inconsistent tracking may compromise the value of cumulative absolute measures of foodprint (e.g., the various ways of contextualizing foodprint on the stats page). Also, comparing shopping trips based on the total foodprint of each separate trip may be a little informative as the number of purchased items in a single shopping trip may vary considerably between shopping trips. In contrast, relative measures may be less dependent on consistent tracking and allow comparison of shopping trips over time to track progress. Examples are the average foodprint per 100g of a diet (analogues to the energy density measure in diet health literature (e.g., Aiello et al. (2020), or the foodprint per 100kcal of a diet, e.g., Scarborough et al. (2014)). However, while such relative measures allow for comparison over time, they are not easily compared to other dimensions (e.g., foodprint budget, or flights) and the use of absolute measures may still be meaningful for contextualization. *Iteration recommendation 2.10*: complement absolute measures of foodprint with relative measures of foodprint on the stats page.

5.6 Prototype Version 3

5.6.1 Design Changes

5.6.1.1 Overview

Prototype version 3 implements changes to the ten recommendations from the evaluation of version 2, including a visual makeover of the design¹⁰.

5.6.1.2 Stats Page Updates

The iteration sees the remodelling carbon budget presentation into a credits system (Figure 5.5a) and the IPCC-based budgets (for 1.5°C and 2°C global warming) are complemented with a user-defined goal. Tracking of foodprint over time is also complemented with relative indicators of foodprint: the average product foodprint in foodprint per 100g (Figure 5.5b) and the diet

¹⁰The clickable prototype as viewed by the participants is available at <https://www.figma.com/proto/hzNBdZundT9xcVhZhXpDPl/Figma-Study-Prototype-3?node-id=206%3A50&scaling=scale-down&page-id=0%3A1&starting-point-node-id=502%3A672&show-prototype-side-bar=1>

efficiency, or footprint per 100kcal (Figure 5.5c). A complete overview of the changes and rationales based on related literature is captured in Table 5.5.

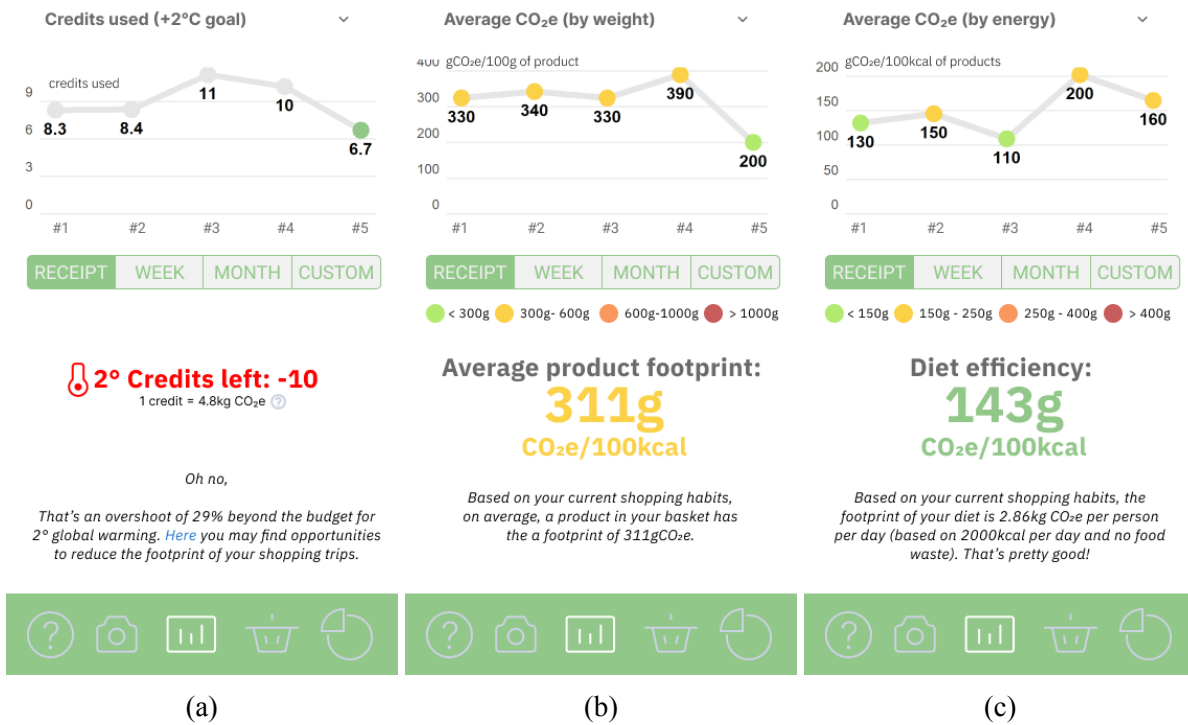


Figure 5.5: Changes to the stats page implemented in prototype version 3.

Table 5.5: stats page implementation in version 3: overview of changes and rationales.

Implementation	Rationale
<p>To address confusion with the carbon budget, expressed in days, this version expresses the carbon budget in credits, meaning that one credit represented the budget for one day. A counter now provided a single number stating the credit balance for either climate budget.</p>	<p>Addressing recommendation 2.7. The term credit is commonly used to specify a limited budget (e.g., credit on a bank account) and this may help in understanding the footprint budget concept.</p>
<p>A message was added that provided an interpretation of the various statistics measures, with information phrased in either a positive or compassionate tone.</p>	<p>Addressing recommendation 2.7. Brief explanatory captions are recommended to assist data interpretation (Knafllic 2015). Consistent with self-determination theory (Ryan and Deci 2000; Ryan and Deci 2020), negative and judgemental evaluations may lead to avoidance (Deci and Flaste 1996; W. Wang et al. 2014; Mönninghoff et al. 2022) while positive or compassionate messages are less likely to do so (W. Wang et al. 2014).</p>
<p>Graphs of footprint of time are changed from bar charts to line charts.</p>	<p>It is common practice to use line charts to denote fluctuations over time (Knafllic 2015)</p>
<p>New statistics are included: a measure that describes the (a) footprint per 100g of the average purchased product (average product footprint), and (b) footprint per 100kcal of the average purchased product (diet efficiency).</p>	<p>Addressing recommendation 2.7. See Section 5.5.2.8. In contrast to tracking towards a cumulative value (e.g., footprint budget), each of these measures provides an alternative performance indicator that allows monitoring progress over time and does not depend on users consistently scanning their receipts.</p>

'Days of calories' is removed.

Addressing recommendation 2.9.

5.6.1.3 Tutorial Updates

Accompanying the user-defined goal, a goal-setting procedure is therefore implemented in the tutorial, where the user can calculate an estimation of the current foodprint based on diet patterns and estimated calorie needs (Figure 5.6). Also, the tutorial is now integrated as an interactive tutorial and its contents are available for later review through question mark buttons on the various pages of the application (Figure 5.7). A complete overview of the changes and rationales based on related literature is captured in Table 5.6.

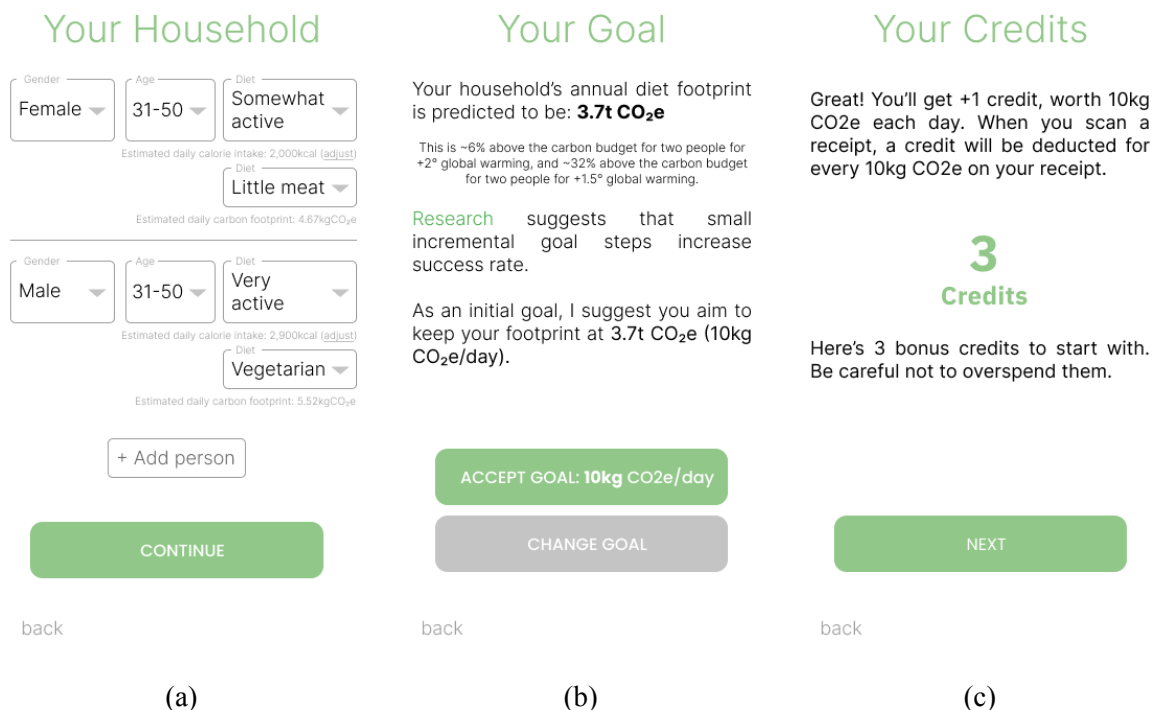


Figure 5.6: Changes to the tutorial in version 3: goal setting procedure. The user provides information to estimate the calorie needs of the household and selects the diet pattern (a). The estimated foodprint is communicated and the user can choose a goal, either by confirming the recommended starting goal or by defining a customized goal (b). The user is then informed how the goal is monitored in terms of credits (c).

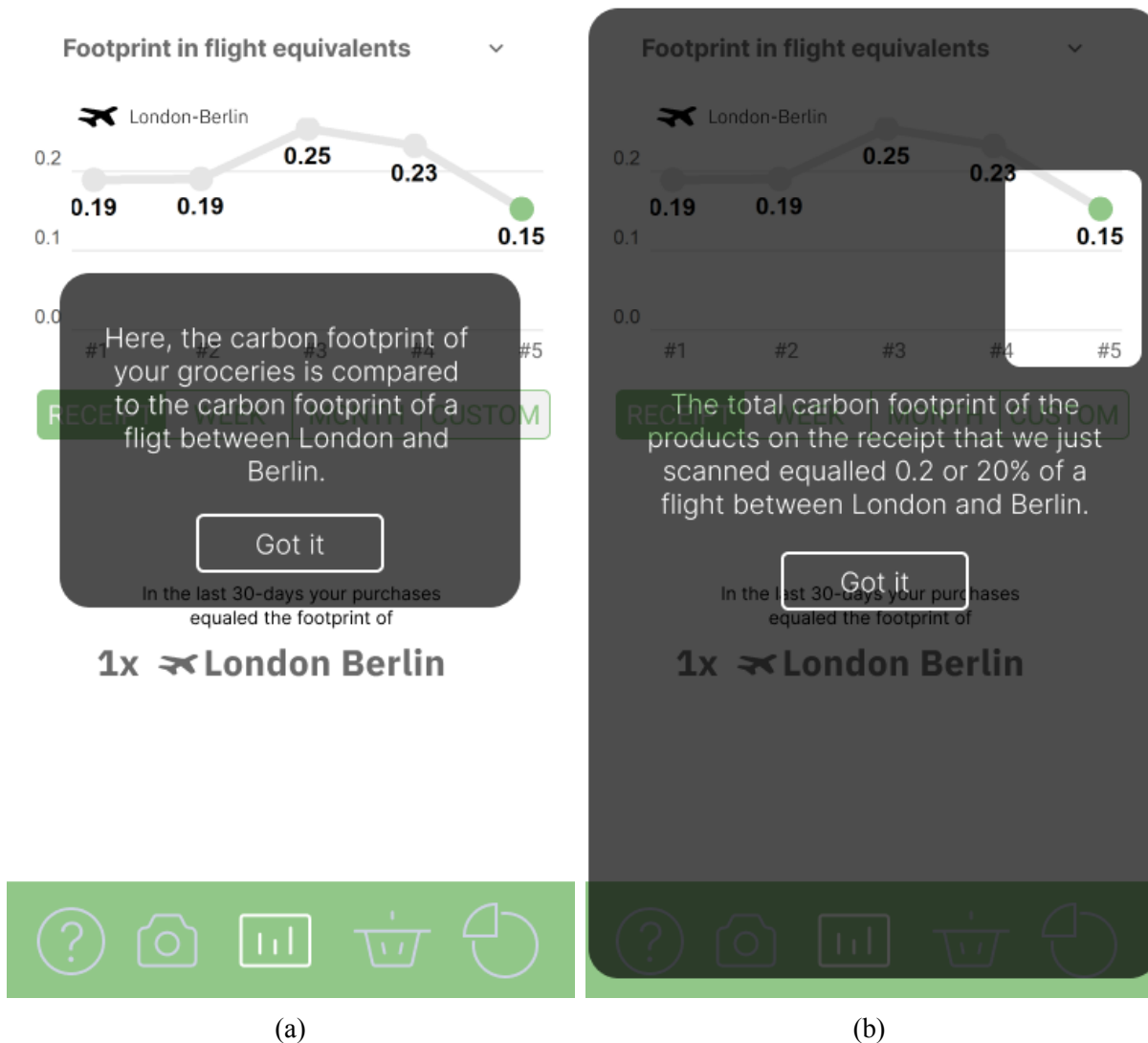


Figure 5.7: Changes to the tutorial in version 3: integrated tutorial. After a moment of viewing a screen for the first time, an information message is displayed providing an overview explanation of the page (a). Individual elements of the page are then highlighted and explained (b).

Table 5.6: tutorial implementation in version 3: overview of changes and rationales.

Implementation	Rationale
<p>Instead of providing a passive up-front tutorial, the tutorial is now integrated as a walk-through tutorial that guides the user through the various actions and concepts in the prototype by highlighting and explaining specific elements on a page, one-by-one, as it is first opened. Users can access the information again at a later stage by clicking the question mark buttons, available on every page.</p>	<p>Addressing recommendation 2.6 (see Section 5.5.2.5). People learn better when they actively engage in information search (Priniski, Hecht, and Harackiewicz 2018; Deslauriers et al. 2019; D. J. Skinner and Price 2019).</p>
<p>A procedure is integrated into the tutorial for users to formulate a personal foodprint goal. The user is asked to provide information about gender, age, activity level, and diet for each of the household members (Figure 5.6a). From this information, a daily household foodprint is estimated (National Heart, Lung, and Blood Institute 2013; Scarborough et al. 2014). The user is then shown their estimated household foodprint and how this compares with the 1.5°C and 2°C climate budgets and advised to improve their foodprint with small incremental goal steps (i.e., graded tasks (Michie, Richardson, et al. 2013)), starting with a modest goal: to maintain and not overshoot the estimated foodprint (Figure 5.6b). The option to adjust this goal is also provided. After goal setting, the user is explained how credits are used to measure performance against the goal. Credits are created that have the value of their foodprint goal and they get to spend one credit per day. Three extra credits are given to start with to reduce the risk of dropping below zero credits right from the start (Figure 5.6c).</p>	<p>The feature builds on participants' framing of climate budgets as goals. Goal setting is considered an effective technique for supporting behaviour change (Humphreys et al. 2021; König et al. 2021; Aguiar et al. 2022). For effective goal setting, goals must be neither too hard nor too easy (J. Clear 2024). Work by Scarborough et al. (2014) quantifies the foodprint per calorie of six different diets, while widely used tools exist that can estimate a person's daily calorie needs using only a few demographics; together allowing estimation of a person's daily foodprint.</p>

5.6.1.4 Product Feedback Updates

The product feedback page is updated to feature a single word cloud that informs both the share of a specific product on a person's total footprint (size) and the product's footprint per 100g (traffic-light colour-code) (Figure 5.8a). As an alternative to the word cloud, the user can toggle to a bar chart view for in-depth investigations (Figure 5.8b). A complete overview of the changes and rationales based on related literature is captured in Table 5.7.

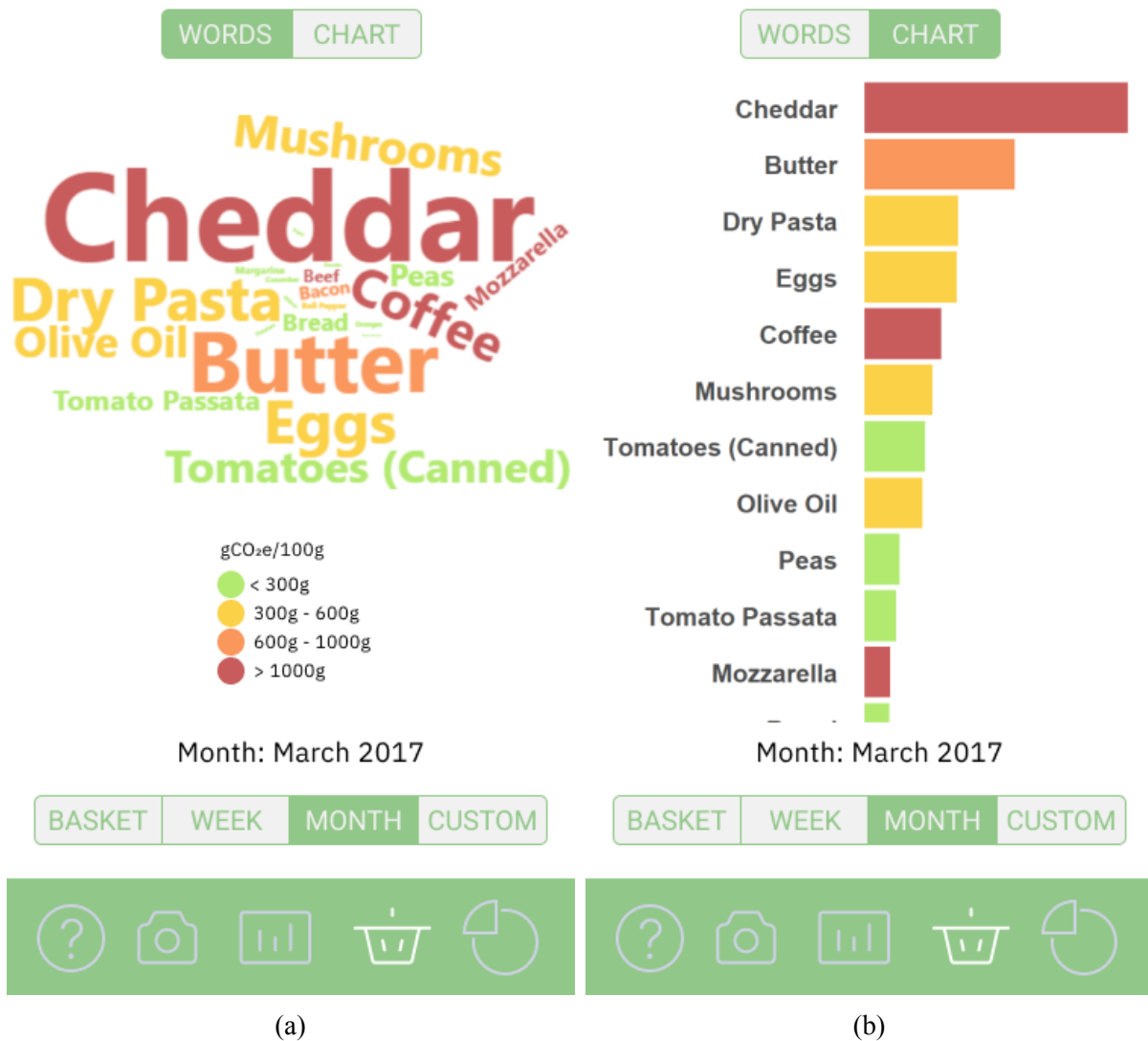


Figure 5.8: Changes to the product feedback page in version 3: a single word cloud that combines two dimensions in a single graph (a), and a bar chart for in-depth investigations (b).

Table 5.7: product feedback implementation in version 3: overview of changes and rationales.

Implementation	Rationale
<p>Instead of presenting separate word clouds for each footprint unit, a single word cloud is now used. Size is used to inform the share of a specific product on a person’s total footprint, while, as a second dimension, traffic-light colour coding is used to categorize products based on their footprint per 100g.</p>	<p>Addressing recommendation 2.1 (see Section 5.5.2.2). Both information on the share of a specific product on a person’s total footprint as well as the footprint per 100g are needed to identify products with the best opportunity for replacement. Colour can be used to add dimension to data visualizations. Prior work has indicated that traffic-light colour coding can effectively inform people of the footprint of items (van Amstel, Driessen, and Glasbergen 2008; Grunert, Hieke, and Wills 2014; Holenweger, Stöckli, and Brügger 2023) (Chapter 4) and found its way in various applications of footprint feedback (A. Clear and F. Friday 2012; Herbig, Kahl, and Krüger 2018; Shakeri and McCallum 2021).</p>
<p>Options to show purchases by week and month are included.</p>	<p>Addressing recommendation 2.3 (see Section 5.5.2.3).</p>
<p>Users can now toggle between the word cloud and a bar chart to visualize their purchases.</p>	<p>Addressing recommendation 2.2 (see Section 5.5.2.2). A bar chart is more suitable for occasional in-depth investigations.</p>

5.6.1.5 Product Alternatives Page And Foodprint Database Updates

The product alternatives page is restyled with graphical indicators of foodprint. A new database of foodprint data was created to expand the variety of alternative product types. With a button, users can optionally change from the default unit of foodprint (foodprint per 100g) to alternative units: foodprint per 100kcal and foodprint per 50g of protein Figure 5.9.

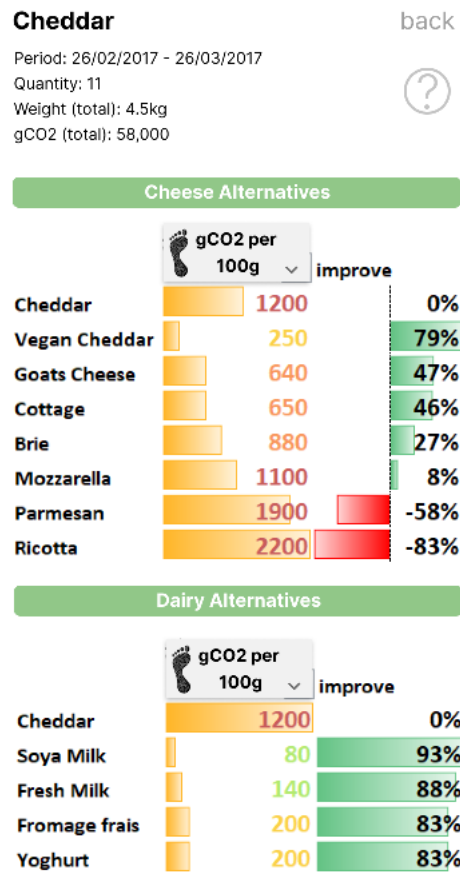


Figure 5.9: Product alternatives page as implemented from version 3.

Table 5.8: product alternatives page and foodprint database implementation in version 3: overview of changes and rationales.

Implementation	Rationale
<p>A new dataset of foodprint data was created for this prototype. It combines data from multiple datasets of foodprint data for the UK (Tesco 2012; Scarborough et al. 2014; Small World Consulting 2015; Berners-Lee 2020), leading to a dataset that has a greater number of different product types than the dataset used before. The dataset identifies products by product type.</p>	<p>Addressing recommendations 2.4 and 2.5 (see Section 5.4.2.1): participants expressed the need for a wider variety of alternative options. Known¹¹ datasets of foodprint data cover only a limited set of products each (Tesco 2012; Scarborough et al. 2014; Small World Consulting 2015; Berners-Lee 2020). This limits the use of individual datasets for providing feedback on the wide variety of common purchases, and some researchers have resorted to combining datasets for practical purposes (Hedin, Grönborg, and Johansson 2022). While differences in methods of foodprint calculation (Berners-Lee 2020) can lead to data inconsistencies when datasets are combined, such imperfections are considered preferable over omission (Adrian K. Clear, O’Neill, and A. Friday 2015) and the practice can be considered acceptable for research purposes.</p>

¹¹Known at the time of the design.

Implementation	Rationale
<p>The alternatives page is restyled using visuals (charts and colour coding). Foodprint values are supported by horizontal bars, and traffic light colour coding is used to categorize foodprint values, as in the product feedback page. A column provides information about the relative improvement; the reduction that can result from switching to the alternative.</p>	<p>See Section 5.5.2.4. A need for improving the visual layout was identified. Charts and colour coding can be valuable tools for data comprehension (Knafllic 2015). Prior work has indicated that traffic-light colour coding can effectively inform people of the foodprint of items van Amstel, Driessen, and Glasbergen (2008); Grunert, Hieke, and Wills (2014); Holenweger, Stöckli, and Brügger (2023).</p>
<p>By default, the alternatives page shows the foodprint of products as foodprint per 100g. Using a dropdown menu, the user has the option to show the information in foodprint per 100kcal or foodprint per 50g of protein.</p>	<p>Addressing recommendation 2.8. See Section 5.5.2.6.</p>
<p>Using a dropdown menu, the user can choose to view the foodprint in units of protein content.</p>	<p>Addressing recommendation 2.8. Many products with the highest foodprint are characterized by their high protein content (i.e., meat) (Poore and Nemecek 2018; Berners-Lee 2020) and the specific dietary choices that people make to meet their nutritional needs can have a profound impact on their foodprint (Scarborough et al. 2014). As such products may be bought specifically to meet protein demands, it may be most informative to compare such products based on their foodprint-by-protein ratio (Berners-Lee 2020).</p>

5.6.2 Results And Discussion

5.6.2.1 Overview

As before, as more interviews were conducted more (both new and nuanced) patterns in the observations from the evaluations could be discovered. Additionally, the content for certain patterns has significantly changed in comparison to previous evaluations (specifically, *difficulty in searching alternatives* and *difficulty in comprehension*). Other patterns were reconfirmed without new insights and have not been repeated here (i.e., *Appeal of the word cloud visualisation*, *Value of various time frames*, *Difficult relationship with calories*, *Restrictions of the diet share visualization*, and *Inconsistencies in receipt scanning*).

5.6.2.2 Appreciation Of The Alternatives View: Exploring Options

Observations. Compared to the evaluation of earlier prototypes I now observe a clear shift in the perception towards the overview of alternatives. Participants now expressed much interest when looking at the overview of alternatives. All participants now spend some time exploring the content and voiced surprise in various ways, e.g., ‘I didn’t know cheese was so bad’ [P7], or explicitly calling the content of the screen ‘thought-provoking, because of large the improvements that can be made’ [P9]. Several participants mentioned that they would also want to use the overview in the store to look up alternatives to products as they go along, although some do remember that time to look up information in the store is limited.

When looking for alternatives, participants often tried first to find whether any alternatives were relatively similar to the original product that had a significantly better foodprint. They seemed particularly interested in comparing the impact of different types of meat and meat alternatives, as well as cheese and cheese alternatives, and additions such as vegan cheese and vegan yoghurt repeatedly received interest for their large relative reduction in foodprint per weight. Participants noted that substantially different alternatives were interesting as a basis for reflection, but it would be harder to implement those.

Participants still mention that, in some cases, alternatives may be hard to find. Replacing products may not be straightforward as they may be selected for specific purposes. For example, baking products are selected for specific chemical properties, while other products may be considered for their specific taste or nutritional profile. The units of foodprint per calorie or protein content were therefore found very interesting by some participants as they considered meeting

protein or calorie demands in their diet choices. However, it was also pointed out that it would be difficult to put information from these units into practice, as people were not used to measuring products in these units, but rather buying products in terms of weight, volume, or unit. All the same, participants were quite resourceful in considering the suitability of alternatives based on internalized product information as they verbalized their consideration of why particular products would or would not be suitable as an alternative for, e.g., meeting protein needs.

Discussion. By eliciting curiosity and surprise, the content of the alternatives page may have a valuable contribution to foodprint literacy and people's ability to make more foodprint-considerate choices. de Boer, de Witt, and Aiking (2016) find that people are often unaware of the differences in the foodprint of various products and found that exposure to products had a significant impact on people's preferences. Hedin, Grönborg, and Johansson (2022) predict that exposure to foodprint information will lead to surprise reactions and benefit foodprint literacy. Moreover, curiosity is indicative of intrinsic motivation (Deci and Flaste 1996; Ryan and Deci 2020), beneficial for problem-solving and memorization of learned material (i.e., increasing foodprint literacy).

Prior work also aligns with—but challenges—the appeal of applications to compare products in store. A prior literature review deducted the appeal of this feature from its dominance in academic literature over other forms of applications for purchase reflection (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024) and other studies report shoppers requesting apps with this feature (Dunford et al. 2014). In practice, however, such applications appeared to suffer from limited engagement as their in-store use was perceived as cumbersome, and empirical results have been found underwhelming (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024). As such, there appears to be limited value in prioritizing a feature to benefit in-store comparison of products.

The repeated challenges with finding suitable alternatives align with prior work that emphasizes the complexity of diet decisions (Bellisle 2006; Lawo et al. 2021), but do not necessarily underline the need for providing information about all of the many product characteristics (e.g., nutritional composition, price, availability) to facilitate people in reducing their foodprint. Similar to the observations in this study, other works found that people can draw on internalized product knowledge to inform their choices (Daniel A. Epstein, Caraway, et al. 2016; Herbig, Kahl, and Krüger 2018). This observation is encouraging as the provision of information on various product characteristics is not only challenging from a technical perspective (e.g., obtaining the data), but people may also quickly become overwhelmed in trying to consider information on various

characteristics together (Kalnikaitė, Bird, and Yvonne Rogers 2013). Algorithms can be used to recommend the best options based on many characteristics at once (e.g., Asikis et al. 2021; Lawo et al. 2021)), but their design is complex and the performance of such algorithms is often modest (Bunten et al. 2021; C. E. Wood et al. 2015; Lawo et al. 2021; Taalesen 2023). Moreover, the use of such algorithms may interfere with people developing generalizable foodprint knowledge as the complex algorithmic calculations are not easily understood, thus making them (unrealistically) dependent on the use of the application for every alternative consideration.

Conclusion. The findings suggest that, in its current form (see, Section 5.6.1.5) the alternatives page is perceived well, plays a valuable role in knowledge gain, and is a valuable addition to support people to explore alternative options. While searching alternatives may remain challenging, there appears to be limited practical value in providing information on product characteristics beyond the foodprint per 100g to facilitate people in exploring options to reduce their foodprint.

5.6.2.3 Difficulties In Comprehension: Gaps And Inconsistencies With Prior Knowledge

Observations. The evaluation of this prototype helped to form a nuanced understanding of the difficulties in comprehension that were observed throughout the various prototypes. Several of the concepts, introduced in the prototypes, are unfamiliar to the participants and this hinders comprehension. For example, participants were often not familiar with the unit of grams of carbon dioxide equivalents (gCO₂e) as a unified measure of carbon footprint. Also, various participants were unfamiliar with the thresholds of 1.5°C and 2°C global warming and intuitively struggled to understand the 1.5°C threshold as the more ambitious one to pursue.

On the other hand, other concepts introduced in the prototype appeared to have definitions that clashed with prior interpretations that participants had for the concepts. For example, some participants understood the concept of foodprint credits as a form of gamified currency system (similar to e.g. lingots in Duolingo, see <https://support.duolingo.com/hc/en-us/articles/360035917472-What-are-Gems-Lingots>), but found that the implementation of credits in the prototype did not meet this prior interpretation, and the concept of foodprint credits was unanimously met with confusion. Similarly, confusion and varied attitudes towards the use of calories (as gCO₂e/100kcal, days of calories [prototype version 1 and 2]) may be the result of inconsistencies between a pre-existing notion of calories as a (negative) health indicator and its use in the prototype (diet efficiency and a proxy of food waste respectfully).

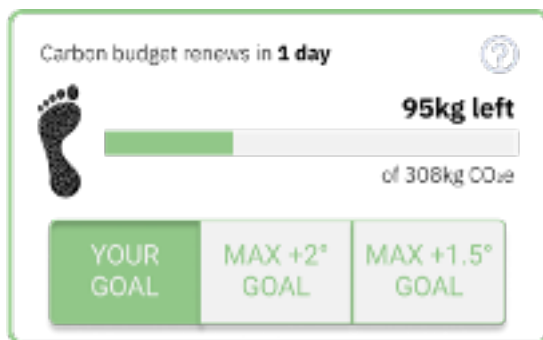
Discussion. As before (see, Section 5.4.2.2 and Section 5.5.2.6), these observations can be understood by considering learning theory. Both limited prior knowledge, but also conflicting prior associations can hinder the assimilation of new knowledge (D. J. Skinner and Price 2019). The rapid rise and popularity of gamification in mobile applications (Orji and Moffatt 2018; Koivisto and Hamari 2019) may have led to specific associations that are incompatible with the intentions behind the design of prototype version 3 (e.g., the credit system). In the current version, many new or incompatible concepts were introduced at the point of goal setting. *Iteration recommendation 3:* explore alternatives for displaying the foodprint limit goals that may help comprehension.

5.7 Prototype Version 4

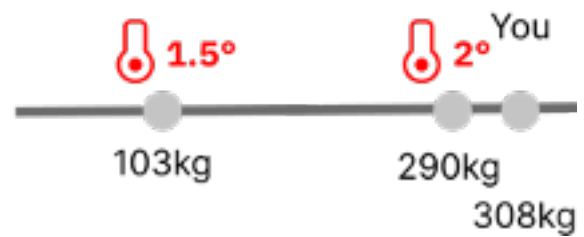
5.7.1 Design Changes

The changes implemented in prototype version 4 all respond to iteration recommendation 3, to explore alternatives for displaying the foodprint limit goals to benefit comprehension¹². The credit system for cumulative tracking against daily carbon budgets was abandoned and instead, a monthly budget is used, visualized by a bar that decreases over time (Figure 5.10a). Also, a graphical visualization is used to help explain how the different IPCC-based budgets and current estimated behaviour compare (Figure 5.10b) when explaining goals (see Section 5.6.1.3 and Figure 5.6b). A complete overview of the changes and rationales based on related literature is captured in Table 5.9.

¹²The clickable prototype as viewed by the participants is available at: <https://www.figma.com/proto/eSZMpx2s8TiUiX3VzIcx2u/Figma-Study-Prototype-4?node-id=206%3A50&scaling=scale-down&page-id=0%3A1&starting-point-node-id=502%3A672&show-proto-sidebar=1>



(a)



(b)

Figure 5.10: Changes implemented in prototype version 4: a new approach to visualizing food-print budgets (a), and a visual to clarify how the different footprint goals compare (b).

Table 5.9: design changes implemented in version 4: overview of changes and rationales.

Implementation	Rationale
Stats page	
<p>The carbon budget is now presented as a monthly budget, visualized as a bar that decreases as the budget is used. A figure next to the bar informs the remaining budget and, in case of a negative budget, takes a negative value and is coloured red.</p>	<p>A visualisation of the budget that people may be familiar with is the percentage stacked bar plot, for example, used to signify the remaining MB of a monthly mobile data bundle. While this graph type is unsuitable for visualising over-spending, a beneficial flip side of this limitation may be the reduced emphasis on negative budgets and the risk of disengagement from perceived negative feedback (Deci and Flaste 1996; W. Wang et al. 2014; Mönninghoff et al. 2022).</p>
<p>The foodprint budget is set to reset after each month.</p>	<p>1. The use of a monthly renewing budget may benefit engagement. People commonly purchase food for several days ahead (Adrian K Clear, O’neill, et al. 2016). On a daily budget, such behaviour may be emphasized as over-spending, which may be perceived as unfair criticism, and lead to disengagement (Deci and Flaste 1996; W. Wang et al. 2014; Mönninghoff et al. 2022). A monthly budget can better accommodate weekly shops. 2. Compared to a rolling budget as in prototypes 1 and 2, a monthly renewing budget increases opportunities for positive effects from goal achievement (Bandura 1978).</p>

Implementation	Rationale
Rather than flipping between pages, the user can now unite on one page. The user can view multiple stats at-a-glance and use scroll movements to view information that is outside the current view.	Reducing the number of clicks can benefit user experience (Krug 2014) and user engagement (Venkatesh, Thong, and Xu 2012).
Tutorial	
A visual representation as added in the introduction comparing the different carbon footprint budgets (the personal goal budget and the budgets for +1.5°C and +2°C respectively).	The relative values of the +1.5°C and +2°C budgets were a prominent source of confusion (see, Section 5.6.2.3). Visual representations can facilitate comprehension (Knafllic 2015).

5.7.2 Results And Discussions

5.7.2.1 Overview

As the number of conducted interviews grew further, more nuanced patterns in the observations from the evaluations could be discovered. Additionally, the apparent improvement in the approach to foodprint goal visualization increased the attention to foodprint goals in the evaluation of the 4th version and added to the reflection on goal setting in the context of the prototype. Complementing the patterns described in the previous results and discussion section (see Section 5.6.2), two new, relatively theoretical, patterns were formed and described below.

