Recommending Path Deviations — A Practice-Based Approach to Sustainable Consumption

DISSERTATION

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Abstract

Western consumption patterns are strongly associated with environmental pollution and climate change, which challenges us with transforming our society and consumption towards a sustainable future. This thesis takes up this challenge and aims to contribute to this debate at the intersection of ICT artifacts and social practices through the examples of food and mobility consumption. The social practice lens is employed as an alternative to the predominant persuasive or motivational lens of design in the respective consumption domains. Against this background, this thesis first presents three research papers that contribute to a broader understanding of dynamic practices and their transformation towards a sustainable stable state. The following research takes up these sections' empirical results that more intensely focus on the appropriation of materials and infrastructures utilizing Recommender Systems. Given this approach, this thesis contributes to three fields — practice-based Computing, Recommender Systems, and Consumer Informatics:

- For Practice-based Computing, this thesis contributes by grounding the research in the ethnographic reconstruction of practice transformation journeys, as well as the practice lens for understanding roles, requirements, and capacities of ICT artifacts within this transformation.
- For Recommender Systems, this thesis presents two design case studies that contribute to a better understanding of how to incorporate more personal settings and feedback mechanisms in the design of Recommender Systems. Furthermore, they help to critically reflect on the capabilities of such artifacts and their limitations by studying their appropriation.
- For Consumer Informatics, this thesis contributes to understanding the consumption realms of food and mobility and their digitization. In this context, the consumer-oriented lens shows that many assumptions of intervention-oriented HCI focused on the wrong problems and left consumers alone with the difficulties of learning new practices and accessing appropriate infrastructures and materials.

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Related Publications

Parts of this thesis have already been published as conference or journal papers.

- Section 5: Lawo, D., Engelbutzeder, P., Esau, M., & Stevens, G. (2020). Networks of Practices: Exploring Design Opportunities for Interconnected Practices. In Proceedings of 18th European Conference on Computer-Supported Cooperative Work. European Society for Socially Embedded Technologies (EUSSET). DOI: 10.18420/ecscw2020_ep03

- Section 6: Lawo, D., Esau, M., Engelbutzeder, P., & Stevens, G. (2020). Going vegan: The role(s) of ICT in vegan practice transformation. Sustainability, 12(12), 5184. DOI: 10.3390/su12125184

- Section 7: Lawo, D., Böhm, L., Flügge, A., Pakusch, C. & Stevens, G. (2021). Going Car-free: Investigating Mobility Practice Transformations and the Role of ICT. In Proceedings of the 5th International Conference on Computer-Human Interaction Research and Applications, ISBN 978-989-758-538-8, ISSN 2184-3244, pages 36-47. DOI: 10.5220/0010652400003060

- Section 10: Lawo D., Neifer T., Esau M., and Stevens, G. (2021). Buying the 'Right' Thing: Designing Food Recommender Systems with Critical Consumers. In CHI Conference on Human Factors in Computing Systems (CHI '21), May 8–13, 2021, Yokohama, Japan. ACM, New York, NY, USA, 13 pages. DOI: 10.1145/3411764.3445264

- Section 11: Meurer, J., Lawo, D., Pakusch, C., Tolmie, P., & Wulf, V. (2019, June). Opportunities for Sustainable Mobility: Re-thinking Eco-feedback from a Citizen's Perspective. In Proceedings of the 9th International Conference on Communities & Technologies-Transforming Communities (pp. 102-113). DOI: 10.1145/3328320.3328391

Moreover, these publications contribute to the presented topic. However, they are not included as section of this thesis.

- Lawo, D., Engelbutzeder, P., Esau, M., & Stevens, G. (2019, November). Towards a Network of Practices: Identifying Central Elements to Inform Design. In Proceedings of the Halfway to the Future Symposium 2019 (pp. 1-4). DOI: 10.1145/3363384.3363470
- Lawo, D., Litz, K., Gromov, C., Schwärzer, H., & Stevens, G. (2019). Going Vegan: The Use of digital Media in vegan Diet Transition. In Proceedings of Mensch und Computer 2019 (pp. 503-507). DOI: 10.1145/3340764.3344447
- Lawo, D., Böhm, L. & Esau, M. (2020). Supporting Plant-based Diets with Ingredient2Vec. ICT4S 2020 - 7th International Conference on ICT for Sustainability. DOI: 10.13140/RG.2.2.33454.54080
- Meurer, J., Lawo, D., Janßen, L., & Wulf, V. (2016, May). Designing mobility eco-feedback for elderly users. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (pp. 921-926). DOI: 10.1145/2851581.2851599

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Part I

Introduction & Overview

1 Introduction

> ”It is now widely agreed that the challenges of climate change are such that many familiar ways of life and many of the patterns of consumption associated with them are fundamentally unsustainable. If there is to be any effective response, new forms of living, working, and playing will have to take hold across all sectors of society. Since social change constitutes core business for the social sciences, one might expect these disciplines to be taking centre stage — generating lively popular and policy debate about what such transformation might entail and how it might come about.”[310]

As the above quote resembles, our consumption patterns are strongly associated with environmental pollution and climate change. However, it remains unclear how to transform our society and consumption toward a sustainable future. In this context, according to Shove, [310] the role of the social sciences is to generate a lively debate about ”how it might come about” this sustainable future.

1.1 Motivation

Given the interdisciplinary nature of Information Systems and Human-Computer Interaction between Engineering and Social Sciences [18, 315], this thesis takes up the call and aims to contribute to this debate. In the sense of these interdisciplinary disciplines, the focus is [18, 315] on investigating the role of digital artifacts in the transformation towards sustainable consumption patterns, as well as the question of how to design these. Since not all consumption practices can be researched within the scope of a doctoral thesis, the transformation of mobility and food practices will be examined as examples.

For **food consumption**, it is acknowledged that dietary choices have significant consequences for sustainability [133, 342]. While food consumption issues arise along the whole supply chain, for private households, in partic-

ular, a reduction of food waste, regional consumption, and meat-reduced or vegan/vegetarian practices are leveraging sustainability [117]. Significantly, the latter is considered to have a much lower carbon footprint [293, 356] and is associated with health improvements [286]. Moreover, "the Intergovernmental Panel on Climate Change (IPCC) includes a policy recommendation to reduce meat consumption" [298]. But it is not only the policy that needs to adapt to these sustainable consumption practices but the consumers who need to appropriate them [355, 356]. This highlights one of the main problems in this field. Reducing the consumption of animal products challenges Western norms and beliefs, which causes social conflicts and difficulties for the preceding consumers [354, 356].

Similarly, for **mobility**, we see how car-ownership and car-based mobility practices are unchallenged social norms that endanger our progress in protecting the world's climate [150]. For example, cars provide certain flexibility and act as wealth symbols. On the other hand, individual mobility is one of the biggest carbon emitters in the average Western household and is responsible for about one-third of private energy consumption [116]. Moreover, car ownership comes with a high resource usage along the lifecycle. A more ecological sustainable solution could be public and shared transport [11]. However, according to Kemp et al. [199] "sustainability transitions include two challenges: on the one hand a long-term change to various technologies and infrastructures, while on the other hand ensuring that consumer criteria change in the same move".

In summary, we see how non-sustainable consumption patterns dominate Western societies and how they create path dependencies that make it difficult for consumers to deviate from this norm. Those are either based on economic advantages, e.g., a cheaper or more flexible consumption, or social norms, e.g., wealth symbols.

Against the background of sustainability and the need for social change, the question of how ICT artifacts can support these goals arises. Related to this question, sustainable Human-Computer Interaction research has been dominated by a 'persuasive' perspective focusing on rational consumers [270, 110, 233]. This approach shows promising results on a short-term

motivation to change behaviors, but the long-term impact on consumption is uncertain [52, 91, 229, 301, 302]. In particular, for the selected examples of mobility [150] and food [356] consumption and green living in general [141], research has shown that the main challenge is not the motivation but the learning of new competencies, appropriation of infrastructures, and the enculturation of new norms.

Addressing these issues, research on (non-)sustainable practices has emerged as an alternative lens [270]. In contrast to (rational) behaviors, practices are understood as the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood" [278]. Thereby, practices exist beyond the individual and the observable routines but as social entities shaped and carried out by different practitioners [294, 295]. Moreover, practice theory emphasizes the structural constraints, social path dependencies, and socio-material context in which the practice is conducted [102]. Materials, competencies, and meanings often describe this context [312].

Different studies already apply a practice lens in the context of sustainability — for example, energy consumption (e.g., [52, 134, 301, 302, 303]), food consumption [117, 120, 197] as well as e-mobility practices [150]. Yet, where studies on the transition to sustainable practices exist, the lens is used to evaluate single artifacts rather than researching the usage of complex artifact ecologies in a naturalistic setting. However, it is precisely this knowledge about the complex evolution of entangled practices and the involvement of ICT artifacts that is important if design aims to support the sustainable transformation from end to end successfully [150].

In light of this research gap, this thesis addresses the **Research Question (RQ1) 'Transformation towards Sustainable Consumption Practices'**:

- *RQ1.1:* How do consumers appropriate sustainable practices and the respective elements?
- *RQ1.2:* How do consumers use and appropriate ICT artifacts to gain access to practice elements, especially infrastructures?

The results of this thesis, to anticipate them briefly, show how consumers ap-

propriate new practices as a co-evolution of ICT artifacts and the elements of sustainable practices. Digital artifacts accompany the whole practice transformation journey and support the acquisition of relevant competencies, the appropriation of new materials and infrastructures, as well as the negotiation of norms. Comparing both consumption domains highlights the importance of consumption infrastructures and access to sustainable niches as one of the emerging themes. This theme is taken up and researched in more detail in the second part of this thesis.

Consumers on their transformation journey [213] are challenged by making consumption decisions in a new and changing practical context entangled with cultural aspects and personal situations, e.g., budget, restrictions, and surrounding infrastructures with different offerings and ten thousand options [259, 60, 129]. This burdens consumers with making decisions with conflicting values, both under information underprovision and information overload [129]. Making aware of information, reducing information overload, and finding matching items are usually addressed by Recommender Systems. However, current systems are designed from a vendor perspective to motivate and nudge more consumption [317, 132] rather than to engage and support sustainable consumption. And even 'independent' Recommender Systems that are presumed to support consumers turn out to be driven by market interests [80, 195]. Here, a lot of research is engaged in nudging mechanisms for sustainable consumption [180]. However, besides the substantial usage of psychological, persuasive theories that can be criticized for similar reasons as persuasive visualizations, there is a lack of personalization, goal-setting, and practice-theoretical approaches to study the impact of recommendations in transforming consumption practices [180].

In light of this second research gap, the **Research Question (RQ2) 'Recommender Systems for Sustainable Infrastructure Consumption'** arises:

- *RQ2.1:* How do consumers interact with infrastructures mediated by ICT, and which design opportunities and requirements for sustainable infrastructure Recommender Systems result from this?
- *RQ2.2:* How do consumers use and appropriate Recommender Systems

for sustainable Infrastructure consumption, and which potential do they have for practice transformation?

1.2 Areas of Contribution

Overall, this thesis contributes to three fields of research that are closely linked to the background of artifacts to support sustainable consumption practices: Practice-based Computing, Consumer Informatics, and Recommender Systems.