5.7.2.2 Foodprint Goals: Practical And Ethical Challenges

Foodprint goals have been present in one way or another throughout the various prototypes. In prototypes 1 and 2, an implicit goal of keeping the number of days-of-foodprint-budget-used (counted from the collective foodprint of logged purchases) below the number of days since purchase logging, in prototype version 3 is the goal of keeping a positive credit balance, and in prototype version 4 as the goal of staying within the monthly foodprint budget in. Also, the recommended food group proportion in the diet share visualisation could be understood as goals. Throughout the interviews, both ethical and practical challenges with foodprint goals started to become clear.

Ethical challenges: While most participants did not seem directly opposed to the concept of goal setting, the phrasing used by several participants suggests a controlling element to foodprint goals. Participants noted how goals and the act of goal setting could feel imposing, emphasise personal responsibility, and lead to obsessive monitoring. One participant explicitly voiced potential ethical issues with setting a foodprint goal. In contrast, another participant suggested that the application should incorporate both social competition and an option to shame other users for poor performance to motivate them to reduce their foodprint despite their assumed otherwise selfish disinterest in doing so.

Mention of a controlling nature of goal setting can be found in various prior works. Goals can emphasize an (inappropriate (Brynjarsdottir et al. 2012)) sense of responsibility and coerce a person through the shame of failing personal and societal norms (Deci and Flaste 1996; Purpura et al. 2011; Brynjarsdottir et al. 2012). Moreover, goal orientation can erode intrinsic motivation for an activity (Deci and Flaste 1996) and can lead to addiction, characterized by the obsessive

pursuit of an over-simplified numeric value (Kim and Werbach 2016; Stibe and Cugelman 2016; Nguyen 2020). In response to such ethical problems, (Arora and Razavian 2021) state that users should be given autonomy over the size and definition of a goal, as well as the way it is displayed, but this notion leaves open questions as to how this can confidently be realised.

Practical challenges: As participants pointed out, they may have created a habit of not taking receipts. Also, particularly as the initial intense use phase wears off, people may not scan receipts straight after shopping, and receipts may be lost and not scanned.

Such inconsistencies in logging purchases complicate tracking against a foodprint budget or limit, like those related to the IPCC global warming budgets. A similar problem is familiar in the field of diet intake monitoring, e.g., for weight loss in cases where people frequently fail to provide complete consumption logs (Osadchiy 2020). This makes it difficult to draw inferences from the data. While various efforts have been made to address this problem, it seems that the problem of inconsistent logging will prevail for the foreseeable future (Cordeiro, Daniel A. Epstein, et al. 2015; Daniel A. Epstein, Caraway, et al. 2016; Osadchiy 2020; Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024).

Another practical challenge was related to the time and manner of introducing a potential foodprint goal. Allowing participants to set their own goals appeared to be important as the use of predetermined goals could be perceived as imposing, and meeting the IPCC foodprint goals seemed too hard might discourage users. However, as discussed earlier, the process of goal setting involved the introduction of various foodprint-related concepts that could confuse the user of the system. Also, some participants pointed out that it would be very hard to determine what goal would be achievable for them when they just started to use the system and had little knowledge about their foodprint and opportunities to change it. Some participants wondered whether goal setting could be introduced after a period of system use.

While this problem might be partly addressed by introducing goal setting after a period of usage, this still leaves open questions as to how long a person should use the system before setting a goal, and whether and how to introduce concepts (like the IPCC climate goals) to facilitate goal setting.

Conclusion. Both ethical and practical challenges complicate goal setting in the context of the proposed application. If goal setting were pursued in the future design of a system, considerable research efforts, with uncertain practical benefits, may be required to mitigate problems with

goal setting. Different strategies to support potential users in lowering their footprint may be preferred.

5.7.2.3 Exploring And Tracking: Different Uses And Their Change In Focus Over Time

Observations. From the participant interactions, two primary uses of the app could be identified. People use the product purchase feedback and alternative overview to explore concrete and actionable opportunities for change. Participants also use the application to track against goals on the stats page or the diet share page. While these two uses could co-exist, the attention to each was not necessarily expected to be in balance.

Several participants expressed how their use of the app would change over time. Participants described an initial intense use phase to explore and learn about their current purchase habits and opportunities for improvements; scanning as many receipts as possible to get the information in the app. In this phase, participants would focus on the product feedback and alternatives pages. Information like flight equivalents and budgets would be valuable to gain perspective about the importance of footprint, more so than to serve goal setting. Once such knowledge was established, a phase of less frequent follow-ups was expected; checking-in whether one is 'still on track' and to refresh their knowledge. In this latter phase footprint goals could start to play a more relevant role and a non-goal-related perspective like flight equivalents would be of limited value in this stage.

Discussion. Prior works of eco-feedback have characterised separate learning and maintenance phases (Broms et al. 2010; Zapico, Katzeff, et al. 2016) and the identification of such separate phases align with stage-based models of behaviour change (Falko F Sniehotta and Aunger 2010). Prior studies of eco-feedback (Broms et al. 2010; Zapico, Katzeff, et al. 2016) and food choice interventions (Zapico, Katzeff, et al. 2016; Bangia, Shaffner, and Palmer-Keenan 2017) found the initial learning stage to have particular importance for an impact of the intervention on behaviour. Similarly, prior literature has argued the important relation between food literacy (the knowledge and skill to acquire and prepare healthy food)(Palumbo 2016; Truman, Lane, and Elliott 2017). S. J. Flaherty et al. (2020) describe this phase as a period of critical reflection in which people reflect on their pre-existing shopping habits and temporarily conduct their shopping with increased awareness, after which new shopping habits settle in. They argue that this process explains the effectiveness of diet-tracking applications.

In this study, participants characterized the learning phase with the use of the product feedback page and the alternatives page. Indeed the findings in the current study indicated that these pages were valuable for learning about foodprint and their behaviour concerning foodprint (see Section 5.5.2.2, Section 5.6.2.2).

The maintenance phase is described as a period of less frequent check-in (Broms et al. 2010; Zapico, Katzeff, et al. 2016) to verify whether the new behaviour has taken hold to the satisfaction of the user. Prior work has noted a tendency for some behaviour regression to occur over time (Bangia, Shaffner, and Palmer-Keenan 2017; Samoggia and Riedel 2020) and suggested that repeated exposure may be needed to prevent regression (Samoggia and Riedel 2020), thus emphasizing the value of information that supports the maintenance phase (i.e., information in the stats page in the context of the prototype).

However, theory and empirical findings may challenge the potential effectiveness of such a maintenance phase. Despite efforts to facilitate continued engagement with behaviour change support systems (BCSS), disengagement with behaviour change support systems BCSS appears ubiquitous and regression is common (Cordeiro, Daniel A. Epstein, et al. 2015; Daniel A. Epstein, Caraway, et al. 2016; T. Greenhalgh et al. 2017; C. Young et al. 2019; Attig and Franke 2020; J. Park, Choi, and Rhee 2021; Melo, Andrade, and Darin 2022). Also, regression could be considered a normal and healthy process following a period of increased intention for the behavioural aspect that was highlighted by the BCSS. The use of the BCSS can be marked by a period of increased intention for the behavioural aspect (S. J. Flaherty et al. 2020), potentially at the expense of other values Tengland (2012). After a time, the imbalance with other values may become clear and the person may settle into a new normal (S. J. Flaherty et al. 2020) that lies somewhere between the old behaviour and the behaviour during the attention-bias-driven intense phase. Instead of targeting long-term engagement and maintenance, prior works suggest investing efforts in supporting the initial learning phase (Benthem De Grave, Bull, Monjardino De Souza Monteiro, Margariti, et al. 2024) and supporting revived interest after a period of abandonment (Daniel A. Epstein, Caraway, et al. 2016). As such, there may be limited value to prioritise features that support the maintenance phase.

Conclusion. The study findings emphasize the relative importance of the product feedback and alternatives pages (dominant in the learning phase) and suggest that further work on the prototype should prioritize the content of these pages.

5.8 General Discussion

5.8.1 Overview

In this study, I used rapid iterative design cycles and UX evaluations (research through design) and design informed by theory and empirical research (research for design) to address the thesis research question, how can digital technology be designed to support people in making climate-sustainable purchases in an autonomy-respectful way. Patterns were observed in the evaluations which were discussed and framed with existing literature. The outcomes of these discussions can now be combined and formulated as design implications for future design.

5.8.2 Design Implications

5.8.2.1 Overview

Design implications can be structured according to different angles of providing foodprint feedback that was represented in the prototype: product feedback, foodprint tracking (represented by the stats page), and diet guidelines (represented by the diet share page).

5.8.2.2 Product Feedback Recommendations

1. Evaluations suggest that most value of a system of purchase feedback is likely derived from a relatively short and intense learning phase in which users learn about the foodprint of products that are relevant to them. Future design efforts may want to focus on supporting an intense learning phase, rather than long-term maintenance or goal-tracking (see Section 5.7.2.3). Specifically,
2. Valuable for learning about the impact of one's choices and opportunities for reducing foodprint can be a visualization presenting recorded product purchases in two dimensions: (a) presenting the relative contribution of specific products to the total of their recorded purchases, and (b) the foodprint of the products in a unit of comparison (e.g., foodprint per 100g) (see Section 5.5.2.2 and Section 5.7.2.3). Specifically (next points):
3. To visualize this data, a word cloud may be particularly suitable as an intuitively understood and inviting visualization, effectively drawing attention to 'problem products' and starting the process of searching for alternatives (see Section 5.5.2.2).

4. A word cloud could be complemented with a structured chart, e.g. a bar chart, to provide support for incidental in-depth investigations (see Section 5.5.2.2 and Section 5.7.2.3).
5. Also supporting the learning phase, the provision of alternatives for ‘problem products’ is important for supporting people in forming concrete intentions of behaviour change (see Section 5.4.2.1 and Section 5.5.2.4). An overview of alternatives may be effectively combined with a visualization of product feedback (e.g., word cloud) (see Section 5.5.2.2). Important considerations in the design of this are (next points):
6. Visual aids (e.g., chart and colour scheme) informing the relative foodprint of products are recommended to guide users in their search (see Section 5.4.2.1, Section 5.6.1.4, and Section 5.6.1.5).
7. The inclusion of a wide variety of product types, in particular low foodprint alternatives (e.g., vegan alternatives), may be important to facilitate change (see Section 5.5.2.4). Researchers are advised to search for comprehensive foodprint datasets listing various product types (but not necessarily brands), combine datasets or calculate their own by extending on primary foodprint datasets (e.g., Wrieden et al. 2019; M. Clark et al. 2022) (see Section 5.6.1.5).

5.8.2.3 Foodprint Tracking Recommendations

8. Designers and researchers are recommended to design systems that do not rely on either constant or long-term tracking (see Section 5.5.2.8) and not to prioritize the design of features that provide feedback of change over time (see Section 5.7.2.3). Specifically:
9. It is recommended to apply hesitation when it comes to implementing goal-setting features, as this may introduce practical and ethical problems (see Section 5.7.2.1)
10. Optionally, to facilitate users to inform progress over time, information about the trend of foodprint in relative terms (e.g., foodprint per 100g or foodprint per 100kcal of the weight-balanced average product) can however be useful (see Section 5.7.2.3).

5.8.2.4 Diet Guideline Recommendations

11. Designers are recommended to take precautions when considering implementing the Lancet study (W. Willett et al. 2019) guidelines for a healthy and sustainable diet in a purchase feedback application. Due to the complexity and implementation of the Lancet

guidelines for a healthy and sustainable diet, this guideline is best pursued as a separate research project (see Section [5.5.2.7](#)).

5.8.2.5 General Recommendations

12. In general, in the design of a system of foodprint feedback, it is important to minimize the complexity of information and terms as people may easily get overwhelmed (see Section [5.5.2.5](#) and Section [5.6.2.3](#)). E.g., foodprint per 100g is best used as a unit for foodprint. Other units and other more complex perspectives of considering foodprint are best omitted or included only as advanced features and should not appear by default.

5.8.3 Limitations

The study had various limitations. In no specific order:

Rather than presenting people with their purchases, I used the purchases of an example person. I do not know how people would respond if they would see their purchases. However, it was observed people engaged well in the interviews, were able to pretend that the purchases were their own and provided valuable insights that helped in the formulation of design implications.

In some cases (i.e., in the evaluation of the earlier prototype versions), iteration recommendations were formulated after the analysis of very few interviews, which may appear insufficient to do so. However, these patterns could be confirmed in later versions, as well as with relevant literature.

The exploration of design paths was not exhaustive. Specific to the implementation of goals and carbon budgets, alternative modifications to the design could have been conceived that might have helped participants to better understand the budgets. For one, the reduction to a single budget or goal may well have reduced the confusion. However, the recommendation against the use of goal in the context of the design was not informed by the observation of difficulties with comprehension alone, but rather the recommendation was informed by a combination of issues, contextualized in related literature.

Misunderstanding of visualizations may have biased participants' responses. I prioritized ecological validity over the avoidance of misunderstandings and therefore provided minimal guid-

ance to participants in using the application. As such, we gained valuable insights about the non-intuitive nature of some visualizations.

Several UX topics were given little attention in the design of the prototypes. For example, knowingly, little attention was paid to the use of colour schemes that are colour-blind friendly. Also, people may have wanted to define flight routes relevant to themselves personally for contextualizing their foodprint. UX topics like these were considered high-level design issues that are well documented in the literature and can be addressed straightforwardly. Notably, it was not the intention to propose a final design, but rather to generate recommendations for future development of a design. Attention to topics such as tailoring colour schemes was not considered to provide valuable insights. Also, there was little indication that such high-level UX topics limited the value of the UX evaluations.

5.9 Conclusion

The study discussed in the current chapter combined RfD and RtD in the form of theory-informed design and iterative design cycles with UX evaluations. From a contextualization of the results with prior literature various design implications were derived. Specifically, it is recommended that future designs of eco-feedback technology for the reduction of foodprint focus on supporting a short and intense period of (practical) foodprint learning, rather than aiming to support a user in long-term tracking of their foodprint. Furthermore, the chapter contributes concrete designs, presented in four prototype versions, which can inspire future eco-feedback design. Particularly, the study contributes a novel and promising way of providing feedback on purchases by using a word cloud to empower users to easily identify practical opportunities to reduce their foodprint.

Chapter 6

Evaluating MyFoodPrint, A Field Study

6.1 Introduction

6.1.1 Aims Of The Study

This study aimed to answer the thesis research question by developing and evaluating a functional prototype of MyFoodPrint in a real-life setting. Field studies with a qualitative component are an important step in a system development process as they can uncover a range of problems (and potentials) that lab-based usability evaluations are unlikely to uncover (Yvonne Rogers, Connelly, et al. 2007) and such early-stage evaluations can provide basic confidence as to whether the system is doing what it is designed to do (Klasnja, Consolvo, and Pratt 2011).

As such the primary aim was to develop the application and evaluate whether the application could contribute to foodprint literacy (knowledge and self-efficacy/skill) and, if so, what are the important mechanisms driving these results. Additionally, the aim is to investigate what other effects (positive or negative) may result from using the application; e.g., whether certain active components backfire (Klasnja, Consolvo, and Pratt 2011; Irmak, Murdock, and Kanuri 2020) or spillover to other positive behaviours (Lauren et al. 2016).

While I will try to quantify any behaviour change that may result from using the application, this is not a primary aim of the evaluation. Behaviour change is a complex, and fragile process (Klasnja, Consolvo, and Pratt 2011), and properly assessing it requires large-scale longitudinal studies in the order of years (Prochaska and Velicer 1997; Marcus et al. 2000) with hundreds or thousands of participants (Klasnja, Consolvo, and Pratt 2011). Validating a behaviour change

impact is therefore often unfeasible for the error-prone early stages of development. Moreover, such evaluations fail to produce answers to why and how a change is recorded; answers that are often more important to HCI research as they are critical for understanding how better systems can be developed in the future (Klasnja, Consolvo, and Pratt 2011). Klasnja, Consolvo, and Pratt (2011) argue that evaluations should instead focus on narrow efficacy assessments of intervention mechanisms, as well as qualitative evaluations. By assessing the psychological processes that the intervention components target, the researcher can gain basic confidence as to whether the system does what it is designed to do. Through qualitative evaluations, researchers can better understand how the system is used and what potential problems may arise.

6.1.2 Contributions

This chapter contributes to HCI research in various ways. The contributions are: - Artifact: - A functional prototype of an application that provides feedback based on scanned grocery receipts, suggests alternative products, and monitors foodprint over time. - Empirical: - It informs of important mechanisms through which an application of foodprint feedback, monitoring, and suggestions can contribute to the development of foodprint literacy and climate sustainable food purchases, specifically through sparking curiosity, gentle guidance, and sparking conversation. - It highlights the value of designing for the household to benefit the opportunities for behaviour change. - It provides design recommendations to: - Harness curiosity and contribute to foodprint learning. - Provide gentle guidance and benefit self-efficacy. - Harness the potential of social facilitation through conversations, sparked by the application.

6.1.3 Outline

In the following sections I:

- Describe the application ‘MyFoodprint’ (see, Section 6.2).
- Describe the method of study design, data collection and analysis (see, Section 6.3).
- Provide the study results (see, Section 6.4), separated in descriptive statistics (Section 6.4.1), quantitative analyses (Section 6.4.2), and qualitative analyses (Section 6.4.3).
- Discuss the results (see, Section 6.5), in which the important mechanisms behind the study results are discussed and translated into design recommendations (Section 6.5.1

to Section 6.5.3) and limitations to the generalizability of the findings are discussed (Section 6.5.4).

6.2 MyFoodPrint: The Application

6.2.1 Overview

The two previous chapters have informed how the application should be developed. First a conceptual idea of the application was formulated and then, in the previous chapter, the application was shaped through four iterations that were informed by participant feedback in interactive user studies (Chapter 4) as well as theoretical and empirical insights from prior works (Chapter 5). For the study presented in this chapter, a functional prototype was developed based of the final iteration and the design recommendations that were formulated. In this section, the interface and the workings of the app are presented.

6.2.2 User Interface

6.2.2.1 Main Views Of The User Interface

The user interface consists of three primary pages with data visualizations that encompass four primary visualizations (Figure 6.1). I will describe these pages here. Later, in section Section 6.2.2.3, I describe how the user navigates the application as a whole and provide an application site map.

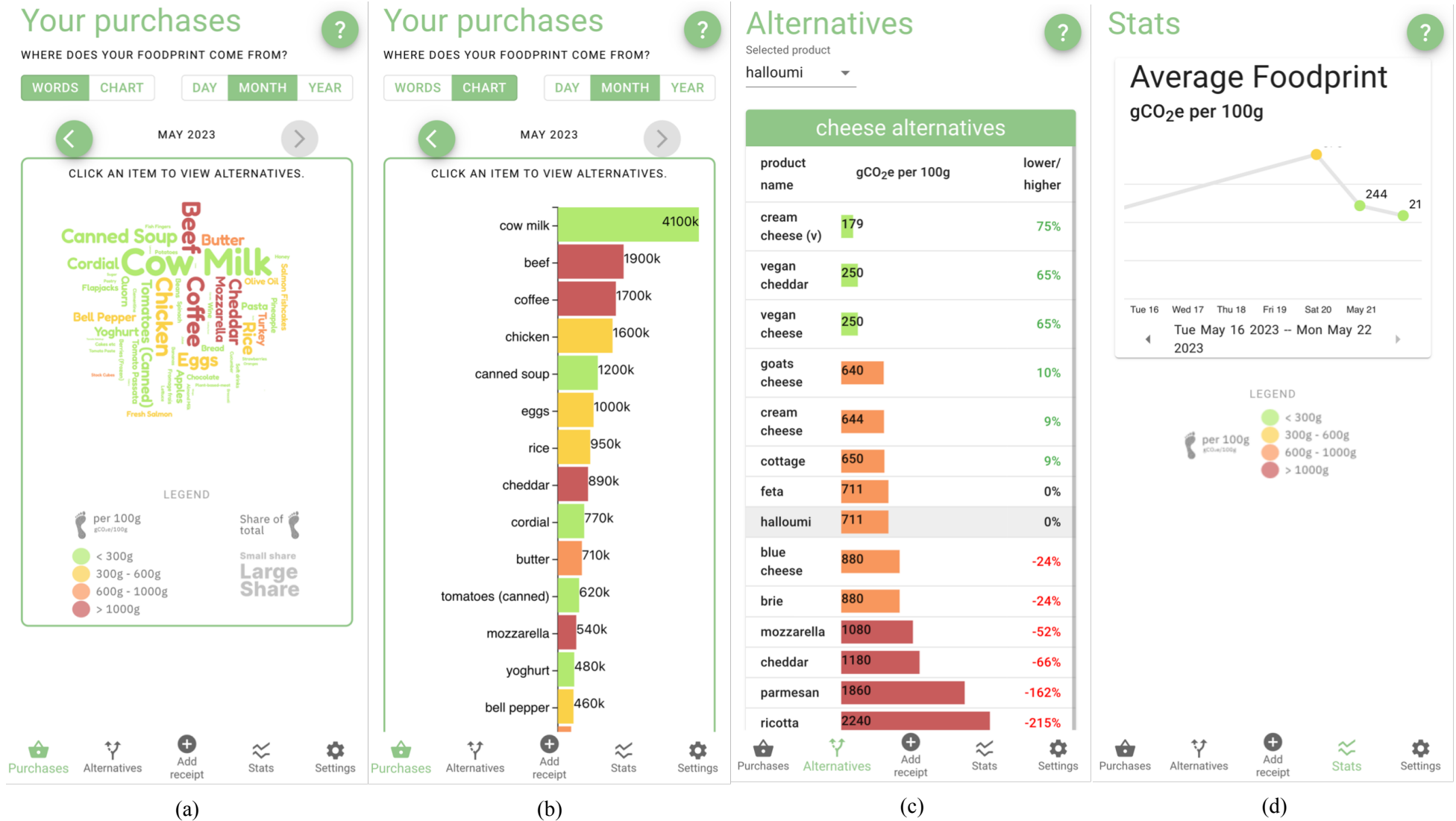


Figure 6.1: The primary data views of the application. Feedback on purchases is provided in the form of a word cloud (a) or bar chart (b). Through selecting a product in the purchase feedback view, the user is presented an overview of alternative suggestion (c). This view can also be visited through the bottom navigation menu. A stats view (d) visualises the average foodprint per 100g of shopping trips over time.

Purchase feedback page: This page provides feedback on the foodprint impact from the various purchased products on the product type level (e.g., *bread* instead of a branded alternative, such as *Warburtons seeded brown*). The user can choose between two different graphs to visualise the purchase feedback that both provide information about the product's foodprint per 100g, as well as the product's foodprint share (i.e., the relative contribution of each product to the total of purchases—which considers the foodprint per 100g as well as the quantity purchased). The purchase feedback is either visualized through a word cloud (Figure 6.1a) where the size of the word reflects the product's foodprint share, or a bar chart (Figure 6.1b), where the length of the bar reflects the foodprint share. The foodprint per 100g is reflected with a traffic-light colour scheme in both graphs. The user can choose to aggregate purchases from receipts by day, month, or year and use arrow buttons to move to the previous/next day/month/year of data. By selecting a product (word), the user is taken to the page with alternative suggestions that is filtered to show alternatives for the selected product.

Alternatives page: The alternatives page (Figure 6.1c) shows a ranked overview of alternative suggestions for a selected product. Products are either selected from the purchase feedback page, or from a dropdown list on the top of the page, organised by group (e.g., protein sources) and subgroup (e.g., meat & meat alternatives). A bar chart-styled-list presents the alternatives from the subgroup of the product that was selected. Here, the length of the bar reflects the product's foodprint per 100g and next to the bar a green-or-red coloured value indicates how much higher (red) or lower (green) the foodprint of the alternative product is, compared to the selected product. Below the bar chart-styled-list for the subgroup of the selected product, another bar chart-styled-list for the higher-level product group (e.g., protein sources) is shown (not visible in Figure 6.1c).

Stats page: The stats page visualizes the average foodprint of shopping trips over time. The average foodprint is weight-balanced, meaning that the weight of the purchased product is considered in calculating the average foodprint, rather than treating each item equal. This way, an average foodprint is calculated for each receipt and visualized as a traffic-light-colour-coded dot on a line chart. The active view shows one week of time on the line chart and the user can scroll to previous and future weeks (weeks without data are automatically skipped when moving forward or backward in time).

6.2.2.2 Implementation Of Design Recommendations.

The functional prototype presented in this chapter is an iteration on prototype 4 (see Section 5.7), presented in the previous chapter and follows from an implementation of various recommendations that conclude Chapter 5. Specifically, to benefit from a relatively quick turn-around of data collection and reporting (Hekler, Klasnja, Riley, et al. 2016), the decision was made not to develop all possible features, but to prioritise certain elements of the design. The previous chapter helped in formulating a ranking of various components in their importance to empowering users in making climate sustainable food purchases. Information from this ranking, together with design recommendations, were used to define priorities for the development of the functional prototype.

Compared to the last iteration in the previous chapter, the following modifications to the design are made:

- The page that maps food purchases against categories of a healthy-sustainable diet is eliminated, reflecting its relatively low importance ranking, and its complications for design.
- Reflecting the requests for enhanced clarity about the data, I implemented help sections for each page that explain, in detail, what the presented information means, and what is possible on the page. There is also a general help section about foodprint and how the app reflects current knowledge about this concept.
- Reflecting its relatively low importance ranking, only a minimal version of the purchase statistics page was implemented. The view only included the average foodprint per 100g (determined to be the most relevant stats value) and did not include the flight equivalents, nor an overview of calorie equivalent average foodprint or total foodprint, nor a visualization against a foodprint goal (for which the exclusion was also motivated by its potential to be controlling rather than enabling).

6.2.2.3 User Journey

Figure 6.2 provides an overview of the user journey within the application. Upon first use, an overlay (Figure 6.3b) appears on the welcome screen (Figure 6.3a), informing the user of the research nature of the application and requiring the user to confirm the study invitation and consent form submission before proceeding. The user can then choose to read through the tutorial

(explicitly requested¹) or skip immediately to the login page. The tutorial describes how to use the application and how to interpret its contents (Figure 6.4). After completing the tutorial, users can explore detailed help pages (Figure 6.3c), including background information on footprint and underlying data, or access this information later from any page via a question icon in the top right corner (see Figure 6.1). The user then proceeds to register with their designated email address² and login. After login, a bottom bar allows the user to navigate the remaining content of the application, which include the main views (see Section 6.2.2.1 and Figure 6.1), an add receipt feature (Figure 6.3e), and a settings page³ (Figure 6.3f). Users are automatically signed in on subsequent visits⁴.

The user adds data by uploading receipts with the add receipts button in the middle of the bottom bar. Upon clicking this button, the phone camera activates, allowing the user to take a picture of a receipt. A banner alerts users if phone tilting affects image readability when positioning the phone to take a photo, and the button to take a picture is temporarily disabled. Instead of taking a live picture of a receipt, users can also upload stored images (e.g., receipts from online orders). After confirming the image, the user receives a message that the data will be processed and become available in the app within the next 48 hours. The user also receives an email notification when the new data is available.

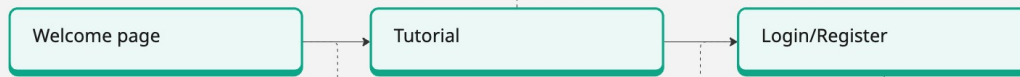
¹The researcher is present at the first time the participants open the application (see Section 6.3.3.2) and instructs the participant to go through the tutorial.

²The application is setup such that registration is only possible for confirmed email addresses. This is done as to mitigate the potential use of the application by anyone that has not read and formally agreed to the contents of the study participation information.

³Settings is a misnomer in the context of the current prototype as no settings are set here (Figure 6.3f).

⁴Unless they explicitly signed out, or three weeks have passed after the last manual login, after which users are automatically signed out.

Logged out | First visit



Logged in | Subsequent visits

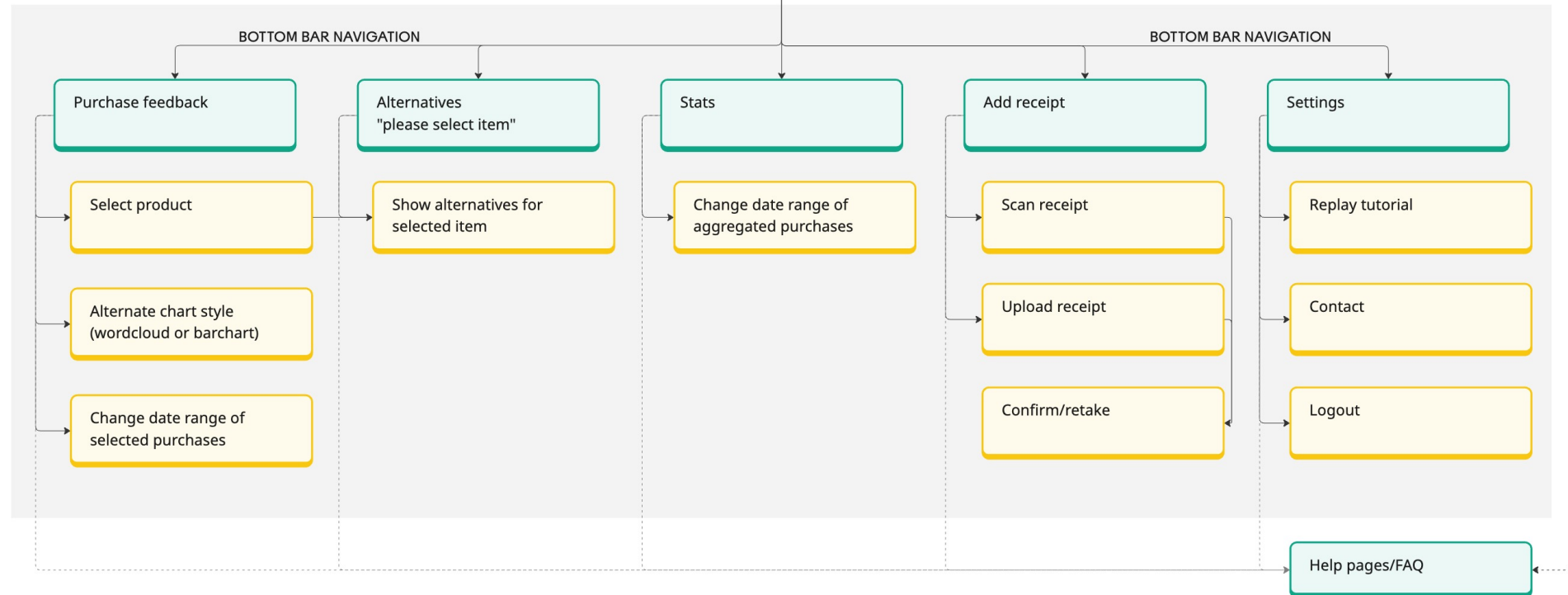


Figure 6.2: MyFoodprint site map. Green boxes mark views/pages. Yellow boxes mark functions within views.

6.2.3 Technical Development And Operation

Development was done using a MERN (Mongo DB, Express, React, Node.js) stack. Data visualizations were made using the d3.js framework. React JS was chosen for the front-end for its favourable characteristics of being a browser-based framework that is optimised for mobile design (React is a so-called mobile-first framework⁵). Scaling contents to various device widths can be done with relative ease, particularly with design frameworks like MUI⁶, which provides the flexibility of accessing the application through a wide range of devices, rather than being limited to devices running iOS or Android. React JS is also optimised for building the application as a so-called Progressive Web App⁷. A Web App is a feature that popular browsers like Chrome and Microsoft Edge provide that allows local installation of (part of) the browser-based application, such that it appears as any other app, featuring a dedicated home-screen icon, is viewed without a browser menu, and provides the possible offline use of the app. I designed the app as a Progressive Web App.

For text recognition, I used AWS (Amazon Web Services)⁸. This service provides an AI feature that can identify the table structure that characterises receipts. Notably, receipts commonly feature a table structure with a row for each item and a separate column for the name, the quantity, and the price. This characterises a more advanced task for machine reading paper-based text sources that go beyond common OCR (Optical Character Recognition) and at which—at time of writing—open source OCR software such as Tesseract [<https://github.com/tesseract-ocr/tesseract>] does not perform well. By signing the consent form, participants consented to their receipt being sent to AWS. Due to the relatively small number of receipts that were expected to be scanned with the app in a day during the study (meaning, less than 100 receipts a day), no costs were expected to occur from using the service, as AWS provided 100 free scans per day.

For storing images of the receipts, I made use of Digital Ocean's spaces service. This is a cloud bucket for stable storage of large files, such as images, that cannot (reasonably) be stored in a database platform like MongoDB or MySQL.

The application was hosted on Digital Ocean through their app platform. The app platform allows the application to be built⁹ on Digital Ocean through automatic detection of changes of

⁵<https://react.dev/>

⁶<https://mui.com/>

⁷https://developer.mozilla.org/en-US/docs/Web/Progressive_web_apps

⁸<https://aws.amazon.com/textract/>

⁹Build: building is the optimisation of the development code for the benefit of a responsive interaction. Development code is optimised for readability and involves the use of white space and comments, whereas this whitespace is removed in the built version to reduce file size.

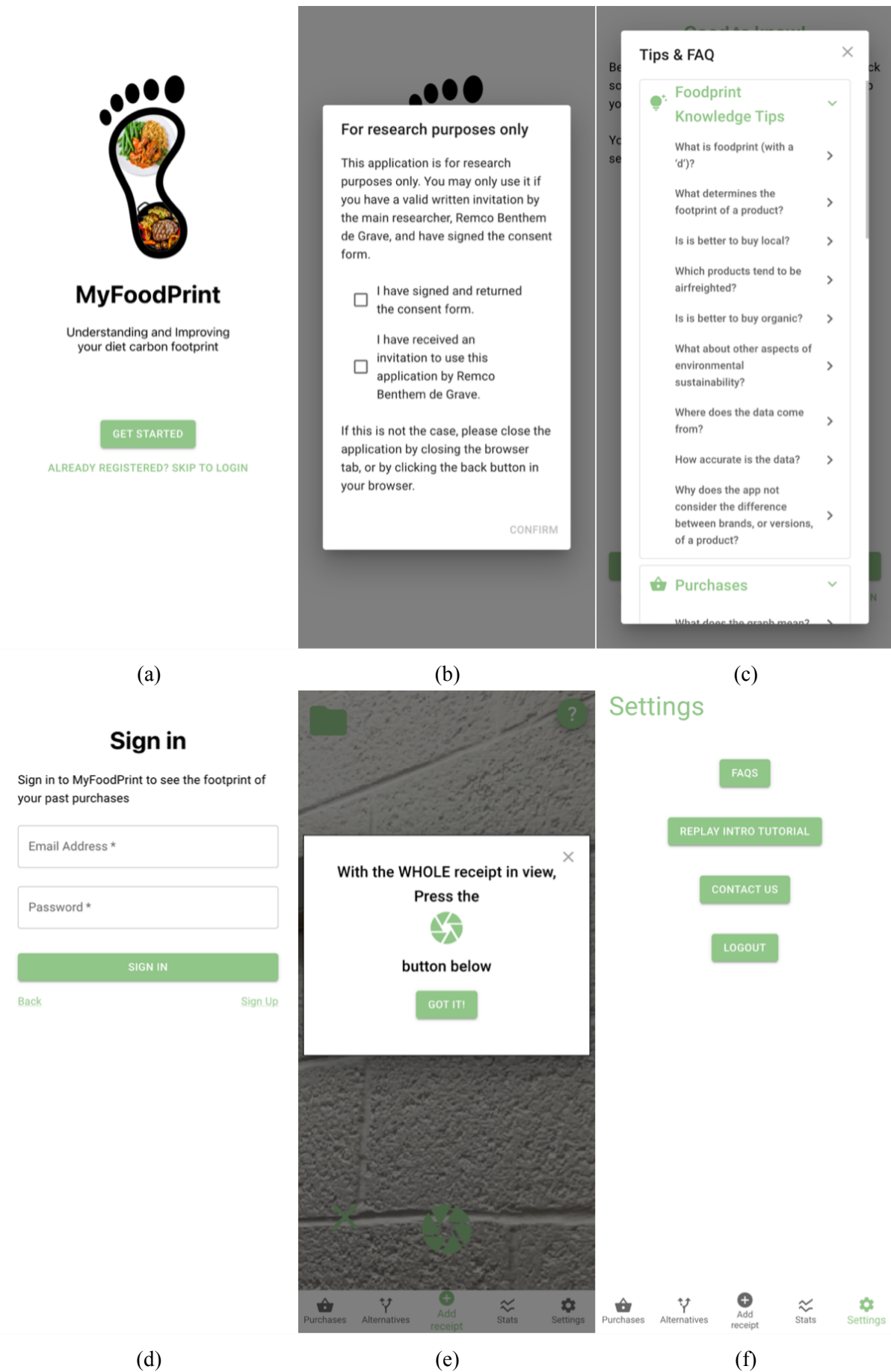


Figure 6.3: Example images from the user journey. The welcome screen (a), confirmation of consent and invitation (b), help (c), signup (d), add receipt view, showing a starting instruction (e), and the settings page (f).

Welcome!

Welcome to MyFoodPrint, an application aimed to help you find more carbon-emission friendly grocery alternatives.

Our diets make up a large proportion average person's carbon footprint (about 30%). The choices we make in the grocery store play a big role in this. Rethinking some of our choices can have a profound impact on our individual (or family) footprint. [For example, [Clarke et al., Science, 2020](#)].

Unfortunately, it's hard to know the impact of each specific choice. And it can be hard to know what meaningful changes you can realistically make. MyFoodPrint aims to help you by providing you insights about your past purchases by analysing your grocery receipts.