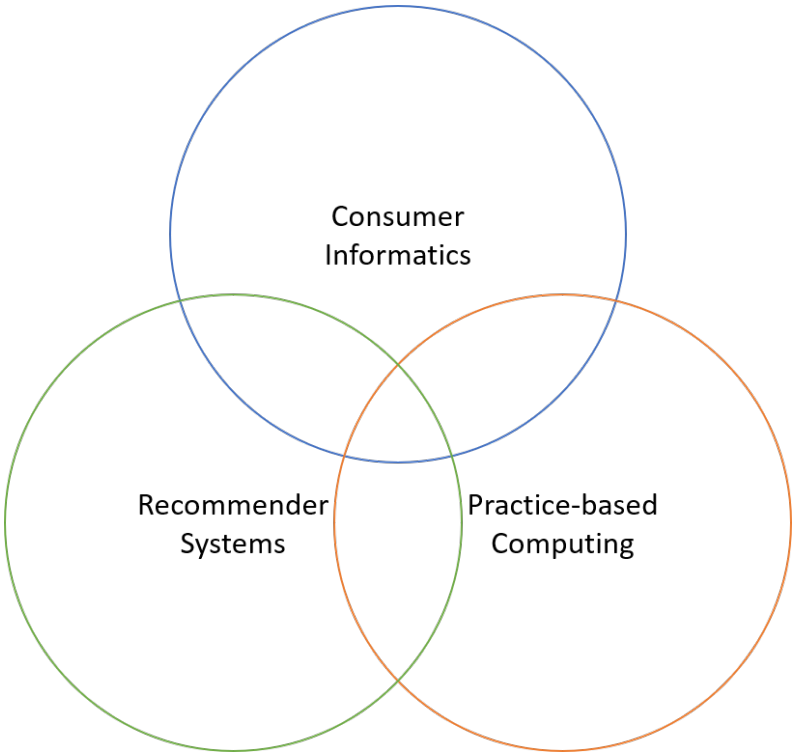

Figure 1: Areas of Contribution.

In contrast to psychological theories and the economic allegory of the rational consumers, the field of **practices-based computing** relies on the theory of social practices [378]. As mentioned, Reckwitz describes practices as the emergent level of the social, a routinized behavior that is constituted by several elements. Embodied knowledge and routines, mental activities and meanings, as well as the materials and tools in use [278]. One group of materials that shapes practices are the group of ICT artifacts [102].

Based on this understanding, Practice-based Computing assumes that ”these artefacts need to be appropriated within the social practices of their specific fields of application” [378]. This broadens the lens of understanding the capabilities and functions of ICT towards an entity that the designer does not only shape, but that is shaped during its usage by the consumers and their roles within consumption practices. This thesis contributes to this field by grounding the research in the ethnographic reconstruction of practice transformation journeys, as well as the practice lens for both understanding requirements and evaluating the designed artifacts.

A further field that this research contributes to is the field of **Recommender Systems**. This class of information systems deals with filtering overwhelming information and finding matching items. These systems are pervasive in everyday consumption practices. However, current systems are instead designed from a vendor perspective to motivate and nudge more consumption [317, 132, 208, 209] rather than to engage and support sustainable consumption practices. Also, in academia, recommender systems neglect the complexity and diversity of practices, e.g., they do not work well for sustainable diets [346] or do not consider sustainability metrics.

Moreover, they often reinforce current behavior rather than allow for exploration and setting of new goals [324, 180] and rely on non-transparent ethics and measurements of sustainability [195]. Their evaluation usually relies on psychological/persuasive theories [180] that neglect the complexity of everyday practices, similar to the critique on persuasive design in general [52, 91, 229, 301, 302]. Against this research gap, this thesis presents two design case studies that contribute to a better understanding of incorporating more personal settings and feedback mechanisms in the Recommender Systems. Furthermore, they help to critically reflect on the capabilities of such artifacts and their limitations by studying their appropriation.

Consumer Informatics is an emerging field of research that is closely connected to Consumer Sciences, Information Systems, and Human-Computer Interaction [372]. The underlying premise of this field is that the pervasive nature of ICT artifacts does not only transform the industry but also private households and their consumption practices [330]. While Consumer Infor-

matics aims to understand this transformation holistically, a particular focus is on digitally-enabled sustainable practices and the consumer-centric design of artifacts to support these [330].

By focusing on transforming consumption practices, especially by uncovering the role(s) of ICT artifacts for sustainable food and mobility practices, this thesis contributes to understanding these digitized consumption realms. In this context, the consumer-oriented lens shows that many assumptions of intervention-oriented HCI focused on the wrong problems and left consumers alone with the difficulties of learning new practices and accessing appropriate infrastructures. In addition, the design focus of this research, which is reflected in the two design case studies, contributes by presenting the requirements of consumers on designing Recommender Systems that support sustainable practices. Although the design focuses on one type of artifact, the results are generalizable towards ICT design to access infrastructures and materials as part of new practices.

1.3 Structure of the Thesis

This thesis consists of four parts:

Part I started with the Introduction and further includes a summary of related research. Moreover, the overall methodology of this thesis and the connection between the different sections are outlined in section 3.

Part II presents three research papers published in peer-reviewed journals and conference proceedings. The focus of section 5 is on a theoretical understanding of the dynamics and interconnectedness of consumption practices. This understanding is picked up by the subsequent two sections 6 and 7 which report on the role(s) of ICT in consumers' sustainable practices transformation by using the examples of Going Vegan (6) and Going Car-Free (7). Finally, the results are summarized comparatively in section 8.

Part III presents the results of two design case studies that focus on the design and appropriation of Recommender Systems in the area of mobility 11 and food 10. While section 11 presents a Route Recommender System that includes eco-feedback mechanisms to allow for a reflection on the previously

driven routes and better planning support, section 10 focuses on individualized and practice-related settings for Recommender Systems to plan grocery shopping.

Part IV discusses the results and their contribution to the background of the current literature. Moreover, the limitations of this thesis are discussed.

2 Related Work

This section introduces the relevant related research. The first section 2.1 introduces the theoretical lens of this thesis. Besides the general introduction of social practice theory, the focus is on materials (e.g., ICT artifacts) and infrastructures as essential elements in the focus of this thesis, the complexity of transforming social practices, and how this social science theory is applied as a lens in design research. Section 2.2 introduces the field of sustainable consumption with a particular focus on the use cases of this thesis, namely food and mobility. Moreover, current design approaches to promote sustainable consumption are reviewed to explain the different threads and directions. Lastly, section 2.3 introduces the field of Recommender Systems as a class of systems that is key to this thesis's technology design and technical-analytical lens.

2.1 Social Practice Theory

Practice theories attempt to overcome the "existing dualism between actor and structure, by finding ways to give voice to human agency without neglecting structural constraints"[102]. Reckwitz [278] understands practices as embodied routines that express themselves in the handling of objects and a described understanding of the world. These routines, according to Schatzki [294, 295], can be understood as entities as well as performances, that can be observed as an instance of the entity.

Another central distinction that Schatzki draws is between dispersed practices and integrative practices. Dispersed practices are generic, usually tacit, spread across a realm of actions (e.g., explaining, following rules, or imagining) and mainly need some form of understanding. Integrative practices are "the more complex practices found in and constitutive of particular domains of social life"[294].

According to Reckwitz, practices are "a routinized type of behavior which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background

knowledge in the form of understanding, know-how, states of emotion and motivational knowledge"[278]. Practices exist through the connection of these elements.

Shove and Pantzar [311] developed a framework for empirical research based on this understanding. This framework focuses on the connection of different elements that are commonly used to describe practices and their socio-material context [311, 204, 312, 102]:

- **Materials:** According to Shove et al. [312], materials are "objects, infrastructures, tools, hardware and the body itself". For example, 'cooking' entails all the relevant items used during the process, e.g., the pan, the oven, and the food itself. Moreover, electricity or gas provisioning infrastructure needs to be considered for cooking in Western households.

- **Meanings:** Meanings are mental activities, emotions, and motivational knowledge [312]. Sticking to the example of 'cooking', this can be the positive emotion of a beloved childhood meal, the perception of unknown food as strange, or just the relaxation during cooking after a long working day. Those meanings are not just shaped by the individual but also rooted in the social, e.g., 'sugar' is generally associated with obesity.

- **Competencies:** Lastly, competencies are several forms of understanding and practical knowledge [312]. For 'cooking', this means formal knowledge, e.g., knowing the recipe for a cake, but also informal knowledge, e.g., using the own senses to examine food before consumption.

As the example of 'cooking' already indicates, those elements are not static but dynamically connected. This can be shown best for an electric stove, a commonly used material in modern Western cooking practices. However, a few hundred years ago, the heating device looked utterly different. And with a different device, other competencies were needed. For example, knowing how to set up a fire and control it was properly part of the cooking, while today, a simple switch needs to be used. According to Shove et al. [312],

this dynamic can be described by three categories: (Current) practices, proto-practices, and ex-practices. While practices are currently carried out by the carriers of practices, proto-practices are future arrangements with elements yet not incorporated. Lastly, ex-practices describe a nexus of abandoned elements that once were part of practices.

In HCI, a particular interpretation of practice theories was developed – the contextual wheel of practices. This lens has been adapted to understand the relationship between infrastructures and the near material, in particular ICT artifacts [102]. This relationship is significant in this thesis to understand the complex entanglement of consumption infrastructures, services, and practices [213]. Within this framework, it is essential to understand that the materials of Shove et al. [312] are divided into individual materials, such as artifacts, and shared materials, such as infrastructures [102]. More details on the characteristics of these elements are given in the next section.

2.1.1 Near Material ICT & Infrastructures

While near materials, such as individual ICT artifacts, tools, and other systems in direct control of the consumers, are simpler to understand, infrastructures and the related activities need further introduction.

Roughly spoken, infrastructures can be understood from two perspectives [224]. From a techno-centric perspective, infrastructures are the materialistic foundation to enable social life and activities (such as streets, electricity grid, internet, etc.). In contrast, to this definition, this thesis relies on a socio-technical perspective, where infrastructures are not just the foundation of economic activity but the outcome of social life and activities. From this perspective, infrastructures are embedded in and shaped by practices and socio-technical contexts [323]. They can be seen as the ”entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual [...] or the collective rely to carry out the tasks and achieve the goals assigned” [266]. From a consumption perspective, this also entails the production and distribution mechanisms of consumable goods that are shaped by share usage but not steered and controlled by individual consumers [102].

In line with the socio-technical interpretation of infrastructures, they not just exist in a physical realm, but infrastructures are built through their usage. In this sense, the development of infrastructures does not stop with their completion by professional designers and engineers but is an ongoing accomplishment [193, 353, 266]. Star [323] calls such making of infrastructures *infrastructuring*. Hence, infrastructuring "can be seen as an ongoing process and should not be seen as being delimited to a design project phase in the development of a free-standing system. Infrastructuring entangles and intertwines potentially controversial 'a priori infrastructure activities' (like selection, design, development, deployment, and enactment), with 'everyday design activities in actual use' (like mediation, interpretation and articulation), as well as 'design in use' (like adaptation, appropriation, tailoring, re-design and maintenance)"[37].