How it works

You take pictures of your grocery receipts.



The app analyses the receipts...



...and gives you insights about your footprint...

How it works

This information is then given back to you in a graph. It shows you your opportunities for footprint reduction.

Where does your footprint come from?



Tap the question mark for some hints.

TELL ME HOW

BACK

SKIP TO LOGIN

NEXT

BACK

SKIP TO LOGIN

NEXT

BACK

SKIP TO LOGIN

(a)

(b)

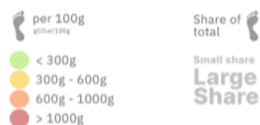
(c)

How it works

This information is then given back to you in a graph...

What do the color and size mean?

The color coding shows the footprint per 100g of the item. The size of a word reflects the combined footprint from your purchases of this particular item (so, footprint-per-100g x weight-purchased).



This way, the graph uses size and color suggest were to focus your efforts. By replacing large red or orange foods, you can expect most impact. Small red or orange foods have a high footprint per 100g, but you didn't buy much of it. Large green products are great choices that you seem to like and buy much of. These can be great alternatives for the red and orange foods.

BACK

SKIP TO LOGIN

(d)

Finding replacements

By clicking a word, the app shows you a list of alternatives for this type of food.

Product: cheddar

Product	gCO ₂ e per 100g	Lower
vegan cheddar	250	79%
goats cheese	640	46%
cottage	650	45%
brie	880	25%
mozzarella	1080	8%
cheddar	1180	0%
parmesan	1860	-58%
ricotta	2240	-90%

Dairy & Alternatives alternatives

NEXT

BACK

SKIP TO LOGIN

(e)

Good to know!

Before you get started, we recommend you check some tips about footprint in the FAQ. It will help you to make most out of the app.

You can revisit the FAQs at any time in the settings menu.

SEE TIPS & FAQ

LOGIN / SIGN UP

BACK

SKIP TO LOGIN

(f)

Figure 6.4: App tutorial

the code in the GitHub repository. This enabled easier and prompt updates to the live versions of the app.

The source code is available on GitHub¹⁰. At the time of writing, the code resides in a private repository. The content will be made public when an article on this chapter has been published in a peer-reviewed journal or conference proceeding. Interested readers can request the thesis author for access to the folder.

6.2.4 Receipt Processing

6.2.4.1 Overview

For this feasibility study, receipts processing was semi-automatic and involved multiple databases, which were continuously expanded during the study.

6.2.4.2 Databases

6.2.4.2.1 Product Identification Database

This database was used to identify the product type and weight based on the information found on the receipt. The database contained the following fields:

- Receipt data
 - Item description on the receipt
 - Item price
 - Store branch
- Item description
 - Full item description
 - Item weight

Each item on a scanned receipt was identified through the product identification database. If an item existed in this database, then the mapping was automatic. If an item was not found in the database, then the information would be searched:

¹⁰<https://github.com/>

- When a participant scanned a receipt, Amazon Web Services (AWS) was used for identifying the items (description, quantity, and price). Also receipt meta-data (grocery chain and receipt date and time) were captured.
- Each item was matched with a product identification database. This database contained
 - Receipt item description
 - Price of product
 - Store name
 - Type of product
- Matching the product with the foodprint
 - Foodprint per 100g
 - Product name
- Manual process
 - Use a product description database
 - For each item on the receipt, the product information was collected
- Carbon foodprint data mapping

6.2.4.3 Carbon footprint data

As no complete open-source dataset of foodprint data appeared to exist at that could be used for the study, a database of foodprint data was created by combining contents from multiple sources. As primary sources of foodprint information, I used two publications by Mike Berners-Lee (Small World Consulting 2015; Berners-Lee 2020). This data was complimented by data from two other sources (Tesco 2012; Scarborough et al. 2014) and foodprint inferences made in the case of missing data (see Figure 6.5). Except for one of the complementing sources, these data sources provide information on the product type (e.g., broccoli, or candy bar). In some cases, different foodprint values were available for in-season and off-season, and fresh, canned, and frozen varieties. When these differences were above 15%, I included multiple varieties in the database (generally in the case of airfreighting, which applies to highly perishable foods—those with expiry dates of ~3 days, e.g., berries and green beans—that are sourced from beyond Europe and therefore cannot reasonably be transported by truck (Berners-Lee 2020)). If the differences were less, an average foodprint value was used. For one complementing source that included foodprint values on a brand level, I averaged over the product type.

It was judged that providing brand-level footprint values provides a false sense of accuracy of the footprint values. Calculation of carbon footprint values is complex and requires many assumptions and loose regulations for calculating footprint values that allow for flexibility in the calculations. Moreover, providing different values per brand may promote incremental change, rather than the impactful reduction that can be achieved from changing the product type (Brynjarsdottir et al. 2012; Poore and Nemecek 2018; Berners-Lee 2020).

6.3 Methods

6.3.1 Study Design

For this feasibility study, we use a cohort study design (i.e., within-participant changes without the use of a control group) and use a mixed methods approach to data collection and analyses (i.e., both quantitative and qualitative data). The study involves a 3+ week in-the-wild (Yvonne Rogers and Marshall 2017) field study where people use the application with minimal restrictions imposed by the study design, such as to mimic natural use of the application. Surveys are conducted at the start and end of the field study to assess concepts of interest and the study is concluded with an exit interview to explore the important mechanisms that drive the change (or lack thereof). See sections Procedure (Section 6.3.3) and Instruments (Section 6.3.4) for further details.

6.3.2 Recruitment

6.3.2.1 Overview

I aimed to recruit people from 15 households who care about the environmental footprint of their behaviour¹¹. This choice is motivated by a calculation of statistical power (paired sample t-test, large effect size, and normal standard deviation [meaning $SD=1$])(Kohn and Senyak 2024) and common sample sizes in HCI research (Hwang and Salvendy 2010; Klasnja, Consolvo, and Pratt 2011).

¹¹A reminder that the outset of the thesis was to empower people, i.e., support people in their ability to pursue their values. The aim is not to impose extrinsic values on people as doing so is considered ethically questionable (see also Chapter 1, Chapter 2, and Tengelnd (2012))

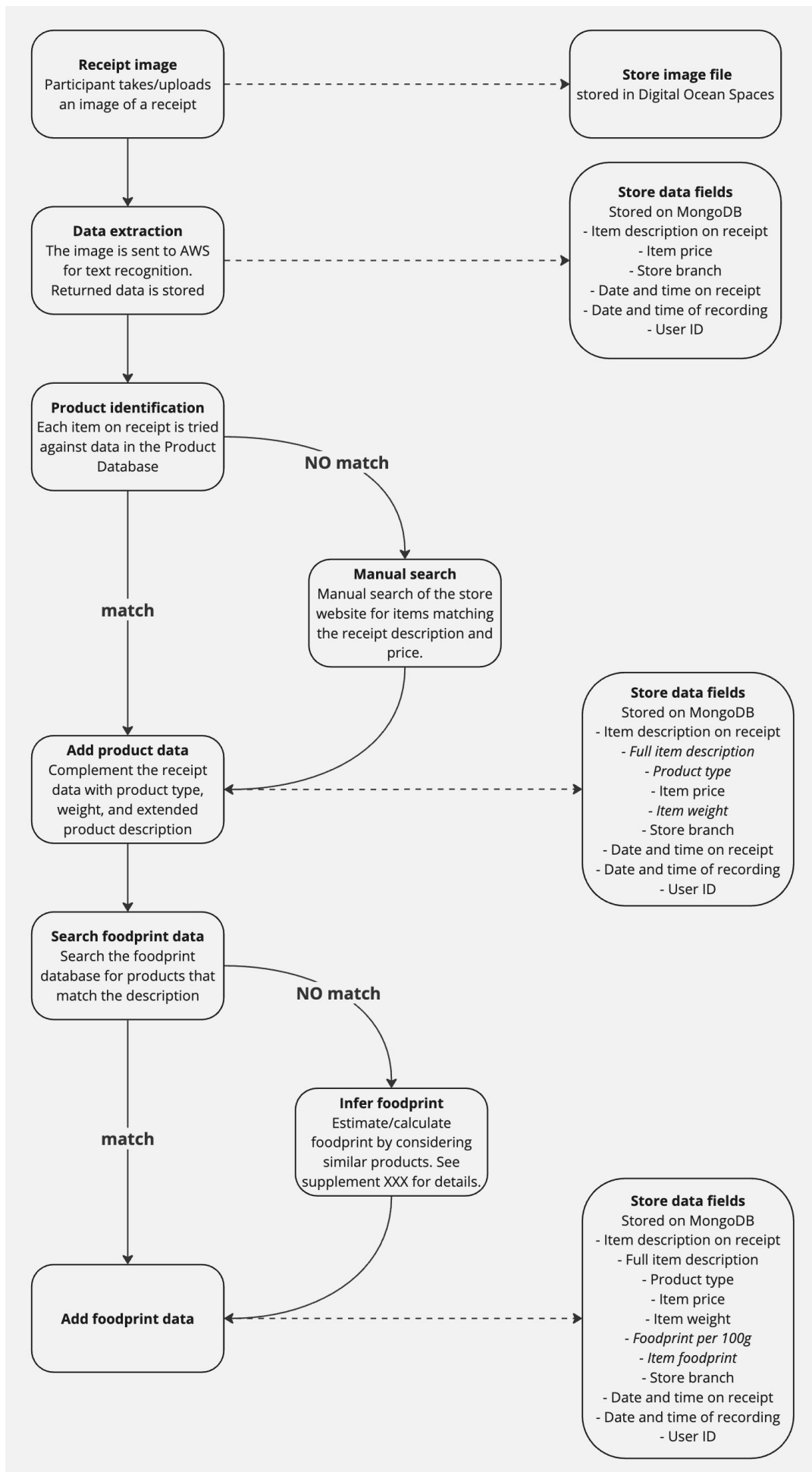


Figure 6.5: Flow-chart of receipt processing steps. The right side of the flowchart shows the data stored at each step. Data fields that are added to the Mongo database in subsequent steps are shown in italics.

For recruitment, I used a multi-step sampling technique where we first recruited people for a general expression of interest, and then filtered participants based on 3 inclusion criteria.

6.3.2.2 Step 1: Recruitment For Interest

I used convenience sampling as a first approach to select potential study participants (contacts in the local community where the primary researcher lived; contacts at the university; and contacts through the private network of the main researcher that had expressed prior interest in environmentally sustainable behaviours). Contacts were asked for their interest in participating in a 3-week trial with a smartphone application that would provide feedback on the carbon footprint of items on their grocery receipts.

6.3.2.3 Step 2: Filtering Interested Participants

People who expressed an interest were directed to a form¹² that contained further information and a short questionnaire that asked them whether they:

1. were interested in learning about their carbon footprint,
2. would reduce their carbon footprint if they felt it was relatively easy to do so,
3. had a smartphone available that was no older than 5 years.

The form also asked candidates to start saving grocery receipts.

6.3.2.4 Step 3: Preparation For Participation

Candidates who confirmed all 3 questions were invited to participate in the study. They were sent the complete participant information form (Appendix Q) and asked—if they agreed with the contents of the information sheet—to schedule an onboarding meeting (through Calendly.com) and start sending pictures of receipts to the primary researcher.

6.3.2.5 Step 4: Formal Consent

At the start of the onboarding meeting, candidates were given the opportunity to voice remaining concerns and ask questions about the study participation. If no questions remained and all concerns were addressed satisfactorily, they signed the consent form (Appendix R).

¹²See Appendix P for the form.

6.3.2.6 Compensation

Participants were offered a £20 shopping voucher for their participation.

6.3.2.7 Ethical Approval

Ethical approval for the study was received on 12 January 2023 (Ref: 28368/2022), and before recruitment had started.

6.3.3 Procedure

6.3.3.1 Overview

The active study phase can be divided into three phases, in which different study instruments were used: (1) the start, or onboarding, phase, (2) the application use phase, and (3) the end phase.

6.3.3.2 Start (Onboarding) Phase

The onboarding phase concerned a 20-40 min interaction that included the following steps:

- Voicing remaining concerns and questions and signing the consent form (see Section 6.3.2 Recruitment).
- Completing a 5–10-minute survey (see Section 6.3.4 Instruments).
- Visiting, installing, and opening the web-application.
- Going through the tutorial pages of the app (see Figure 6.4). This was participant-led and without active involvement of the researcher.
- Registering an account. Participants were required to register with the email account that they shared with the researcher through the recruitment survey as only this email address was listed as an approved email address for registration in the admin side of the app and added to the list while the participant completed the start survey. This action was taken to mitigate the potential of anyone using the app who was not part of the study and had not signed the consent form.

- The participant exploring the app and scanning their first receipt (which they had shared a copy of with the researcher in advance and brought along to the meeting). To benefit the onboarding phase, the primary researcher had pre-processed the data from the receipts that the participant had shared in advance of the meeting (see Section 6.3.2 Recruitment), such that they could be made visible immediately after the participant scanned the receipt. The participant could ask remaining questions.
- The participant was handed a form with some FAQ's¹³ and talked through those questions. These (and more) questions were also incorporated in the FAQ pages of the app.

6.3.3.3 Application Use Phase

After the onboarding meeting, the participant could use the application for three weeks. Use of the application was uncontrolled in the sense that participants could scan as many or as few receipts as they liked and explore the data in the app as much or as little as they liked. Only if a household did not scan a receipt for more than a week, did the researcher reach out to ask whether there were any difficulties that prevented the participant from using the application. In this case, the researcher explicitly affirmed that the participant was not obliged to use the application.

Whenever a participant scanned a receipt, a message would appear that the data would be processed and available for the participant within the next 48 hours, to accommodate the semi-automatic processing of receipts. After the data was ready for the participant (see Section 6.2.4), the researcher would send an email to the participant that new data was available for them in the app.

As the 3 weeks of app use came to an end, the researcher sent an email to the participant to inform them of this fact and that the participant would have the opportunity to upload receipts until the end of their 20th study day and that they would have at least 12h to review the new data after it became available to them. After this period, their account would be deactivated.

6.3.3.4 End Phase

The end phase of the study consisted of the end survey and the exit interview. After the application use phase ended and the participants' account was deactivated, they received an email with a link to the end survey (Section 6.3.4). The last page of the interview contained a link to

¹³See Appendix S for the FAQ's that were provided to the participants.

schedule the exit survey (Section 6.3.4). This step completed the participant involvement in the study.

6.3.4 Instruments

6.3.4.1 Surveys

The two surveys¹⁴ in the study are used to record demographics and estimates for various relevant concepts. Attention was paid to following best practice advice for designing surveys (Zdatny, Segall, and Temkin 2020) and surveys were intentionally kept short to mitigate the risk of disengagement and to benefit consistency in the quality of answers throughout the survey (Chudoba 2024). Table 6.1 provides an overview of the measures that were recorded in the different surveys.

6.3.4.1.1 Survey Questions: Environmental Attitudes

Control variable, measured in both surveys. For Environmental attitudes we used recommended personal conservation behaviour items from the validated short version of the environmental attitudes inventory (EAI) (Milfont and Duckitt 2010). These items also share similarities with the environmental identity questions (Fielding, McDonald, and Louis 2008; Lauren et al. 2016). Four questions were answered on a 7-item Likert scale, ranging from ‘strongly disagree’ to ‘strongly agree’.

6.3.4.1.2 Survey Questions: Self-Efficacy Beliefs

Measured in both surveys. Self-efficacy is assessed through 3 questions, adapted from White, Macdonnell, and Dahl (2011). Three questions were answered on a 7-item Likert scale, ranging from ‘strongly disagree’ to ‘strongly agree’.

6.3.4.1.3 Survey Questions: Foodprint Knowledge

Measured in both surveys. Average score from two foodprint quizzes. The quizzes involved (1) rearranging 7 randomly ordered attention points from most to least impactful for reducing foodprint (e.g., reducing packaging, or, reducing airfreighted products), and (2) rearranging 8

¹⁴See Appendix T for the start survey and Appendix U for the end survey.

randomly ordered items from highest to lower item footprint per 100g. The ground truth order of items is determined from the contents of a publication by Berners-Lee (2020); specifically, the items for the second quiz were drawn from the table of foodprint of dietary items on pages 439-445 of this publication. Care was taken to choose items that resulted in a ranking that was in agreement with other sources of foodprint data (Tesco 2012; Scarborough et al. 2014; Poore and Nemecek 2018).

6.3.4.1.4 Survey Questions: Intention

End survey only. The questions aimed to assess the participants' intentions to reduce footprint in the following months. Two items were adapted from White, Macdonnell, and Dahl (2011). Two questions were answered on a 7-item Likert scale.

6.3.4.1.5 Survey Questions: Spill-Over

End survey only. The questions intended to assess a ripple effect, or spill-over, to other environmentally sustainable actions by the participants, based on self-reported increase in engagement in environmentally sustainable topics over the period of the field study. Two items were inspired by Lauren et al. (2016). They were answered on a 7-item Likert scale.

6.3.4.1.6 Survey Questions: User Experience

The widely used 10-item User Experience Questionnaire (Schrepp, Hinderks, and Thomaschewski 2017; Hinderks, Schrepp, and Thomaschewski 2018) was used to assess user experience. Two more bespoke items assessed the ease of finding alternatives with the app, and the interest for continued use. Questions were answered on a 7-item Likert scale.

6.3.4.1.7 Survey Questions: Other Items

To support the aim of understanding the mechanisms of app impact, we included additional bespoke questions that served as potential discussion points for the exit interview. These questions included three bespoke 7-item Likert scale, assessing the perceived impact of the app on environmental goals, control, and behaviour change.

Table 6.1: concepts measured in the surveys.

Concept	Survey	Items n	Format	Source
Environmental attitudes	Start and end surveys	4	7-scale Likert	environmental attitudes inventory (EAI) Milfont and Duckitt (2010)
Self-efficacy	Start and end surveys	3	7-scale Likert	White, Macdonnell, and Dahl (2011)
Foodprint knowledge	Start and end surveys	2	Reorder items	Bespoke design based on contents Berners-Lee (2020)
Intentions	End survey	2	7-scale Likert	White, Macdonnell, and Dahl (2011)
Spill-over	End survey	2	7-scale Likert	Lauren et al. (2016)
User Experience	End survey	12	7-scale Likert	Hinderks, Schrepp, and Thomaschewski (2018)
Other	End survey	3	7-scale Likert	Bespoke

6.3.4.2 MyFoodPrint Application

Described in detail in section Section 6.2, the application served as an instrument for recording purchase behaviour and app use activity.

6.3.4.2.1 Purchase Behaviour

For the identification of purchase behaviour, the application recorded images of receipts and stored a text analysis in a database. This data could then be used to determine a household's foodprint over time (see Section [6.2.4 Receipt Processing](#) and Section [6.3.5.1.5 Foodprint change](#)).

Purchase data was collected throughout the 3 weeks. This included the collection of images of receipts. For each receipt, store name, receipt data and time, and purchases (item name, quantity, and price) were stored in the database, alongside the ID of the participant that had scanned the receipt and the time and date the receipt was scanned. This data was then complemented by information about the weight and footprint of the items (see Section [6.2.4 Receipt Processing](#)).

6.3.4.2.2 Application Use

App usage data was recorded through the integration of Google Analytics. A user ID was coupled to the activity from the moment that the participant signed in to the application. A trigger was sent when the app screen became the active device screen and when it was left. Triggers were also sent upon each click, together with information about the element that triggered the click. Although participants consented to the use of Google Analytics to track their usage of the app, the collection of Google Analytics data could still be blocked by tracking prevention applications that may be installed on the user's device.

6.3.4.3 Interviews

Semi-structured interviews of 30 to 60 minutes in length were conducted. Each interview consisted of a combination of default questions (see Appendix [V](#)) and interviewee-specific questions. For the definition of interviewee-specific questions, the researcher scanned the survey answers for answers that deviated from the hypothesized answers (e.g., below average rating on one of the questions of perceived self-efficacy). Questions were then added to the interview to clarify the reasons behind the deviating answer. An example of a complete set of interview questions can be found in Appendix [W](#).

6.3.5 Data Analysis

6.3.5.1 Quantitative Analyses

6.3.5.1.1 Overview

(Müller 2020) Data preparation and analysis was done using the R Statistical Software (R Core Team 2023) and packages Tidyverse (Wickham et al. 2019), Magrittr (Bache and Wickham 2022), Here (Bache and Wickham 2022), and GT (Iannone et al. 2024).

6.3.5.1.2 Self-Efficacy And Environmental Attitude

For Likert-scale questions a Cronbach alpha was calculated for assessing internal consistency in the data and a composite score was determined by averaging the responses on the individual items. For self-efficacy and environmental attitude, separate scores were calculated for the two time points (the start survey, T_1 , and the end survey, T_2). These scores were then compared in a 1-sided two-sample Pearson t-test statistic, reflecting the hypothesis of a higher score at T_2 than T_1 , and a Cohens-D effect size measure was calculated.

6.3.5.1.3 Intention And Spill-Over

For intention and spill-over, only scores exist for T_2 . In this case, a 1-sided Pearson t-test statistic was performed by comparing the T_2 composite score with a sample mean of 4, reflecting a ‘neither agree nor disagree’ answer. A Cohens-D effect size measure was calculated in the same manner.

6.3.5.1.4 Foodprint Knowledge

For the two foodprint knowledge quizzes, I first calculated an individual test score for each quiz. This was done by assigning a point for each time an item was correctly positioned above another item. This would theoretically result in a maximum of $T_n = \sum_{i=1}^n i$ 28 and 36 points on the first and second quiz respectively. However, because of potential ambiguity in the question that would logically lead to a different order in the answers, I chose to rank some items as equal, which reduced the potential points to 14 and 24 points respectively. For each participant, the score on each quiz was then determined as a percentage of the maximum score. Composite foodprint knowledge scores were then calculated for the two time points (the start survey, T_1 , and the end survey, T_2). These scores were then compared in a 1-sided two-sample Pearson t-test statistic, reflecting the hypothesis of a higher score at T_2 than T_1 , and a Cohens-D effect size measure was calculated.

6.3.5.1.5 Foodprint Change

To assess whether participants' foodprints changed during the study period, I investigated how the average foodprint of an item on a receipt varied over subsequent receipts (with the contents of the preloaded receipts considered as the first receipt). As the data concerns nested timeseries data (participants nested in households), a linear multilevel model was used, using the LME4 package (Bates et al. 2015). First, a weight-balanced average foodprint value for each receipt (r) was calculated by $\text{foodprint}_r = \frac{\sum_{i=1}^n \text{item}_i \cdot \text{weight}_i(r)}{\sum_{i=1}^n \text{weight}_i(r)}$. Then, I assessed whether the sequence of receipts (as a proxy for time) was a significant predictor by comparing a model with and without the predictor and computing a Likelihood Ratio Test for the difference between the models. Statistical assumptions were assessed by visual examination of a Q-Q plot of normalized residuals vs. fitted values.

6.3.5.2 User Experience

For analysis of the user experience questionnaire (UEQ-S), I followed the direction of the UEQ handbook and used the standardized tool provided by Dr. Martin Schrepp¹⁵. This tool calculates composite scores for hedonic and pragmatic performance, as well as an overall performance score. For interpretation of the resulting scores, the tool also evaluates the scores against a benchmark that is determined from 21175 persons from 468 studies and classifies the scores into one of five categories ranging from bad to excellent.

6.3.5.3 Qualitative Analyses

Interviews were audio recorded using video conferencing software Zoom¹⁶. Transcripts were created by listening to the audio recordings and correcting the automated transcriptions that were provided by Zoom. Data was inductively coded in NVivo. A thematic analysis was then conducted with the support of Miro online whiteboard, which was used to organize the codes into themes. While the intention was to form the themes inductively, my perception of the data will have been influenced by the conceptual framework, and themes thus evolved from a combination of inductive and deductive reasoning.

¹⁵Available from <www.ueq-online.org>

¹⁶<https://zoom.us/>

6.4 Results

6.4.1 Descriptive Statistics

6.4.1.1 Participants

In total, we recruited 22 people from 16 households, with no more than two participants from a single household. An overview of participant and household demographics is shown in Table 6.2. While a range of ages and educational backgrounds were included in the study, most participants (roughly 2/3) were male, aged between 25-34 years, had a university degree lived in a household of two, and reported a meat-restricted diet (e.g., vegetarian, pescetarian, or flexitarian). About half of the participants perform grocery shopping as a shared activity. On average, most purchases are done in-person, at a store, although a small portion of individuals report doing most of their purchases online. All participants make at least some purchases in store¹⁷.

Table 6.2: Participant demographics

Characteristic	Overall (N = 22)	Participant role	
		primary (N = 16 ^l)	secondary (N = 6 ^l)
Age			
18-24 years old	1 (4.5%)	1 (6.3%)	0 (0%)
25-34 years old	14 (64%)	10 (63%)	4 (67%)
35-44 years old	3 (14%)	2 (13%)	1 (17%)
55-64 years old	4 (18%)	3 (19%)	1 (17%)
Sex			
Man	15 (68%)	11 (69%)	4 (67%)
Woman	6 (27%)	4 (25%)	2 (33%)
non-binary	1 (4.5%)	1 (6.3%)	0 (0%)
Degree			
High school graduate	1 (4.5%)	1 (6.3%)	0 (0%)
Associate degree in college (2-year)	1 (4.5%)	0 (0%)	1 (17%)
Bachelor's degree in college (4-year)	7 (32%)	5 (31%)	2 (33%)

¹⁷Note that this was not a restriction for the study as participants could also upload receipts from online purchases or food box orders.

Master's degree	8 (36%)	6 (38%)	2 (33%)
Doctoral degree	4 (18%)	3 (19%)	1 (17%)
Professional degree (JD, MD)	1 (4.5%)	1 (6.3%)	0 (0%)
Adults in household			
1	4 (18%)	4 (25%)	0 (0%)
2	16 (73%)	11 (69%)	5 (83%)
3	2 (9.1%)	1 (6.3%)	1 (17%)
Children in household			
0	21 (95%)	15 (94%)	6 (100%)
2	1 (4.5%)	1 (6.3%)	0 (0%)
Who does the groceries			
I do	9 (41%)	8 (50%)	1 (17%)
Another person in my household	3 (14%)	0 (0%)	3 (50%)
We do most groceries collectively	10 (45%)	8 (50%)	2 (33%)
Diet			
Omnivorous (no restrictions)	7 (32%)	5 (31%)	2 (33%)
Flexitarian	6 (27%)	5 (31%)	1 (17%)
Pescaterian	3 (14%)	2 (13%)	1 (17%)
Vegetarian	5 (23%)	3 (19%)	2 (33%)
Dairy free	1 (4.5%)	1 (6.3%)	0 (0%)
Used apps to calculate carbon footprint before	2 (9.1%)	2 (13%)	0 (0%)

¹The primary, or dominant, participant is the household participant who contributed the most receipts. The secondary participant is the other household participant.

Table 6.3: Where participant report sourcing their food from.

	store	online	meal box	veggie box	farm store	out-of-home
none/very little	0%	59%	77%	73%	82%	41%
some	23%	14%	14%	5%	14%	59%
about half	36%	14%	9%	23%	5%	0%
most	14%	9%	0%	0%	0%	0%
almost all	27%	5%	0%	0%	0%	0%

Table 6.5: Descriptive overview of app usage.

	Overall	By participant ^l	By session ^l
Sessions			
N	233	11 [6, 16]	NA
Time spent [hh:mm:ss] or [mm:ss]			
Total	12:45:32	30:47 [16:03, 57:27]	01:45 [00:47, 03:38]
Basket	08:26:16	14:23 [07:34, 44:48]	00:49 [00:11, 02:01]
Alternatives	02:44:06	07:09 [03:31, 09:14]	00:00 [00:00, 00:40]
Camera	01:47:05	04:17 [02:49, 07:56]	00:00 [00:00, 00:33]
Stats	00:19:22	00:20 [00:03, 01:41]	00:00 [00:00, 00:00]
Clicks			
Total	1759	96 [42, 134]	5 [2, 9]
Product	168	6 [3, 12]	0 [0, 1]
Help	57	3 [1, 4]	0 [0, 0]
Help detail	1	0 [0, 0]	0 [0, 0]
Take picture	73	2 [1, 6]	0 [0, 0]

^lmedian [Q1, Q3]

6.4.2 Quantitative Inferences

6.4.2.1 Survey Analyses

Figure 6.8 and Table 6.6 provide an overview of the relationship between study participation and the scores for the various concepts assessed through the survey. Both footprint knowledge and self-efficacy show a significant and large increase over the study period, while the control variable, environmental attitude, remains relatively stable over the two measurements. The intention to reduce footprint is significantly higher than a neutral at a very large effect, and the spill-over to other environmental behaviours is significantly higher than a neutral at a medium effect.

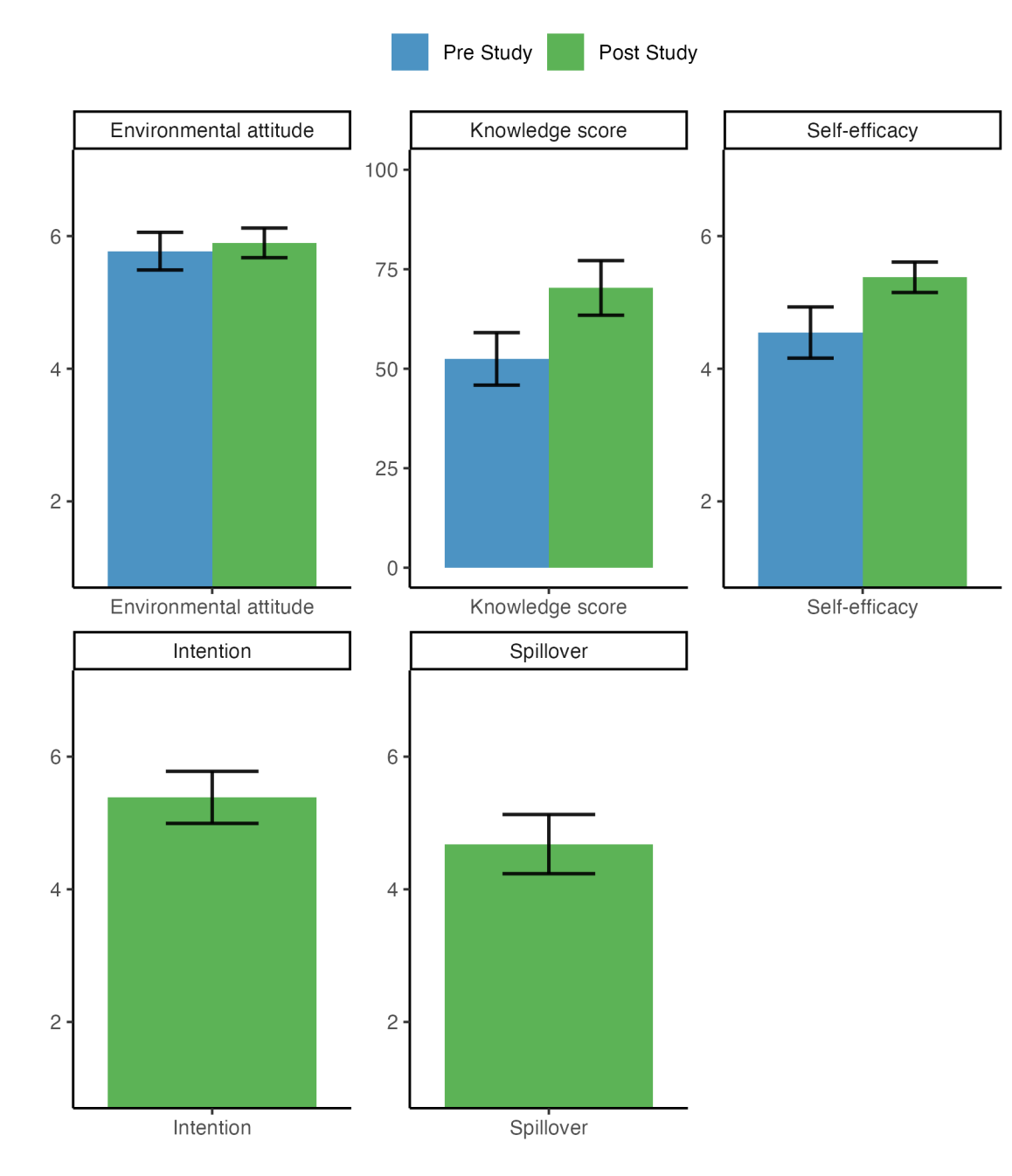


Figure 6.8: Mean and 95% confidence intervals for the concepts assessed through the surveys.

Table 6.6: Test results for the concepts assessed through the surveys.

	Estimate ¹		Test statistics				Effect size	
	Mean	SD	Method	t	df	p	Cohen-D	Magnitude
Environmental attitude	0.12	0.44	Paired t-test	1.33	21	0.099	0.17	Negligible
Knowledge score	17.83	20.36	Paired t-test	4.11	21	<0.001	0.83	Large
Self-efficacy	0.83	0.80	Paired t-test	4.92	21	<0.001	0.80	Large
Intention	1.39	0.89	One Sample t-test	7.34	21	<0.001	1.57	Very large
Spillover	0.68	1.01	One Sample t-test	3.18	21	0.002	0.68	Medium

¹When pre- and post-study measures are recorded, these are the mean and standard deviation of the difference between pre- and post-study scores. When only post-study measures are recorded, these are the mean and standard deviation of the post-study scores compared to a population mean of 4 (the mid-way Likert value).

6.4.2.2 Receipt Analyses

Figure 6.9 shows the progression of the households' average purchase footprint over the duration of the study. The figure shows no clear change in footprint over the duration of the study. Equally, the multilevel statistical analysis fails to produce a significant effect of the receipt sequence (Estimate = -3.93 (7.35), Chisq(1) = 0.268, $p = .605$).

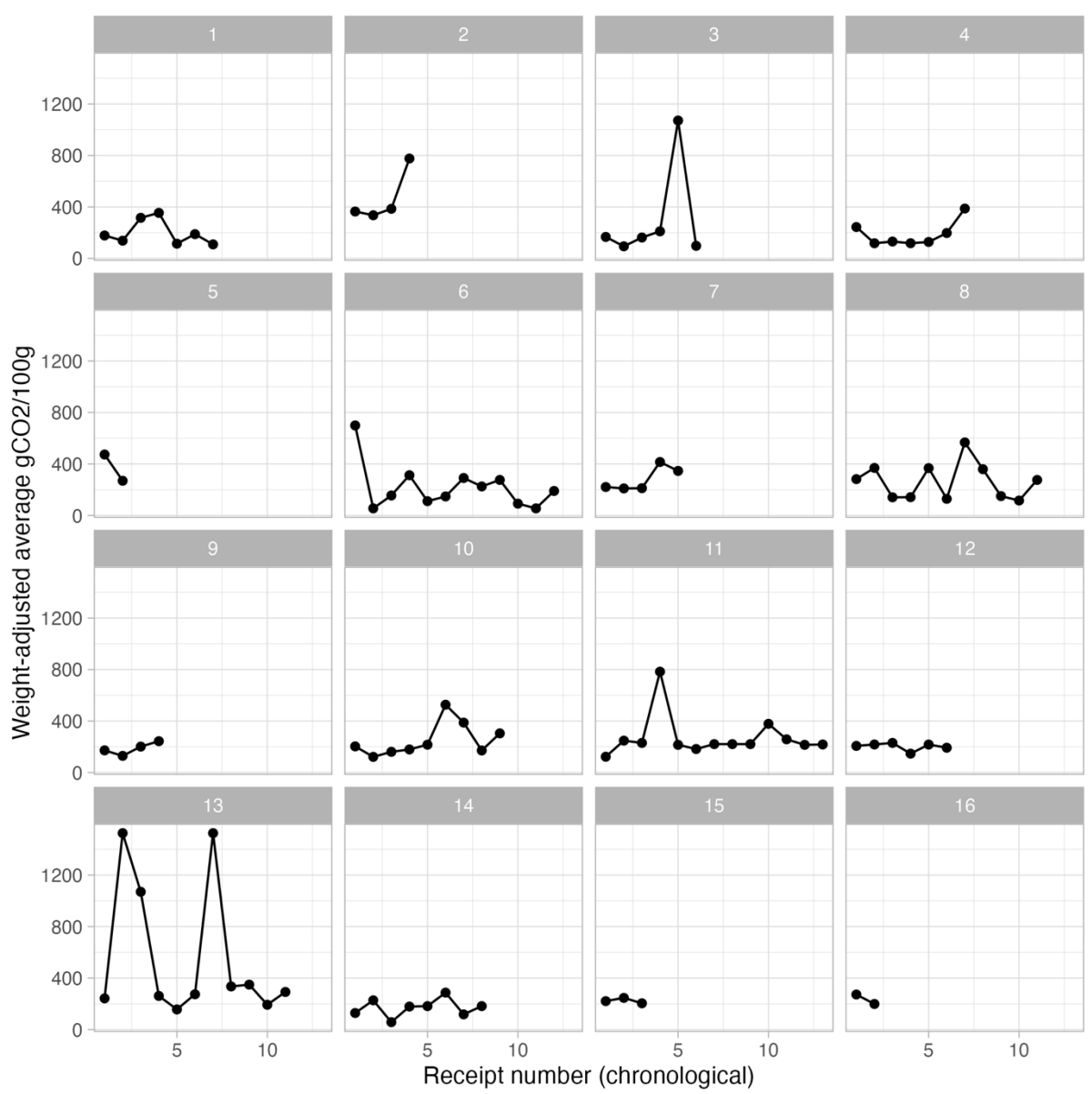


Figure 6.9: Receipt footprint progression by household. Receipt footprint is quantified by the weight-adjusted average item footprint.