In infrastructuring, the so-called 'Point of Infrastructuring' is of particular interest. According to Pipek et al. [266, 224], this moment describes the start of a re-consideration and a re-conceptualization of one's infrastructure to align with practices. Such particular points of infrastructuring are triggered by different events [266, 224]:

- Actual infrastructure breakdown: The infrastructure fails or breaks from a technical perspective.
- Perceived infrastructure breakdown: The purpose of the infrastructure breaks as entangled (work) practices change.
- Extrinsically motivated infrastructural Innovation: The practices adapt to new infrastructural developments that change the context of practices and make it impossible to conduct practices further the old way.
- Intrinsically motivated infrastructural Innovation: The practices themselves remain unchanged, but new infrastructural opportunities allow the user to adapt its practices to be more efficient and pleasant.

As figured out by various authors, infrastructuring does not happen in isolation but is embedded in the social context [263, 265, 61]. Moreover, the

infrastructuring of newcomers to a practice involves enculturation into a community of practice. Such enculturation is characterized by interactional features such as forming and negotiating identities and exchanging experiences and stories with users of the infrastructure [213]. For instance, becoming a marijuana user does not only mean learning to smoke technically but also learning the norms, rules, and identities that are relevant among the other users [30]. With the ongoing performance of a practice, the community implicitly communicates knowledge, values, and identities that newcomers can learn. The members share their commitment to the community as well as the competencies, materials, and meanings, "in short a shared practice" [370]. This sharing of practices is related to the concept of 'resonance activities', as the connection of different users and their points of infrastructuring [266]. These articulations of practices, infrastructures, and their usage "can be understood to be all of those kinds of activities that may become visible to other users engaged in related practices"[224]. In this sense, these collaborative efforts of infrastructuring are manifested in the moments of exchange about practices and individual experiences of technology appropriation [224].

2.1.2 Regime & Niche Practices

To further understand the infrastructuring efforts of sustainable consumers, we adopt the notions of 'regime' and 'niche' as it is already used in other research on sustainable transitions [123, 124, 77].

A socio-technical regime presents the dominant systemic reproduction, manifested in the interactions between practices, technologies, policy, and infrastructures [316, 122]. It describes the "depiction of the dynamic stability of a contemporary dominant functioning within the interaction of societal domains, actors and rules" [77]. The regime poses a certain stability due to its network externalities and the economies of scale [15, 90]. Furthermore, from a more practice-based perspective, meanings, norms, and rules reinforce the predominant regime and make exploring alternative practices dependent on the regime [308, 123]. Attempting to deal with those dependencies and the reinforced paths of doing, strategic niche management tries to overcome the circularity such that regime practitioners move to the evolving niche [316].

In contrast, niche describes an alternative mode of doing to the contemporary dominant path. In transition research, the niche is understood as ”new technologies, new rules and legislation, new organizations or even new projects, concepts or ideas” [222]. However, our understanding is shaped by Crivtis et al. [77], who adapted the concept of 'niche and regime' as practice theoretical categories. *Niche practice* describes the carrying of alternative practices and doing and saying things differently, especially in the context of sustainability in a non-sustainable society. In contrast, regime practices are understood as the dominant way of doing things, with their entangled infrastructures and meanings.

Sustainability has an increasingly recognized value in society. However, in empirical HCI studies [150, 141, 204], we find repeated indications that sustainable and critical-consumer practices still have the status of a niche. For instance, in these studies, critical consumers describe that others perceive their practices as ”odd” [150], ”going against the [. . .] society” [141], or in conflict with the predominant perception of hygiene and the body [204].

Faced with such rejection from the regime, niche practitioners make sense of their alternative practices as they adapt to other ideas and ways of doing. For instance, other perceptions and arrangements of what 'convenience' for the purchase of shopping [77], time for traveling [150], and hygiene [204] means evolve.

Carrying out niche practices also affects the infrastructures' choice and usage. For example, to compensate for the niche existence of the own practice, Hasselqvist et al. [150] found the appropriation of new mobility practices to be mediated by ICT artifacts. For example, the usage of artifacts to access public transport infrastructures more conveniently. Furthermore, Håkansson et al. [141] study simple living families. The term refers to a lifestyle of material simplification for both the environment and quality of life. They observed how those families could not rely on regime infrastructures but had to spend effort on building their own infrastructures collaboratively.

This perspective highlights the politics of niche infrastructuring, expressed by the rivalry of infrastructures and practices. From an economic perspective [15, 90], for instance, the regime creates a path dependency as it provides

more comfortable, economically cheaper, and more accessible infrastructures [316]. From a symbolic perspective, the regime's dominance is resembled in the sovereignty over the interpretation of consumption infrastructures, as the regime reinforces meanings, norms, and rules. Moreover, the regime and its infrastructures constitute a reference point for niche infrastructuring activities. Given this, the exploration of new alternatives always comes with comparing the niche and the regime [308, 123].

2.2 Sustainable Consumption

Before diving into sustainable consumption, it is necessary to understand the term sustainability and its importance.

Starting from a purely ecological perspective on sustainability, the term was further developed into an integrated concept based on ecological, economic, and social sustainability pillars [126, 275]. The goal of sustainability, no matter what perspective is quoted, is a life for today's generations that takes into account their own needs but also the needs of future generations and their living conditions. In a more operationalized form, these perspectives can be found in the Sustainable Development Goals of the United Nations, where more concrete objectives are communicated politically based on 17 goals [246]. Besides their political function, these goals are also crucial for HCI and Information Systems design [145].

In the following, the three perspectives of sustainability [163, 97, 189, 299, 368] will be introduced as well as their relation to the Sustainable Development Goals:

Ecological Sustainability is closely linked to the production and consumption of natural resources, entailing the impact on flora and fauna. Resources should only be used to the extent that the environment's regenerative forces can compensate for it. Therefore, production should be as efficient as possible, e.g., using resources and energy within the limits of the environment. Similarly, consumption should limit itself to a necessary extent and focus on demanding sustainable goods and services. This pillar of sustainability is also reflected in the SDGs. On the one hand, for example, in Goal 12 "Sustainable

Consumption and Production", but also in specific habitat goals, such as the protection of water (14), land (15), and the global climate (13) [246].

Economic Sustainability relies on a similar concept. However, rather than considering the environmental conditions, economic sustainability focuses on the thoughtful use of the economic foundations of our societies. These foundations can be financial, but also other resources such as the workforce or the production facilities are included in this perspective. Thereby, this pillar is vital for long-term economic developments of societies but also for organizations and individuals who act economically in a rather short to midterm fashion. Within the SDGs, this pillar is reflected in goals, such as Decent Work and Economic Growth (8) but also the goal of building resilient infrastructure, promoting sustainable industrialization, and fostering innovation (9) [246].

A society acts **socially sustainable** when it aims for distributive fairness. This entails distributing resources along generations, nations, genders, and communities. Thereby, resources are understood as material resources, e.g., when fighting poverty, but also as education and other services that fulfill basic human needs. Again, this perspective does not only address global institutions and governments but also other organizations that distribute those essential services or goods on the market. For example, a company acts in line with social sustainability when fair wages are paid, and human-friendly working conditions are maintained. Within the SDGs, this pillar is reflected in goals such as No Poverty (1), Gender Equality (5), Good Health (3) as well as Education (4) [246].

> "There is an emerging recognition of the importance of consumption within international debates about sustainable development. The actions people take and the choices they make – to consume certain products and services rather than others or to live in certain ways rather than others – all have direct and indirect impacts on the environment, on social equity and on personal (and collective) well-being." [174]

Now that the basics of sustainability are introduced, the question of what

constitutes sustainable consumption, in particular, arises. Therefore, in the following, we will focus on the basics of consumption.

In general language, consumption is understood as the use of energy, materials, services, or even food. In addition to use, the process of purchase can also be seen as part of consumption [83]. However, this very general definition does not account for the complex topic of sustainable consumption. It primarily disregards a practice-theoretical perspective [103], adopted as the primary theoretical lens in this thesis. In light of this, Evans [103] combines the different perspectives on consumption, as given by the important contributions of Shove et al. [310], Warde et al. [364, 369] as well as the critique of Hetherington [158] and Gregson [136]. Warde [364] emphasizes the positive side or, as Hetherington [158] calls it, the front side of consumption to understand what general language refers to as *use*.

> ”I understand consumption as a process whereby agents engage in appropriation and appreciation, whether for utilitarian, expressive or contemplative purposes, of goods, services, performances, information or ambience, whether purchased or not, over which the agent has some degree of discretion.”[364]

This focus on appropriation and appreciation strongly emphasizes the positive consumption of a good in terms of an appreciating use. Based on this definition and view, Evans [103] further defines the three As of consumption as:

- **Acquisition** is very much connected to the production and delivery of services and goods. This perspective entails how consumers gain access to the service or good, e.g., based on market transactions. This perspective, therefore, is in line with economic views that discuss the political, organizational, and economic entanglements with consumption.
- **Appropriation** goes beyond the acquisition of the good or service but focuses on the integration of the item into everyday practices. This includes the handling of the item and the meanings that emerge over time. ”For example, when a commodity assumes particular significance

to somebody – a garment that is cherished for flattering one's physique or serving as a reminder of an experience shared with a significant other – it is said to have been appropriated."[103]

- **Appreciation** refers to the utility of the good, service, or experience in the sense of pleasure and satisfaction. This view is very much related to "Bourdieusian notions of taste, distinction and stratification"[103], which, e.g., is described in Becker's [30] work on marijuana consumption and the therein observed judgments.

Gregson [136] and Hetherington [158] criticize the narrow focus on positive consumption. Their research highlights, in addition to the three As, the disposal and abandonment of consumable goods and services. On this basis, Evans[103] defines that a definition of consumption should consider not only the three As but also their counterparts, the three Ds:

- **Devaluation** describes the process of losing interest and appreciation for a good or service. For example, the economic value of a good might decrease over time, or there is a lack of pleasure, loss of meaning, and other more non-economical factors that lead to devaluation. "For example, the experience of frequenting a hard-to-reach travel destination may be devalued if it becomes more widely and easily accessible."[103]

- **Divestment**, as the counterpart of appropriation, describes not just the economic transaction of losing ownership but the undoing of attachment and the disintegration of the good or service from everyday practices. For example, a car that was part of practices for several years might be divested once the children moved out of the family's home.

- **Disposal** describes the act of getting rid of a product or service, e.g., when disposing of the goods or canceling the service's contract. Again, this perspective is strongly related to an economic view, where value decreases, and a market transaction is finally abandoned. Nonetheless, political, economic, organizational, and technological conditions are essential factors influencing the consumers' disposal, as they shape how these transactions are fulfilled. For example, leftover food, like any

other good, can be disposed of or shared with others, which then re-appropriate/reacquire the good [103, 247].

Concluding from these perspectives, consumption is a construct that entails the six moments Acquisition, Appropriation, Appreciation, Devaluation, Divestment, and Disposal. These moments thus represent a kind of cycle of interaction with consumable goods and services, as already described in a similar form by Ng et al. [247]. Consumption thus begins with the front side, the three As where a good is appropriated, purchased, and (hopefully) valued. It ends with devaluation processes, divestment, and disposal. It should, however, be noted that according to Evans, [103] this only ends the cycle of the product-human relationship for a specific human being because the discarding of one also offers the chance of re-appropriation for other people who can consume the good again. This is precisely where consumption comes together with sustainability. Based on the practices of the three As or the three Ds, the infrastructural setup, or the policy, those moments can be altered towards a measurable sustainability optimization. For example, food sharing requires organizational effort to allow consumers to share their leftovers with others rather than just getting rid of them in the bin [120].