6.4.2.3 Usability

The analysed results from the user experience questionnaire (UEQ-S) are shown in Figure 6.10. Compared to the benchmark, the results show a good to excellent overall performance. This is

broken down into a good pragmatic performance and an excellent hedonic performance. The distribution of answers to the individual questions can be viewed in Table 6.7.

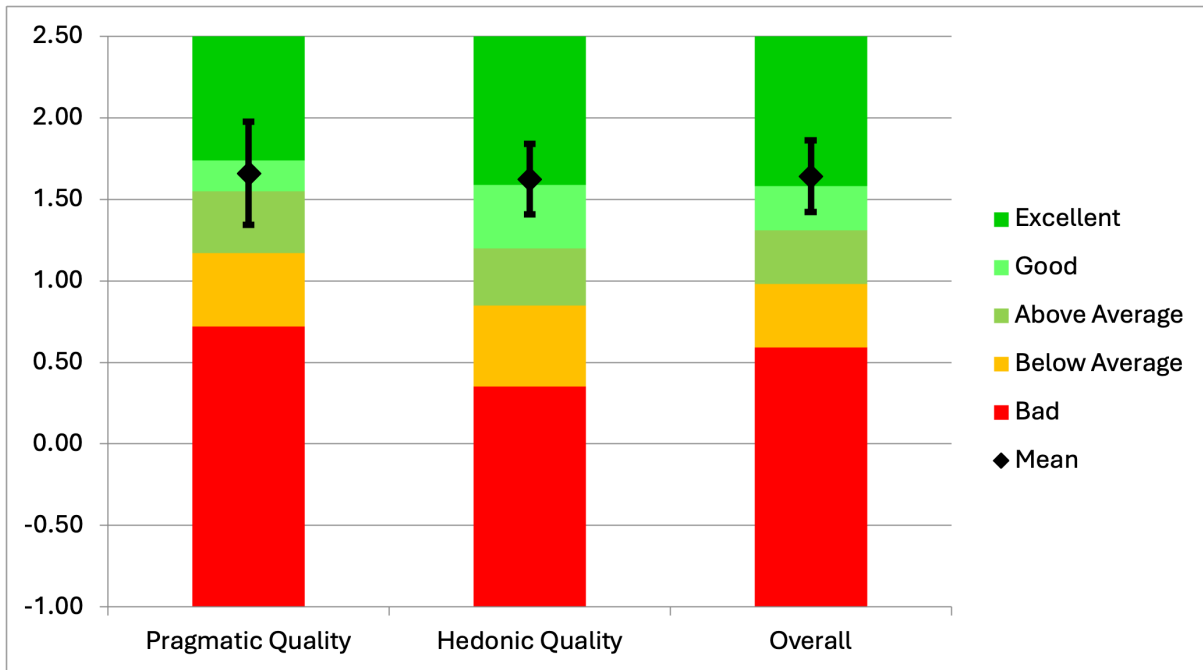


Figure 6.10: UX assessment of app compared to the benchmark.

Table 6.7: Aggregated results from the user experience questionnaire.

	Very R-	R-	Slightly R-	Neither R+ nor R-	Slightly R+	R+	Very R+
Supportive(R+)/Obstructive(R-)	0%	0%	0%	14%	23%	50%	14%
Easy(R+)/Complicated(R-)	0%	0%	9%	5%	18%	50%	18%
Efficient(R+)/Inefficient(R-)	0%	0%	5%	5%	23%	45%	23%
Clear(R+)/Confusing(R-)	0%	0%	5%	0%	55%	14%	27%
Exciting(R+)/Boring(R-)	0%	0%	0%	14%	59%	27%	0%
Interesting(R+)/Not interesting(R-)	0%	0%	0%	0%	18%	41%	41%
Inventive(R+)/Conventional(R-)	0%	0%	0%	5%	27%	64%	5%
Leading edge(R+)/Usual(R-)	0%	0%	0%	9%	50%	27%	14%

6.4.3 Qualitative Analysis

6.4.3.1 Overview

In the previous section, it was observed that participation in the study and using the application led to increases in foodprint knowledge and self-efficacy. Positive intentions to purchase more sustainably in the future were recorded, while no changes in actual foodprint was seen during the study. I will now continue with an in-depth exploration of the reasons for these observations with a thematic analysis of the exit interviews.

In the quotes below, participants are referred to by a pseudonym.

6.4.3.2 Knowledge Gain

Driven By Curiosity

Curiosity and an eagerness to learn was a frequent theme in many of the interviews. Many participants expressed a sense of surprise when viewing the purchase visualizations, as the prominence of items in the visualizations was sometimes substantially at odds with their expectations and left memorable imprints.

“Paul: You upload the receipt, look at the result, and you go, oh wow, so-and-so is red, I didn’t expect that to be, like, so high...”

Sparked in their curiosity, participants expressed an interest to repeatedly engage with the application to discover new knowledge around their choices and learn more about the impact of their behaviour. Some participants even perceived the cycle of shopping, scanning, and viewing the feedback as a gamified ritual.

“Nick: ...the gamification, you know, like scanning the receipt and seeing, ‘Ohhh’, that’s you know, that’s interest of seeing that result.”

The curiosity towards the results (Nick:) “makes you want to upload more things to see if you’ve changed anything”. Notably, a participant pointed out that information on foodprint was much easier to engage with in the way it was delivered in the app than the passive knowledge from a book on the topic.

Also, the curiosity that was sparked by the surprise of products appearing differently than expected led some participants to engage in a deeper dive in information to explain the observations, through the application, but also elsewhere, e.g., online. The application sometimes failed to provide the desired level of detail and participants asked for more background information for the specific products. Some participants also asked for features that would help them compare the footprint of their choices with other behaviours famous for their footprint emissions (e.g., flying, or heating), to gain a wider perspective.

6.4.3.3 Self-Efficacy

Valuing Gentle Guidance

This theme highlights the value that participants perceived in the non-controlling and transparent guidance that the application provided. Participants expressed their appreciation of the word-cloud for quickly highlighting the ‘pain points’ and guiding the search to more sustainable alternatives. To go from the purchase overview and see a list of alternatives to their ‘pain point’ products (Figure 6.1c) was expressed by many as very valuable, as this information is generally hard to come by and it would be much harder to decide what switches are viable.

Participants expressed appreciation for a non-manipulative and non-judgemental character of the design, but instead ‘letting the facts speak for itself’. The information was found to ‘help you to form a judgement.’

Dan: “it’s like ‘hear are the facts’. It doesn’t say ‘you are a demon for eating red meat’. ...It’s just saying, ‘here’s the information. Do with the information what you want to do.’ It’s like doctor saying smoking is bad for you. You are given the information. You then either choose to stop smoking or not.”

For some participants, being presented (confronted) with the footprint of their behaviour caused a level of discomfort which they wanted to act upon.

Mark: “...I do feel slightly more guilt about some of the purchases...I don’t like, you know, regret that guilt. I think it’s quite useful...and that’s not too bad motivator for actually trying to change a behaviour. Yeah, it’s not a level of guilt that would make me avoid [the information]”.

While some participants asked for features that would support their self-judgement by providing them scores to rate their performance and improvement, it seemed that they were acutely aware of a potential conflict with the appreciated non-judgemental character of the application.

John: “it’s [i.e., to compare with the population average] like halfway between [a rating that comes without any judgement and] comparing yourself directly to other people, which could make you feel demoralized, because you’re doing better already...”

Boundaries of the data: there’s more to it than foodprint

Boundaries of the data however also played a role in limiting the opportunities to pursue a change. As the application focuses on the carbon footprint of products, it does not provide information on other sustainability and ethical measures, like biodiversity, water use, and labour conditions, which some participants want to factor in into their choices. As a result, some participants were sceptical about the ordering of product alternatives as a representation of their values in some cases, and these participants would wish for more measures of sustainability to be included in the application. One participant also noted that the chosen unit of comparison (100g of product), does not always provide for fair alternatives, since products do not have the same nutritional value per 100g. This participant wished for the opportunity to compare products based on other units of comparison, like, e.g., protein.

John: “...milk was our worst thing [as in, biggest contributor to our foodprint] by miles... but it [milk] is [labelled] green. So, it’s like, oh, well... per weight... this is a low carbon food. But obviously the difference is that you consume way more milk in a portion than you would like, you know, Mozzarella, or something...”

Participants also pointed out that external factors could dampen the opportunities to change. Stores sometimes stock a limited range of product alternatives in the store. Also, competing priorities like cost or the perceived importance of specific choices for the health of the children in the household could pose a boundary.

6.4.3.4 Behaviour change, intention and spillover

Change is slow

While participants expressed a sincere interest for reducing their foodprint, most participants thought the period of the study was too short for achieving a significant change in their overall foodprint.

Simon: “By the time that you’ve got enough data in there. it’s almost the end, you know. I imagine if it was an extended period, it probably would have had an effect...”. However, some participants noted that they had already made some changes. Dan “[I’m] certainly buying less of the top end items.”

Phil: “Yeah, I’m not gonna get rid of coffee.”

Also, many participants noted that they had increased their attentiveness during grocery shopping, like paying more attention to whether a produce might have been airfreighted.

Change happens together

This theme highlights that food-purchase, and food-consumption decisions are rarely an individual matter. Rather, they are shaped through discussion and negotiation with the members of the household, friends, peers, and communities. This could lead to a dampening effect on change intentions, but also contribute to the social facilitation of others to make a change:

Sparking household interactions. Participation in the study sparked discussions in most of the participating households. Discussions seemed to be used to help joined sense-making of the implication of the information for the diet values of the household, and to decide whether a different approach to the shopping behaviour should be taken. Several participants expressed their appreciation for the household-level feedback, for supporting a sense of collaborative effort.

Henry: “we would be talking about it [choice options] as we were doing the groceries.” No, like this is probably not going to get a good rating”, or... “how about this, how good will this be?” I think that was quite a good discussion for us.”

Emma: “my sister is just buying things that are grown locally, and so we had more conversations with her, to be honest, because I was like, well, look at cheese, and that’s like British Cheddar cheese is like British, and that’s really high, whereas some of the things that aren’t British like the vegetables, some of the vegetables weren’t.”

Conversations outside the household. Engagement with the application was also described as a conversation starter outside the household. People used their new foodprint insights to spread

awareness by providing their new learned insights, or by mentioning the existence of the application and the concept in general. Some participants also pointed out that the process of scanning receipts created curiosity from their environment which sparked topic conversation.

Phil: “I told a bunch of people that I I’m like in the study that kind of works on this, and I’ve had a few people already asking that.” Oh, you sent me the link”.”

Sara: “I guess what it did was pump into conversations and discussions around like “do you know where food is grown?”, and then “the climate in those places?”, and also “... how are they growing it there? Where is that energy coming from?”.”

Empowering arguments. Participants also pointed out feeling empowered to provide arguments in discussions on the topic. For example, one participant pointed out that he felt more able to justify specific food choices to other household members with the support of the data visually demonstrated in the app, while other participants expressed their increased confidence to contribute to discussion on the topic with colleagues.

Mark: “There’s a bit of...extra armoury there: being about to talk about like the reasons why we can’t have those things now... it would actually be quite a useful thing to talk to them about and show them [the impact of our choices]”

6.5 Discussion

In this study I assessed the effect of using an application that provides feedback on the foodprint impact of grocery choices on people’s foodprint literacy—through assessing knowledge and self-efficacy constructs with pre- and post-study surveys—and conducted interviews to gain in-depth understanding of the mechanisms responsible for the observed change. I observed increases at large effect size for both foodprint knowledge and self-efficacy, thus providing support for the hypothesis that the application benefit foodprint knowledge. The interview analysis suggests that curiosity, sparked by the data in the app, together with the gentle—non-controlling—form of guidance, were major drivers for gaining foodprint literacy.

I also investigated the direct and indirect impacts of application use on people’s carbon footprint, by assessing the change in foodprint over consecutive shopping trips, by analysing the receipts, and by assessing intentions for reducing foodprint and spill-over to other behaviours relevant to environmental sustainability in the post-study survey. Again, quantitative findings

are supplemented with qualitative results from the exit interviews. While participants reported positive intentions to reduce foodprint at a very large effect, three weeks for the study was found too short to allow for a change in foodprint as habits take time to change. While the effect on spill-over recorded through the survey—measuring spill-over to other behaviours—was only moderate, the potential of the application to provide a spark for conversation suggests spill-over to other people (i.e., indications of spill-over was observed *between* people, rather than *within* people).

In the following sections, I will elaborate on these findings in more detail, link them to existing literature, and formulate their implications for future design and research.

6.5.1 Design to spark curiosity

Through analysis of the interviews, I observed that curiosity was a prominent theme. This observation also resonates with the observation of the high score for hedonic quality in the user experience evaluation (see, Section 6.4.2.3). Sparked by surprises, many participants were eager to learn about their data—even talked about it as a gamified experience—and were curious to investigate why some products had a high foodprint.

This finding aligns with literature in the related fields. Personal informatics literature points out that curiosity is an important driver in the pursuit of self-tracking (Daniel A. Epstein, Eslambolchilar, et al. 2021) and plays an important role in learning, sense-making, and integration of the knowledge (Whooley, Ploderer, and K. Gray 2014). According to self-determination theory, curiosity is a form of intrinsic motivation (Ryan and Deci 2020) that has been shown to lead to better problem solving, integration and long-term retention than common approaches to learning, which are extrinsically motivated (Ryan and Deci 2020)—and promises to be more impactful on behaviour than the modest impact seen from common educational approaches (Hawkes et al. 2015). Moreover, as a hedonic factor, curiosity plays an important role in technology acceptance and use (Venkatesh, Thong, and Xu 2012) that appears to receive less than optimal attention in behaviour change (Bomfim and Wallace 2018; Bomfim, Kirkpatrick, et al. 2020). This literature suggests that there is value in harnessing curiosity.

Several aspects of the design seem to have contributed to sparking and harnessing curiosity. First, by designing the app as a self-tracking app, the natural curiosity to learn about oneself (Li, Dey, and Forlizzi 2010) is harnessed. Second, we observed that the word-cloud was effective at drawing attention to the prominent purchases that sparked curiosity for further investigation.

This may have been the result of making the words ‘pop’ by combining the name and value (rather than separating label and value). Third, by linking a click on the word to an overview of alternative suggestions people could follow their curiosity and learn how their impactful choices compared to other products that they could consider as alternatives for future shopping trips. It is recommended to consider incorporation of these, or similar elements for future design.

I also identified further opportunities for harnessing the potential of curiosity that were not yet present in the current design, but that could be considered for future designs. Several participants expressed their desire to find more background information, e.g., they wanted to know why certain products had a high foodprint. Sparked by their curiosity, this case could have presented an opportunity for the participants to gain more generalizable knowledge about foodprint. For example, the prominent role of using fertilizers or heating (Berners-Lee 2020) could be highlighted (if applicable to the specific product). A potential way of integrating such information could be by clicking the product in the list of alternatives Figure 6.1c. Some publications (e.g., Small World Consulting 2015; Poore and Nemecek 2018) provide a breakdown of foodprint for the different stages of the life-cycle analysis (e.g., growing, transportation, processing) that can provide as a source of inspiration for explaining the foodprint of a product. Further knowledge tips could be provided, e.g., ‘The foodprint of rice is dominated by the excessive quantities of fertilizer that are commonly used in rice production. These fertilizers are rich in nitrogen-oxide, a potent greenhouse gas (Berners-Lee 2020)’, or linking to alternative options, e.g., ‘When berries are out of season in the EU, frozen berries can be a good choice. These are berries that were picked while they were in season and Industrial freezing is an efficient process that adds only a few percent to the foodprint. Herbig, Kahl, and Krüger (2018) present another example to present background information.

6.5.2 Design to facilitate conversations

The interviews revealed that participation in the study sparked conversations within households for collective sense-making and negotiating decisions around food, as well as conversations outside the household that draw others into foodprint thinking.

Studies by Comber, Hoonhout, et al. (2013) and Brynjarsdottir et al. (2012) highlight the importance of considering social dynamics. Persuasive solutions that assume individual responsibility for behaviour change often “begin to fall apart” when social influences are considered. By considering household behaviour and providing behaviour feedback, the application may have

supported household members to engage in discussions around their choices. I have observed that the introduction of the application facilitated household interactions that allowed members to make sense of the data and negotiate their position with respect to certain choices. Similarly, Ferdous et al. (2016) find that technology can be designed to support household interaction and can lead to reflective and educational experiences. Reitberger, Spreicer, and Fitzpatrick (2014) found that a system monitoring and providing feedback on food purchase fosters dialogues around choices that can work as social facilitation to contribute to change. Similarly, in this study, the feat of sparking discussions in the household may be critical for sustainable behaviour change to happen in the household.

The observation that study participation sparked conversation outside the household aligns with self-determination theory (SDT) (Ryan and Deci 2000; Ryan and Deci 2020). According to SDT, people are more likely to engage in a subject when they feel competent in it. Thus, the more knowledge people gain in relation to foodprint, the more likely they are to engage in discussions about foodprint, particularly if they are able to acquire generalizable knowledge. As such, by sparking conversation, I expect an indirect impact of the app through users influencing non-users.

There are opportunities to further harness the propensity of the application to exert an indirect impact through conversations. One of these lies in recognizing the value that people often put in data (Porter 1996; Porter 2020; Steensberg 2023; Starr 2024). By making data accessible, users of the app can be empowered in their arguments. Clear, quick accessible, searchable, and verifiable data is of value. Beyond an overview of purchases, lists of alternative suggestions, and documentation (FAQ) with background information, the application could benefit from a clever search function to allow quick retrieval of facts, as well as comprehensive background information that is easily accessible, e.g., by clicking on an item of interest (as already mentioned under Section 6.5.1). When investigating a product, users should also be able to link back to the source of foodprint information, which ideally is a well-known and trusted institution (Lawo et al. 2021). For each receipt, users should be able to verify the mapping and adjust as needed.

Moreover, there is value in accommodating different perspectives on the factors that matter in comparing products. How people prioritise various factors in their food decisions can vary substantially from person to person (Bellisle 2006). E.g., in the interviews, I have observed that for some people a reasonable comparison requires consideration of relative protein content. To accommodate for such variations, it is valuable to consider allowing people to compare products on various dimensions, rather than only foodprint per weight. Various macro- and micro-

nutrients could be considered. Note should be taken that such variation in comparability might complicate interpretation of the data that could confuse and dis-empower users (Normark and Tholander 2014) and designers should verify that a positive balance between viewpoints and interpretation clarity is maintained.

As we have seen that children may be involved in negotiations around food and may be recipients of education through use of the app, there will be value in involving children for collecting input for the design of appealing and accessible data presentations. Notably, the word-cloud has been credited as an accessible data visualization (DeNoyelles and Reyes-Foster 2015; Tonidandel, King, and Cortina 2015) and may present a good option in negotiating information with children.

6.5.3 Design for gentle guidance

I observed that, while people value a non-judgemental and non-controlling interaction, they do request guidance in interpretation and decision-making. Providing guidance in interpretation, however, increases the chance of a judgemental attitude to penetrate in the interaction. This observation is in line with work by Normark and Tholander (2014) who developed an application that presents users with collected source data with minimal interpretation in an aim to motivate the user to reflect and form their own interpretations. They observed that participants expressed frustration about the lack of interpretation and that the ambiguity limited practical use. Similarly, Lawo et al. (2021) find that even critical consumers prefer to outsource decisions on criteria as how to compare products. Also, in their comprehensive mapping review of self-tracking technology, Daniel A. Epstein, Eslambolchilar, et al. (2021) stress the need to support the reflection-to-action step, that may require designers to go beyond presenting behaviour data.

The application in this study provided guidance in several ways. Traffic-light colour coding of products by their foodprint-per-weight, ranking products by their relative share to total foodprint, and comparing products by weight are several ways in which interpretational decisions are made. Also, participants were guided to alternative suggestion when they clicked on a product in the basket view. However, the application avoided comparisons to others behaviour to avoid being perceived as judging the household's choices and pressuring (controlling, rather than enabling) the users to change behaviour. Our observations however indicated that this may have limited participants to form their own judgements about their behaviour and need for change. Designers

may want to look into options to allow comparisons of behaviour to that of others or to norms such as those derived from carbon budgets (e.g., Masson-Delmotte et al. 2018; Berners-Lee 2020; M. A. Clark et al. 2020), in ways that pose limited risk for pressuring users into behaviour change. Opportunities could lie in providing comparisons to the average foodprint of various diets. Also, providing limited prominence to such a comparison, e.g., by choosing not to make it the first visualization to see as participants view feedback on their receipts.

An additional technical difficulty arises when comparing foodprint based on the data collected with the application. Purchase recordings are likely to be incomplete (e.g., as a result of forgetting or losing receipts, not consistently scanning receipts, or acquiring food through means that do not provide receipts [e.g., dining out]), a common problem in behaviour tracking (Daniel A. Epstein, Caraway, et al. 2016; Osadchiy 2020). This complicates making comparisons based on total behaviour. Extrapolating from the recorded receipts to predict a household's foodprint may be possible by making assumptions about daily caloric needs, food waste, and representativeness of the scanned receipts for those receipts that have not been scanned. However, it is possible that faulty assumptions have a harmful effect (Irmak, Murdock, and Kanuri 2020). Further investigations would be required to assess this risk as well opportunities to mitigate it.

6.5.4 Limitations

There were several methodological limitations that limit the generalizability of the results from the study. In no particular order:

The study period of three weeks was too short to measure long-term impact from using the application. The short study period was in line with recommendations for HCI research by Klasnja, Consolvo, and Pratt (2011) and Hekler, Klasnja, J. E. Froehlich, et al. (2013) to evaluate technology use, rather than evaluating long-term behaviour impact. Nonetheless, this study period proved to be too short to assess whether the increases in food literacy have a significant direct impact on the climate sustainability of households' food purchases and a longer study period would be needed to quantify behaviour impact. Moreover, as observed in other applications of purchase tracking (e.g., Zapico, Katzeff, et al. 2016), there may be a shift from tracking-for-knowledge-gain to tracking-for-verification one's understanding. Research indicates that incidental reactivation of knowledge, e.g. through tracking-for-verification, is important for sustained impact (Zapico, Katzeff, et al. 2016; Bangia, Shaffner, and Palmer-Keenan 2017). The

study period appeared to be too short to record this shift and to understand whether the application design could satisfy the demands of tracking-for-verification. The limited-effort approach of receipt scanning (Lurz et al. 2023) is expected to be acceptable for tracking-for-verification and the choice to present the progression of foodprint over time by each basket's weight-balanced average foodprint per 100g allows for meaning time-trend data, even in case of longer gaps in use (this in comparison to drawing meaning from the absolute basket foodprint as a measure of assessing a household's foodprint which would require consistent recording of receipts—or at least non-trivial assumptions to estimate missing data). However, the study period was too short to assess whether these measures were sufficient to satisfy the needs of tracking-for-verification. Likely there will be value in expanding the time statistics in the stats view (Figure 6.1d) with more data to support interpretation for self-judgement (see also Section 6.5.3).

The sample of participants is dominated by educated and young or middle-aged participants; a sample characteristic, common in empirical academic research, that is criticised for representing a narrow population with similarities to the researcher, rather than a representative population sample. While this is the case, the aim was to empower people that care about the environmental footprint of their behaviours; These values appear to be mostly represented in educated and young or middle aged people (Nielsen 2016).

6.6 Concluding summary

In this chapter, I discussed the development and a 3-week field study evaluation of a functional prototype of the MyFoodPrint application. The results from the study indicate that the application design—that provides feedback on food purchases from grocery receipts and provides alternative purchase suggestions—can provide a valuable contribution to foodprint literacy and spark valuable conversations about grocery choices and their foodprint. Through these impacts, the application may eventually benefit a transition to more climate sustainable diets. Important mechanisms that appeared to contribute to a gain of foodprint literacy were the ability of the application to spark curiosity and the gentle guidance that was provided. Recommendations are made to harness the potential of the application to spark of curiosity, provide gentle guidance, and to spark conversations.

Chapter 7

Discussion

7.1 Chapter Aim

This chapter discusses how the findings presented in this thesis address the central research question: *How can digital technology be developed to empower people to pursue climate-sensitive food purchases in an autonomy-respectful way?* By synthesizing the outcomes of the empirical and conceptual chapters, the discussion aims to show how the design and evaluation of the MyFoodPrint prototype, together with the theoretical contributions, provide an answer to this question. Furthermore, this chapter reflects on the broader implications of the findings for design of Persuasive Technology, outlines the contributions of the work to the field, and considers key limitations.

7.2 Answering the Thesis Research Question

This thesis set out to answer the overarching question: How can digital technology be developed to empower people in climate-sustainable food purchases in an autonomy-respectful way? In addressing this question, a multi-method Research through Design approach was employed, combining a literature review, design activity with participants as co-designers, theory-informed prototyping, and field evaluation. Through these steps, the research has demonstrated that it is indeed possible to design a behavior change intervention for sustainable food purchases that empowers users rather than coercing them, thereby aligning with both effectiveness and ethical considerations. The key to this balance was emphasizing user education, reflection, and autonomy in the design. By focusing on foodprint literacy – improving users’ knowledge and skills

regarding the climate impact of their food – the developed application (MyFoodPrint) was able to increase users' awareness and confidence in making sustainable choices without resorting to manipulative tactics. In essence, digital tools can facilitate climate-sensitive purchasing by acting as an informative guide and enabler for the user, rather than a forceful persuader.

Crucially, the research found that an autonomy-respectful approach does not diminish the tool's impact – in fact, it may enhance long-term efficacy. Users in our studies engaged positively with features that sparked curiosity and learning (such as visual feedback on their grocery emissions) and reported feeling more capable of change as a result. At the same time, the design deliberately avoided heavy-handed persuasive techniques (like guilt-tripping or excessive gamification), and this avoidance did not hinder outcomes. On the contrary, participants appreciated the gentle guidance and informational support, and none reported feeling their autonomy was compromised. This suggests that empowering design strategies can yield meaningful improvements in sustainable purchasing behaviors (or precursors to behavior, like knowledge and self-efficacy) while respecting personal agency. Furthermore, the thesis reveals that expecting prolonged or frequent app use is often unrealistic – people tend to abandon behavior-change apps early, so effective climate support tools should deliver value in relatively short, focused engagements. The MyFoodPrint case exemplified this: even within a few weeks of use, users gained lasting insights, indicating that short but intense learning phases can be sufficient to achieve the desired educational outcomes.

In summary, the thesis research question is answered by the demonstration that a carefully designed, autonomy-supportive digital intervention can empower individuals to make climate-sensitive food purchases. By educating users about the climate impacts of their groceries, providing personalized feedback and suggestions, and avoiding manipulative or overly intrusive features, the MyFoodPrint app and the surrounding studies illustrate a viable path for technology to foster sustainable consumer behavior in an ethical manner. The following sections discuss how each study contributed to this conclusion (Section 7.3), delve into the principles of designing for behavior change with autonomy in mind (Section 7.5), outline the key contributions of this work (Section 7.4), and reflect on broader implications, limitations.

7.3 Synthesizing Findings from Chapter 3 to Chapter 6

The thesis comprised four core studies (Chapter 3 through Chapter 6), each addressing a specific research question related to our overall aim. Together, their findings build a coherent understanding of how to design an empowering climate-focused food shopping tool. In this section, we synthesize the insights from each chapter, linking them to the research questions posed.

7.3.1 Findings from Chapter 3: Reviewing Existing Food Purchase Apps

Research Question Chapter 3: What design approaches have been used in smartphone applications to support consumers' food purchase choices, and what key opportunities and challenges do these approaches reveal for designing effective climate-sensitive food purchase support tools?

Chapter 3 addressed this question through a systematic scoping review of existing smartphone applications aimed at influencing or assisting food purchase decisions. By surveying the scientific literature on apps for grocery shopping and related consumer choices, the review identified a wide range of design approaches and features used in practice. These ranged from apps focusing on purchase planning (e.g. creating shopping lists), through those assisting with in-store selection of products (providing nutritional or sustainability information at the point of decision), to tools for reflection after purchase (providing feedback on past shopping). Importantly, the review was not limited to climate-oriented apps; it included health apps as well, thereby capturing a rich variety of interaction patterns and intervention strategies beyond the climate domain. This broad scope allowed identification of general opportunities and challenges applicable to climate-sensitive design.

The review drew awareness to the possibility of intervening at various stages of the consumer's decision process and various features that could potentially be employed. This overview provided a valuable basis for considering design routes for a future design of a tool to support climate-sensitive purchases. For example, the review found that many apps employ components, like tailored labels or tips, which could be repurposed to raise awareness of climate impacts (an opportunity to improve consumers' "foodprint literacy"). Another opportunity is leveraging users' existing routines and data – for instance, using grocery receipts or loyalty card data to provide personalized feedback, which was a relatively under-explored idea in prior work and became a cornerstone of our approach.

At the same time, the review uncovered a persistent challenge in the field: many apps hinge on regular use—whether daily scanning or frequent check-ins—yet users typically abandon them within weeks. This mirrors a broader pattern in persuasive technology research: long-term retention is more the exception than the rule.

This finding led to a key insights for my design approach:

- **Pursue Learning over Nudging:** To have lasting impact, apps should focus on building generalizable knowledge and skills—what users can carry forward—rather than on repeated nudges alone. By concentrating core educational content into brief, high-impact interactions, one could still influence behaviour even after users stop regular use. This observation also provided a first spark to the potential of pursuing foodprint literacy.
- **Pursue Reflection Apps:** Tools for reflection after purchase appear most suitable for pursuing learning. These tools excel at providing feedback on many choices at once. Also, as they are not designed to be used specifically during shopping or grocery-list creation (moments of decision making), they may cause less task interference and may be more suitable for reflection and learning. Furthermore, as provide feedback on choices that actually happened (rather than potential choices), they include a personal component and can be more relevant and engaging for users.

These insights formed the basis for a conceptual design in the next study.

7.3.2 Findings from Chapter 4: User-Involved Design Insights

Research Question Chapter 4: How can user-involved design with target users inform the development of an app to support climate-sensitive grocery shopping? Specifically, what features and support functions do users propose and value for an app that provides feedback on grocery purchases to encourage climate-sustainable choices and how can this knowledge be used to inform design recommendations?

Chapter 4 approached this question by directly involving end users in the design ideation process. Through a user-involved design workshop – notably using a card-sorting activity – prospective users were invited to propose and discuss features for a hypothetical app that would allow users to scan receipts from shopping trips and give them feedback on the climate impact of their grocery shopping and enable them to make more climate sustainable choices during future grocery shopping. By engaging users in co-design, this study aimed to uncover which functionalities

people find most useful and acceptable, and how they envision an app could support (rather than disrupt) their shopping behavior.

The user-involved sessions yielded rich insights into user preferences and values. A clear theme was that prospective users value features that support their understanding, rather than features that prompt them to ‘better’ choices. As such, participants expressed a general enthusiasm for features that would increase their awareness of the environmental impact of their food. This observation aligns well with the emphasis on learning in the previous chapter. It further emphasizes the value of focussing on foodprint literacy and recommends designs that support it (eg, visualizations that highlight patterns in past shopping). Notably, in doing so, the research emphasized the importance of attending to potential complexity of the information. The units in which foodprint could be quantified might cause confusion. Participants expressed preferences for intuitive visual cues (e.g., color-coded scores or graphics) to help them quickly grasp which items that they purchase are “high impact” vs “low impact.”

Crucially, the creative design activity with participants as co-designers also shed light on the kind of support functions users are comfortable with. When reflecting on how the app should encourage change, participants leaned towards educational and enabling approaches rather than features that aim to influence their motivation in a direct way, such as overtly persuasive or punitive features. Importantly, participants did not want to feel judged. This suggests that users themselves favored an autonomy-supportive design: they wanted to retain control over their decisions, with the app serving as a guide and informer. They were wary of features that might feel controlling or guilt-inducing, such as constant reminders or competitive gamification, worrying that these might diminish their intrinsic motivation to improve and might lead them to avoid the app altogether.

The study also flagged the importance of convenience and integration. Participants indicated they would value an app that is sensitive to people’s busy lives and does not disrupt their normal shopping routine. This reinforced a design decision to use grocery receipts as the primary data source: rather than requiring manual input of purchases (which users felt they would not keep up with), the app should automatically capture data (e.g., by scanning a receipt or linking to a loyalty account). The participatory feedback confirmed that such automation would greatly reduce user burden, a direct response to the engagement challenges noted in Chapter 3.

In summary, Chapter 3 provided a user-driven blueprint for a climate-sensitive shopping app. The target users envision a tool that educates them about their food’s climate impacts, and re-

spects their autonomy by avoiding ‘pushy’ motivational features. These findings directly informed the design requirements for the prototype: the app should prioritize informative feedback (e.g., clear carbon footprint displays) and maintain a tone of encouragement rather than enforcement. The participants’ input also highlighted the need for usability and seamless integration (like receipt scanning, personalized content) as key to adoption. Essentially, this chapter answered the research question by showing that user-informed design can elicit valuable feature ideas. These user-generated ideas and preferences set the stage for the next chapter, where theory and iterative refinement would turn them into a concrete app design.

7.3.3 Findings from Chapter 5: Iterative, Theory-Informed Design

Process

Research Question: How can a theory-informed, iterative design process be used to develop a smartphone application that empowers people to reduce their “foodprint”? What design improvements and user feedback emerge across multiple prototype iterations, and how do they inform the final climate-sensitive food purchase support tool?

Chapter 5 addressed this question by employing a structured, iterative design process informed by insights from previous chapters and behavior-change theories, particularly the Behaviour Change Wheel framework. Across four cycles of prototyping and evaluation, the design was continuously refined based on user experience feedback and contextualized through academic literature, culminating in the app named MyFoodPrint.

Throughout this iterative process, the integration of theory and empirical research ensured changes were not merely reactions to user feedback but also aligned with state-of-the-art knowledge in HCI and related fields. When user suggestions conflicted with theoretical considerations (for example, a small number of users suggested a competitive leaderboard for comparing footprints), I carefully reviewed relevant literature, paying particular attention to ethical implications. In this case, despite some users finding the feature appealing, it was not implemented due to concerns around introducing social pressure, shifting motivation extrinsically, or potentially alienating certain users—thus maintaining our commitment to an autonomy-respecting design ethos. This illustrates how the iterative design decisions consistently prioritized both usability and the core ethical values of the project.

Early prototypes focused on testing key functionalities, such as intuitive visualizations of grocery purchases. Initial evaluations quickly demonstrated user enthusiasm for visual representations, particularly word clouds that effectively highlighted key areas of concern within existing purchasing habits. Participants described this visualization as engaging and easy to interpret, successfully sparking curiosity and reflection about their food choices. Conversely, feedback indicated that more detailed data displays, while informative, could overwhelm users and discourage deeper engagement.

Subsequent iterations addressed this feedback by prioritizing simplicity and relevance in visual communication. Specifically, visualizations were streamlined to enable users to quickly identify their most impactful purchases. The concept of “foodprint budgets” (providing personalized carbon targets) was also explored. Although initially intriguing, user evaluations revealed that introducing multiple quantitative measures could confuse or overwhelm users, detracting from the educational objectives of the app. Efforts were made to simplify this feature, but it was ultimately omitted from the functional prototype (see Chapter 6), as confusion around foodprint goals persisted, and autonomy-related concerns regarding goal setting surfaced.

The iterative process further introduced and refined the presentation of product alternatives—suggestions for lower-impact substitutions for previously purchased, high-impact items. This feature was considered essential for foodprint skills: enabling users to translate knowledge into tangible changes. User feedback consistently highlighted the value of presenting a curated list of alternative options, rather than prescribing specific alternatives that might not align with personal preferences or requirements.

Additionally, design iterations underscored the importance of accessible help sections. Users appreciated clear explanations and background information, particularly when unexpected or surprising information triggered curiosity (e.g., when a product had a higher-than-anticipated foodprint).

Reflecting earlier findings regarding technology abandonment in Chapter 3, it became clear that the app’s design should not depend on consistent, frequent scanning of receipts. Users favored an app that allowed flexible, intermittent use, without the pressure associated with daily tracking.

In summary, the iterative, theory-informed design process effectively translated theoretical insights and user preferences into meaningful design enhancements. The evolving prototypes consistently revealed user preferences for simplicity, clarity, and autonomy-supportive features.

These iterative improvements shaped the final MyFoodPrint prototype, ensuring it was educational, respectful of user autonomy, and seamlessly integrated into everyday routines, thereby laying a solid foundation for real-world evaluation in the subsequent field study.

7.3.4 Findings from Chapter 6: Field Evaluation of MyFoodPrint

Research Question: What is the user experience and potential impact of the developed MyFoodPrint prototype on encouraging climate-sustainable food purchases in a real-world context? In what ways does using the app influence users' foodprint literacy, decision-making, and engagement with sustainable food choices during a field deployment?

Chapter 6 tackled this question by conducting a real-world evaluation of the MyFoodPrint prototype in everyday household shopping contexts. Through a multi-week (approximately three weeks) field deployment involving target users, the study explored actual interactions, experiences, and the app's potential influence on household purchasing decisions and foodprint literacy. This study was critical for evaluating whether the theoretically grounded and user-refined design from Chapter 5 could actually empower users and influence their behavior (or precursors to behavior) in practice. I collected both quantitative and qualitative data: usage logs from the app, pre- and post- study surveys (to gauge changes in knowledge, attitudes, and self-efficacy), and interviews capturing user experiences and any changes in their grocery decision-making.