Based on this basic understanding, in the following, the domains of food consumption and mobility consumption are introduced to account for this thesis's use cases. The focus is on understanding what makes these domains (un-)sustainable and what are the main issues and barriers for consumers. This emphasizes a more detailed perspective on altering the various moments of consumption toward a more sustainable state.

2.2.1 Food

Coming to one of the fields of application of this thesis – food consumption practices – we also find circular practices ranging from the As to the Ds of consumption [103]. Ng et al. [247] researched a food consumption cycle that starts from the procurement of food and ends with the actual eating or, in a worse case, with the disposal of the food.

Given this lifecycle as a more nuanced instance of the As and Ds of consump-

tion in the domain of food, the question of sustainability and sweet spots for influencing those moments arises. (Un-)sustainable consumption is caused by three main issues (see, e.g., [117]):

1. The consumption of animal products is entitled to cause a higher carbon footprint than consumption patterns that rely on more plants [260, 293]. In this context, mainly vegan and vegetarian diets show a possible path to increased sustainability of consumption. This is also reflected in "the Intergovernmental Panel on Climate Change (IPCC) [that] includes a policy recommendation to reduce meat consumption" [298]. Moreover, those diets are associated with health improvements [286].

2. A second issue is the procurement of non-organic, non-regional, and non-seasonal food. While organic food does not necessarily reduce the resources needed, it is often tied to bundles with other improved conditions, e.g., seasonality and regionality [188]. Such bundles of improved conditions in production or transport allow consumers to decrease their food miles [251], as well as decrease the environmental impact of the high pesticide usage [375, 21].

3. Moreover, food waste is an essential issue for sustainable food consumption [267, 322]. Private households contribute to overall food waste by 47% to 65% [107] (42% for the European Union [196]). In this context, consumer practices, e.g., limited overview about the goods in stock or overbuying are a major driver of food waste [267, 328, 107].

Even if these challenges and problems can be identified, it remains unclear and complex how exactly to stimulate change in consumption. From a practice-theoretical perspective, sustainable change involves appropriation and change of the various elements of consumption practices [355, 356, 152], in short, an altering of the As and Ds. In particular, research shows how different practices from planning, purchasing, eating, and throwing away need to be included in the transition.

This is challenging as consumption infrastructures are dominated by the needs of an omnivorous consumer group [77, 356] that is far more prominent than

the group of niche consumers [200, 81, 273]. Still, this niche is growing in importance and facilitating its consumption practices using several initiatives [273], for example, food labels, such as the vegan label (issued by a European Vegan NGO [273]), as well as other private labels. Still, there is only little regulation on labels and definitions in advertisement to support consumers in making sustainable choices [125]. This lack of political interest and support resembles the predominant perspective of consumerism, which treats the (rational) consumers as the ones to make informed choices rather than supporting them with policies [231]. In contrast, some European countries even issued regulations that make sustainable consumerism more difficult and complex [255, 59].

Also, from a cultural perspective, meat and overconsumption are traditionally understood as a symbol of prosperity and wellbeing [354]. The media often enforces this attitude and reproduces unsustainable consumption patterns [75]. Resulting from this, sustainable practices, especially veganism, are still perceived by many as somewhat abnormal and characterized by a puritanical view of life [354]. Such an attitude places consumers in the position of explaining and justifying their 'niche' practice [77] in their social environment.

2.2.2 Mobility

For mobility practices, the second domain of this thesis, we again can shed light on the consumption patterns from an abstract perspective by considering the As and the Ds [103]. For mobility, we can distinguish between different cycles. First, from the perspective of a single consumption event, quite similar to Ng et al.'s [247] perspective, we can understand mobility practices as ranging from activities *pre-trip*, e.g., planning the trip, to the actual *trip*, and finally, *post-trip* practices, e.g., reflection on the trip or giving feedback [282, 203]. Nevertheless, given the dominant role of the car [150], we also need to consider a second life cycle. In contrast to food, a car is not bought, consumed, and disposed of within one week or just a few hours but acquired for multiple years. Given such a life cycle perspective [155], we can assume that, besides the daily cycle from pre-trip to post-trip, there is a much longer cycle for most consumers that is much more difficult to alter as it comes with

high investments and long-term decisions.

From a sustainability perspective, the reliance on the car as the primary mode of transport is the biggest issue [238]. In contrast to other modes of transport such as cycling, but also other motorized transportation modes, such as public transport, the car is less environmentally friendly and less resource-efficient per mile traveled [127]. However, also from a broader perspective on the life cycles of the car itself, with its acquisition, the usage, and the disposal, individually owned cars are less efficient than other modes of transport, even car-sharing or ride-sharing, e.g., with services such as Uber [58]. Thereby, it is especially problematic that cars seem to remain the dominant mode of transport and that projections even predict a trend of growing ownership worldwide [376].

Even if these challenges and problems can be identified, it remains unclear and complex how exactly to stimulate change in consumption. Hasselqvist et al. [150] already showed how sustainable practices, in their case with small electric vehicles in an urban environment, come with the appropriation of these new materials, new competencies, and meanings. In particular, the appropriation of these new practices comes with different planning and consumption routines and affects multiple other practices that are connected to transport [160]. Still, a consideration of public transport and multi-modal practices is missing [377] to support the transformation towards using shared mobility infrastructures rather than individualized means of transport.

Therefore, we should understand practices within their socio-material context, shaped by owned materials and shared infrastructures [102]. Although individually owned cars are the number one mode in Germany [297] and are a growing mode worldwide [376], most German cities offer some public transport infrastructures. Still, those infrastructures are often inefficient and do not offer sufficient coverage [128]. Therefore, we can also consider such infrastructures as a niche that does not attract most consumers. Thus, they are path-dependent on their car usage. For example, Urry et al. [358] state that participation in many parts of social life would not be possible with the flexibility of the individually owned car and its availability. Against this background, one can even describe car ownership as being enforced, as the personal situation

and the available infrastructures do not allow for reliance on the public infrastructures only [78]. Here, new services such as flexible ride-sharing offer new opportunities [128]. Nevertheless, also increasing other modes of transport offers a chance to solve the described sustainability issues of current mobility practices [127].

Also, from a cultural perspective, sustainability [354] and using public transport are perceived as 'odd' and extreme by non-users [150]. Again, such an attitude, places consumers in the position of explaining and justifying their 'niche' practice [77] to their peers and their social context.

2.2.3 Promoting Sustainable Consumption with ICT Artifacts

In recent years, environmental issues have become increasingly important in public and HCI discourses. Sustainable Interaction Design [39], for instance, addresses the sustainability of design, first during its production (development & design) and second during consumption (usage). Especially the latter perspective focuses not just on the usage of the artifacts themselves but also on promoting more sustainable behaviors or practices.

We find many design studies aiming to foster more sustainable production and consumption for both domains presented in this thesis. For food consumption there are, for instance, studies that focus on sustainable and local shopping [219], foster food waste reduction in private households [10, 341, 221], make supply-chain more transparent by collecting and visualizing information [45], or nudge better procurement decisions [191]. Similarly, we find research focusing on the different phases and modes of mobility consumption. We find research on public transport [360], walking [374], cycling [281], and car or ride-sharing [49]. There is also research on navigation [172], payment [85], and information [146]. Nevertheless, studies on ICT and public transport are still rare [377].

From a domain-independent perspective, those attempts to promote sustainable consumption [87] primarily relied on theories of environmental psychology [115], as well as gamification and persuasive technologies [110]. These approaches usually have a positive short-term impact on the motivation to

change behaviors, but their long-term impact is uncertain [52, 91, 229, 301, 302]. Here, research [135, 134, 301, 303] argues for a better understanding of how consumers construct sustainable practices themselves and how their perception is influenced and shaped by their personal situation and their socio-material context.

Addressing those issues, He et al. [151], who adopt the Transtheoretical Model of Behavior Change (TTM) [269], argue that the diversity of individual motivations must be taken into account and that behavioral changes usually take place in several phases. The TTM has also been used by Maitland et al. [229] to support diet change. They argue that people do not lack motivation but lack financial, strategic, or social resources. It follows that interventions would be more effective if they focused on the action phase, where people try to implement a behavioral change [229]. Similarly, researchers such as Beverland et al. [34] recommend ”unfreezing” the change through informational and empathetic messages.

Other research claims that using a TTM or process-based lens is, in general, not appropriate for complex tasks such as consumption [236] or for promoting more physical activity [3]. Mhurchu et al. [236] especially point to the heterogeneous nature of consumers' motivation, behavior, and commitments.

At the same time, research on (non-)sustainable practices has emerged as an alternative lens [270] that studies, for instance, energy consumption (e.g., [52, 135, 301, 303, 302]), and also food waste [117] as well as food sharing [120] and also electric mobility [150]. Practice-theoretically informed ICT interventions found a deeper understanding of sustainable consumption practices and the socio-material context that shapes them [179, 117, 119, 270]. This lens has been used to uncover ICT design opportunities, such as food sharing as a means to procure and dispose of food [120], studying sweet spots in consumption practices to prevent food waste [117], or opportunities for other food-related practices, such as gardening [225], foraging [68], and recently, organic food consumption [197].

Despite this corpus of research, the question of how to transform practices from end to end remains unanswered. For consumption practices, as for any other routinized conducted practice, the practice elements are connected sta-

bly, creating a kind of equilibrium [333]. It is assumed that a change in one of the elements creates an imbalance, resulting in a ”crises of routine” [278]. This crisis results in a dynamic that might transform the nexus of practices. As a simplified model, Shove et al. [312] distinguish between practices, proto-practices, and ex-practices. While practices are currently carried out, proto-practices can be seen as a future possible state. For this state, the elements are yet not incorporated into the nexus of practices of the consumers. Ex-practices, in contrast, are prior practices that were abandoned, and so were their elements. Based on this understanding, interventions aim to destabilize practices and/or re-establish new practices. However, due to the complex entangled nature of practices [117] and how sustainable practices are still considered ”odd” [150] as the benefits of ”good individual choices” [117] are not consistently recognized equally, designing and understanding these interventions is not straightforward. Here, the main problem of current research is that it studies practices from a prospective perspective that focuses on unsustainable practices and tries to spot a point for intervention or follows the practice transformation journeys, which end with the first significant barrier. We lack research and, connected to this, strategies [74] that overcome the different barriers [215] and provide an understanding for end-to-end transformation.

Shove et al. [312] provide important theoretical contributions to the theoretical lens of this thesis, but still, it remains open how to operationalize this lens into the design of interventions. Regarding this, Shove et al. [313] already launched a manifest of practice-oriented design. Several researchers [205, 204, 304, 362] use this manifest to understand the design space and the implications of their interventions. In short, Shove et al. [309] provide a new perspective that differs from the predominant product- or user-oriented design paradigms. Rather than users, design should take practices as the central unit of empirical analysis and the design space. Here, the dynamics of social practices become essential, as the goal should be a transformation of practices over space and time.

Regarding this, Kuijer et al. [204] suggest introducing unfamiliar elements, e.g., ’Trigger-Products’ that can cause a ”crises of routine” [278]. From a different perspective, the product does not necessarily need to trigger change but facilitate change once another event causes momentum [213]. In this sense,

it is the access to elements or infrastructures (such as restaurants or food in local markets) that is sometimes perceived as a barrier that can cause further dynamics of sustainable transformation [355, 356, 215]. From a more pragmatic perspective on practice-theoretical consumption interventions, such access can be facilitated by providing consumers with relevant and complementary information within their daily practices [152]. Still, informational requirements [137], as well as diversity and entanglement of consumption practices [117, 212], need to be considered in the sense that one information design does not fit all practices.

Again, from a critical perspective, one should acknowledge that change in practice(s) is not a matter of technological transformation alone. Cettina et al. [67] stress the connectedness of their investigated practice: ”Ideas of cleanliness or perceptions of the body for example, are not elements of bathing alone. Reconfiguration of bathing may require reconfiguration of a wide range of related practices.” [204]. In this sense, multiple interventions might be required, as well as a reconfiguration of various non-technological spaces.

2.3 Recommender Systems

Anticipating the results of section 8, this thesis deals with Recommender Systems as one possible type of information system to introduce new elements into practices, interact with infrastructures and thus minimize barriers to change. Therefore, this class of information systems will be introduced in more detail in the following. Besides the general introduction, sustainability-related design approaches will be introduced.

2.3.1 Fundamentals

Starting from a relatively broad perspective, Recommender Systems can be described as ”software tools and techniques providing suggestions for items to be of use to a user [227, 284, 53]. The suggestions relate to various decision-making processes, such as what items to buy, what music to listen to, or what online news to read. ’Item’ is the general term used to denote what the system recommends to users” [285]. Thereby, Recommender Systems are well

known for reducing information overload and filtering items for their users. These users are assumed not to have the experience or competence to search or filter the overwhelming amount of items independently [284].

In addition to this perspective, a more detailed and fine-grained distinction can be made between different use cases and algorithmic approaches of Recommender Systems [5].

The use cases, thereby, are usually determined by the item to be recommended. Here, Recommender Systems cover a wide range of different items [5], for example, videos on Netflix [132], products on Amazon [317], News on Google [79], Friends on Facebook [9], music on Last.fm [226], or closely related to the research domains of this thesis, public transport [82], and food [156]. While all these items need their unique approaches and arrangements of data, it can be distinguished between three fundamental algorithmic classes [5, 177]:

- **Collaborative Recommendations:** Fundamental to this type of recommendation is the assumption that consumers with similar interests and consumption patterns in the past will consume similar items in the future. Thereby, different types of similarity can be considered, including the similarity of consumption events, e.g., consumption yes/no or consumption patterns, but also ratings, e.g., 1 to 5 stars. The models used in such context usually just make use of those consumption feedback measurements rather than considering any detailed information about the user or item itself. This, on the one hand, offers an easy-to-use approach that comes with a reduced effort of measuring additional distances between users and items. But on the other hand, important information might be missing that could provide even better matching items. Typical examples of such Recommender Systems are found in e-commerce, where recommendations are motivated by *Costumers who bought A, also bought B*.

- **Content-based Recommendations:** In contrast to collaborative, consumer-centric approaches, content-based filtering exploits the knowledge about the actual item. Thereby, the central assumption is

that consumers will consume products in the future that are similar to those they consumed in the past. The similarity itself is usually determined by a measurement method that considers the properties of the item as well as the consumers' ratings for the respective property. Such rating is retrieved from a prior rating of products, including their properties in a relatively similar manner as described above. This can be implicit feedback, such as the consumption pattern, but also star ratings. The main advantage of this recommendation approach is the little need for user interactions with the system and thus the negligible influence of cold-start issues. Still, not all properties of an item can be retrieved, and thus, hidden characteristics might lead to less performance in the recommendation.

- **Knowledge-based Recommendations:** Knowledge-based approaches are usually used for domains with infrequent purchase decisions, as they rely on the active setup of a profile or constraints within the session that is then matched with the properties of the item. Moreover, external knowledge is often exploited to consider connections between consumer and item properties. Still, in other domains where the cold-start problem leads to significant issues or needs to be bridged, such approaches are suitable. Within this class of approaches, consumers explicitly define what they want, e.g., by describing the properties of the items in the sense of is search an item within a certain range of properties (min. or max. value) or most similar to a specific value. The rating itself is closely related to the actual measurement unit, e.g., time to mobility or calories for food. The main advantage of this approach is that the consumers can specify what they want, which might differ from their history of consumption. Still, this comes with an effort to specify the own profile, knowledge about the own needs, and from a data perspective, quite detailed descriptions of the items.

Besides these main approaches, there are other approaches that, e.g., consider the context of the user, their behavior in a specific session, demographic details, or just the time of the day [5]. Moreover, different recommendation approaches and their respective algorithms are combined to exploit the distinct

advantages and disadvantages to provide better matching recommendations [177]. In addition, Recommender Systems, as a class of systems between algorithmic developments (machine learning) and consumer decision-making with computers (HCI), according to Jannach et al. [177, 180], can be understood as persuasive systems (see Fogg et al. [110]). Accordingly, it is closely related to other approaches, such as eco-feedback and persuasive information. Thus, they are often researched together as complementary strategies to foster different consumption [252, 256]. In this sense, the eco-feedback can, for example, highlight social norms of consumption to embed the recommendation into broader normative decision patterns [326, 325].

In the following, this thesis distinguishes between Recommender Systems in a broader sense, which are also referred to as *recommending* Systems, and Recommender Systems in a narrow sense.

The definition of Recommender Systems, in a narrow sense, is closely connected to the traditionally used algorithms and their function to order a list of items and recommend the top-n items to a user based on different interactional data. This data can be collected through direct interactions, e.g., in knowledge-based Recommender Systems or based on interactions with other items and users (content- and collaborative filtering) [177]. Nevertheless, in this narrow sense, Recommender Systems are considered information systems that are strongly connected to the interacting users and their preferences [5, 177]. Therefore, this definition also considers mechanisms that persuade consumers to choose based on the provided list of recommendations [180].

The broad definition of Recommender System, from now on referred to as *recommending* Systems, is reflected in the work of Karpati et al. [195], for whom Recommender Systems start with platforms or search systems such as Google or Yelp as a specific food-context example. Such a definition is also reflected in the work of Pu et al. [274]. They describe their so-called multi-attribute product search tools as the interaction of Search, Decision Support, and Recommender Systems. For those systems, a search would result in multiple results, such that additional information needs to be considered for ranking the results or helping the consumers make a decision. In this context, Karpati et al. [195], for example, consider systems such as Yuka that allow

consumers to scan an item and get a recommendation on whether to buy the item or not as Recommender Systems. This system is not based on a specific list of items but on information on the user preferences and a rating algorithm that assesses scanned items.

Similarly, Herbig et al. [156] researched a scan-based system with recommendation features in the context of sustainable food recommendations, assistance systems, and persuasive design. This shows how recommendation features are often part of broader persuasive or assistive initiatives to promote sustainable consumption. As those systems are pretty different from the traditional approaches of Recommender Systems but still ”help[...] consumers to choose products based on some shared preferences” [195], they can be considered Recommender Systems. However, they should be distinguished from the traditional approaches, which is done by the explained annotation in this thesis as *recommending* Systems.

Anticipating the results of the following parts of this thesis, this differentiation becomes vital to bridge the gap, in the sense of a joint (technical) analytical lens, between the systems observed in part II and the designs in part III.

2.3.2 Supporting Sustainable Consumption

While the fundamentals were introduced in the previous section, this section gives a broader account of sustainable recommendations and sustainability features in Recommender Systems.

Most Recommender Systems are designed from a vendor perspective to motivate and nudge more consumption [317, 132, 208, 209] rather than engage and support sustainable consumption. Furthermore, even ’independent’ Recommender Systems that are presumed to support consumers turn out to be driven by market interests [80, 195]. Against this background of creating business value, Recommender Systems proved to have a significant impact on the choices and decisions that consumers make [132, 176, 4]. Thereby, Recommender Systems themselves have the inherent property of, on the one hand, reducing information overload and helping consumers to find items, but, on the other hand, the reduction of information and recommendation in

the form of a reduced list of items can be seen as a nudging towards a particular decision [180, 46]. These mechanisms can be used to not recommend and nudge consumers towards items that serve the business interest only but sustainable items.

In the following, different approaches to sustainable recommendations and nudges are presented. Moreover, the goal is to explain and understand the main challenges and downfalls of current approaches.

According to a literature study conducted by Jesse et al. [180], one can distinguish between four main categories of mechanisms to influence and nudge the consumer's decisions:

- **Decision Information**, as the first of the four categories, deals with a change of the information that is given along the recommendations. Thereby, different mechanisms are used in literature to 'nudge' decision-making. For example, the adaptation of the information, the change of salience of information, the addition of information (e.g., comparisons, goals, or explanations), and an adapted phrasing of the information.

- **Decision Structure**, in contrast, does not change the visual appearance and information architecture but the ranking of the items. The focus is on changing the decision by providing better default options, increasing effort for unwanted items, changing of rank or composition of items (e.g., re-order options), and finally, changing option consequences, such as providing direct benefit and cost overviews.

- **Decision Assistance** more strongly focuses on supporting the consumer to make choices along with their goals and preferences, without changing the recommendation or its appearance. This group of mechanisms comes with the provision of reminders, e.g., reminders of goals or normative concepts, and making commitments easier, e.g., connecting with their previous behavior and plans.

- **Decision Affection** is, according to Jesse et al. [180], similar to decision information but focuses on the social comparison of behaviors

and choices rather than visualizing the implications. This comes with an increase in messenger (recommender) reputation, the provision of social reference points, e.g., showing what others did or how good they performed, and finally, the instigation of empathy, e.g., reinforcing the consumers' behavior.

Different studies have already shown the positive effects of using such mechanisms. Still, according to Jesse et al. [180], there are only 16 studies that incorporate such mechanisms into Recommender Systems to promote better choices. The number of approaches for sustainability is even smaller.

While there is much research on sustainability and nudging towards sustainable choices, this research does not investigate the personalization and goal-setting of consumers, where Jesse et al. identify huge potential [180]. For such personalization, however, systems need to understand the user's current situation [194]. Here, current approaches start to re-explore the opportunities of knowledge-based approaches where the aim is a holistic user profile that, e.g., includes individual health conditions [244]. Karpati et al. [195] argue for researching systems that allow for the personalization of ethical values and consideration of consumers' needs for transparency and trust. For those, ethical guidelines, algorithms, and the underlying business model are often non-transparent [80, 195]. Thus, there is still a gap in research on Recommender Systems that consider the preferences of individual consumers in a profile [345] and bring personalized values and ethics into action [195].

Moreover, current research heavily uses psychological perspectives [320, 180] that come with formalized controlled experiments rather than field trials evaluated from a practice-based perspective. For the latter, there is only little research available [329]. Still, this lens can help to understand their potential in everyday consumption decisions, even in complex environments where access to sustainable infrastructures is difficult.