Participants reported positive experiences with the MyFoodPrint app, highlighting its role in increasing users' awareness and understanding of their groceries' climate impact. The visual feedback, particularly the word-cloud visualization, was repeatedly praised for its clarity and ability to quickly highlight key insights about household shopping habits. Users expressed that this visualization effectively sparked reflection, curiosity, and, importantly, conversations with others about food sustainability.

The app not only facilitated individual reflection but also turned out to be a social spark – a few participants mentioned they showed the word cloud to family members or roommates, which ignited conversations about why certain items (like cheese or lamb) were so prominent. Thus, an indirect benefit of the app was catalyzing dialogue about sustainable food choices among users' social circles. Such discussions can reinforce learning and potentially influence others, expanding the impact of the tool beyond the individual user. It's noteworthy that this happened organically, without any built-in social sharing features beyond users voluntarily talking about it;

it underscores how providing compelling information can motivate users to become advocates of the knowledge they gain.

A notable outcome of the field study was the increased confidence (self-efficacy) among household members in making more sustainable choices. Participants felt better equipped with the knowledge and practical tools provided by the app, empowering households to make informed decisions without feeling pressured or judged. This reinforced earlier findings emphasizing the importance of an autonomy-supportive approach.

The study also confirmed earlier expectations regarding flexible usage patterns. Participants did not consistently scan receipts but instead engaged in short, intermittent bursts of activity, aligning with real-world behaviors and reflecting the realities of technology abandonment discussed in earlier chapters. Crucially, intermittent use did not diminish the app's impact: even brief interactions led to lasting insights and meaningful increases in users' foodprint literacy.

Furthermore, users appreciated the gentle, non-intrusive suggestions provided by the app, supporting the notion that autonomy-respecting approaches are not only ethically preferable but also practically effective. None of the participants felt that the app was trying to "force" them to do anything; instead, they characterized it as informative and supportive. This aligns with our design intent – by avoiding pushy notifications or punishments, the app allowed users to engage on their own terms. Some used it every time they shopped; others used it intermittently when it was convenient. This reinforced the idea that respectful and educational designs can successfully encourage sustainable choices within household contexts.

In conclusion, Chapter 6 provided compelling evidence that MyFoodPrint effectively enhanced users' foodprint literacy, self-efficacy, social interactions, and engagement with climate-sustainable purchasing behaviors in real-world settings. This final empirical validation strongly supports the thesis's central claim: digital interventions can empower sustainable consumer behavior effectively and ethically through autonomy-respecting educational and reflective approaches. While the study duration was relatively short to detect long-term habit formation, these small trials of new behaviors are promising signs of the app influencing decision-making in real time.

7.3.5 Synthesis of Findings

Together, the findings across Chapters 3 to 6 demonstrate that designing for empowerment in climate-sensitive food purchases is feasible by centring interventions around enabling strategies rather than motivational control. The literature review highlighted the importance of learning mechanisms over sustained engagement, while the user-involved design and iterative prototyping showed that autonomy-supportive features are both feasible and appreciated by users. The field evaluation further confirmed that minimal but meaningful digital interventions can enhance foodprint literacy, spark critical reflection, and foster sustainable food purchasing behaviours, without resorting to external pressure or manipulation. Collectively, these results show that a design approach grounded in empowerment, reflection, and respect for autonomy can successfully support climate-sensitive choices through digital technology.

7.4 Contributions to the Field

This thesis contributes to several critical areas within sustainable Human-Computer Interaction (HCI), eco-feedback technology, and digital behaviour change interventions, particularly addressing gaps identified in Section 2.7.2.

Firstly, addressing the identified gap of a narrow emphasis on awareness rather than actionable support (gap 1), this thesis advances the understanding of how digital applications can effectively support sustainable food purchases. Chapter 3 systematic scoping literature review highlighted this limitation, while the empirical studies presented in Chapters 4 to 6 demonstrated practical approaches that move beyond mere awareness. Specifically, these chapters illustrate how foodprint literacy can be meaningfully enhanced through targeted education, reflective support, and actionable guidance, thereby translating awareness into skill acquisition and sustained behavioural change.

Secondly, the thesis contributes by aligning metrics with real-world Context (Gap 2). With MyFoodPrint (chapters 5 and 6), I introduce longitudinal foodprint aggregation of shopping data and allow users to reflect on behavioural trends rather than isolated snapshots. By visualizing total item foodprint (as apposed to per 100 g), the visualizations emphasize how behaviours actually impact the users foodprint and help users prioritise changes.

Thirdly, addressing the underdeveloped consideration of autonomy and empowerment (gap 3), this thesis explicitly emphasizes autonomy-respectful design throughout its empirical and theoretical work. The participatory and iterative design processes described in Chapters 4 and 5 document explicit user attitudes towards various autonomy-supportive design elements, highlighting clear preferences for reflective rather than motivationally coercive features. Furthermore, this thesis provides a systematic classification framework mapping common Behaviour Change Techniques (BCTs) according to their alignment with user empowerment versus manipulation. These insights feed into the Autonomy Respectful Design Guide, a practically-oriented design framework presented later in this chapter under Broader Implications, which provides clear, actionable guidance for ethical persuasive technology design.

Fourthly, this thesis critically addresses unrealistic assumptions regarding long-term use and technology abandonment prevalent in current literature. Acknowledging typical patterns of infrequent use, this work specifically optimises designs (as shown through MyFoodPrint) to achieve meaningful impacts through short-term interactions. Chapter 6 validates that even minimal engagement with reflective and educational features can significantly enhance users' foodprint literacy and self-efficacy. Specifically, findings of the iterative design study in Chapter 5 and the field study in Chapter 6 highlighted the potential of the word cloud visualisation as a powerful tool to engage users and spark curiosity that prompts users to reflect and explore data in the app—facilitating gains in foodprint literacy through active learning. Thus, this thesis contributes realistic assumptions and robust design recommendations that acknowledge typical engagement patterns, ensuring effectiveness despite limited sustained technology use.

Fifthly, the thesis makes important contributions towards scalability and overcoming data limitations. By designing and testing MyFoodPrint in real-world contexts, the thesis validated data visualisations, such as personalised word clouds, which clearly and intuitively convey complex product-level information in an engaging and accessible manner. This directly addresses scalability and data limitations by providing an accessible and compelling means of visualising personal data to support empowerment and foodprint literacy, thereby overcoming critical barriers related to trust and user adaptability.

In sum, this thesis provides substantial contributions addressing key literature gaps related to actionable support, empowerment and autonomy, self-efficacy, realistic technology use assumptions, transferability of findings, and scalable, engaging data visualisation. These contributions collectively enhance both scholarly understanding and practical capabilities for designing effective, autonomy-respectful eco-feedback technologies.

7.5 Broader Implications for Design Practice

At the outset of this thesis, I argued that respecting user autonomy within a design approach other than participatory design requires explicit attention to potential manipulation. Throughout the work presented here, a deeper understanding has emerged regarding common behaviour change techniques and their alignment (or misalignment) with user empowerment. Specifically, the thesis has highlighted critical tensions around motivation. Based on this deeper understanding, I now move beyond merely stating that special attention to autonomy is necessary, and instead propose a more systematic and practical approach to safeguarding autonomy in the design of persuasive technologies. The next section introduces this approach as the Autonomy Respectful Design Guide, a set of principles intended to support designers in creating digital interventions that actively protect and foster user autonomy.

7.5.1 Towards an Autonomy Respectful Design Guide

The Autonomy Respectful Design Guide builds upon the insights developed in this thesis and is structured around two central principles intended to protect and enhance user autonomy in persuasive technology design. The first principle involves avoiding direct motivational techniques, instead prioritising enabling and reflective strategies that support individuals in finding their own intrinsic motivations. The second principle highlights the importance of actively involving intended users throughout the design process to ensure the technology aligns closely with their values and supports autonomy in practice. The sections below present each principle in detail, illustrating how they can practically guide the development of digital interventions that respect and empower users.

7.5.2 Enabling vs. Motivating: The Problem with Motivating People

Motivating people plays an important role in the design of many Persuasive Technologies (Fogg 2009; Michie, Atkins, and West 2014; Villalobos-Zúñiga and Cherubini 2020). An important choice, made early in the intervention design processes, is whether to centre intervention design on motivating or enabling (educating or opportunity creating); choice that has important implications for subsequent design choices (Michie, van Stralen, and West 2011; Michie, Atkins, and West 2014; Bartholomew Eldredge et al. 2016; Ruiters and Crutzen 2020).

Yet, we can observe a contrast between motivating and enabling (Deci and Flaste 1996; Fogg 2009; Tengland 2012)—with enabling being core to empowerment. In the Fogg Behaviour Model (Fogg 2009), Fogg uses orthogonal axes for motivation and ability, both factors that we can influence through technology. Tengland describes that empowerment assumes that the person has sufficient internal means (or, motivation) to instigate change and no persuading, rewarding, or coercing is needed (Tengland 2012). Deci and Flaste (1996) emphasize that we should not ask how we can motivate people, but rather provide autonomy support to help them find their own (intrinsic) motivation.

Motivating people reflects an instrumental focus and risks becoming controlling. When it comes to motivating people, we can also note that it performs unfavourably on Botes' (2023) attention point of person vs. resource. In the case of a top-down design, the definition of the value is per definition extrinsic. Then, when we motivate people, we attempt to make them adopt extrinsically defined values—thus performing unfavourably on Botes' attention point of person vs. resource (Botes 2023). Incentives such as rewards, praise and information on others' approval are used as external forms of control to motivate people—thus performing poorly on Botes' control vs free choice attention point.

The (lack of) a critical stance towards motivating people through technology also reflects on the three dimensions of autonomy, either directly or indirectly.

Links can be observed between the act of motivating and our three dimensions of autonomy (see section, 1.2). Freedom of choice: As discussed in the previous paragraph, the aim of motivating places priority on an externally defined goal and risks becoming controlling. Tools to exert pressure (incentives, e.g., penalties, rewards, or rejection) are used to align the recipient's behaviour with the externally defined goal, effectively infringing on their freedom of choice. Rationality: The emotions that are elicited through the incentives that draw our attention to the potential of gain or loss (reward or punishment, acceptance or rejection) and make recipients increasingly vulnerable to decision making based on cognitive biases (Kahneman 2003; Thaler and Sunstein 2008) rather than rational reflection of options based on their values and beliefs. Moreover, systematic associations between behaviour and incentives are potent for developing automatic (as opposed to reflective, rational) responses; the basis for the theory of operant conditioning (B. F. Skinner 2007) that harnesses rejection of autonomy. Transparency: While there appears to be no direct relationship between the intent to motivate and transparency about the intent of the influencer, prominence in indirect relationship is expected. This indirect relationship is based in a common origin: the priority to perform on an instrumental goal. Both the act of motivating

people and manipulating people through a lack in transparency are methods that serve the aim of eliciting a desired behaviour in another. A lack of transparency, or deceit, can be very effective, since the receiver—not knowing what to resist against—has few means to resist the influence (Hansen and Jespersen 2013). The use of deceit doesn't have to be ill-natured or exploitative as is the case in some uses of the method (Nyström and Stibe 2020). A lack of transparency can be inspired by a benign intent to prevent receivers' resistance—based on 'trivial' grounds—to adopt the 'right' behaviour, 'for their own good'; with 'trivial', 'right', and 'for their own good', obviously from the perspective of a well-meaning interventionist applying top-down intervention to achieve an honourable aim, like increased health of the receiver; unfortunately perhaps unknowingly doing so at the cost of the quality of life of the receiver (Tengland 2012).

7.5.3 Expected Objections to Criticism of Motivating and Responses

When condemning attempts to motivate people as infringement on autonomy, this piece does not explicitly distinguish between extrinsic and intrinsic motivation—also called autonomous motivation (Deci and Flaste 1996; Ryan and Deci 2020). By supporting people to find their intrinsic motivation for a behaviour we support them in their autonomy (Deci and Flaste 1996). While this is the case, it is important to point out that we do not motivate people into intrinsic motivation. Rather, we support people in finding their intrinsic motivation for a behaviour (Deci and Flaste 1996; TEDx Talks 2012). When an intervention design is top-down, this means that the embodied values are determined top-down. Motivating people from the basis of these values is then an attempt to control their values and beliefs and infringes with their autonomy to self-determine their behaviour.

One may argue that the values embodied by the BCSS could align with those of the intended user and attempt to motivate would therefore not infringe with a person's autonomy. Such an argument aligns with that made by Aylsworth (2022) who states that manipulation is acceptable when this happens in line with the receiver's values (Aylsworth 2022). This argument however has important limitations. First, people may understand values differently. For example, a healthy diet may be understood by one as a diet that is calorie controlled, while another may understand this as diet that involves a balanced distribution of the various food groups. Second, even if value definitions align, we can expect difficulty with the attention given to this value relative to other values. Attention for one value competes with attention for other values (Rosenberg 2008, p. 35). External control interferes with an individual's ability to autonomously regulate

the balance between competing behaviours. Notably, Tengland (2012), argues that no form of manipulation is respectful to an individual’s autonomy.

7.5.4 Rule 1: Avoid Direct Attempts to Motivate People

The task becomes then to take a critical stance to the use of motivating techniques, and ideally avoid direct attempts to motivate people. A designer can appraise an active ingredient (behaviour change technique or persuasive technique (Silva, Hay-Smith, and Graham 2023)) for its expected contributions for enabling or motivating (or, controlling) based on logic and theory. To aid the designer, I will do this with a classification and mapping of common behaviour change techniques (Edwards et al. 2016; Hedin, Katzeff, et al. 2019; Van Rhoon et al. 2020; Benthem De Grave, Bull, Monjardino De Souza Monteiro, and Smeddinck 2023) (Figure 7.1).

I categorize the active ingredients into—in descending order of preferrability for empowering autonomy—(a) those that are mostly enabling, (b) those that are conditionally enabling or controlling, largely dependent on the specific implementation and (c) those that are mostly motivating (controlling). In the case of conditional techniques, a controlling effect may result as an unintended side effect of an enabling intent (see Table 7.1).

Table 7.1: Categorization of common behaviour change techniques for their contributions to enabling or motivating (controlling) behaviour. Further descriptions of the techniques can be found in Michie, Richardson, et al. (2013) and Michie, Atkins, and West (2014)

Category	Technique	Rationale and Link to Thesis Findings
Mostly enabling	Self-monitoring	Enabling, as it provides users with information to evaluate and judge their own behaviour independently. In Chapter 6 (field study), personalised feedback (e.g., word cloud visualisations) allowed users to self-monitor their food choices, fostering reflection without external pressure.

Category	Technique	Rationale and Link to Thesis Findings
	Action planning	Enabling, because it helps users anticipate barriers and prepare strategies, reducing behavioural difficulty. This aligns with user preferences for educational and enabling support identified in Chapter 4 (user-involved design workshop), where users valued practical guidance over direct motivation.
	Problem solving	Strongly autonomy-supportive, as it invites users to identify their own barriers and define their own solutions. Reflects the learning from Chapter 6, where empowering users to understand and tackle their high-impact food purchases fostered genuine engagement.
	Demonstration of the behaviour	Enabling when used to build skills through modelling (e.g., showing how to identify lower-impact alternatives), but can become pressuring if framed as a social norm. This distinction is critical given Chapter 4 findings, where users resisted judgmental or prescriptive features.
	Focus on past success	Enabling by reinforcing self-efficacy through recalling successful behaviour changes. This technique supports users' confidence, consistent with field study insights (Chapter 6) where participants expressed increased confidence after engaging with positive, reflection-oriented feedback.

Category	Technique	Rationale and Link to Thesis Findings
Conditional techniques	Adding objects to the environment	This technique is often counted when a digital technology is made available (Mauch, Wycherley, et al. 2018). In this sense, an opportunity is created to voluntarily adopt a tool that may support behaviour change.
	Social comparison	Enabling when transparently showing others' behaviour for inspiration; controlling when setting a normative standard (Deci and Flaste 1996). Users in Chapter 4 warned against competitive features like leaderboards, reinforcing the need for careful framing to avoid social pressure.
	Social support	Enabling when framed as coaching (e.g., offering encouragement without evaluation), but controlling when used for praise/reward (Deci and Flaste 1996). Chapter 4 participants explicitly preferred support that fostered autonomy rather than social competition.
	Credible source	Can be enabling by fostering trust in information. However, reliance on authority risks pressuring users to conform to externally imposed standards (Tengland 2012).

Category	Technique	Rationale and Link to Thesis Findings
	Feedback	Basic feedback is enabling by providing neutral, informative insights; but evaluative feedback (e.g., judgmental scores) risks becoming controlling (Deci and Flaste 1996; Tengland 2012). Iterative design study data (Chapter 5) confirmed that users preferred non-judgmental, curiosity-sparking feedback (e.g., word clouds).
	Goal setting	Goal setting can be enabling when it helps users monitor and structure their own behaviour in a flexible and user-driven way. It supports reflection by offering an anchor for progress evaluation. However, goal setting becomes controlling if goals are externally imposed, inflexible, or tied to external rewards or accountability measures (Deci and Flaste 1996; Ryan and Deci 2020). Learnings from Chapter 5 showed that rigid goal systems confused or pressured users, ultimately leading to their omission from the MyFoodPrint prototype in favour of more autonomy-supportive alternatives.
Motivating (controlling) techniques	Information about other's approval	Primarily motivational (controlling); it seeks behaviour change based on social acceptance rather than personal values. In Chapter 4, users resisted features suggesting social approval or disapproval.

Category	Technique	Rationale and Link to Thesis Findings
	Rewards	Purely motivational, with little connection to skill-building or self-efficacy. Reward systems risk shifting motivation extrinsically (Deci and Flaste 1996; Ryan and Deci 2020), as highlighted in Chapter 4, where participants disliked gamified or reward-driven incentives.
	Incentives	Like rewards, incentives work through extrinsic motivation (Deci and Flaste 1996; Ryan and Deci 2020) without enhancing users' internal skills or capacities. Field study (Chapter 6) results indicated that users valued the autonomy to choose change without needing external carrots or sticks.

7.5.5 Rule 2: Involve Intended Users Throughout the Design Process

While the aim of the rules proposed here is to support an alternative to participatory design as a design method for empowerment, this does not mean that users can reasonably be excluded from most parts of the design process. Indeed, involving the intended user group throughout the design process plays at least two important roles.

The first role is directly related to the implementation of active ingredients as discussed under rule 1. Involvement of intended users is an important step to verify whether the implementation of the active ingredients is enabling as intended and an (unintentionally) controlling impact results in undue infringement on autonomy. Unintentional controlling impact can particularly be expected for the conditional techniques and involvement of intended users is particularly important to verify appropriate implementation in these cases.

Involvement of the intended user group is also important at the earliest stages of the design process to understand actual user needs. Capturing the user needs allows designers to support users' autonomy by accommodating these needs (J. Davis 2009; J. Davis 2012; Friedman et al.

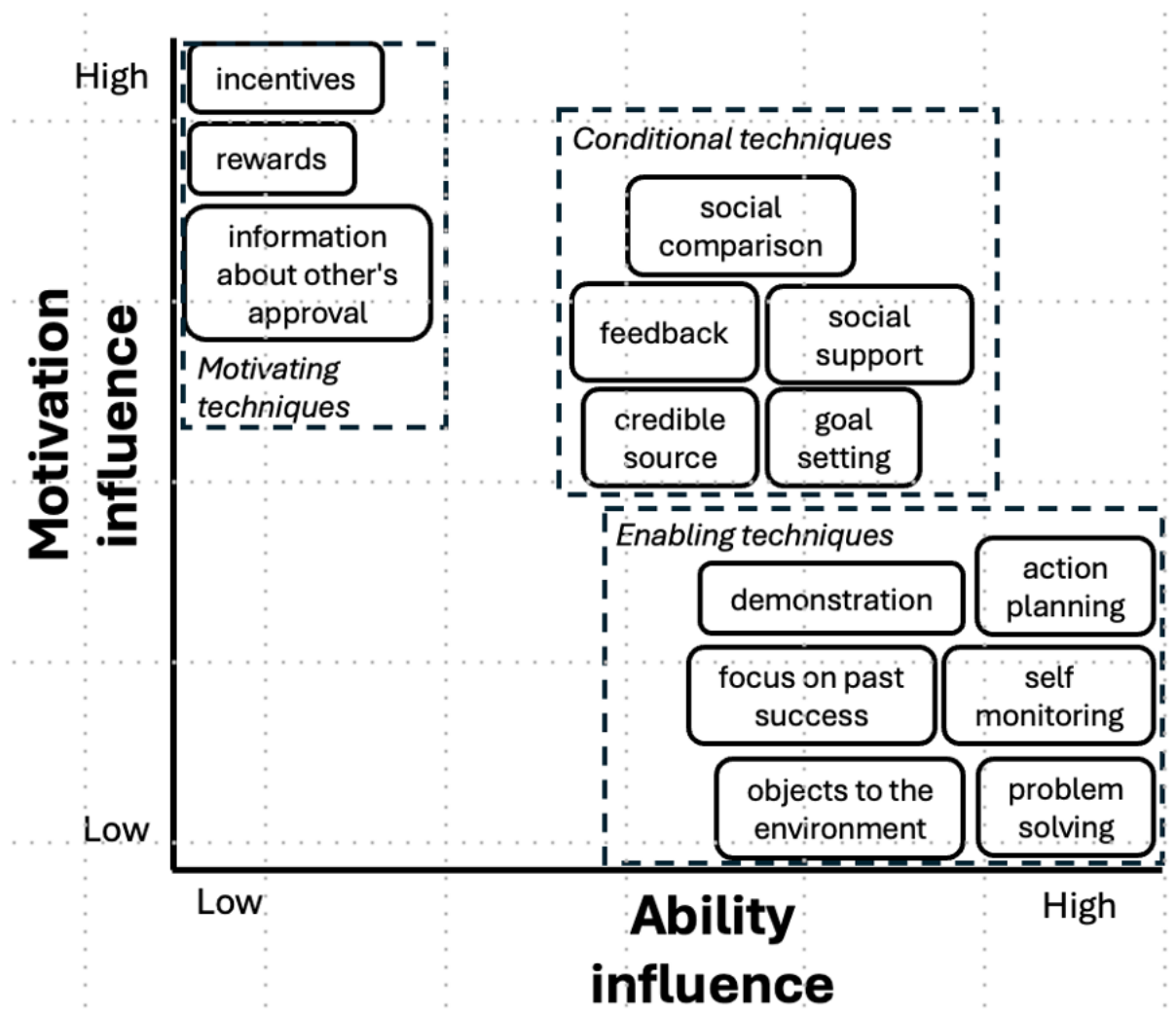


Figure 7.1: Common behaviour change techniques clustered by their theoretical likelihood to influence the user's ability or motivation to perform a behaviour or pursue a behaviour outcome. Three clusters categorize techniques into—in descending order of preference for empowering autonomy—(a) those that are mostly enabling, (b) those that are conditionally enabling or controlling, largely dependent on the specific implementation and (c) those that are mostly motivating (controlling).

2013) and prevent infringement on autonomy by misaligning users' values and those embodied by the design (J. Davis 2009; Friedman et al. 2013; Aylsworth 2022). As such, this instruction is similar to that of Human-Centred Design (Norman 2013; International Organization for Standardization 2019), but with the subtle difference that the important focus in human centred design is to benefit the effectiveness of the design (J. Davis 2009), whereas the focus here is to support and protect users in their autonomy.

7.5.6 Summary and Broader Relevance of the Autonomy Respectful

Design Guide

In summary, the Autonomy Respectful Design Guide provides a practical and ethically robust approach to designing persuasive technologies aimed at fostering climate-sensitive behaviours. It builds on the thesis findings by clearly articulating strategies that avoid manipulative tactics, support intrinsic motivation, and centre user values and autonomy. By adopting this systematic approach, designers can create impactful digital interventions that not only achieve behaviour change outcomes but do so in a manner that respects and empowers users. This approach has the potential to inform design practice well beyond the specific context of sustainable food purchasing, serving as a generalizable framework for responsible persuasive technology design in other behavioural domains.

7.6 Limitations

While this thesis contributes substantially to sustainable HCI, eco-feedback, and persuasive technology design, several important limitations must be acknowledged.

Firstly, the findings presented here are context-specific, being closely tied to the particular domain of climate-sensitive food purchases within a UK cultural and consumer context. Generalizability of insights and the applicability of the Autonomy Respectful Design Guide to other behavioural domains or cultural contexts thus remain to be validated. Future research should examine the transferability and adaptability of these principles across different user groups, behaviours, and cultural settings.

Secondly, although the MyFoodPrint application demonstrated promising short-term impacts on user awareness, reflection, and self-efficacy, the relatively short duration of the field trial (ap-

proximately three weeks) limits our ability to claim long-term behavioural change. Longitudinal research is necessary to determine whether initial changes in awareness and self-efficacy translate into sustained behavioural modifications over extended periods and in varied contexts.

Thirdly, the emphasis on autonomy-respectful design and the prioritization of enabling strategies over direct motivational techniques present theoretical and practical tensions. The balance between enabling users to find their intrinsic motivations and effectively guiding behaviour change remains delicate and may differ significantly across individuals. Additional empirical research could explore further how different user groups respond to varying degrees of autonomy support and motivational nudging, contributing further nuance to the *Autonomy Respectful Design Guide*.

Fourthly, despite efforts to minimize complexity, presenting personalised and relevant footprint data inevitably involves simplifications and assumptions. Variability in product-level carbon footprint data, inaccuracies due to incomplete databases, or user misunderstandings of visualisations could limit the reliability of user interpretations and subsequent actions. Addressing these limitations requires ongoing improvements in data quality and transparency, as well as further iterative refinements of data visualisation methods based on rigorous user testing.

Finally, although the thesis argues for and demonstrates the benefits of autonomy-respectful designs, practical constraints such as resource availability, scalability concerns, and real-world commercial pressures may challenge full adherence to the proposed guidelines. Designers working in commercial settings might face constraints that necessitate compromises in autonomy-supportive practices. Future work could explore practical strategies for maintaining autonomy respect within commercial realities, providing a more comprehensive understanding of how to implement these ethical principles in diverse design environments.

These limitations notwithstanding, this thesis offers clear, actionable pathways for future research and practice, highlighting both immediate applications and broader directions for ongoing exploration in the responsible design of persuasive technologies.

7.7 Directions for Future Research and Design

This work highlights various avenues for future work, e.g.:

- The prototype presented in this thesis may be pursued into a fully deployed application and released to the public. Doing so would require a solution to automate or crowd-source mapping of receipt items on products and product weight (or both). Additionally, the approach to calculating foodprints proposed by Clark et al. M. Clark et al. (2022) can be followed to establish a unified database of foodprints underpinning the foodprint feedback in the application. Collaboration with an NGO that focuses on environmental sustainability may furthermore contribute to visibility and longevity (read, maintenance of the application), possibly without the need to compromise the integrity of the values underlying the design that may result from commercializing the application.
- Future work can investigate the long-term impact of this application and assess the effects of the design on people's diet foodprint.
- Researchers may want to further investigate the indirect effects of the application, and similar applications, on behaviour relevant to environmental sustainability and potentially seek ways to quantify this effect.
- While an increase in foodprint literacy is expected to benefit a reduction in the value-behaviour gap in an autonomy-respectful way, behaviour change remains difficult (Papies 2017). One approach that may benefit the follow-through of change intentions that research may want to investigate to complement the proposed design is implementation intentions (Gollwitzer 1999; Gollwitzer, Gawrilow, and Oettingen 2010). This concept—a form of action planning (Michie, Richardson, et al. 2013)—builds on the value of cues (prompts) to trigger a behaviour without the need to consciously activate the behaviour. But rather than adding something to the external environment to provide this cue, the implementation intention relies on the person defining their cue. When forming an implementation intention, the person visualizes to their best ability the environment in which the intended behaviour is to be executed and visualizes themselves performing the behaviour. As such, there is no need to (un-opportunistically (see Chapter 3)) intervene in the purchase environment itself and use controversial nudges that influence the automated execution of behaviour (see Section 2.6 and Hansen and Jespersen (2013)). Researchers can explore opportunities to integrate features to help people form implementation intentions, for example, through a stepwise guided procedure of defining the cue and behaviour.
- Research can also build on the work in this thesis by investigating the potential of focusing on supporting a relatively short and intense knowledge and skill learning phase (e.g., by designing to spark curiosity) in the design of applications in other domains.
- Researchers may want to investigate the potential of word cloud visualization in other

behaviour feedback applications, for example in nutritional-health-tracking applications.

- Researchers can investigate the impact on design and user experience by applying the guiding principle from the *Autonomy Respectful Design Guide* (Section 7.5): to avoid direct attempts to motivate, and instead enable people to self-determine behaviours.
- Informed by the challenges of applying the Lancet guidelines for a healthy and sustainable diet (W. Willett et al. 2019) in feedback, researchers may want to define a project proposal to address these challenges and define a set of instructions that allows the use of the Lancet guideline to provide people with actionable feedback on the sustainability and healthiness of their diet.

Chapter 8

Conclusion

This thesis set out to explore how digital technology can be designed to empower individuals to make climate-sustainable food choices in an autonomy-respectful way. Through a Research through Design approach combining literature review, co-design workshops, iterative prototyping, and field evaluation, this work culminated in the development and deployment of the MyFoodPrint application—a tool that translates theoretical values into practical support for users seeking to align their food choices with climate goals.

The key insight emerging from this work is that digital interventions do not need to rely on motivational control to be effective. Instead, empowering users through reflection, education, and unobtrusive guidance can build foodprint literacy and self-efficacy without infringing on autonomy. This approach has shown to be appreciated, effective, and ethical, confirming that autonomy-respectful design is not a trade-off but a foundation for sustainable behavior change.

The contributions of this thesis are both conceptual and practical. Conceptually, it offers a critical stance on common persuasive design strategies, proposing an alternative framework that foregrounds empowerment and autonomy. Practically, it demonstrates the viability of this approach through a concrete, real-world intervention. The findings not only inform the design of climate-sensitive food apps but also provide broader implications for the responsible development of persuasive technologies across domains.

While limitations remain—particularly regarding generalizability and long-term impact—the research provides a compelling case for autonomy-supportive strategies in behaviour change interventions. The insights, frameworks, and prototype developed in this work pave the way for more humane, empowering digital tools that help users take meaningful steps towards sustainability on their own terms.

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Appendix A

Completed PRISMA-ScR Checklist (Chapter 3)

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	
Limitations	20	Discuss the limitations of the scoping review process.	
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	

JB1 = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JB1 guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: 10.7326/M18-0850.



Appendix B

Included Articles in Scoping Systematic Literature Review (Chapter 3)

Table B.1: Included Articles in Scoping Systematic Literature Review

citation	Publisher	Year	Study type
Abao, Malabanan, and Galido (2018)	Elsevier	2018	design and development + feasibility
Ahn et al. (2015)	ACM	2015	design and development + feasibility
Akay, Kandemir, and Dalkilic (2022)	IEEE	2022	design and development
Asikis et al. (2021)	Royal Society Publishing	2021	design and development + feasibility + evaluation
Bangia, Shaffner, and Palmer-Keenan (2017)	Elsevier	2017	evaluation
Bird et al. (2013)	ACM	2013	design and development + evaluation
Bohné, Zapico, and Katzeff (2015)	ACM	2015	design and development
Bomfim and Wallace (2018)	ACM	2018	design and development
Bomfim, Kirkpatrick, et al. (2020)	ACM	2020	design and development + feasibility + process evaluation
Broll et al. (2013)	IEEE	2013	design and development + feasibility

citation	Publisher	Year	Study type
A. Clear and F. Friday (2012)	ACM	2012	design and development
Díaz-Hellín et al. (2015)	Springer	2015	design and development
Dorman et al. (2010)	MobiCASE 2009	2010	design and development
Dunford et al. (2014)	JMIR	2014	design and development + feasibility
Eyles, McLean, et al. (2017)	Sage	2017	feasibility + evaluation
Eyles, Grey, et al. (2023)	JMIR	2023	feasibility + evaluation
Fagerstrøm et al. (2023 Apr-Jun)	Routledge	2023	Feasibility
S.-J. Flaherty et al. (2018)	Cambridge University Press	2018	app store review
S. J. Flaherty et al. (2020)	Elsevier	2020	feasibility
Fuchs et al. (2019)	ACM	2019	design and development + feasibility
Govoruhina and Nikiforova (2022)	IEEE	2022	design and development
Gutiérrez, Verbert, and Htun (2018)	ACM	2018	design and development
Harada et al. (0018–2022)	IEEE	2022	design and development
Head et al. (2014)	Elsevier	2014	design and development
Hedin, Grönborg, and Johansson (2022)	MDPI (sustainability)	2022	design and development + feasibility + evaluation + process evaluation

citation	Publisher	Year	Study type
Hegen (2016)	Association for Information Systems	2016	feasibility
Herbig, Kahl, and Krüger (2018)	ACM	2018	design and development + feasibility
Hormann et al. (2019)	IEEE	2019	design and development + feasibility
Isley, Ketcham, and Arent (2017)	IOP publishing	2017	design and development + feasibility
Jayananda et al. (2018)	IEEE	2018	design and development
Kassim et al. (2012)	IEEE	2012	design and development
Katzeff et al. (2020)	MDPI	2020	design and development + feasibility
Kulpy and Bekaroo (2017)	IEEE	2017	design and development + feasibility
Lawo et al. (2021)	ACM	2021	design and development + feasibility
López et al. (2017)	Healthcare informatics research	2017	design and development + feasibility

citation	Publisher	Year	Study type
Lurz et al. (2023)	IEEE	2023	design and development + feasibility + evaluation
Mahdi, Chilcott, and Buckland (2022)	Elsevier	2022	feasibility
Mauch, Wycherley, et al. (2018)	JMIR	2018	app store review
Mauch, Laws, et al. (2021)	JMIR	2021	feasibility
Mönninghoff et al. (2022)	JMIR	2022	design and development + feasibility + evaluation
Normark and Tholander (2014)	ACM	2014	design and development + feasibility
Palacios et al. (2018)	MDPI	2018	feasibility + evaluation
Reitberger, Spreicer, and Fitzpatrick (2014)	Springer	2014	design and development + feasibility + evaluation
Röddiger, Doerner, and Beigl (2018)	ACM	2018	design and development
Sackey and Ullmann (2012)	IEEE	2012	design and development
Samoggia and Riedel (2020)	Elsevier	2020	process evaluation
Serhani et al. (2019)	IEEE	2019	design and development

citation	Publisher	Year	Study type
Tomlinson (2008)	IEEE	2008	design and development + feasibility
Tsai et al. (2021)	IEEE	2021	design and development
van der Laan and Orcholska (2022)	Elsevier	2022	evaluation
Vintsarevich et al. (2011)	Maxwell	2011	design and development + feasibility
Waltner, Schwarz, Ladstätter, Weber, Luley, Bischof, et al. (2015)	Springer	2015	design and development + feasibility
Waltner, Schwarz, Ladstätter, Weber, Luley, Lindschinger, et al. (2017)	Springer	2017	feasibility
Wiley et al. (2011)	Springer	2011	design and development + feasibility
Zapico, Katzeff, et al. (2016)	ACM	2016	design and development + evaluation

Appendix C

Included Apps in Scoping Systematic Literature Review (Chapter [3](#))

Table C.1: Included Apps in Scoping Systematic Literature Review (Chapter 3)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 01	App 01	Vintsarevich et al. (2011)	selection	nutritional content	independent	Educating (background information), Identifying (barcode), Evaluating (normative rating)
App 02	App 02	Broll et al. (2013)	selection	nutritional content	unknown	Identifying (RFID/NFC), Evaluating (normative rating + personalised rating)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 03	App 03	Díaz-Hellín et al. (2015)	selection	nutritional content	unknown	Profiling, Shopping list, Identifying (RFID/NFC), Evaluating (descriptive + personalised rating)
App 04	App 04	Hegen (2016)	selection	environmental impact + nutritional content	dependent	Identifying (QR), Evaluating (descriptive + normative rating + customer ratings)
App 05	App 05	Bangia, Shaffner, and Palmer-Keenan (2017)	contemplation	nutritional content	independent	Educating (tips + background information)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 06	App 06	Isley, Ketcham, and Arent (2017)	approach	environmental impact + nutritional content	unknown	Profiling, Live search, Identifying (image), Evaluating (personalised rating)
App 07	App 07	Herbig, Kahl, and Krüger (2018)	selection	environmental impact	independent	Profiling, Educating (background information), Identifying (barcode), Evaluating (personalised rating)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 08	App 08	Hormann et al. (2019); Asikis et al. (2021)	approach	nutritional content + environmental impact + societal impact	dependent	Profiling, Educating (background information), Identifying (location based), Evaluating (personalised rating)
App 09	App 09	S. J. Flaherty et al. (2020)	planning	nutritional content	independent	Profiling, Shopping list, Educating (tips)
App 10	App 10	Tsai et al. (2021)	selection	freshness	independent	Identifying (image), Evaluating (descriptive)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 11	App 11	Akay, Kandemir, and Dalkilic (2022)	approach	nutritional content	dependent	Profiling, Shopping list, Live search, Identifying (QR)
App 12	App 12	Harada et al. (0018–2022)	selection	authenticity	independent	Identifying (image), Evaluating (descriptive)
App 13	App 13	Lurz et al. (2023)	reflection	nutritional content	independent	Identifying (receipt scanning), Evaluating (normative rating), Monitoring
App 14	App 14	Fagerstrøm et al. (2023 Apr-Jun)	selection	nutritional content	dependent	Identifying (QR), Evaluating (customer ratings)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 15	ARFusion	Ahn et al. (2015)	approach	nutritional content	dependent	Live search, Identifying (image + location based), Evaluating (descriptive + normative rating)
App 16	ARMart	Röddiger, Doerner, and Beigl (2018)	approach	nutritional content	unknown	Profiling, Live search, Identifying (image), Evaluating (normative rating + personalised rating)

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 17	ARSA	Serhani et al. (2019)	selection	nutritional content	independent	Profiling, Identifying (image), Evaluating (descriptive + personalised rating)
App 18	Baked Potatoe	Sackey and Ullmann (2012)	selection	nutritional content + environmental impact + societal impact	unknown	Profiling, Educating (background information), Evaluating (personalised rating), Recommending

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 19	BetterChoice	Fuchs et al. (2019)	selection	nutritional content	independent	Profiling, Educating (tips), Identifying (barcode), Evaluating (normative rating + personalised rating), Recommending
App 20	Change4Life Food Scanner	Mahdi, Chilcott, and Buckland (2022)	selection	nutritional content	independent	Identifying (barcode), Evaluating (descriptive + normative rating + analogues), Recommending

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 21	Diet Helper	Govoruhina and Nikiforova (2022)	selection	nutritional content	independent	Profiling, Identifying (image), Evaluating (personalised rating)
App 22	Dirk app	van der Laan and Orcholska (2022)	selection	nutritional content	dependent	Prompting, Identifying (barcode), Recommending
App 23	Easy Shopping	Jayananda et al. (2018)	selection	nutritional content	dependent	Profiling, Identifying (image), Evaluating (personalised rating), Recommending

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 24	EcoFriends	Normark and Tholander (2014)	selection	environmental impact	independent	Educating (background information), Identifying (barcode), Evaluating (descriptive)
App 25	EcoPanel	Bohné, Zapico, and Katzeff (2015); Zapico, Katzeff, et al. (2016); Katzeff et al. (2020)	reflection	environmental impact	dependent	Educating (background information), Identifying (loyalty card), Monitoring

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 26	EDO App	Samoggia and Riedel (2020)	selection	nutritional content	independent	Profiling, Educating (background information), Identifying (barcode), Evaluating (personalised rating), Recommending
App 27	F-RS4CC	Lawo et al. (2021)	planning	nutritional content + environmental impact	dependent	Profiling, Shopping list, Educating (background information), Evaluating (descriptive), Recommending

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 28	FoodGo	Abao, Malabanan, and Galido (2018)	selection	nutritional content	independent	Profiling, Identifying (barcode), Evaluating (descriptive + normative rating + analogues), Monitoring
App 29	FoodQualculator	A. Clear and F. Friday (2012)	planning	environmental impact	independent	Shopping list, Educating (tips), Evaluating (normative rating)
App 30	Foodswitch	Dunford et al. (2014); Eyles, McLean, et al. (2017); Eyles, Grey, et al. (2023)	selection	nutritional content	independent	Identifying (barcode), Evaluating (normative rating), Recommending

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 31	Fruitify	Kulpy and Bekaroo (2017)	selection	nutritional content	independent	Identifying (image), Evaluating (descriptive), Monitoring
App 32	FutureMe	Mönninghoff et al. (2022)	reflection	nutritional content	dependent	Profiling, Educating (tips + background information), Identifying (loyalty card), Evaluating (personalised rating + simulation future), Recommending, Monitoring

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 33	GreenCobra	Hedin, Grönborg, and Johansson (2022)	planning	environmental impact	independent	Shopping list, Evaluating (descriptive + analogues)
App 34	GreenScanner	Tomlinson (2008)	selection	environmental impact	independent	Educating (background information), Identifying (barcode), Evaluating (descriptive)
App 35	Healthy Shopping App	Bird et al. (2013)	reflection	food category	independent	Identifying (barcode), Monitoring

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 36	MANGO	Waltner, Schwarz, Ladstätter, Weber, Luley, Bischof, et al. (2015); Waltner, Schwarz, Ladstätter, Weber, Luley, Lindschinger, et al. (2017)	selection	nutritional content	independent	Profiling, Educating (background information), Identifying (image), Evaluating (personalised rating), Recommending
App 37	My Food Guide (MFG)	Bomfim, Kirkpatrick, et al. (2020)	planning	food category	independent	Shopping list, Evaluating (descriptive + normative rating)
App 38	MyHalal	Kassim et al. (2012)	selection	nutritional content	independent	Identifying (barcode)
App 39	MyNutriCart	López et al. (2017); Palacios et al. (2018)	planning	food category	independent	Profiling, Shopping list

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 40	Nutriflect Home	Reitberger, Spreicer, and Fitzpatrick (2014)	reflection	food category	dependent	Profiling, Identifying (loyalty card), Evaluating (normative rating + personalised rating), Monitoring
App 41	Nutriflect Mobile	Reitberger, Spreicer, and Fitzpatrick (2014)	selection	food category	unknown	Identifying (RFID/NFC), Evaluating (descriptive + personalised rating)
App 42	Nutrition Monitor	Dorman et al. (2010)	selection	nutritional content	independent	Identifying (barcode), Evaluating (descriptive), Monitoring

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 43	Phara	Gutiérrez, Verbert, and Htun (2018)	approach	nutritional content	independent	Profiling, Live search, Identifying (image), Evaluating (descriptive + normative rating + simulation future), Recommending
App 44	Pirate Bridgitte's Grocery Adventure (PBGA)	Bomfim and Wallace (2018); Bomfim, Kirkpatrick, et al. (2020)	multi-stage	nutritional content + food category	independent	Shopping list, Educating (tips), Identifying (barcode), Evaluating (normative rating), Monitoring

Application ID	Application name	Appears in (citation)	App Type	Product information	Dependency on retailer	Functions
App 45	QuestionMark	Head et al. (2014)	selection	environmental impact	independent	Educating (background information), Identifying (barcode), Evaluating (normative rating), Recommending
App 46	SCIP	Wiley et al. (2011)	selection	nutritional content	dependent	Profiling, Identifying (RFID/NFC), Evaluating (descriptive + personalised rating), Recommending

Appendix D

Function Descriptions of Apps Considered in Scoping Systematic Literature Review

Table D.1: Function descriptions of apps considered in scoping systematic literature review.

Function	Description
Profiling	Users can setup a user profile to allow for tailored feedback. This function thus generally coincides with tailored feedback. One of the designs (Díaz-Hellín et al. 2015) uses behavior tracking (physical activity) to dynamically update the user profile.
Shopping list	Choice support is provided around shopping list creation, or the application uses automatic generation of a grocery list based on a personal profile and recommendations for a healthy diet.
Live search	A function that allows the user to search amongst products on the shelf by providing information of a multiple products simultaneously. This function can take the form of (a) virtual PI projections on products, seen through the phone camera, or (b) a live-updated list of nearby products.

Function	Description
Prompting	The user receives a notification of product information that does not follow a direct request for information. E.g., a pop-up message of healthier alternatives that appears when the user scans the barcode of an unhealthy product when the users scan the barcode as part of a payment process (van der Laan and Orcholska 2022).
Educating	
Tips	Some applications provide short messages that contain practical knowledge, with the intention to supporting the user in making deliberate food purchase choices.
Background information	Some applications provide the user with background information. For example, if a product rating was provided, the application may provide a breakdown on the data that was used for this rating and how the rating was calculated. Application may also provide links to webpages with further information relevant to the product evaluation.
Identifying	
Barcode	Barcode scanning.
QR	QR code scanning.
Image	Computer vision is used to recognize the product with the phone camera.
RFID/NFC	RFID and NFC are electromagnetic communication methods used for contactless data transfer, used e.g., in bank cards.
Location based	The location of the smartphone relative to a mapped store layout.
Loyalty card	For customers with a loyalty card, purchased items can be identified from digital records of past purchases.
Receipt scanning	Using algorithms to recognize the characters and the layout of the receipt.
Evaluating	
Descriptive	Statistics or raw numeric data, leaving the value judgement to the user.

Function	Description
Normative rating	Evaluation against a standardized norm, like presenting a traffic-light label (Dunford et al. 2014) (a label with four colored circles—each circle is either green (best)/yellow/orange/red (worst)—providing a rating for the fat, saturated fat, sugar, and salt content of the product), or a NutriScore (Julia et al. 2017) label (a 1-score label that consists of a letter—A to F—and associated color—dark green to dark red—that is based on a standard calculation of nutritional characteristics).
Tailored rating	Scores for the product based on a profile entered by the user (see the profiling function). The rating can be presented in various forms, examples are a score on a scale from 1 to 10 (e.g., Asikis et al. 2021), or an adjusted form of the traffic-light label or NutriScore based of personal data.
Comparison	Contrasting the product characteristics to that of one or more other products.
Analogues	Using another dimension to help the user put the value in context. For example, expressing calories in jogging minutes (Abao, Malabanan, and Galido 2018), or carbon footprint in driving miles (Hedin, Grönborg, and Johansson 2022).
Simulation	An estimation of a future state (e.g., body weight (Mönninghoff et al. 2022)) from consuming the product.
Rewards	acknowledgement of goal achievement in form of a virtual trophy.
Recommending	A list of alternatives for a selected product, or suggestions in relation to a user profile or behavior data.

Function	Description
Monitoring	Tracking purchases and returning statistics, e.g., in the form of progress over time (EcoPanel (Bohné, Zapico, and Katzeff 2015; Zapico, Katzeff, et al. 2016; Katzeff et al. 2020)), performance against a goal (Kalnikaitė, Bird, and Yvonne Rogers 2013; Bomfim and Wallace 2018; Bomfim, Kirkpatrick, et al. 2020), or by estimating a future body state (FutureMe (Mönninghoff et al. 2022)). Note: this is a distinct function from evaluation. In case of monitoring, there is also a form of evaluation, but this evaluation form is not unique to monitoring.

Appendix E

Sankey Diagram of App Designs in Scoping Systematic Literature Review (Chapter 3)

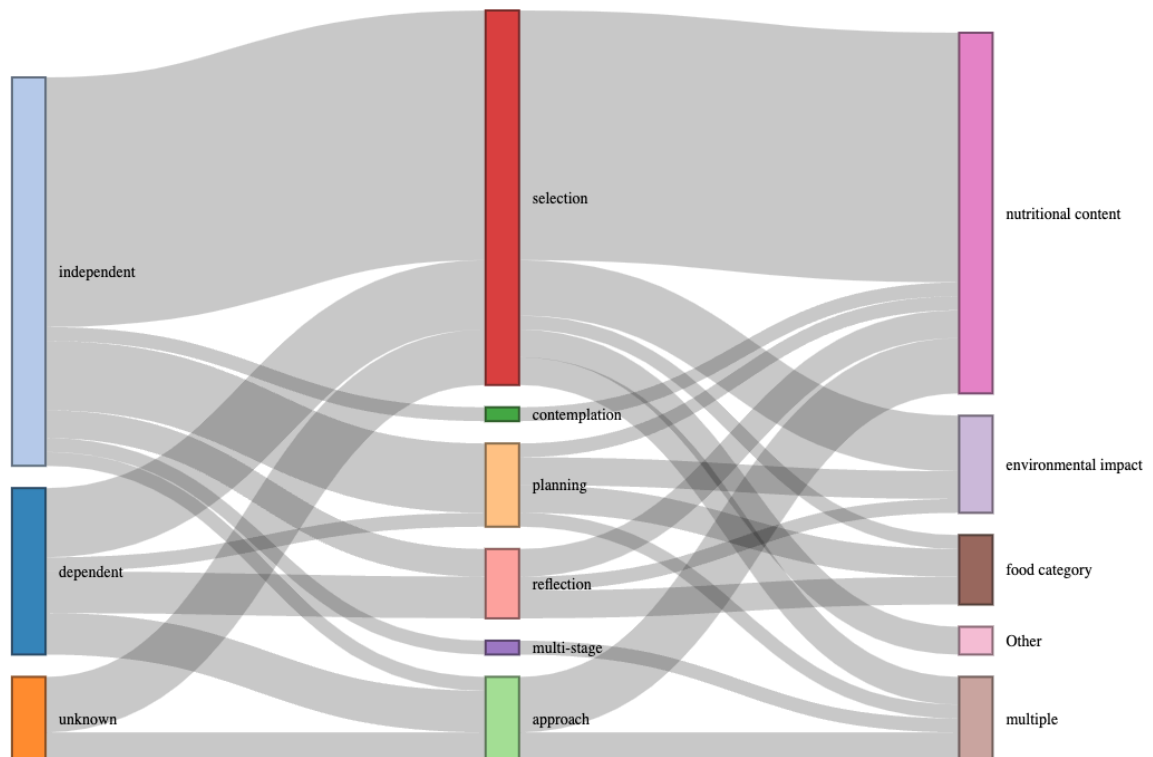


Figure E.1: Sankey Diagram of App Designs in Scoping Systematic Literature Review

Appendix F

Evaluation Studies by Product

Information in Scoping Systematic

Literature Review

Table F.1: Table of evaluation studies by product information in scoping systematic literature review (Chapter 3)

Product Information (PI)	App name	Citation	Design/duration/participants	Findings
Nutritional content	AppX05	Bangia, Shaffner, and Palmer-Keenan (2017)	cohort/6 mnt/251p	sig. increase in omega-3-rich purchases.
	AppX13	Lurz et al. (2023)	cohort/2 wks/31p	n.s. change in the healthiness of purchases.
	Dirk app	van der Laan and Orcholska (2022)	3 UI variations (1x with and 2x with health note and 1x without) vs. control/5 wks/1783 scans	(1) sig. healthier purchase when presenting alternatives without health info, (2) n.s. when adding health info.
	Foodswitch	Eyles, McLean, et al. (2017)	app vs. no app/4 wks/33p + 33p	sig. reduction sodium concentration in purchases.
	Foodswitch	Eyles, Grey, et al. (2023)	app + reduced sodium salt vs. no app/12 wks/84p + 84p	n.s. change sodium intake.
	FutureMe	Mönninghoff et al. (2022)	app + future-self simulation vs. app without/12 wks/42p + 53p	n.s. difference in the healthiness of purchases.
Food category	Healthy Shopping App	Bird et al. (2013)	cohort/4 wks/7p	sig. healthier diet balance of purchases.

Product Information (PI)	App name	Citation	Design/duration/participants	Findings
	MyNutriCart	Palacios et al. (2018)	app vs. education + cohort/8 wks/27p + 24p	sig. healthier diet balance of purchases.
	Nutriflect Home	Reitberger, Spreicer, and Fitzpatrick (2014)	cohort/4 wks/21p	sig. healthier diet balance of purchases.
Environmental impact	EcoPanel	Zapico, Katzeff, et al. (2016)	app vs. no app/5 mnt/65p + 2587p	sig. increase organic purchases.
	GreenCobra	Hedin, Grönborg, and Johansson (2022)	cohort/2 wks/30p	n.s. change in the carbon footprint of purchases.
Multiple	AppX08	Asikis et al. (2021)	cohort/7 mnt/69p + 323p	sig. increase higher-rated purchases.

Appendix G

Challenges and Opportunities Identified in Scoping Systematic Literature Review

Table G.1: Challenges and Opportunities Identified in Scoping Systematic Literature Review (Chapter 3)

citation	Application Type AT	direction	Topic	Details
Vintsarevich et al. (2011)	selection	direct	Interaction, engagement	engagement is limited by the limited product coverage.
Vintsarevich et al. (2011)	selection	direct	Tech. Feasibility, source data	engagement is limited by the limited product coverage.
Broll et al. (2013)	selection	direct	Interaction, burden of use	switching attention between the app and the physical environment is found effortful and information may be missed.
Broll et al. (2013)	selection	direct	Trust, privacy	some feedback modes have privacy issues (audio).

citation	Application Type AT	direction	Topic	Details
Hegen (2016)	selection	indirect	Behavior Change, scope of impact	unfavourable information can deter customer, more so than positive information helps purchase decisions. retailers may be biased to present information in a favourable light, or not be interested in incorporating systems.
Hegen (2016)	selection	indirect	Trust, ulterior motives	unfavourable information can deter customer, more so than positive information helps purchase decisions. retailers may be biased to present information in a favourable light, or not be interested in incorporating systems.

citation	Application Type AT	direction	Topic	Details
Bangia, Shaffner, and Palmer-Keenan (2017)	contemplation	direct	Interaction, learning	the behavioural impact from the knowledge intervention erodes over time.
Bangia, Shaffner, and Palmer-Keenan (2017)	contemplation	indirect	Interaction, learning	study shows significant behavior change impact from a one-off knowledge intervention, with results still significant 6 months after the intervention.
Isley, Ketcham, and Arent (2017)	approach	direct	Tech. Feasibility, performance	computer vision. detection water bottles by image did not work and needed shelf labels.
Isley, Ketcham, and Arent (2017)	approach	indirect	Interaction, other	use of the application was perceived as fun.

citation	Application Type AT	direction	Topic	Details
Herbig, Kahl, and Krüger (2018)	selection	direct	Interaction, burden of use	using a phone to scan an item and inspect the data is perceived as effortful. participants report using such technology only occasionally, not regularly, once per product category only “all participants agreed that such an app is not made to be used every single time”
Herbig, Kahl, and Krüger (2018)	selection	direct	Tech. Feasibility, source data	various dimensions of sustainable data are not readily available and needed to be manually compiled for the study.

citation	Application Type AT	direction	Topic	Details
Herbig, Kahl, and Krüger (2018)	selection	indirect	Interaction, learning	participants state that knowledge about the product category is quickly learned, and there would be little need to use the application again for the product category.
Herbig, Kahl, and Krüger (2018)	selection	indirect	Trust, ulterior motives	recommendation can be perceived as adds (reflecting on recommendations provided by a store-integrated system).

citation	Application Type AT	direction	Topic	Details
Hormann et al. (2019)	approach	direct	Tech. Feasibility, source data	authors report that it was challenging to gather product information due to restricted retailer database access. data maintenance is required due to seasonal changes in retail. a high workload was involved in making unstructured information structured. the provided map of retail space was different from actual layout, leading to inaccurate or incorrect listed location of products. shifting responsibility of the system to the stakeholder may result in challenges and jeopardise the system.

citation	Application Type AT	direction	Topic	Details
Hormann et al. (2019)	approach	direct	Trust, ulterior motives	shifting responsibility of the system to the stakeholder may result in challenges and jeopardise the system.
Asikis et al. (2021)	approach	direct	Tech. Feasibility, source data	considerable effort was involved in establishing the database and the required maintenance may be challenging.
Asikis et al. (2021)	approach	indirect	Interaction, burden of use	the app, used in the store, may be perceived as disrupting to the shopping.
Asikis et al. (2021)	approach	indirect	Trust, ulterior motives	to protect customer privacy, calculations of tailored fit scores were done on the device so that data from the personal profile did not need to be send to the server.

citation	Application Type AT	direction	Topic	Details
S. J. Flaherty et al. (2020)	planning	indirect	Interaction, learning	behavior change can be achieved by disrupting purchasing routines, which lead to a period of more conscious reflection, after which new routines are established.
Tsai et al. (2021)	selection	direct	Tech. Feasibility, source data	2200 labeled images were used to train freshness recognition on one fish species. more labeled images are needed to train other fish species.
Harada et al. (0018–2022)	selection	direct	Tech. Feasibility, performance	computer vision. as articles were loaded into the system, there was a drop in detection accuracy and time required for authentication increased to several seconds.

citation	Application Type AT	direction	Topic	Details
Lurz et al. (2023)	reflection	direct	Tech. Feasibility, source data	product data on openfoodfacts was incomplete for various products and scores could not be calculated for these products. participants could complete the information themselves.
Ahn et al. (2015)	approach	indirect	Tech. Feasibility, performance	achieving sufficient position accuracy was challenging. position data.
Röddiger, Doerner, and Beigl (2018)	approach	direct	Tech. Feasibility, performance	only rectangular shapes can currently be identified.
Fuchs et al. (2019)	selection	direct	Interaction, engagement	unexpected high level of drop-out.

citation	Application Type AT	direction	Topic	Details
Fuchs et al. (2019)	selection	indirect	Interaction, engagement	tailoring labels appears to have improved engagement with the application, compared to standard nutrition labels.
Fuchs et al. (2019)	selection	indirect	Tech. Feasibility, source data	70% of the scanned barcodes could be identified.
Mahdi, Chilcott, and Buckland (2022)	selection	direct	Interaction, engagement	high levels of dropout, decreases in engagement over time, low acceptability to aid purchases.
van der Laan and Orcholska (2022)	selection	direct	Trust, ulterior motives	people may perceive nudges as manipulative and show reactance against it.

citation	Application Type AT	direction	Topic	Details
Normark and Tholander (2014)	selection	direct	Interaction, burden of use	users expect an application like ecofriends to ‘simplify’ for them in making responsible and sustainable actions. The violation of this expectation causes irritation and poor acceptability.
Bohné, Zapico, and Katzeff (2015)	reflection	indirect	Behavior Change, scope of impact	retailer incentives limit opportunities in data presentation. the store may not engage if the customer receives too much information. presenting biological information is possible because they lead to higher sales prices.

citation	Application Type AT	direction	Topic	Details
Bohné, Zapico, and Katzeff (2015)	reflection	indirect	Trust, ulterior motives	retailer incentives limit opportunities in data presentation. the store may not engage if the customer receives too much information. presenting biological information is possible because they lead to higher sales prices.
Zapico, Katzeff, et al. (2016)	reflection	direct	Behavior Change, scope of impact	limited to the specific retailer.
Zapico, Katzeff, et al. (2016)	reflection	indirect	Behavior Change, barriers to change	putting choices into perspective: monitoring makes behavior visible and actionable, a barrier to behavior change is the difficulty of inability to mentally aggregate data.

citation	Application Type AT	direction	Topic	Details
Zapico, Katzeff, et al. (2016)	reflection	indirect	Behavior Change, scope of impact	a central aspect to persuasive (aka non-coercive) technology is that it supports pre-established values and intentions. this limits the scope of impact to those that are interested in the behavior.
Zapico, Katzeff, et al. (2016)	reflection	indirect	Interaction, engagement	only few visits to the system. participants quickly make sense of the information (learn). the number of visits did not correlate with the behavior change impact.
Zapico, Katzeff, et al. (2016)	reflection	indirect	Interaction, learning	the first view was most determining for behavior impact.

citation	Application Type AT	direction	Topic	Details
Samoggia and Riedel (2020)	selection	direct	Interaction, learning	subjective health knowledge is higher than objective knowledge. this may lead to over-confidence in an individuals food knowledge and result in preliminary abandonment of the technology.
Samoggia and Riedel (2020)	selection	indirect	Interaction, engagement	subjective health knowledge is higher than objective knowledge. this may lead to over-confidence in an individuals food knowledge and result in preliminary abandonment of the technology.

citation	Application Type AT	direction	Topic	Details
Lawo et al. (2021)	planning	direct	Interaction, burden of use	participants report resistance to engaging with the shopping list app at the moment of list creation. use of the tool is perceived as too effortful for that. The tool is used for exploring new products instead.
Lawo et al. (2021)	planning	direct	Interaction, engagement	the app information is used infrequently, not on every trip.
Lawo et al. (2021)	planning	direct	Tech. Feasibility, source data	the complexity of choice factors makes it nearly impossible to recommend the 'right' product.
Lawo et al. (2021)	planning	direct	Tech. Feasibility, performance	data errors lead to disTrust in the system.

citation	Application Type AT	direction	Topic	Details
Lawo et al. (2021)	planning	direct	Trust, performance	data errors lead to disTrust, and negativity impact technology use.
Lawo et al. (2021)	planning	indirect	Trust, ulterior motives	even supposedly consumer-friendly third parties do not have transparent recommender algorithms.
Lawo et al. (2021)	planning	indirect	Trust, ulterior motives	people may be willing to exchange Trust for convenience (ease of use): participants request outsourced profiles.

citation	Application Type AT	direction	Topic	Details
A. Clear and F. Friday (2012)	planning	indirect	Interaction, learning	additional information with tips is available to address different levels of motivation. this way a balance is sought between the need for minimal interruption and maximizing impact.
Dunford et al. (2014)	selection	direct	Behavior Change, scope of impact	the scope of a behaviour intervention is limited to small subset of engaged app users.
Eyles, McLean, et al. (2017)	selection	direct	Interaction, engagement	low response rate. 32% declined participation for dislike of using an app to guide choices.

citation	Application Type AT	direction	Topic	Details
Eyles, Grey, et al. (2023)	selection	direct	Interaction, engagement	limited use of the app, per person average was 29 items scanned in 12 weeks of the intervention. lack of time, difficulty in use of technology, and limited products covered by the system were barriers to using the system.
Eyles, Grey, et al. (2023)	selection	indirect	Tech. Feasibility, source data	the app did not return information for all scanned items and this was disliked by the participants.

citation	Application Type AT	direction	Topic	Details
Mönninghoff et al. (2022)	reflection	direct	Interaction, engagement	high attrition that was attributed to disTrust in tailored simulation performance, challenges in the setup, discouragement by negative feedback, limited scope of the data that covers only 2 retail chains and step count as exercise measure, however very well received for those participants that were well covered by the two retailer chains and step counting.
Mönninghoff et al. (2022)	reflection	direct	Behavior Change, scope of impact	by using a loyalty card api, the scope is limited to only 2 (largest) retail chains.

citation	Application Type AT	direction	Topic	Details
Mönninghoff et al. (2022)	reflection	direct	Trust, ulterior motives	data accessed through the loyalty card api is regulated by law.
Hedin, Grönborg, and Johansson (2022)	planning	direct	Behavior Change, barriers to change	competing priorities: participants report lacking resources (time and ideas) to come up with alternatives for the 'bad' products. competing priorities (price, health reasons) restrict opportunities for change.

citation	Application Type AT	direction	Topic	Details
Hedin, Grönborg, and Johansson (2022)	planning	direct	Behavior Change, barriers to change	putting choices into perspective: participants struggle with determining which problem areas to prioritise (the app provides carbon footprint values per 100g, but typical purchase quantities vary a lot between products). participants struggle with subjectivity evaluating how good/bad a score is, since the score is abstract.
Hedin, Grönborg, and Johansson (2022)	planning	indirect	Tech. Feasibility, performance	some characters were not accurately read from the receipt, causing items not to be identified correctly.
Hedin, Grönborg, and Johansson (2022)	planning	indirect	Interaction, learning	learning was observed.

citation	Application Type AT	direction	Topic	Details
Hedin, Grönborg, and Johansson (2022)	planning	indirect	Trust, privacy	using the phone camera to detect products has privacy issues.
Tomlinson (2008)	selection	direct	Interaction, engagement	slow technical performance and mixed quality of user reviews were a hindrance to engagement.
Tomlinson (2008)	selection	direct	Tech. Feasibility, performance	slow technical performance and mixed quality of user reviews were a hindrance to engagement.
Bird et al. (2013)	reflection	indirect	Behavior Change, barriers to change	preferences: participants improved their overall diet balance, but struggled meeting fruit and vegetable targets

citation	Application Type AT	direction	Topic	Details
Bird et al. (2013)	reflection	indirect	Trust, ulterior motives	data from a store independent application is more likely to be Trusted than from a store dependent application.
Waltner, Schwarz, Ladstätter, Weber, Luley, Bischof, et al. (2015)	selection	indirect	Tech. Feasibility, performance	computer vision. recognition accuracy around 80%.
Waltner, Schwarz, Ladstätter, Weber, Luley, Lindschinger, et al. (2017)	selection	indirect	Tech. Feasibility, performance	computer vision. recognition accuracy ranges from 52-94%.
Bomfim, Kirkpatrick, et al. (2020)	planning	direct	Behavior Change, barriers to change	preferences: participant struggled meeting fruit and vegetable targets
Bomfim, Kirkpatrick, et al. (2020)	planning	indirect	Interaction, other	use of the application was perceived as fun.

citation	Application Type AT	direction	Topic	Details
López et al. (2017)	planning	direct	Behavior Change, barriers to change	preferences: dislike for, and unavailability of recommendations limited acceptance of recommended purchases. only 37% of recommended items are purchased. this is argued to be the main reason for an insignificant result.
López et al. (2017)	planning	direct	Interaction, engagement	1/3 of participants dropped out. only 37% of recommended items are purchased.

citation	Application Type AT	direction	Topic	Details
Reitberger, Spreicer, and Fitzpatrick (2014)	reflection	indirect	Behavior Change, barriers to change	putting choices into perspective: users reported that their memories of their diet balance from the nutriflect home system were unreliable and that syncing the selection app with the monitoring app helped making the right choices
Reitberger, Spreicer, and Fitzpatrick (2014)	reflection	indirect	Behavior Change, scope of impact	by sharing the feedback within the household, the impact extends beyond an individual user. social facilitation extends the impact. involving others.
Reitberger, Spreicer, and Fitzpatrick (2014)	reflection	indirect	Interaction, burden of use	external factors limit the opportunities to interact with technology in the store.

citation	Application Type AT	direction	Topic	Details
Reitberger, Spreicer, and Fitzpatrick (2014)	reflection	indirect	Interaction, other	participants express preference for the more informative visualization.
Reitberger, Spreicer, and Fitzpatrick (2014)	selection	indirect	Behavior Change, barriers to change	putting choices into perspective: users reported that their memories of their diet balance from the nutriflect home system were unreliable and that syncing the selection app with the monitoring app helped making the right choices
Reitberger, Spreicer, and Fitzpatrick (2014)	selection	indirect	Behavior Change, scope of impact	by sharing the feedback within the household, the impact extends beyond an individual user. social facilitation extends the impact. involving others.

citation	Application Type AT	direction	Topic	Details
Reitberger, Spreicer, and Fitzpatrick (2014)	selection	indirect	Interaction, burden of use	external factors limit the opportunities to interact with technology in the store.
Reitberger, Spreicer, and Fitzpatrick (2014)	selection	indirect	Interaction, other	participants express preference for the more informative visualization.
Bomfim, Kirkpatrick, et al. (2020)	multi-stage	direct	Behavior Change, barriers to change	preferences: participant struggled meeting fruit and vegetable targets
Bomfim, Kirkpatrick, et al. (2020)	multi-stage	indirect	Interaction, other	use of the application was perceived as fun.
Head et al. (2014)	selection	indirect	Tech. Feasibility, source data	effort involved in creating the database has led to retailers abandoning efforts to do so in the past.
S.-J. Flaherty et al. (2018)	reflection	direct	Interaction, burden of use	manually logging items is found effortful and reduces acceptability.

citation	Application Type AT	direction	Topic	Details
S.-J. Flaherty et al. (2018)	reflection	direct	Interaction, engagement	low nutrition quality, potentially hindering engagement.
S.-J. Flaherty et al. (2018)	reflection	direct	Tech. Feasibility, source data	low nutrition quality, potentially hindering engagement.
S.-J. Flaherty et al. (2018)	reflection	indirect	Behavior Change, scope of impact	an smartphone app is easily scalable and can thus reach many people.
Mauch, Wycherley, et al. (2018)	multi-stage	direct	Interaction, engagement	application score relatively poorly on engagement. authors recommend designs to be improved to attain better engagement.
Mauch, Laws, et al. (2021)	multi-stage	direct	Interaction, engagement	application score relatively poorly on engagement. authors recommend designs to be improved to attain better engagement.

citation	Application Type AT	direction	Topic	Details
Mauch, Laws, et al. (2021)	multi-stage	indirect	Interaction, burden of use	participant balance benefit with the use burden that the app gives. many participants found they had no need for the scanning app.

Appendix H

Participant Information and Informed Consent (Chapter 4)

Participant Information Sheet

Title of Study: MyFoodPrint workshop

Document version: 1

Document date: 12 May 2021

Conductors: Anonymous

Contact: Email me on anonymous@anonymous.org, or call me on 012 34 12345. You can also contact our lab team at anonymous@anonymous.org, or, by phone on 012 34 12345. Anonymous

Description: You are invited to participate in a research study that aims to understand how a grocery purchase tracking application should be designed. The application should help people find acceptable solutions to reduce the footprint of their purchased groceries.

Due to COVID-19 related restrictions, the workshop will take place entirely online. You will receive a Zoom call invitation and at the start of the session, you will receive a link to the workshop board, using the platform Miro. If you have any doubts

During the workshop you will do a few card sorting tasks and take part in discussions with your fellow (max 5) participants. The tasks and discussions concern your priorities when grocery shopping, and what you would like to see in an application that gives you insight in your grocery footprint. The exact procedure will be explained at the start of the task. Clarifications can be asked at any time.

Please note your participation in this research is voluntary and you may choose to withdraw your participation at any time without any penalty. You also have the right to refuse to answer questions.

Risks: There are no known risks. If you do feel upset at any aspects of the discussion, then please feel free to stop the discussion at any time.

Confidentiality: Yes, everything discussed will be confidential. All information will be stored anonymously. All participants of the focus group, as well as the conductor are bound by confidentiality to assure that no one, apart from those present at the interview, will know what was said by whom. There is a small risk for breaches of said confidentiality, but the topic and questions of the focus group have all been evaluated to not be privacy-critical and you are free to refrain from answering any questions. We will be writing up parts of our interview at which point I will anonymise what you say. Only we will have access to any recordings for the purposes of this research project.

Duration: Your participation will take approximately one hour.

Audio/video/photographic recordings: The workshop will be recorded in support of the scientific analysis. The recordings will only be accessible to the primary researcher (Remco). In case I would like to use any part of the recording for other purposes than the anonymized analysis, I will request explicit consent of anyone identifiable in that part of the recording. You may deny that consent without any repercussions.

Informed consent

- I confirm I am over 17 years old and that I have read and understood the Participant Information Sheet (above). – YOUR ANSWER
- I have had the opportunity to consider the Participant Information Sheet, ask questions and had my questions answered satisfactorily. – YOUR ANSWER
- I understand that any audio and photographic recordings will be used for research purposes only. – YOUR ANSWER
- I understand my name and any personal information will be anonymised in any reports resulting from this study. – YOUR ANSWER
- I understand I can withdraw my participation at any time without giving a reason. – YOUR ANSWER
- I understand I can request all my information to be deleted if I make the request up to four weeks after this participation. – YOUR ANSWER

Appendix I

BCW worksheets - Identify intervention options following the Behaviour Change Wheel (Chapter 5)

1 Supplement. Identify intervention options following the Behaviour Change Wheel (Michie, Atkins and West, 2014)

Problem: product purchases seemingly inconsistent with values

Question	Response
What behaviour?	Making product purchases inconsistent with values of climate-sustainability.
Where does the behaviour occur?	Grocery store, online grocery order portal, farmers market.
Who is involved in performing the behaviour?	Household members conducting grocery purchases.

Table 1, Worksheet 1 – Define the problem in behavioural terms

Potential target behaviours
Reflection on new information; reminder of intention; outsourcing decisions; intentionally (and freely) purchasing lower foodprint items; automatically purchasing lower foodprint items; autonomously purchasing lower foodprint items.

Table 2, Worksheet 2 – Select the target behaviour

Target behaviour: autonomously choose to replace products with lower foodprint alternatives.

Question	Response
<i>Who</i> needs to perform the behaviour?	The household member who is going to make the grocery purchases.
<i>What</i> do they need to do differently?	Given information about the foodprint of a product, they need to reflect whether a purchase of the product aligns with their values and, if not, choose a more suitable alternative.
<i>When</i> do they need to do it?	Reflection: any time, purchase: when purchasing groceries
<i>Where</i> do they need to do it?	Reflection: anywhere, purchase: at the point-of-purchase
<i>How often</i> do they need to do it?	Reflection: once (at least). Purchase: several time a week or less (depending on the level of exposure to products inconsistent with their values).
<i>With whom</i> do they need to do it?	Either alone or in discussion with household members.

Table 3, Worksheet 3 – Specify the target behaviour

Com-B Model	Needs to happen for the target behaviour to occur	Change needed?
Physical Capability	NA	No
Physiological Capability	Need to belief that better alternatives exist. Needs to belief that they are able to identify alternatives with acceptable ease.	Yes
Physical Opportunity	Needs access to alternative products	No
Social Opportunity	Needs to identify alternatives acceptable to the household.	Yes
Reflective Motivation	Needs to belief that the reduction in value-behaviour gap outweighs the (cognitive) costs of searching and testing alternatives.	Yes
Automatic Motivation	NA. Not consistent with autonomous behaviour.	No
Behavioural diagnosis of the relevant COM-B components: knowledge and beliefs should be altered.		

Table 4, Worksheet 4 – Identify what needs to change

COM-B	TFD	Relevance of the domain
Physical capabilities	Physical skills	NA.
Psychological capabilities	Knowledge	People need to have knowledge about the footprint of their current choices and the relative footprint of viable alternative choices.
	Cognitive and interpersonal skills	NA. However, it is acknowledged that people need to have sufficient cognitive resources to engage in the reflection and that this may pose a barrier.
	Memory, attention and decision processes	NA. However, it is acknowledged that deficiencies in these processes can thwart the behaviour outcome (eg, people may mis-remember, forget, be inattentive, or get distracted, and fall back on habitual choices or select suboptimal alternatives).
Physical opportunity	Behavioural regulation	NA. However, it is acknowledged that impulses may interfere with rational choices at point-of-purchase.
	Environmental context and resources	NA. However, it is acknowledged that better alternatives need to be accessible.
Social opportunity	Social influences	NA. However, it is acknowledged that social unacceptability of the alternative purchases can pose a barrier to change.
Reflective motivation	Professional/social role and identity	NA. However, it is acknowledged that a target behaviour is only likely to follow if the person identifies with climate sustainable values.
	Beliefs about capabilities	The person needs to believe that they can identify alternative items that are both (a) lower in footprint and (b) viable as an alternative.
	Optimism	As above.