Having established a basic understanding of Recommender Systems and their relation to sustainable consumption, we want to, in more detail, shed light on Recommender Systems in the consumption domains of interest. While Recommender Systems are always entangled with consumption, some specifics of the food and mobility domain are to be highlighted.

2.3.2.1 Food Recommender Systems According to Tran et al. [345], we can distinguish between four types of food Recommender Systems. The first type gives recommendations of recipes or products based on similarity to consumer preferences [113, 147, 95, 345]. Type two integrates the recommendations of (health) professionals and their assessments [357, 1]. While type three represents a link between the food preferences of individual consumers and nutritional recommendations [98], type four generates recommendations for consumer groups, e.g., a family or group of peers [96, 345].

Within these attempts, primarily content-based, collaborative filtering, or hybrid approaches were used for food recommendations [345, 350]. Thus, recommendations are mainly based on the popularity or similarity of food. Based on this dominant approach, Food Recommender Systems do not work well for critical consumer practices, e.g., recommending vegan food [346]. While this approach ensures broad acceptance of the recommendation, the recommended foods are rather unhealthy and unsustainable [324, 347, 348]. This arises from neglecting the complexity and diversity of diets and practices, e.g., the systems do not work well for vegan or vegetarian diets [346], as they focus on popular food rather than niches and do not take the implications, e.g., allergies or values, into account. Moreover, they reinforce current behavior instead of allowing for exploration and setting new goals [324] and rely on non-transparent ethics [195].

Still, some studies show how sustainable choices can be effectively implemented. For example, Elsweiler et al. [99] show how increasing the ranking of similar, more healthy recipes increases the choice of more healthy food options. Other research [217, 112], however, does not show nudging within Recommender Systems to be an effective way to promote more healthy choices. Studies for sustainable choices are missing.

2.3.2.2 Mobility Recommender Systems For the mobility consumption domain, there are also different types of Recommender Systems approaches found in the literature. The main goal of these systems is to recommend suitable routes and services before and on the trip [228, 106, 157]. For Mobility Recommender Systems, the different data sources play a particularly impor-

tant role. While for traditional approaches, the system usually makes use of static map and transport schedule data, newer systems include dynamic data, such as live traffic monitoring data [82]. Also, user preferences, in the sense of frequent visits, points of interest, or events, can be considered [228].

Still, the focus is mainly on Recommender Systems for traveling rather than everyday mobility [46]. For everyday mobility, Tumas et al. [352] as well as Nadi et al. [245], for example, engaged in researching personalization for route recommendations that consider personal preferences for modes. However, those studies focus on providing a general route recommendation rather than supporting sustainable mobility [46]. Nonetheless, some studies use the concept to support more sustainable mobility consumption within everyday routines, which shows how consumers accept most recommendations [46]. Still, other approaches are limited in their effectiveness. For example, Bothos et al. [47] found empathic messages to have little effect on sustainable transportation choices.

Research within the broader domain of persuasive design combined eco-feedback mechanisms and route recommendations towards 'awareness-related' strategies [233, 321]. Examples here include systems like the Quantified Traveler [178] or EcoMobil [232]. Those approaches deliver detailed information about the own mobility patterns, show a personalized footprint, as well as give suitable recommendations for sustainable mobility. For such systems, Hasselqvist et al. [150] state that combining planning with personalized perspectives, such as fitness or free time, could further motivate sustainable behaviors. Nevertheless, there is little research on evaluating such approaches.

3 Study Outline & Methodology

Designing ICT artifacts for consumers is challenging as they must be technically feasible, on the one hand, and attractive for consumers, on the other hand [242]. Both properties are not necessarily aligned. From this perspective, it is necessary to understand consumers' practices and consider them throughout the design process. Design, thereby, is understood as a learning process where designers learn from qualitative research methods, such as interviews and fast prototyping and evaluation cycles [131].

Before engaging in prototyping, designers need to understand the context of consumer practices, discover design opportunities, and identify consumers' needs and requirements. Due to the complexity and diversity of personal situations and a vaguely defined design space, it is pretty difficult to determine precise design requirements without engaging in consumer research, which is by its very nature exploratory and qualitative [56]. Therefore, according to Creusen et al. [76], qualitative interviews [373], focus groups [241], brainstorming [56], and observational consumer research [277] are commonly used to deal with those challenges.

However, in line with the critique on linear software engineering models that they do not cover the "iterative nature of exploratory development" and that it is "unrealistic to expect accurate requirements [...] early in project" [243], it is argued by different authors, that the evaluation of ICT artifacts should also be qualitative and explorative [378, 230, 327, 242]. In contrast, commonly used methods for evaluating artifacts in research are instead striving for confirmatory or quantitative results [159]. Those methods usually rely on questionnaires to confirm specific hypotheses, e.g., improved usability [184, 22], rather than to bring forward an iterative and explorative design process.

In line with these arguments in favor of qualitative and explorative research, early prototypes can be used for sustainable design to "stimulate productive dialog with [...] users" and further define their needs [280]. The goal of such productive dialogue must be a solution to the paradox of consumer-oriented design. On the one hand, consumer requirements are needed to start the design process, but on the other hand, consumers often lack the ability to know

and articulate what exactly they require [108]. Following Stevens [333], it is not just a matter of articulation, but following the German idealism, artifacts, needs, and knowledge come into the world in parallel through human actions. For example, before the innovation of the freezer, there was no need for frozen products. In other words, needs and products co-evolve. For ICT artifacts, this means that consumers often lack the ability to articulate the requirements, as technical opportunities are abstract and practice transformations to complex and vague. For this reason, the prototype needs to serve as a boundary object that helps consumers to understand the technology and reflect on their practices, as well as designers to better understand the consumer's actual requirements [288].

Against the background of this turn of consumer-oriented design, this thesis adopts and follows the design case study approach [378]. Moreover, the design projects described in part III follow this framework on a micro-level as well. In the following, the basic idea of the design case study and the related research activities used in this thesis are presented in greater detail.

3.1 Design Case Study

As motivated in the previous section, design case studies follow a multi-stage approach that combines design research approaches with qualitative and ethnographic user research methods [378]. This approach is particularly suited to a practice lens. Related research activities focus on detailed exploration and an in-depth understanding of practices before the intervention and afterward.

According to Wulf et al. [378], the design case study approach follows three phases:

1. **Empirical Pre-Study:** This phase represents the beginning of any research activity. The goal is to illuminate the design space for an intervention and understand users' practices. Practices, thereby, include the actual observable behavior of the users and their infrastructures, technologies, tools, meanings, and competencies [312, 102]. From this perspective, the problem to be solved or the need for support to transform

their practices from one current state to the desired state emerges.

2. **Technology Design:** In the subsequent technology design phase, the (preliminary) requirements, formulated based on the empirical pre-study, are transferred into an artifact. Here, the design activities are not the sole responsibility of the researchers or designers, but the later users can also be involved in the technology design, e.g., in the form of workshops, joint analyses of data, or other activities.

3. **Evaluation:** An iterative design case study cycle is completed with the evaluation of the design artifact. The goal of this phase is the user-centered evaluation of the artifact in a real-world setting. This means that the artifact should be available to the users and their practices. With this, the focus should be on understanding its practicality and appropriateness within the design space. The analysis of the insights generated can then be used as a basis for further requirements and optimization of the design, especially as it is often only possible for users to formulate precise requirements with a prototype at hand.

This arrangement of phases can not be understood as a linear approach, for example, in the waterfall model in software engineering [243], but as iterative phases of a framework that relies on the alternation between the understanding of practices, related design activities, and the understanding of the changes caused by the design intervention. Thus, even the evaluation serves to re-examine the design space and the generation of new requirements for adapting the artifact [378]. This is in line with the concept of Grounded Design [287], which stresses that needs, knowledge, and design need to co-evolve.

Now that the theoretical foundations of the research framework and its research activities are described, the individual sections in connection with the research questions will be classified. In the following, the content and relevance of the sections are briefly described along the three phases of the design case study framework.

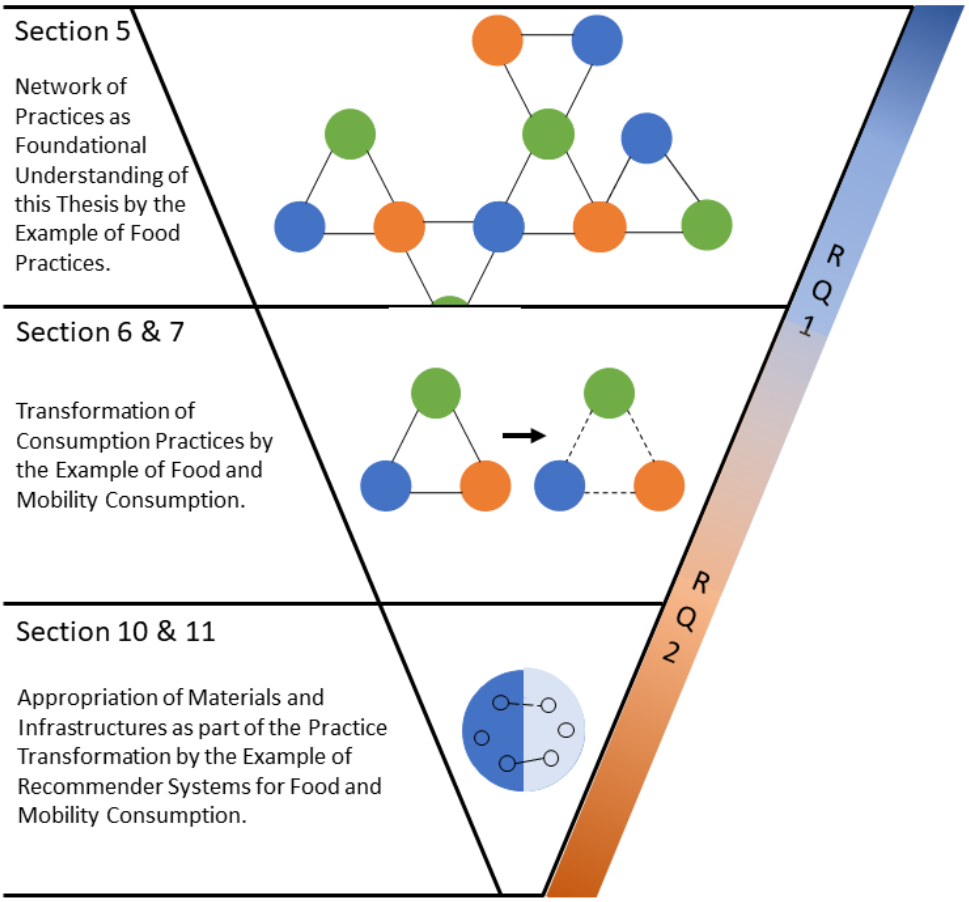

Figure 2: Mapping of Chapters to Practice Theoretical Perspectives.

3.1.1 Empirical Pre-Studies

The empirical pre-studies of this thesis that present empirical studies on the role of ICT in sustainable practice transformations are found in part II. From a research question perspective, this section primarily aims to answer research question R1.

Section 5 presents a theoretical/methodological view on the dynamics and interconnectedness of practices based on an empirical study, which emphasizes a basic understanding of the complex dynamics in the following studies.

In sections 6 and 7, based on semi-structured interviews, practice transforma-

tions and the role of ICT artifacts in the domains of food and mobility are examined as empirical pre-studies. On the one hand, these sections describe the dynamic consumption practices, and on the other hand, they identify starting points for the design, which will be taken up in the following phases.

Finally, the insights are compared and summarized in section 8 as a joint consideration of the mobility and food consumption fields.

3.1.2 Technology Design & Evaluation

Building on the empirical pre-studies, part III presents the technology design as well as the evaluation of the same on the basis of two design case studies on Recommender Systems. From the perspective of the research questions, this section primarily aims to answer research question R2.

Section 10 represents a design case study, which itself consists of a renewed empirical pre-study for detailed consideration of the design space as well as the actual design and its evaluation. The study focuses on a Recommender System that provides personalized recommendations for sustainable food items based on a preset user profile. The evaluation does not focus on usability and technical accuracy but the appropriation and potential of such systems.

Section 11 is a similar study in the context of sustainable mobility. Here, eco-feedback mechanisms are evaluated as part of a multi-modal Mobility Recommender System. The corresponding design is briefly presented in section 9. The focus of this study is also on the appropriation and potential use of the system rather than on any usability issues and the technical accuracy of the tracking or the recommendations.

Analogous to the pre-studies of this thesis, the findings from the technology design and evaluation phase are also compared and summarized in the sense of a joint consideration of the consumption fields of mobility and food in section 12.

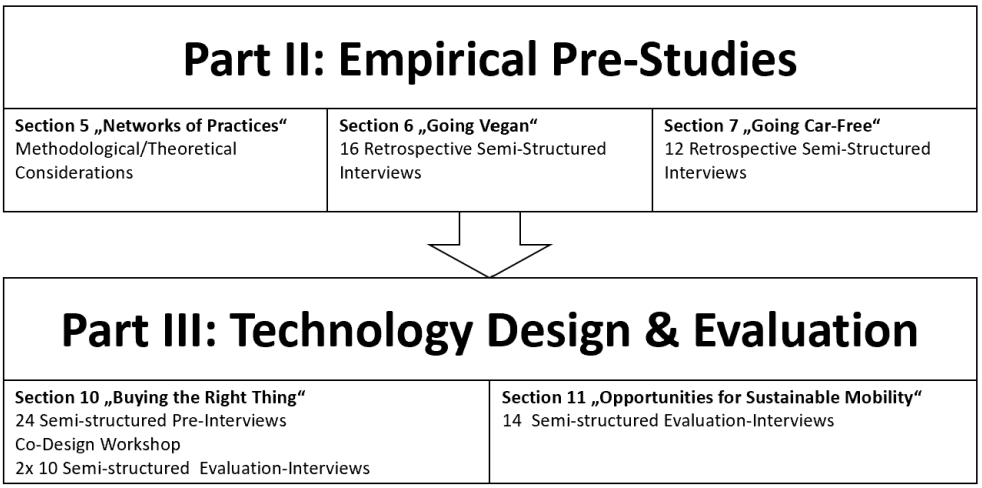

Figure 3: Overview of the Research Activities in the Different Sections.

3.2 Research Activities

Now that the higher-level methodological framework of this thesis is introduced, it is necessary to describe the individual research activities that are primarily used in the different studies of this thesis. In the following paragraphs, these activities are examined from an abstract perspective. Further details on their adaptation can be found in the specific studies of this thesis.

3.2.1 Semi-structured Interviews

Interviews are conducted in a multitude of studies and settings. Interviews constitute a dialogical situation in which the interviewer and the interviewee are equally involved in the course and success of the interview. Thereby, interviews are particularly suitable for getting information about narratives used by people to present their stories to others. However, by its very nature, people do not present a neutral, objective report of the world but their own subjective experiences and perspectives [167]. But it is primarily this subjective experience that is interesting for ethnographic studies to understand how people make sense of the world [166].

Interviews are not a uniform method but a group of techniques, with struc-

tured, semi-structured, in-depth, and other varieties [154]. In this research, especially the semi-structured interview technique is used. This technique is often used to explore specific but complex topics such as consumption practices [213, 117, 150, 356, 301]. The advantage is that the interviewer can deviate from the questions when they recognize an opportunity to gather even more or unforeseen information [2]. In particular, semi-structured questions should ensure that specific topics are addressed in a standardized fashion that enables better analysis but are formulated so openly that narrative potential and not considered views of the interviewee are engaged. This achieves a high degree of comparability but also a certain level of flexibility in data gathering [167]. To gather information on specific situations, interviews should be conducted briefly after the events or situations of interest. Otherwise, inaccuracies may occur due to a temporal distance to a situation, the risk of neglecting details in a personal experience report, and distortion through rationalization of reflections and editing of self-reports according to social desirability [154, 187, 307]. However, such immediateness is not always possible, such that the narrative needs to be gathered after a period of events (for example, in [356, 213] or multiple interviews over time [319].

Interviews are a commonly used method to engage in consumer practices. For instance, studies by Ganglbauer et al. [119, 117], Lim et al. [221], and Farr-Wharton et al. [104] use interviews to gain insights into food practices or evaluate their interventions. Similarly, for mobility, e.g., Hasselqvist et al. [150, 149] use interviews to understand consumer practices. Stein et al. [329] evaluate their artifacts by interviewing the consumers after a certain usage period. Often interviews are conducted within the context of the practices, for example, within the kitchen, where consumers can directly refer to particular objects or perform specific actions to exemplify their answer, e.g., in the study of Ganglbauer et al. [119]. Similarly, to enrich the qualitative data, the interviewers can take photos or collect data from the usage of the artifacts [104, 117].

Figure 3 shows how semi-structured interviews are used within this thesis. In section 6 and section 7 semi-structured interviews are used to research the practice transformation of consumers retrospectively. Here, the focus is on understanding their practice transformation's narrative and artifact usage.

This approach is inspired by other retrospective practice theoretical research (e.g., Twine [356]).

In part III, semi-structured interviews are used to gather data on current practices and to evaluate a specific artifact. In section 10 interviews are used to understand consumers' current practices and reflect on their practice transformation retrospectively. The respective data is then used to sensitize and inspire the design of an artifact. Similarly, for section 11 such interviews are reported on in Meurer et al. [232]. Moreover, for sections 10 and 11 interviews are used to evaluate the usage of an artifact after a certain period of usage. This is in line with other research on sustainable consumption practices [329] that follows the design case study approach.

3.2.2 Co-Creation Workshops

Co-Creation, without any specific method relation, is understood as a process of ongoing interaction between various stakeholders, e.g., technology designers and consumers, to collaboratively shape innovations [173, 216].

A specific point of interaction is the workshop format, which allows the different stakeholders to come together and engage in exchanging perspectives, fostering creativity, and designing prototypes [140, 216]. The goal is to understand better the various stakeholders' personal needs and perspectives on a future design solution. Co-creation workshops are "an effective tool in the process, creating an environment, in which knowledge and skills are taught, practiced and learned"[140]. However, as already seen with the interviews, workshops are not a uniform format but a variety of activities that need to be well planned and adapted to the needs of the stakeholders and the current stage of the technology design [140]. To align the method with this, researchers face the challenges of deciding "whom to involve and how to open the process for those who are affected and secondly, how to scaffold the setting for fostering people's collective creativity" [216]. The planning decisions, therefore, include the themes and tasks that need to be done, for example, if the workshop focuses on the co-creation of user interface designs (sketching) or on general concepts and ideas (brainstorming). Moreover, the location, materials, and time need to be planned appropriately. Lastly, also the relevant stakeholders

need to be identified [140].

Such co-creation workshops are used in various consumer-centric design projects. For example, in the context of energy consumption, Castelli et al. [62] used a workshop to validate their initial design and the individual requirements and further understand consumers' needs. Another instance of using such an approach can be found in the research of Stein et al. [329], who conducted over 40 co-creation workshops, all with different goals, to further engage in the design space, understand consumer requirements and iteratively approach a design for their Travel Planning System. Co-creation methods, such as card sorting, can even be used for non-user interface-related design projects. For example, van Pixteren et al. [361] showed how they incorporated consumers' model of recipes to come up with a new Recommender System.

In section 10 this thesis makes use of a co-creation workshop to involve consumers in the design of a Recommender System. Thereby, the focus is on further understanding the consumers' requirements for an artifact but also on making use of the collective creativity [216] that yields the perspective of the potential users or using consumers.

3.2.3 (Design) Probes

Like the other presented methods, probes are not a uniform method but a group or family of methods [117, 121]. Depending on their setup, researchers can use them to investigate the daily practices of people but also to provoke critical conversations about the design itself or (non) changing practices. From this stance, probes can be seen as a critical design that uses various methodological strategies to accentuate conflicts and social-material conditions taken for granted and empower utopian thinking to imagine realistic but genuinely better worlds [25].

A common theme in probing studies is to create a situation in which the participant reflects on their practices. Probes intervene in social practices by provocative, bewildered, surprising, and open-ended artifacts to reevaluate old behavior patterns to stimulate debates around common stereotypes, par-

ticular technological innovations, or envisions [339]. The intervention should joyfully take place in a way that invites people to have an aesthetic experience and reflect on the existing from different angles. Moreover, technology probes enable the exploration of future perspectives [171] that provide an experience that may change participants' views of the world and offer equally inspiring answers for design researchers [121].

Newer studies use probes with extended capabilities [171, 301, 247] to log the (digital) behavior of the participants, e.g., with the help of sense cams, smart meter, or smartphone loggers. The logged data is then used in two ways: First, the data serves as a thick description of context that the interviewer can consider. Second, the data is typically reported back in an adequate format such that participants can recognize patterns in their own behavior that would otherwise be overlooked due to fragmentation of experiences. In a practice-based setting, Ganglbauer et al. [117], for instance, use fridge cams as a technology probe to intervene in households. They aimed at logging moments of the fridge access via camera to uncover patterns in the personal consumption practice at home and stimulate reflection. In addition, they made time-lapse videos of the fridge to facilitate the reflective learning about their food waste practices in the following interview settings.

In summary, the probe methodology presents a kind of action-research-oriented, explorative ethnography [230] to understand human phenomena and explore design opportunities through self-documentation and encouraging reflection on the personal context and habits [230]. Yet the self-documentation fostered by deployed probes does not provide an objective view of the existing, real and untouched social life but instead a more impressionistic account of the participants' self-images, needs, desires, cultural narratives, and aesthetic preferences [121].

Taking up the examples that this section already mentioned, we see how probes are used in various consumption contexts. For instance, Ganglbauer et al. [117] use the fridge prototype as a probe, or Ng et al. [247] let consumers log their food practices to foster reflection within a later interview session. Also, in energy practices [301] or mobility practices [233], probes are used to facilitate such reflection. This aligns with the qualitative evaluation ap-

proaches as explained earlier in this section.

Design Probes are used twice in part III of this thesis. In sections 10 and 11 an artifact is introduced to the consumers and their practices to trigger reflection on their practices and evaluate the potential of the design approach. While section 10 does not make use of any tracking functionality, section 11 also uses self-documentation functionality [230] as part of the eco-feedback within the Mobility Recommender System. Still, the probes are not evaluated by any formal or quantitative measure but by interviews, as described in section 3.2.1.