	Beliefs about consequences	People need to be aware of the consequences of their purchases on their footprint.
	Intentions	People need to form intentions to replace certain items in the future, and form intentions about the purchases to replace these with (not necessarily simultaneously).
	Goals	NA. As behaviour change should result autonomously, their value-informed goals should not actively be addressed.
Automatic motivation	Reinforcement	NA. Reinforcement interventions seem inconsolable with autonomously driven behaviour.
	Emotions	NA. Emotion interventions seem inconsolable with autonomously driven behaviour.

Table 5, Worksheet 4a – Identify what needs to change using the Trans-Domain Framework (TDF)

Candidate intervention functions	Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness/cost-effectiveness, acceptability, side-effects/safety, equity)?
Education	Yes (in the form of an eco-feedback application)
Persuasion	Only in truest sense of persuasion, where only the unbiased information persuades. There is no sense (emotional) pressure.
Incentivisation	No. In this case the behaviour is no longer value driven; it distracts from it.
Coercing	No, this interferes with autonomy.
Training	No, it is not economically and practically feasible to train people
Restriction	No, this interferes with autonomy.
Environmental restructuring	No, this interferes with autonomy.
Modelling	Slightly. Only to inform how something can be done. And it may be restricted by applicability (food choices are rather individual).
Enablement	No, not along the definition in the BCW (eg, increasing means/reducing barriers to increase capability [beyond education and training]) or opportunity [beyond environmental restructuring]).
Selected intervention functions:	Education and (in its purest form) persuasion

Table 6, Worksheet 5 – Identify intervention functions

Michie, S., Atkins, L. and West, R. (2014) *The behaviour change wheel: a guide to designing interventions*. London: Silverback Publishing.

Appendix J

Survey for Prototype Version 1 (Chapter 5)

Preferred visualization

* Required

1. Email *

2. Which information would you view most frequently? *



Mark only one oval.

- #1
- #2
- #3
- #4

3. ...second most frequent... *

Mark only one oval.

- #1
- #2
- #3
- #4

4. ...third most frequent... *

Mark only one oval.

- #1
- #2
- #3
- #4

5. Which of these screens would you use most often? *

1 Item footprint ▾

DAY TOTAL

2 Item footprint (per 100g) ▾

DAY TOTAL

3 Item footprint (per kcal) ▾

DAY TOTAL

Mark only one oval.

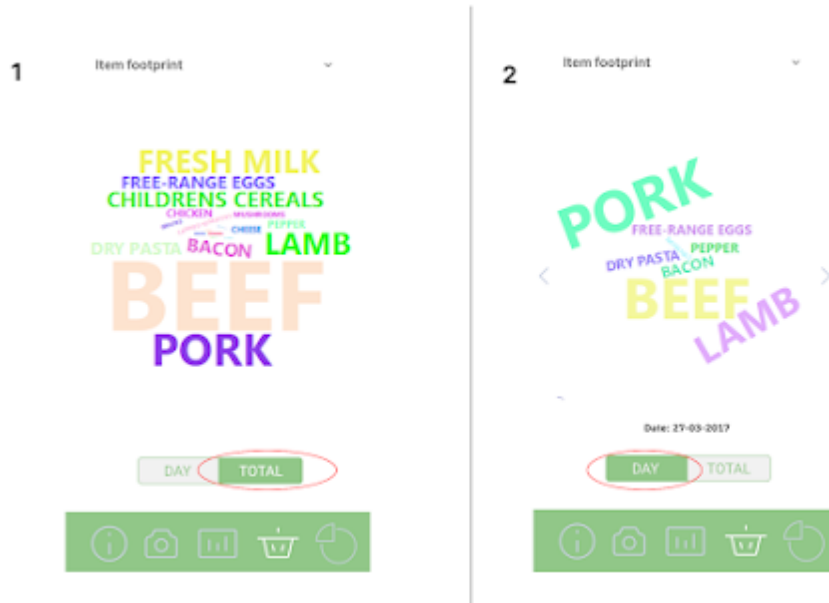
- #1
- #2
- #3

6. ...next most often...

Mark only one oval.

- #1
- #2
- #3

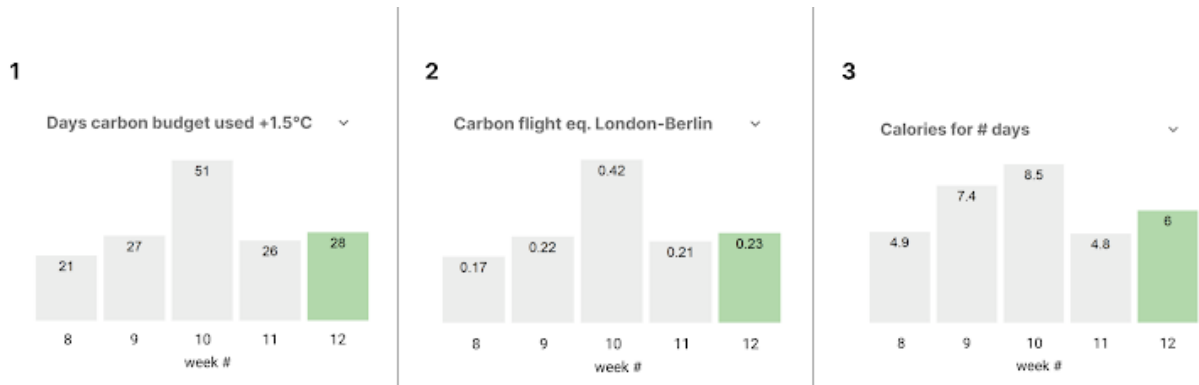
7. Which would you use more often? *



Mark only one oval.

- #1
- #2

8. Which would you use more often? *



Mark only one oval.

- #1
- #2
- #3

9. ...next most often... *

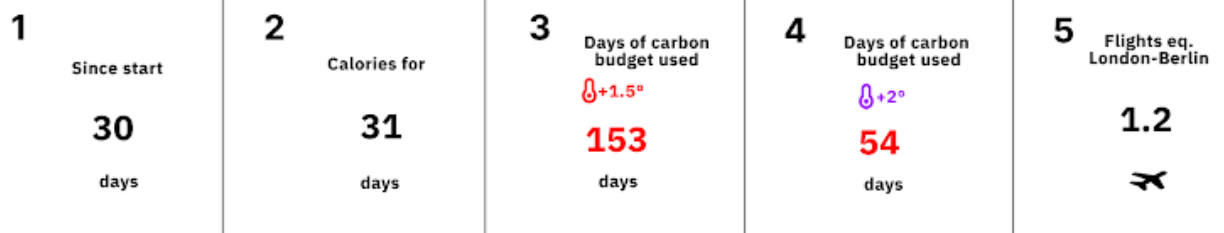
Mark only one oval.

#1

#2

#3

10. Which information would you consult most often *



Mark only one oval.

#1

#2

#3

#4

#5

11. ...and then... *

Mark only one oval.

#1

#2

#3

#4

#5

12. ...and then... *

Mark only one oval.

#1

#2

#3

#4

#5

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Appendix K

Survey for Prototype Version 2 (Chapter 5)

Preferred visualization

* Required

1. Email *

2. Which information would you view most frequently? *

1

Days carbon budget used +1.5°C

week #	Days carbon budget used
8	21
9	27
10	51
11	26
12	28

2

All time statistics		
Since start	Flights eg. London-Berlin	Calories for
30 days	1.2 ✈️	31 days
Days of carbon budget used		
+1.5°		+2°
153 days		54 days

3

FRESH MILK
FREE-RANGE EGGS
CHILDRENS CEREALS
CHICKEN
MUESLI
CHEESE
PEPPER
DRY PASTA
BACON
LAMB
BEEF
PORK

4

Stacked bar chart showing food categories: Whole grains, Starchy veg, Dairy, Protein sources, and Added sugar.

Mark only one oval per row.

	#1	#2	#3	#4
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. Which of these screens would you use most often? *

1 Item footprint

DAY TOTAL

2 Item footprint (per 100g)

DAY TOTAL

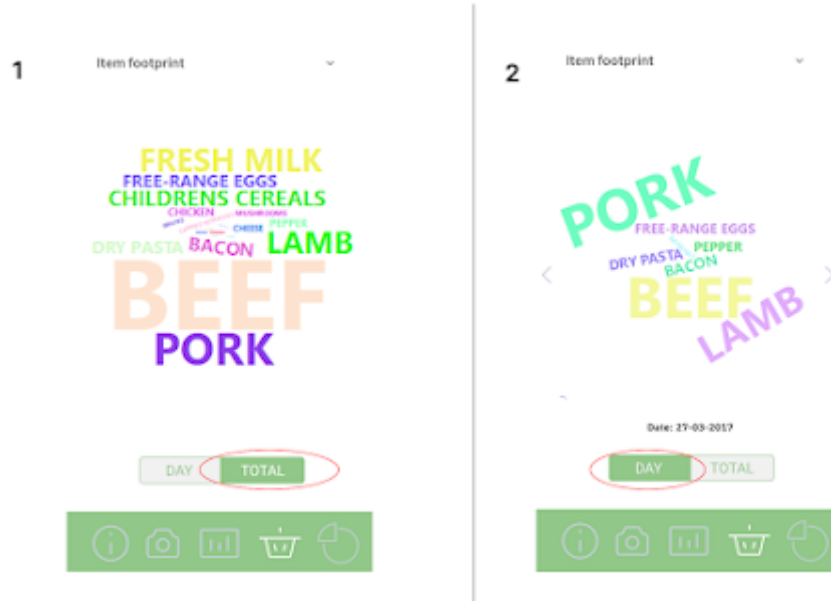
3 Item footprint (per kcal)

DAY TOTAL

Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

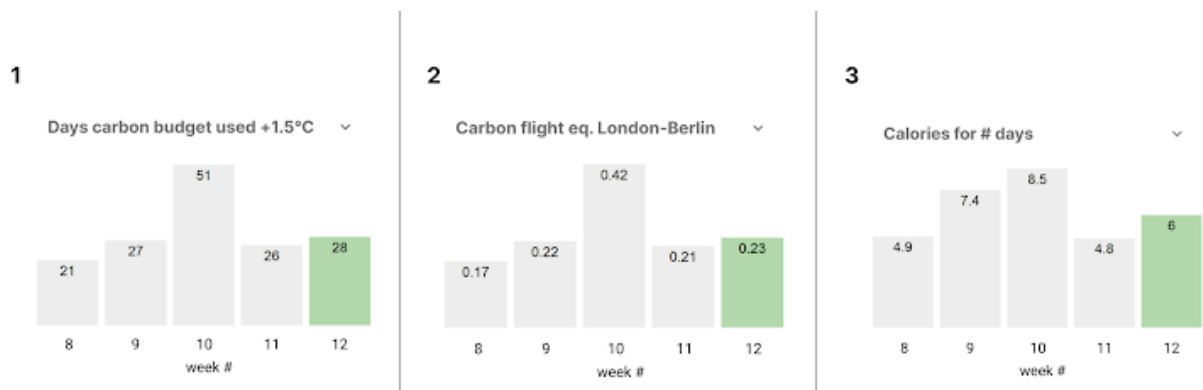
4. Which would you use more often? *



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

5. Which would you use more often? *



Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. Which information would you consult most often *

<p>1</p> <p>Since start</p> <p>30</p> <p>days</p>	<p>2</p> <p>Calories for</p> <p>31</p> <p>days</p>	<p>3</p> <p>Days of carbon budget used</p> <p> +1.5°</p> <p>153</p> <p>days</p>	<p>4</p> <p>Days of carbon budget used</p> <p> +2°</p> <p>54</p> <p>days</p>	<p>5</p> <p>Flights eq. London-Berlin</p> <p>1.2</p> <p></p>
---	--	---	--	--

Mark only one oval per row.

	#1	#2	#3	#4	#5
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second least	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Appendix L

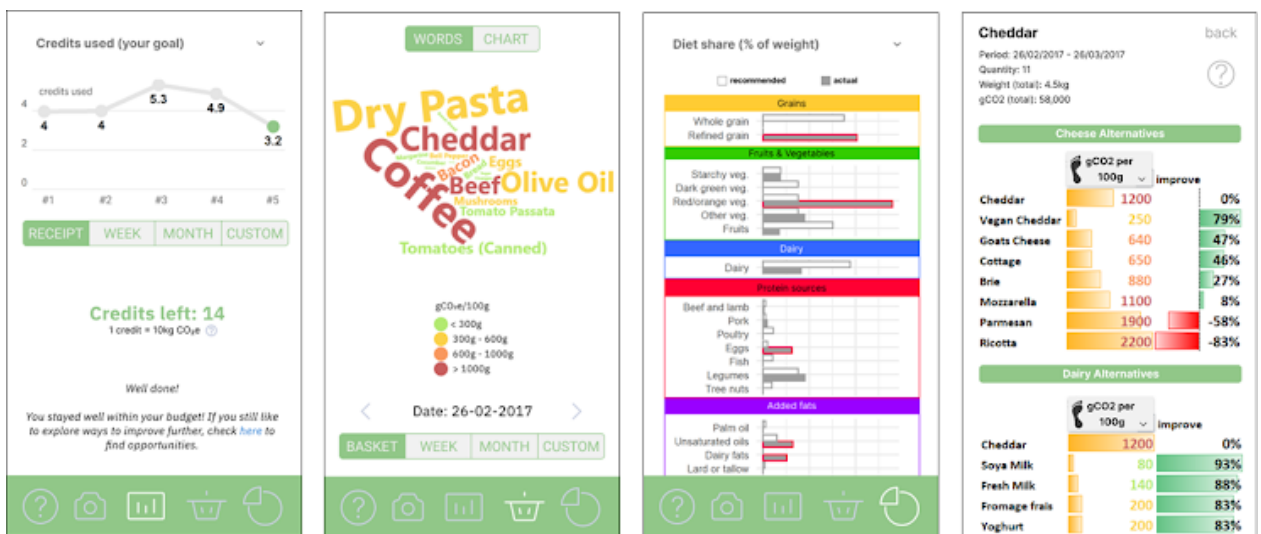
Survey for Prototype Version 3 (Chapter 5)

Preferred visualization

* Required

1. Email *

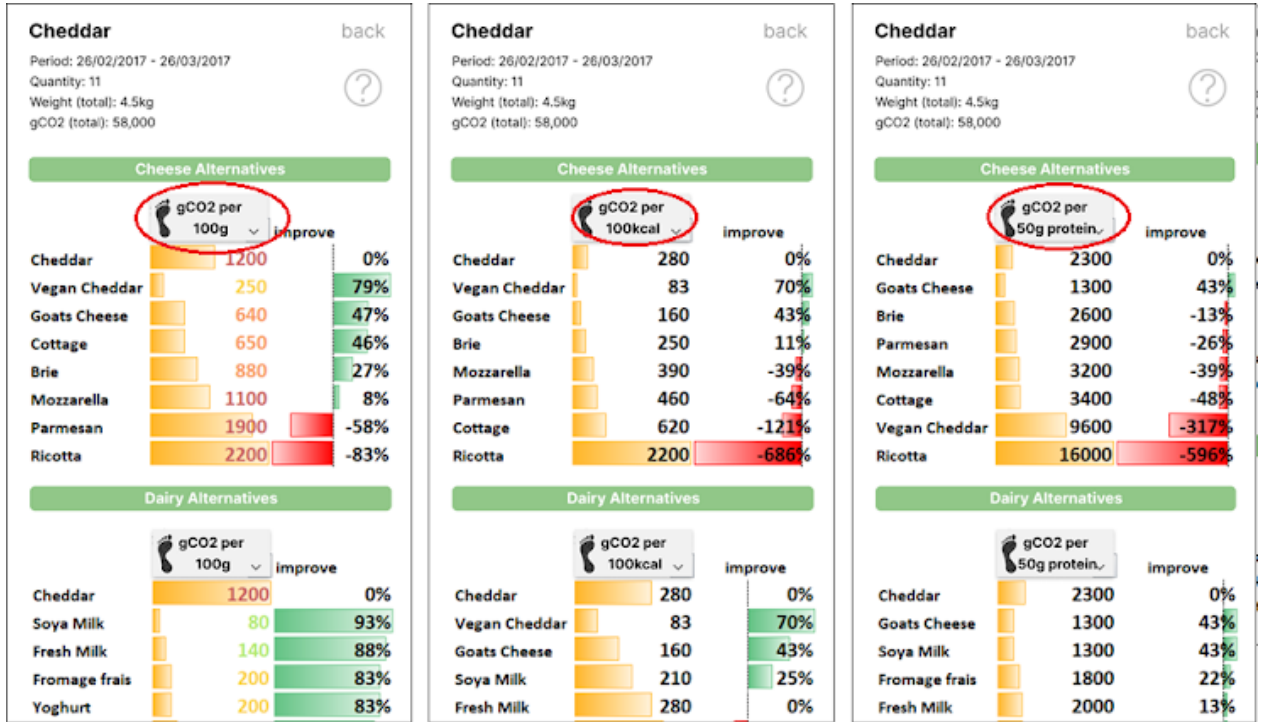
2. Which information would you view most frequently? *



Mark only one oval per row.

	#1	#2	#3	#4
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

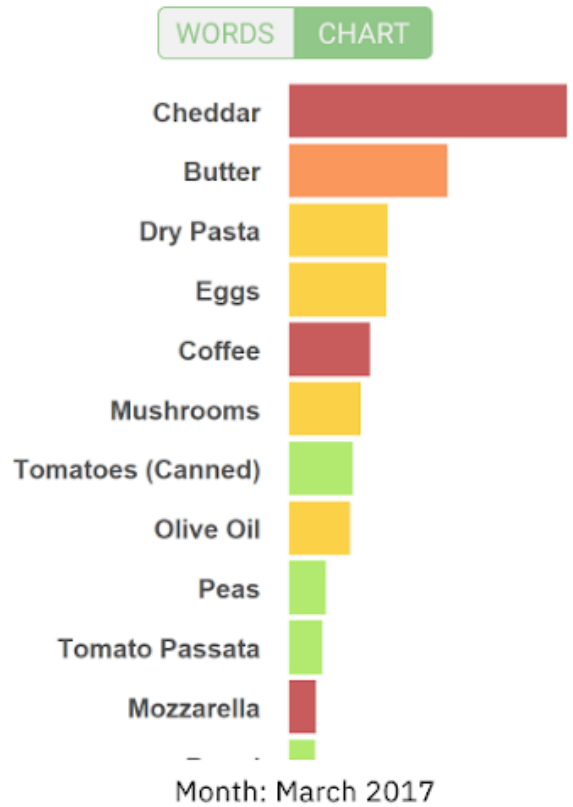
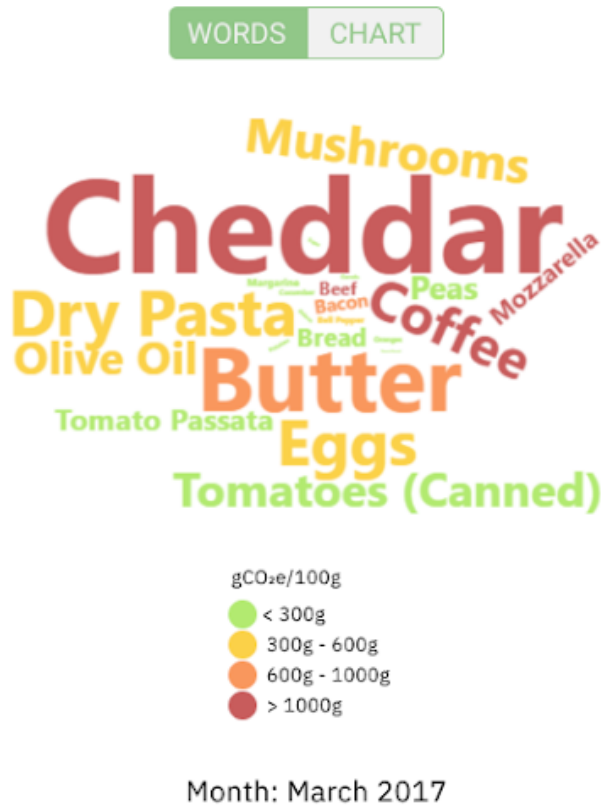
3. Which of these screens would you use most often? *



Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. Which would you use more often? *



BASKET WEEK MONTH CUSTOM

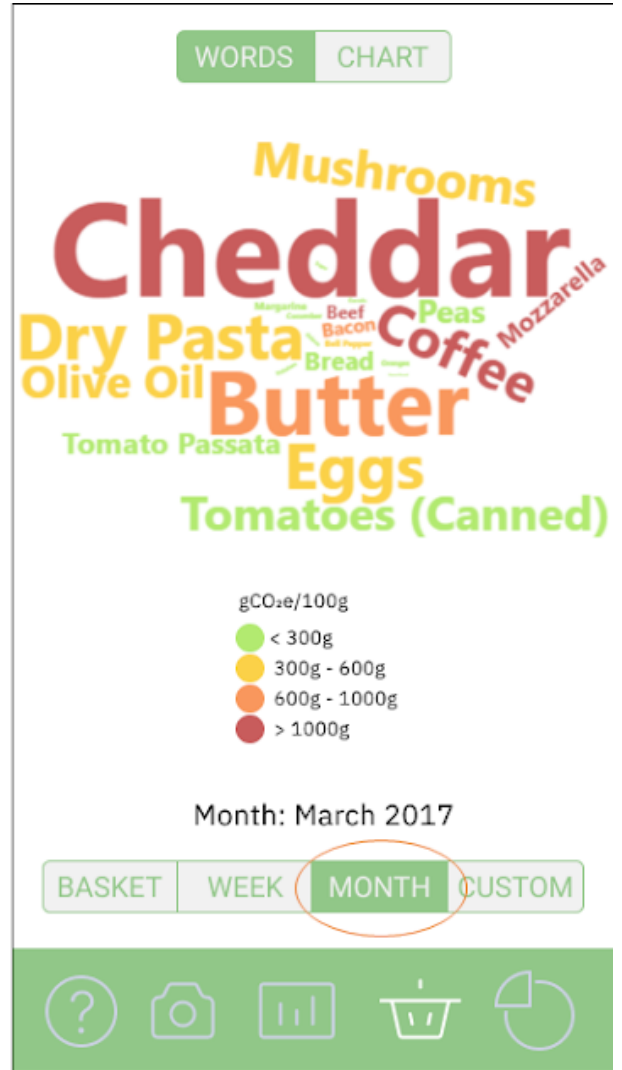
BASKET WEEK MONTH CUSTOM



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

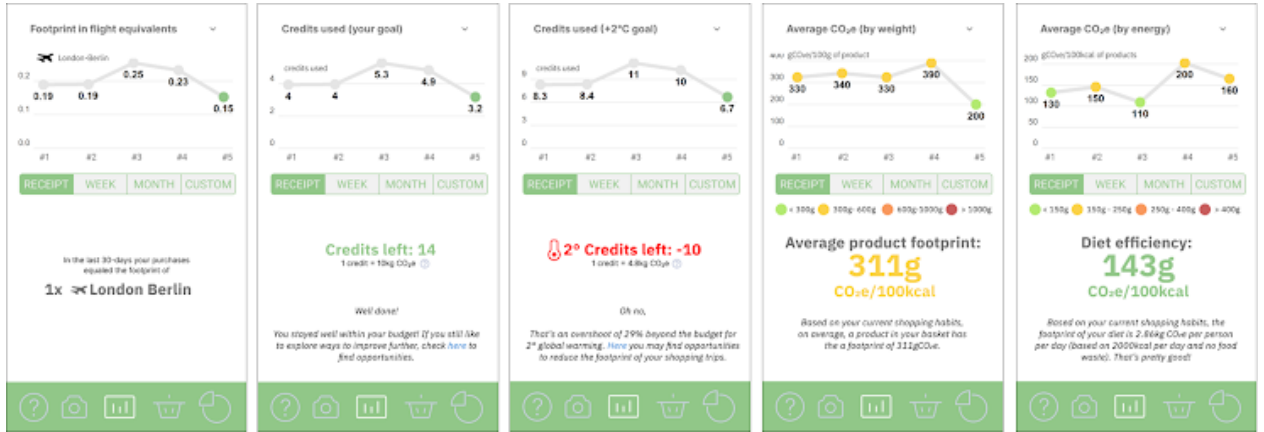
5. Which would you use more often? *



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

6. Which information would you consult most often *



Mark only one oval per row.

	#1	#2	#3	#4	#5
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second least	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Appendix M

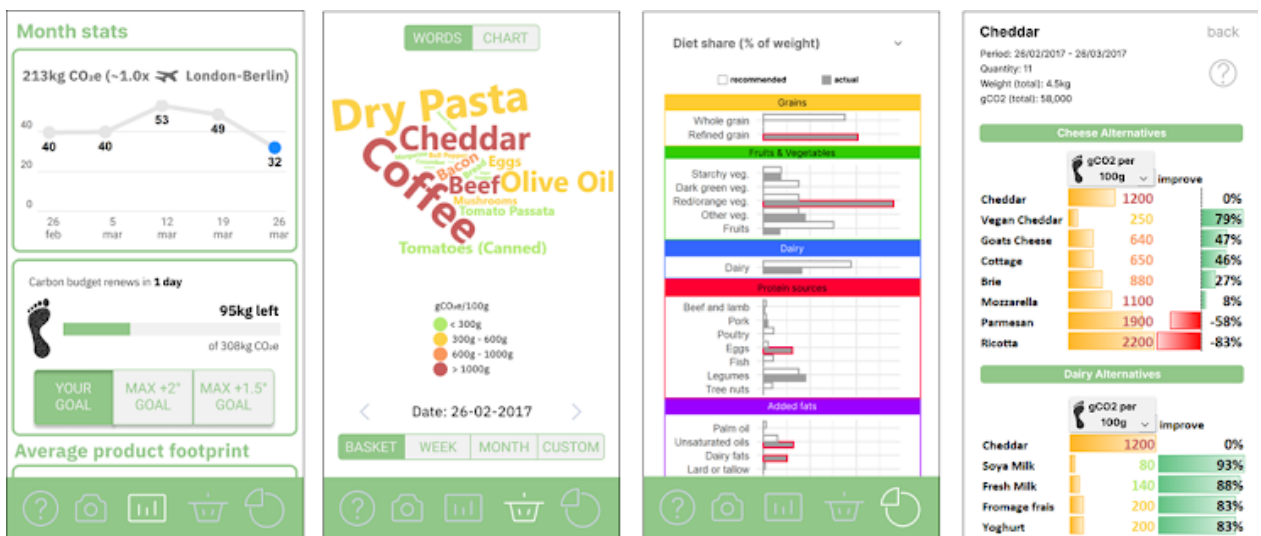
Survey for Prototype Version 4 (Chapter 5)

Preferred visualization

* Required

1. Email *

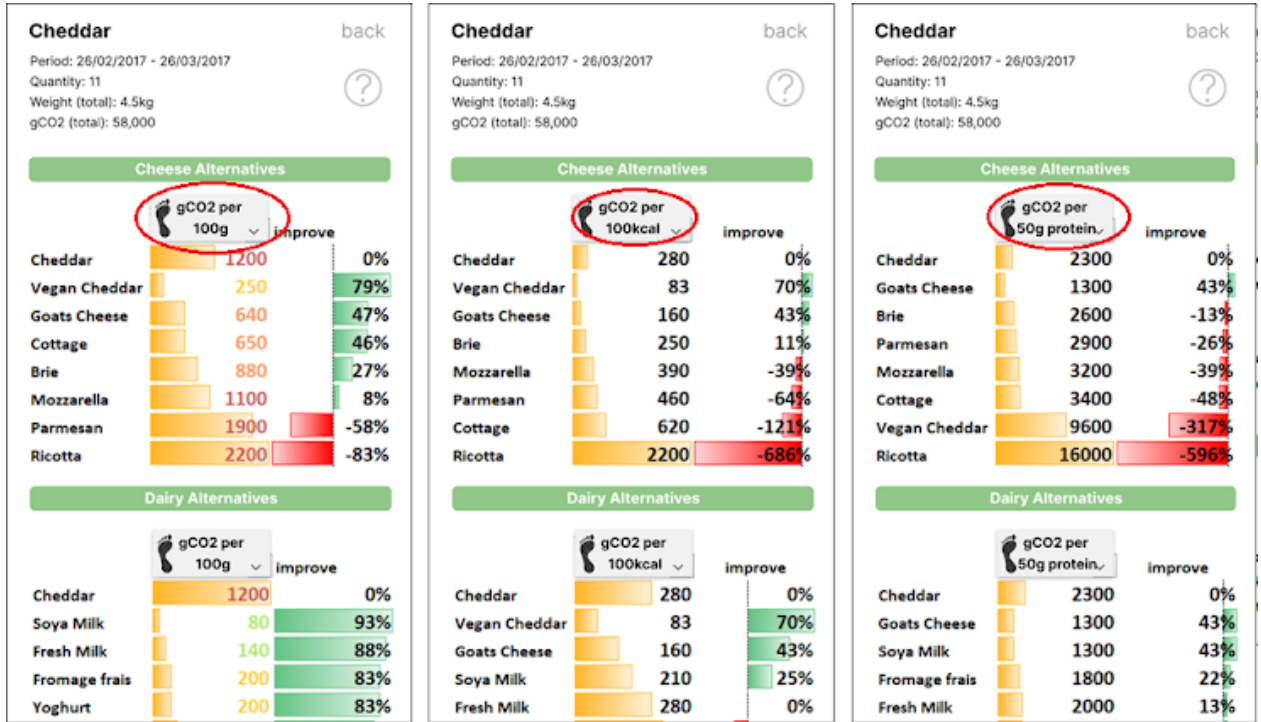
2. Which information would you view most frequently? *



Mark only one oval per row.

	#1	#2	#3	#4
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Third most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

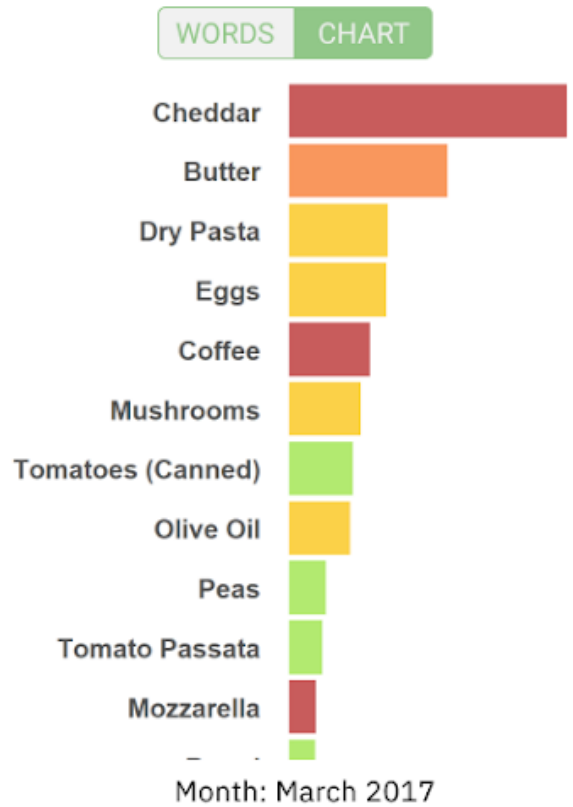
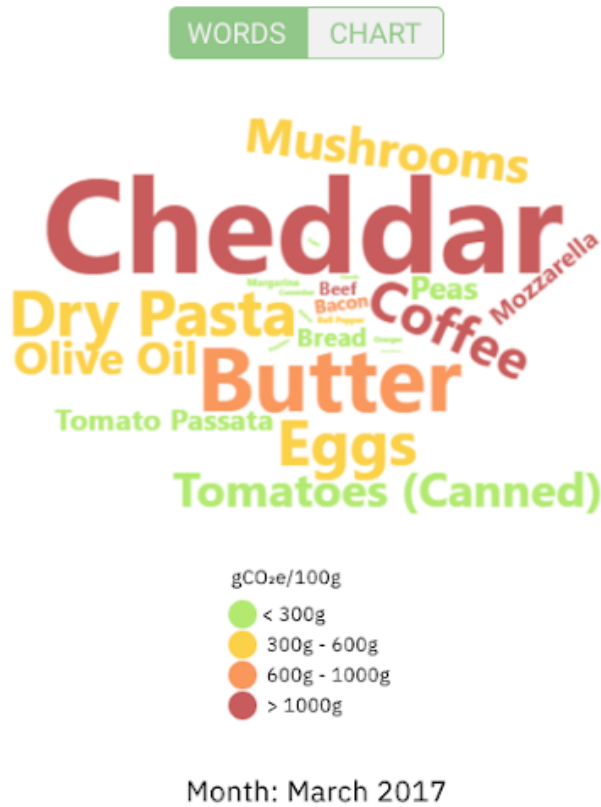
3. Which of these screens would you use most often? *



Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. Which would you use more often? *



BASKET WEEK MONTH CUSTOM

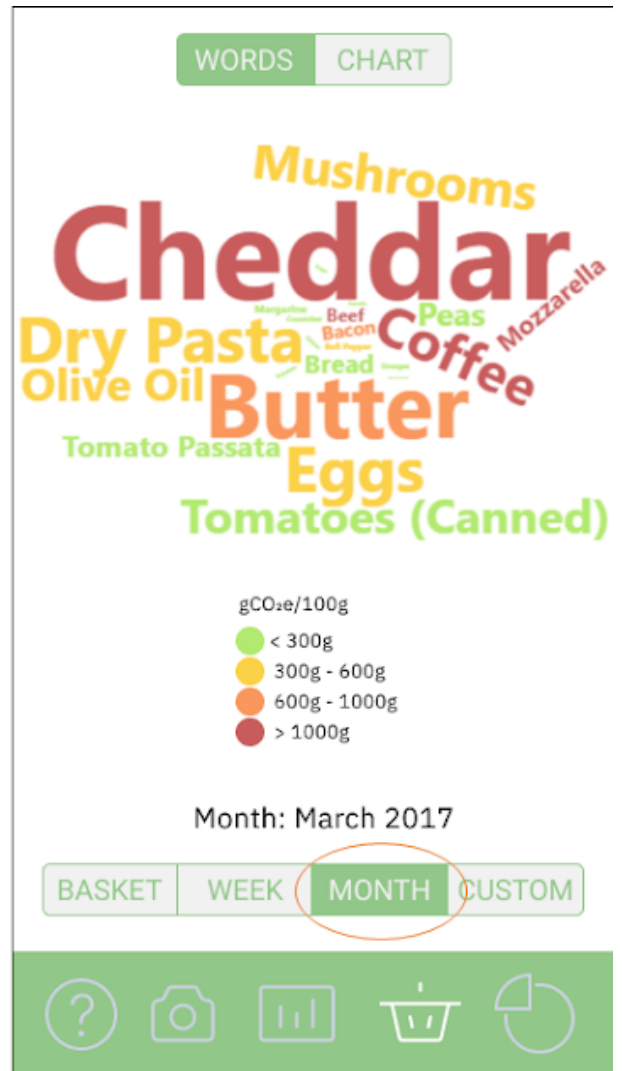
BASKET WEEK MONTH CUSTOM



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

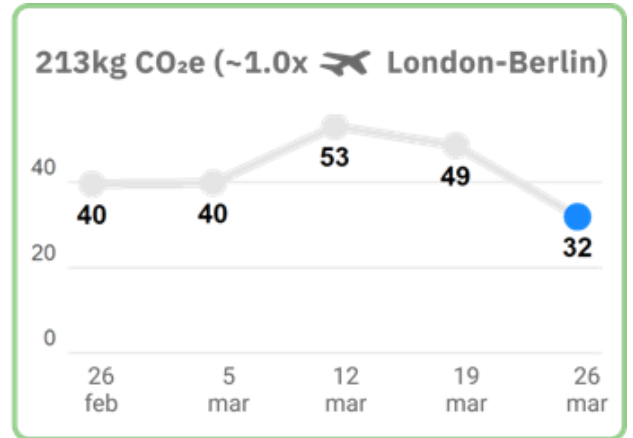
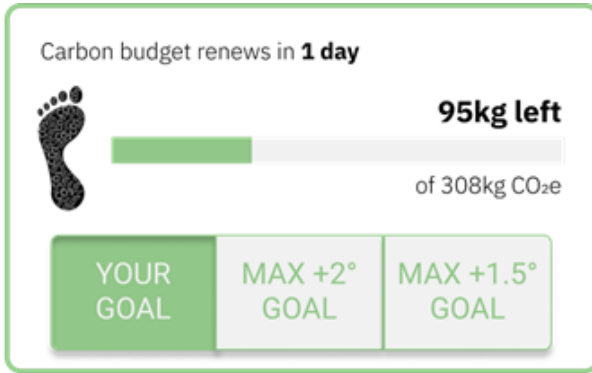
5. Which would you use more often? *



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

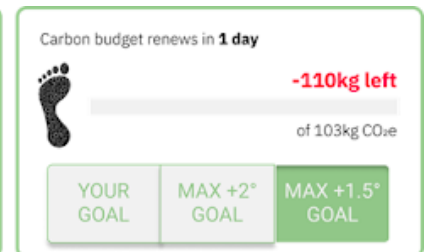
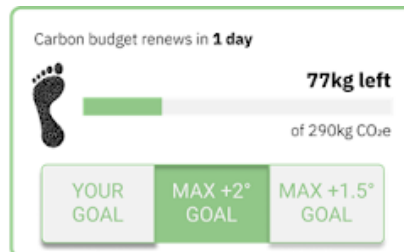
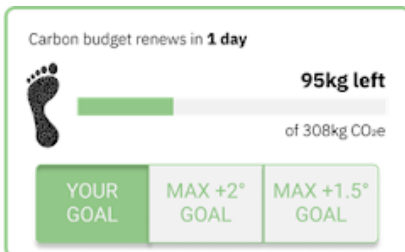
6. Which would you use more often? *



Mark only one oval per row.

	#1	#2
Most often	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>

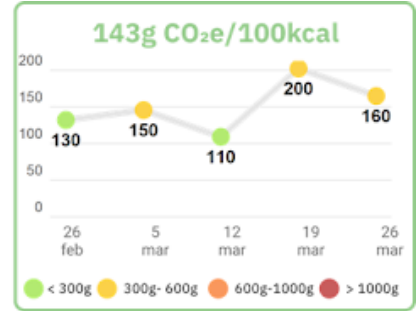
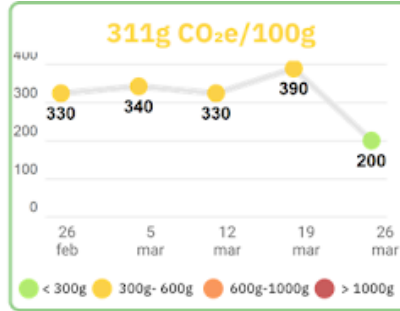
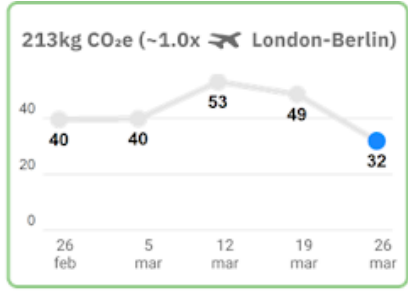
7. Which of these screens would you use most often? *



Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. Which of these screens would you use most often? *



Mark only one oval per row.

	#1	#2	#3
Most often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Second most	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Least often	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Appendix N

Interview Procedure (Chapter 5)

Workshop procedure	Time
Introduction: Participants were welcomed and explained about the procedure of the workshop.	2-5 min
Task 1: Participants were instructed to freely explore the application and make notes about their observations (workshops 1-4) and discuss these afterwards or vocalize them as they went through the application (workshops 5-13). Participants were asked to pay particular notice to (a) how they perceived the visualizations as useful and (b) how it makes you feel.	15-25 min
Task 2a: Participants were asked to imagine the purchases listed in the application as their own and define two concrete changes for the next grocery shopping. They are then asked to elaborate on their choice and the process of getting to the choice. Task 2b: Participant were asked to repeat task 2a, but to mimic a scenario where a person is not willing to change the two products that contributed most to their foodprint, they now could not choose the two largest contributing products as products to find a replacement for.	5-10 min
Task 3: Participants are asked to fill out a questionnaire that involved ranking cards that show (parts of) screens that represent the visualizations used in the application and to elaborate on their choices. The exact content of the questionnaire can be viewed on [add link]. The questions allow direct contrasting comparison and expression of preference between different visualizations.	5-10 min
Task 4: Participants were asked to mention any changes they would like to see in the application and elaborate.	5-10 min
Task 5: Participants were asked to imagine themselves in their daily live with access to the application and asked to imagine when (aka in what context) they would use the application.	<5 min
End & disclaimer: Participants were informed that all information shows was intended to be accurate, but that some information might be faulty or misunderstood and that participants should not accept the information that was shown blindly.	<5 min

Appendix O

Tutorial for prototype version 2 (Chapter 5)

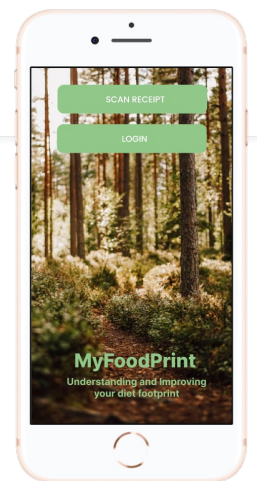


Getting started tutorial

Part of the app exploration

About the app

- Did you know:
 - Our diets contribute to ~30% of our total carbon emissions.
 - If we continue as we do, we will overshoot our carbon budget for +1.5°C threefold with emissions from our diet alone.
 - Changing our diet habits is pointed out as the single most impactful action to reduce our emissions.
- By giving feedback on the carbon footprint of your purchases, MyFoodPrint aims to increase your control over your diet footprint and to find feasible ways to reduce your footprint.



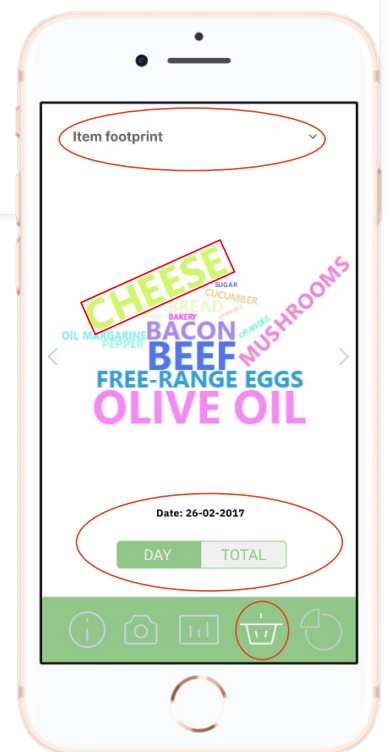
Scan products

- By scanning your grocery receipt, shopping data gets recorded in your account. The app can then show you your data in various informative ways.



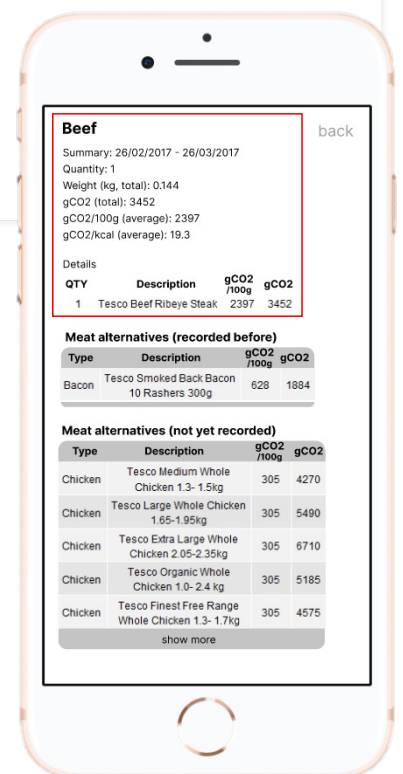
Your basket

- In your basket you'll find an overview of your purchases-
- Your purchases are presented in a wordcloud where the size of the word represents the total carbon footprint of that product type.
- Purchases of one product type are combined in one word. For example, if you bought 2 cheese items, this will mean that the word 'cheese' would still only appear once, but the size of the word cheese would become twice as large.
- By clicking the drop-down at the top, you can change this so the size of the word to represents the footprint per 100g or per calorie, which can be useful when searching for substitute products.
- The cloud covers a specified period. That can be one day (for example the day you scanned your receipt) or a longer period.
- If you click on the word...



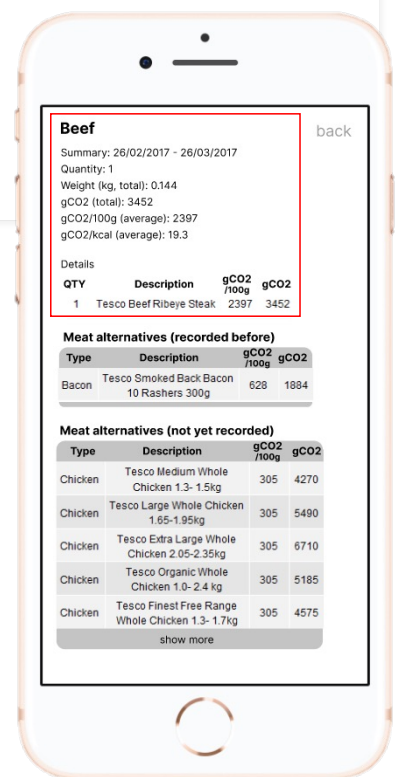
Your basket

- ...then you can see the summary of the product type in numbers.
- Here it shows that you bought 1 beef item between the 26th of February and the 26th of March. This was a ribeye steak.
- Here you also find potential alternatives from the larger product group, in this case the meat group.
- To benefit the acceptability of the recommended alternatives, these alternatives are split in
 - products that were recorded previously, and
 - those that are in our database, but not previously recorded by you



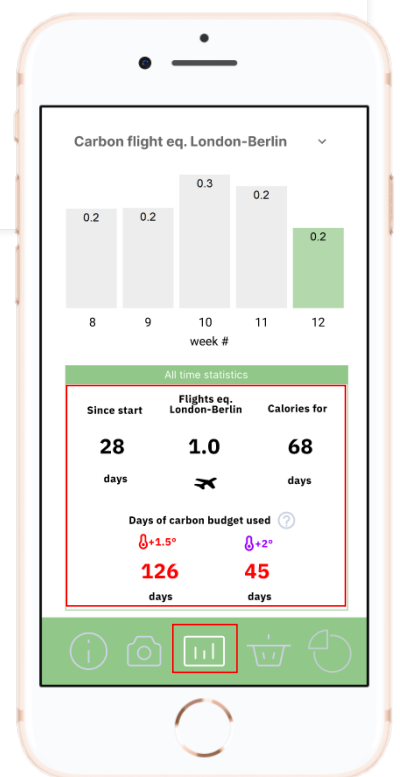
Your basket

- Note: you may already notice that the information focuses on the difference in footprint between products, rather than differences in origin (related to food miles) or packaging. This is because ~85 of the footprint of a product originates from the production (Clarke et al., *Science*, 2020). Although packaging and food miles matter and should be addressed, we think that choices between different types of products are therefore more relevant to focus on.



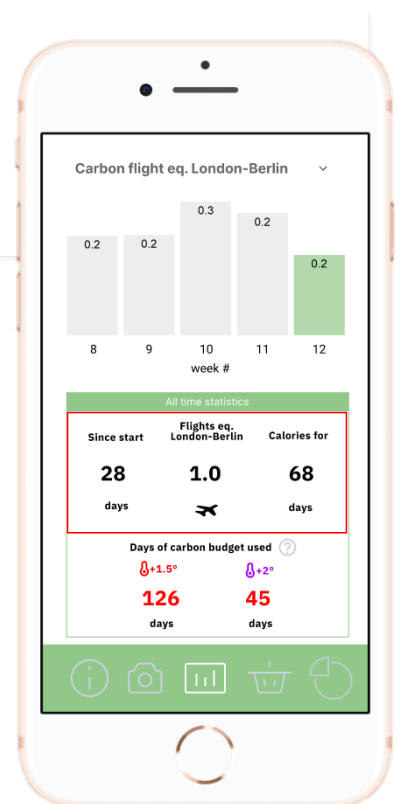
Summary stats

- Next to your basket, you can also find summary statistics by clicking on the chart icon.
- Here you can find information about the total footprint of all your recorded purchases.



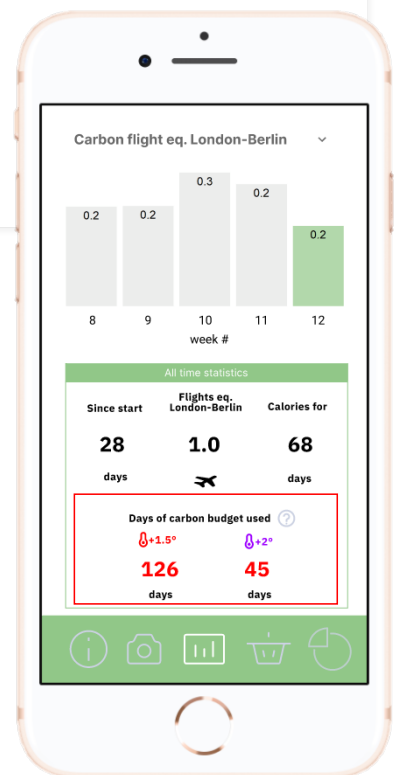
Summary stats

- You can see the equivalent of your purchases in flights between London and Berlin,
- ...the number of days your purchases are predicted to last in terms of person calorie needs,
- ...and the number of days since you started recording with the app. This number provides a benchmark. For example, with calories for 68 days and 28 days we could expect that there was stocking or food waste.



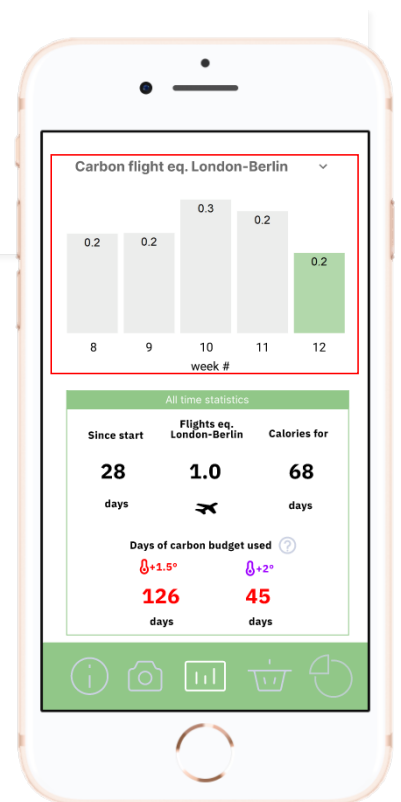
Summary stats

- It also provides you information regarding the carbon budget to prevent global warming beyond 2°C, or 1.5°C.
- In this case, 126 days means that 126 days of the carbon budget, allocated for an individual's diet have used.



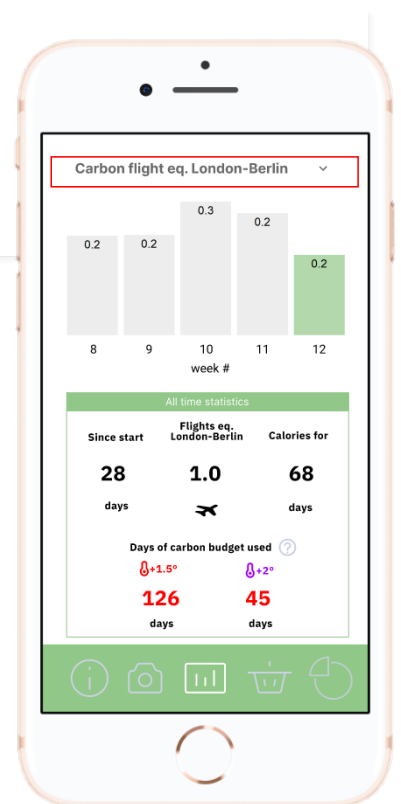
Summary stats

- In the graph at the top, we see how these values varied over time.
- In this case we can see how many flight equivalents were present in each of the 5 weeks of shopping.



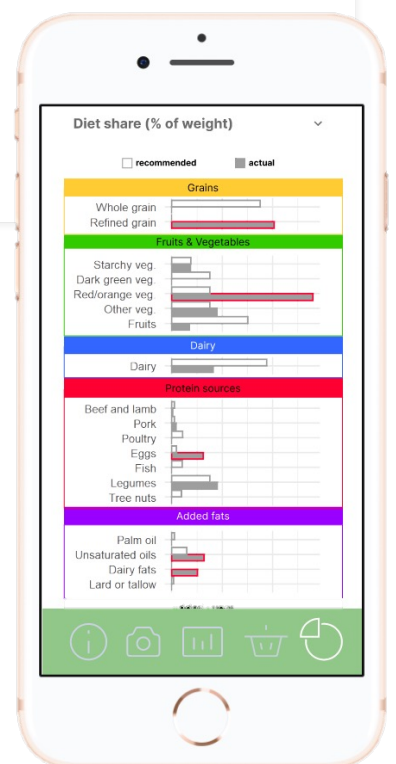
Summary stats

- In the graph at the top, we see how these values varied over time.
- In this case we can see how many flight equivalents were present in each of the 5 weeks of shopping.
- We can change which of the figures are presented by the graph, by clicking the drop-down menu above.



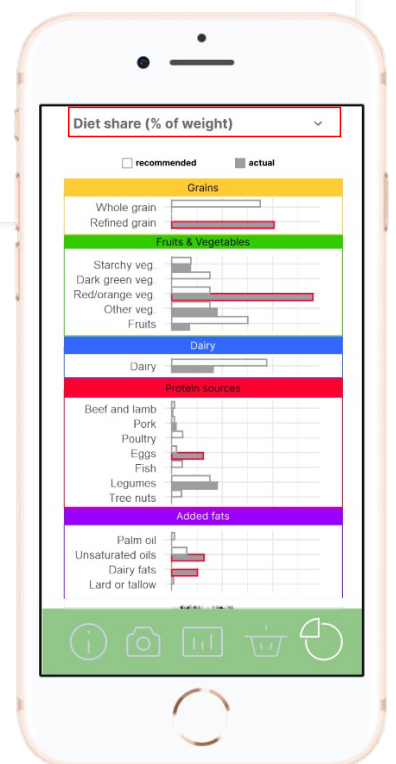
Diet share overview

- By clicking the pie-icon you land on an overview of your diet along recommendations of an health AND sustainable diet.
- White bars represent recommended shares, whereas grey bars represent the share in your purchases.
- Where the purchase overshoots the recommended quantity by 2-fold or more, a red stroke is shown



Diet share overview

- As weight is a relatively crude and imprecise way to record shares, you can also present the shares per calorie by clicking the drop down.



Appendix P

MyFoodprint expression of interest - Google Forms (Chapter 6)

Expression of interest for "MyFoodprint" app study

This form

With this form you can express your interest to participate in a study that evaluates the "MyFoodprint" app.

About the app

"MyFoodprint"

is an app that provides insights in the carbon footprint of your (household's) food and drink purchases. It does this by analysing the grocery receipts that you scan with the app. You can already [have a look at a stack of clickable images](#) from an earlier study.

About the study

The

study involves using an app, "MyFoodprint", for approximately 3 weeks. You scan your grocery receipts with the app and review the information that it provides at your own leisure.

There is an entry and exit

questionnaire to fill out, and I will select some of the participants for a roughly 30min interview about experiences with using the app.

If this topic is of interest to you, I believe that participating will be quite fun. Using the app should also feel easy and like little work. I base this on the short UX evaluations that were done.

When does it take place

April/May 2023

Who can participate

- You are interested to learn about your carbon footprint
- You would reduce your carbon footprint if you felt it was relatively easy to do so
- You have a smartphone running that's no older than 5 years

Compensation

£20 shopping voucher

* Indicates required question

1. Name *

2. email address *

3. I think I would participate as *

Mark only one oval.

- Individual
- Household [I buy food for me and other people in the household]
- Not sure...

4. *

Check all that apply.

- I'm interested to learn about my carbon footprint
- I would reduce my carbon footprint if I felt it was relatively easy to do so
- I have a smartphone running that's no older than 5 years

5. [Optional] Other people you'd like to recommend for the study

6. [Optional] Any comments or questions...

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Appendix Q

Participant Information (Chapter 6)

Participant Information Sheet

Title of Study: MyFoodPrint field study

Document version: 2

Document date: 26 April 2023

Conductor: Remco Benthem de Grave

Contact: Email: r.benthemdegrave2@newcastle.ac.uk, or phone: 074 0191 2373.

About the app: *MyFoodprint* is an application that provides insights in the carbon footprint of your (household's) food and drink purchases. It does this by analysing the grocery receipts that you scan with the app.

Note: The app is currently under development, which means that it is not released to the public and may lack certain features that you may expect from an app that is released in an app store. For one, the app is currently accessed online (no installation needed), and offline access is very limited.

Study procedure

- Read the study information (this form) and get potentially remaining questions answered.
- Sign the consent form.
- Send me pictures of some of your recent receipts ahead of the briefing. ***Please keep physical copies of the receipts you scan.***
- Fill out the entry questionnaire (est. 10 min).
- A briefing where (a) you sign-up for an account in the app, (b) you do a quick run of using the application, scan some receipts, and ask your remaining questions, (c) you are given some advice for the study period and can ask questions. ***Please bring the receipts you sent me.***
- Having fun with 3 weeks of using the application (if necessary, this can be interrupted; please inform me of planned interruptions). ***Please keep physical copies of the receipts you scan.***
- Exit survey (est. less than 10 min).
- Exit interview (est. 15-30 min, but up to 60 min, depending on your availability).

Format: All these tasks can be done remotely, online, but the briefing ideally takes place in person.

For household participants: If you participate in the study together with (an)other member(s) in your household, then your accounts will be linked. The data of receipts you scan will be visible in both your accounts.

Your rights: Your participation in this research is voluntary. You may choose to withdraw your participation at any time without any penalty. You also have the right to refuse to answer questions.

Risks: There are no known risks.

Data privacy: All data that we collect from you regarding your participation in the study will be treated as confidential. Any communications to third parties (e.g., academic journals, magazine articles, or oral presentations) will be based on anonymized data. Exceptions will only be made if you have provided explicit, written, consent to the research conductor (Remco) to do so. You may deny that consent without any repercussions.

For the operation of the application, we use third party services, namely Digital Ocean to host the application and save copies of the receipt pictures that you make in the app. The pictures are sent to Amazon Web Services (AWS) for text recognition, but not stored there. We use Mongo DB Atlas for storing receipt and user data. After completion of the study your data will be moved to dedicated servers assigned by the university and stored in an encrypted format that can only be decoded by the study conductor. Extension of the period that the data remains available in the app can be discussed on request. You can also freely request your data.

Confidentiality: Please note that the content of the study is confidential. Permission needs to be acquired from the research conductor before contents of the application can be shared with third parties.

Compensation: A £20 shopping voucher. We will reach out to determine which voucher has your preference (and fits the university policy).

Appendix R

Informed Consent Form (Chapter 6)

Consent Form for Participants



Title of Study: MyFoodPrint field study

Document version: 1 Document date: 19 April 2023

Conductors: Remco Benthem de Grave

Contact: Email me on r.benthemdegrave2@ncl.ac.uk, or contact our team at, email openlab-admin@newcastle.ac.uk, or, phone on 0191 208 4642, or, post to Open Lab, Newcastle University, Urban Sciences Building, 1 Science Square, Science Central, Newcastle upon Tyne NE4 5TG

Please **tick** each box if you agree.

- I confirm I am over 17 years old.
- I have read and understood the Participant Information Sheet (version 1, 19 April 2023)
- I have had the opportunity to consider the Participant Information Sheet, ask questions and had my questions answered satisfactorily.
- I understand that any audio and photographic recordings will be used for research purposes only.
- I understand my name and any personal information will be anonymised in any reports resulting from this study.
- I understand I can withdraw my participation at any time without giving a reason.
- I understand I can request all my information to be deleted if I make the request up to four weeks after this participation.
- I agree to keep the content of this study (and the application specifically) confidential and will seek permission before sharing content with third persons/parties.

Participant

Name:

Date:

Signature:

Newcastle University conductor:

Name: Remco Benthem de Grave

Date: 20/April/2023

Signature: *RBdeGrave*

Appendix S

Study FAQs (Chapter 6)

Can I add pictures that I took with my phone's camera app?

Yes, you can. Look for the green folder icon in the top left corner of the 'add receipt' screen.

I can't seem to get a clear picture of the receipt, what can I do?

Use your phone's camera app and follow the steps in the question above.

Your phone's camera app generally allows making higher quality pictures. Although uploading the picture may take a little longer to upload, it's generally not too bad when you have a decent WIFI connection.

What if I lost my password?

Just reach out. I can easily reset your account with losing any data.

Can I get notifications?

Let me know if you would like to receive a notification when new data is ready for you.

What if I did online groceries, ordered meal boxes, etc.?

These data can be added, but you'd need to send me an email with the details. You can't currently upload it directly into the app yourself.

Can I show the app to others?

You should not show the app to anyone that has not been covered by the consent form. This has two reasons: it is a research project and falls under the regulations of the university, which require users to be informed and agree to a description of the study and data processing procedures with a consent form. It is also intellectual property.

If you would like to show the app to anyone else, please contact me so I can arrange completion of a consent form with this person. No screenshots should be shared to people outside the study, or on social media.

I have another issue.

Just reach out to me any time.

You can also use the help button to try and get some answers (remember to try scrolling up and down for more answers).

Appendix T

Survey T₁ (Chapter 6)

Intro

MyFoodPrint entry survey



Welcome to the entry survey for the MyFoodprint Study.

Please fill out your study ID before starting the survey.

What is your study ID

Demographics

How old are you?

- Under 18
- 18-24 years old
- 25-34 years old
- 35-44 years old
- 45-54 years old

- 55-64 years old
- 65+ years old

What is your gender identity?

- Man
- Woman
- Non-binary, namely:
- Prefer not to say

What is the highest degree you have received?

- Less than high school degree
- High school graduate (high school diploma or equivalent including GED)
- Some college but no degree
- Associate degree in college (2-year)
- Bachelor's degree in college (4-year)
- Master's degree
- Doctoral degree
- Professional degree (JD, MD)

How many adults live in your household?

- 1
- 2
- other

How many children live in your household?

- 0
- 1
- 2

other

Who does most of the groceries in your household?

- I do
- Another person in my household
- We do most groceries collectively
- People outside my household

How would you describe your diet?

- Omnivorous (no restrictions)
- Flexitarian
- Pescaterian
- Vegetarian
- Vegan
- Other

Food source

The next 7 questions we ask you where you get most of your food from. This can be the supermarket, but can also be meal-boxes, take-away etc.

How much of your food do you get **from the grocery store (offline)**

- none/very little
- some
- about half
- most
- almost all

How much of your food do you get **from online grocery orders**

- none/very little
- some
- about half
- most
- almost all

How much of your food do you get **through meal/recipe boxes (e.g. Gusto, HelloFresh)**

- none/very little
- some
- about half
- most
- almost all

How much of your food do you get **through vegetable delivery boxes**

- very little
- some
- about half
- most
- almost all

How much of your food do you get **direct from the farmstore or farmers market**

- very little
- some
- about half
- most
- almost all

How much of your food do you get from **restaurants or take-away**

- very little
- some
- about half
- most
- almost all

Anywhere else? (If so, where and how much?)

- no
- yes

Footprint applications used

Have you used applications/websites to inform you about your carbon footprint?

- no
- yes

Which applications have you used?

identity and attitudes (adapted from Fielding 2008; Milfont & Duckitt 2010)

I think of myself as a person who cares for the environment

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree

- somewhat agree
- agree
- strongly agree

To engage in environmentally sustainable behaviours is an important part of who I am

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I am NOT the kind of person who makes efforts to conserve the environment

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

In my daily life I try to find ways to minimize my impact on the environment

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

Self-efficacy beliefs (adapted from White et al. 2011)

I feel that I can make a difference by paying attention to the footprint of my groceries

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I feel that I know how to go about pursuing a low footprint*.

*footprint = the carbon footprint of food and drink items.

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I feel capable to pursue a low footprint.

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

What is currently hindering you to pursue a low foodprint?

Knowledge

What do you believe are the best ways you can limit your foodprint*? (drag and drop to order)

*foodprint = the carbon footprint of food and drink items.

Reduce certain types of products, no matter the season or origin

Avoid products grown in hothouses (heated greenhouses)

Avoid airfreighted products

Buy local produce

Buy organic

Reduce packaging

Be considerate in choosing your grocer

Which items do you think have the highest foodprint (on average)?

100g Strawberries (Scotland)

100g chicken (UK)

100g Strawberries (Spain)

100g tiger prawns

100g of banana (Peru)

100g of Brittish cheddar (UK)

100g fresh blueberries, bought in January (Chile)

100g lamb (UK)

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Appendix U

Survey T₂ (Chapter 6)

Intro


MyFoodPrint end survey



What is your study ID

Confirm you're not a robot

I'm not a robot


reCAPTCHA
Privacy - Terms

identity and attitudes (adapted from Fielding 2008; Milfont & Duckitt 2010)

I think of myself as a person who cares for the environment

- strongly disagree
- disagree

- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

To engage in environmentally sustainable behaviours is an important part of who I am

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I am NOT the kind of person who makes efforts to conserve the environment

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

In my daily life I try to find ways to minimize my impact on the environment

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree

- agree
- strongly agree

Self-efficacy beliefs (adapted from White et al. 2011)

I feel that I can make a difference by paying attention to the footprint of my groceries

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I feel that I know how to go about pursuing a low footprint

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

I feel capable to pursue a low grocery footprint.

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree

strongly agree

What is currently hindering you to pursue a low footprint?

App impact self-efficacy

The app helped me in my environmental goals.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

The app made me feel more in control of my footprint.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

The app helped me change my purchase behaviour.

- Strongly disagree
- Disagree

- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

How did the app help you alter your purchase behaviour?

Intentions, adapted from White et al. 2011

How likely are you to reduce your footprint over the next months?

- highly unlikely
- unlikely
- somewhat unlikely
- neither likely nor unlikely
- somewhat likely
- likely
- very likely

How inclined are you to attempt to reduce your footprint over the next months?

- Very little
- Little
- Somewhat little
- Neither much nor little
- Somewhat much
- Much
- Very much

Spill-over, inspired by Lauren et al. 2016

Over the last weeks I have become more attentive to environmental issues unrelated to the MyFoodPrint app.

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

Over the last week I feel I have become more inclined to engage in environmental sustainability matters unrelated to the MyFoodPrint app.

- strongly disagree
- disagree
- somewhat disagree
- neither agree nor disagree
- somewhat agree
- agree
- strongly agree

Knowledge

What do you believe are the best ways you can limit your footprint*? (drag and drop to order)

*foodprint = the carbon footprint of food and drink items.

Reduce packaging

Buy local produce

Reduce certain types of products, no matter the season or origin

Avoid airfreighted products

Avoid products grown in hothouses (heated greenhouses)

Be considerate in choosing your grocer

Buy organic

Which items do you think have the highest foodprint (on average)?

100g tiger prawns

100g chicken (UK)

100g Strawberries (Spain)

100g of British cheddar (UK)

100g lamb (UK)

100g Strawberries (Scotland)

100g fresh blueberries, bought in January (Chile)

100g of banana (Peru)

UX <https://www.ueq-online.org/> + 2 extra

The next questions will ask you about your experience with the app.

How **supportive/obstructive** did you find the MyFoodPrint app?

- Very obstructive
- Obstructive
- Slightly obstructive
- Neither supportive nor obstructive
- Slightly supportive

- Supportive
- Very supportive

How **easy/complicated** did you find the use of the MyFoodPrint app?

- Very complicated
- Complicated
- Slightly complicated
- Neither easy nor complicated
- Slightly easy
- Easy
- Very easy

How **efficient/inefficient** did you find the MyFoodPrint app?

- Very inefficient
- Inefficient
- Slightly inefficient
- Neither efficient nor inefficient
- Slightly efficient
- Efficient
- Very efficient

How **clear/confusing** did you find the MyFoodPrint app?

- Very confusing
- Moderately confusing
- Confusing
- Neither clear nor confusing
- Clear
- Moderately clear
- Very clear

How **exciting/boring** did you find the use of MyFoodPrint app?

- Very boring
- Boring
- Slightly boring
- Neither exciting nor boring
- Slightly exciting
- Exciting
- Very exciting

How **interesting/not-interesting** did you find the use of MyFoodPrint app?

- Not interesting at all
- Not interesting
- Slightly not-interesting
- Neither interesting nor not-interesting
- Slightly interesting
- Interesting
- Very interesting

How **inventive/conventional** did you find the use of MyFoodPrint app?

- Very conventional
- Conventional
- Slightly conventional
- Neither inventive nor conventional
- Slightly inventive
- Inventive
- Very inventive

How **leading edge/usual** did you find the use of MyFoodPrint app?

- Very usual

- Usual
- Slightly usual
- Neither leading edge nor usual
- Slightly leading edge
- Leading edge
- Very leading edge

How easy/difficult was it to find acceptable product alternatives that have a lower footprint?

- Very difficult
- Difficult
- Slightly difficult
- Neither easy nor difficult
- Slightly easy
- Easy
- Very easy

I would use the app in the future.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree

End message

We thank you for your time spent taking this survey. Your response has been recorded.

Please go ahead and pick a date for the experience interview. By clicking next, you will be directed to a page to schedule this.

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Appendix V

Interview Questions (Chapter 6)

Default Interview Questions

Informative Notes

Note: Each question below will only be phrased if the participant didn't already answer the question as part of a previous question.

Note: Many questions are intentionally unspecific to allow the participant to express what was most impactful in their experience, as well as to allow them to express any thoughts they were bringing into the interview and 'need to get off their chest', before specificity is increased in follow-up questions.

Note: what I want to get out of this

- Participants most profound experiences: how it influenced them most in their perception
- Potential mismatch about their perception of change and real change
- How it influenced their household dynamics and communications
- Whether the application was respectful or coercive (missed questions in end survey)
- Understanding why app did (not) facilitate change (if not satisfyingly addressed with the questionnaire)
- Clarify any striking, or suboptimal, responses in the survey
- Unexpected effects

Questions

1. How was it for you to participate in the study and use the application?
2. How did the data make you feel?
 - a. What about the data caused this feeling?
3. On a scale of 1 to 7, how respectful did you feel this application was?
4. On a scale of 1 to 7, how coercive did you feel this application was?
5. How would you say it influenced talks with your partner/household members.
 - a. What about people outside your household?
6. How did you feel your footprint changed during the study period?
 - a. Why?
 - b. Did you change the way you purchased food and planned purchases?
 - c. **Extra:** did the app change anything about the obstacles preventing you from pursuing a low footprint diet?

7. What particular value did the application have for you?
 - a. How was it useful for you?
 - b. What about the application caused this impact?
8. Did the application do what you initially expected of it?
 - a. Why?
9. What did you like / not like about the application?
10. What would have made the application (even) more valuable to you?
 - a. Why?
11. Did the application impact your food waste behaviour?
12. Anything else you'd like to share?

Appendix W

Interview Questions Participant ID018 (Chapter 6)

Interview Questions ID018

Informative Notes

Note: Each question below will only be phrased if the participant didn't already answer the question as part of a previous question.

Note: Many questions are intentionally unspecific to allow the participant to express what was most impactful in their experience, as well as to allow them to express any thoughts they were bringing into the interview and 'need to get off their chest', before specificity is increased in follow-up questions.

Note: what I want to get out of this

- Participants most profound experiences: how it influenced them most in their perception
- Potential mismatch about their perception of change and real change
- How it influenced their household dynamics and communications
- Whether the application was respectful or coercive (missed questions in end survey)
- Understanding why app did (not) facilitate change (if not satisfyingly addressed with the questionnaire)
- Clarify any striking, or suboptimal, responses in the survey
- Unexpected effects

Questions

1. How was it for you to participate in the study and use the application?
2. How did the data make you feel?
 - a. What about the data caused this feeling?
3. On a scale of 1 to 7, how respectful did you feel this application was?
4. On a scale of 1 to 7, how coercive did you feel this application was?
5. How would you say it influenced talks with your partner/household members.
 - a. What about people outside your household?
6. **Participant specific (ID 018):** How would you say the awareness that the app provided about foodprint influenced talks with others?
7. How did you feel your foodprint changed during the study period?
 - a. Why?
 - b. Did you change the way you purchased food and planned purchases?

- c. **Extra:** did the app change anything about the obstacles preventing you from pursuing a low footprint diet?
- 8. What particular value did the application have for you?
 - a. How was it useful for you?
 - b. What about the application caused this impact?
- 9. **Participant specific (ID 018):** You mentioned you got somewhat more attentive to environmental issues. Can you tell me more?
- 10. **Participant specific (ID 018):** You stated that you are much more inclined to try to reduce your footprint, than that you think you will actually reduce your footprint. Is that correct? Can you tell me more?
 - a. Are there specific things interfering with reducing your footprint?
- 11. Did the application do what you initially expected of it?
 - a. Why?
- 12. What did you like / not like about the application?
- 13. What would have made the application (even) more valuable to you?
 - a. Why?
- 14. **Participant specific (ID 018):** You mentioned that the app was slightly confusing. Could you tell me more about this?
- 15. **Participant specific (ID 018):** you mentioned it was (slightly) difficult to find alternatives. Could you tell me more about this?
- 16. **Participant specific (ID 018):** you mentioned you're unlikely to use the app in the future. Could you tell me more about this?
- 17. Did the application impact your food waste behaviour?
- 18. Anything else you'd like to share?

Appendix X

Descriptive Overview of Scanned Receipts By Participant (Chapter 6)

Receipt descriptives by participant							
	Q0 ¹	Q1 ²	Q2 ³	Q3 ⁴	Q4 ⁵	distribution	
scanned							
Receipts (N)	1	2.75	4.0	6.0	12		••
Items (N)	5	34.50	56.5	78.5	254		• •

¹ Q0 = min
² Q1 = 25th percentile
³ Q2 = median
⁴ Q3 = 75th percentile
⁵ Q4 = max

Figure X.1: Descriptive Overview of Scanned Receipts By Participant