Part II

The Role(s) of ICT in Sustainable Consumption Practices

4 Introduction

Against the background of the research questions posed in this thesis, particularly the research questions RQ1, this part deals with the practice transformation journey and the appropriation of practice elements. A particular focus is on the role of ICT artifacts, which accompany the practice transformation.

- *RQ1.1:* How do consumers appropriate sustainable practices and the respective elements?
- *RQ1.2:* How do consumers use and appropriate ICT artifacts to gain access to practice elements, especially infrastructures?

Thereby, in preparation for the next part, Recommender and recommending Systems, i.e., systems that provide access to consumption infrastructures and facilitate their use through information filtering mechanisms, are of particular interest when answering RQ1.2.

From a contribution perspective, this part is intended to provide an alternative technological lens to previous persuasive design approaches [110], increasing consumer motivation but having little long-term impact [52, 91, 229, 301, 302]. The following sections directly connect to previous research on sustainable practices [52, 134, 301, 302, 303, 117, 120, 197, 150] but take a more retrospective perspective that aims to reconstruct the appropriation of practices and infrastructures. Such reconstruction is essential to understand practice transformations as a long-term activity that is not just based on motivational aspects. This broadens the scope of ICT artifacts towards accompanying artifacts in a co-evolving artifact ecology.

Against this background, section 5 shows the dynamics and interconnectedness of changing practices based on a theoretical/methodological view. On this basis, two empirical studies follow in sections 6 and 7 that investigate the practice transformation journey and the respective appropriation of ICT artifacts for the two domains of food and mobility consumption.

Finally, the results are compared and summarized in section 8 in the sense of a joint consideration of the consumption fields of food and mobility. The

focus is on a procedural and dynamic view on practice transformations and the accompanying ICT artifact use. Moreover, we derive implications for design as a preparation for the next part of this thesis, but also to emphasize design in general.

5 Networks of Practices: Exploring Design Opportunities for Interconnected Practices

Abstract

For over a decade, researchers from the practice-centered computing community are taking social practices as a unit of design. While the first generation focused on a social practice in isolation, more recent work argues for the (inter-)connections of mutually influencing practices as the primary unit of design. We discuss these current approaches to motivate the notion of a network of practices. Utilizing the case of food practices, we construct and analyze a network populated by the answers of 60 participants. Based on this network we suggest how to identify central elements and clusters as well as points for intervention within the overall network, but also within and in-between clusters of practices. Based on this, our work critically discusses how an understanding of practices as a network could improve practice-based research and design.

5.1 Introduction

Beginning with the turn from workplaces towards everyday life and culture [42] evermore elements of social practice theory (SPT) find application within practice-centered computing research and design [207]. Starting off with studying single practices in isolation, at least since the special issue on sustainable practices, it became clear that, "it is not appropriate [for HCI scholars] to consider a practice individually, withdrawn from any other practice" [86]. Since then, design research used multiple practice theoretical lenses to better understand the relation of different practices and their interconnection [204, 207] to derive design relevant knowledge [270].

To account for the complexity of interconnected practices [67], several frameworks [102, 117, 247, 340] to structure practices have been proposed. However, these frameworks are rather simplistic by only focusing on specific aspects of practices, e.g. hierarchies [117], consumer lifecycles [247], or ma-

terials [340]. This simplicity does not capture the theoretical connection of practices [248, 249, 312], as interconnected networks forming a 'rhizome' like structure. Nor do they account for the needs of designers, e.g. Kuijer et al. [204] state that identifying overlapping elements of practices should be considered during design. Besides the point that the knowledge about central elements and the connection of practices is valuable for designers, it is also of interest for researchers, who work on a deeper understanding of how practices emerge, persist and mutually influence each other (e.g. [135, 198, 312]).

Aiming to advance models of SPT as a common resource for discussion and exchange between social scientists and engineers, Higginson et al. [160, 161] operationalize Shove et al.'s [312] theoretical ideas of overlapping elements towards a notion of practices as networks. While their paper [161] makes first steps toward a theoretically grounded visualization method, they abandon their theoretical foundation and level of detail in later work [160] for the sake of simplification. Still, their research does not discuss networks from a practice-centered computing perspective and as a source for designers to understand practices. Nonetheless, they [160, 161] prove the general applicability of network theory combined with SPT.

Motivated by a further improvement of the method towards applicability in practice-centered computing research, to derive design-related knowledge from networks of practices and to construct such network, our work presents the example of a network of food practices (FP) based on 60 written-interviews, inspired by Higginson et al.'s survey [160]. The resulting network is exemplarily examined from different perspectives to demonstrate the methodological capabilities. As the focus is clearly on the method and the operationalization of practices as a network, FP are just used a case to populate the network. The method itself is not limited to FP only, therefore we aim to discuss rather general ideas on the usage of such method, by exploring the example of FP.

We choose FP as our domain of interest for three reasons. First, it is already acknowledged by various research in practice-based computing that FP are interconnected and, although we do not fully understand the connections, relevant FP were identified [117, 247, 340]. Second, there exist multiple frame-

works for FP, from hierarchies [117], to lifecycles of consumers [247] to follow the food approaches [340], which offer material for comparison and show the relevancy of modeling this domain. And lastly, Human-Food Interaction is an emerging field in HCI [32, 33], which might benefit from early involvement of a practice lens and a nuanced understanding of practice networks.

By discussing social practices as networks from a methodological perspective our work contributes to future practice-based research and design, by (1) introducing the perspective on practices as a network to the community of practice-centered computing scholars, (2) providing new means to identify central elements, their (dynamic) relationships and interconnections, that otherwise would remain unexplored, and (3) supporting the identification of opportunities for design by the means of network theory.

5.2 Related Work

5.2.1 Social Practice Theory

Attempting to "overcome existing dualisms between actor and structure, by finding ways to give voice to human agency without neglecting structural constraints"[102], practice theory is neither focusing alone on micro nor macro-social phenomena, like individualistic behavior or structural order, but inquire observable effects at both levels. Quite influential contributions to SPT are the ones of Schatzki [294] and Reckwitz [278], who understand practices as the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood"[278]. In Schatzki's [294, 295, 67] initial work two central notions of practice are to be found, one being a linked or organized nexus of different elements ('practice-as-entity') and the other being practice-as-performances. Both are in a recursive relationship, as the performing of doing and sayings "actualizes and sustains practices in the sense of nexuses"[294]. Another central distinction that Schatzki draws is between dispersed practices and integrative practices. While dispersed practices are generic, usually tacit practices that are spread across a realm of actions (e.g. explaining, following rules or imagining) and mainly need some form of understanding, integrative practices are

"the more complex practices found in and constitutive of particular domains of social life"[294].

Building upon Schatzki's work Reckwitz describes practice as the emergent level of the social, "a routinized type of behavior which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge"[278]. Practices are defined by the existence and interconnectivity of these elements and cannot be reduced to any particular one of them. According to that, Reckwitz describes practices as a "block" or "a pattern which can be filled out by a multitude of single and often unique actions"[278].

Shove and Pantzar draw upon Schatzki's and Reckwitz' formulations to develop a framework for empirical research [311]. In current research on SPT, the composition of practices from different elements is largely adopted, even though different authors introduce different key elements [135]. Shove and Pantzar "work with the notion that practices involve the active integration of materials, meanings and forms of competence" [311], which are interdependently related and equally connected. Shove et al. investigate the connections between these key elements and how these connections allow a practice to emerge, subsist, shift and vanish. The three components are described broadly so that different key features can be subsumed. 'Materials' include "encompassing objects, infrastructures, tools, hardware and the body itself"[312]. 'Meaning' has been condensed from what Reckwitz has called mental activities, emotion, and motivational knowledge. For 'competences' several forms of understanding and practical knowledgeability have been summarized. Shove et al. [312] distinguish between practices, proto-practices, and ex-practices. Practices are the well-established and unconsciously performed routines. Proto-practices are practices that are yet not incorporated by the person because relevant elements are not yet existing or are not yet linked. In contrast, ex-practices are practices that have been abandoned because of the breaking of one of the linkages [312].

However, there is still an ongoing debate about which key elements constitute a practice and how a practice is related to other practices via key ele-

ments resp. how the nexus between practice-as-performance and practice-as-entity can be described [135, 170, 198]. Blue and Spurling call for a theory of social practices that includes the "relationships between connections (interconnections)"[41]. They argue that although different descriptions of multi-practice compositions (like bundles, complexes, constellations, and systems) "are useful for understanding how one practice is connected to another, they are of less value in helping us understand relationships between the connections that hold practices together."[41]. For Warde, it is questionable what exactly can be determined in their examination as a constitutive part and where the boundaries of an integrative practice are drawn [365]. Harvey et. al. conclude that the answer lies in the form and focus of the research question being addressed. In studies of practices-as-performances researches narrowly determine practices, while practices-as-entities are investigated within loose, expansive boundaries of a certain bundle of activities to identify common elements that link practices [148].

5.2.2 Interconnected Practices as a Unit of Design

Since Shove et al. first launched their manifest of practice-oriented design [313], several researchers [205, 204, 304, 362] have used their framework as a basis for their design. In contrast to the understanding of product- or user-oriented design, Shove et al. [309] highlight the importance of practices as the unit of analysis and the designability of the evolution of practices over space and time. Within these attempts, similar questions of central elements and (inter-)connected practices arise, not from a theoretical stance, but about the efficacy of interventions and a more integrated view on change.

Kuijer et al. [204] suggest to deliberately introduce unfamiliar elements, e.g. 'Trigger-Products' that can cause what Reckwitz calls a "crises of routine" [278]. However, acknowledging that change in practice(s) is not a matter of technological transformation alone, they stress the connectedness of the investigated practice [67]: "Ideas of cleanliness or perceptions of the body for example, are not elements of bathing alone. Reconfiguration of bathing may require reconfiguration of a wide range of related practices." [204]. Although there is a theoretical debate about the key elements of practices and

their connection, and well-known work in the practice-centered computing community, such as Shove et al. [313] who already account for such relations of practices resp. their elements as well as the need to "identify[...] points for intervention", still there is need to work on the methodological means to identify these elements as well as their relations and interconnections. Similarly, Kuutti and Bannon [207] call for a more holistic approach to practice(s), that does not focus on single aspects only, but rather tries to better understand the role of single elements resp. "computer artifacts in the emergence and transformation of practice"[207].

> "Designing interventions requires a consideration of the complex nexus of interconnected practices (dispersed and integrated) that define food practices" [117].

Considering the interconnectedness of practices is especially important for our example of FP, as e.g. Ganglbauer et al. [117] suggest. To understand and structure the complex entanglements of FP, several constitutional concepts have been suggested:

5.2.2.1 Linear & Cyclic Structure Some authors follow a kind of follow-the-actor [210] approach, where the actor is not the human consumer, but the non-human, consumed food [247, 340]. Tracing the various FP has led to linear [340] and cyclic [247] models resp. Terpstra et al. use a linear model that "shows [...] the route followed by food after its purchase by the customer" [340]. Such an approach proves to be beneficial to identify critical moments within FP [340], but it excludes different perspectives on practices, by focusing solely on the handling of food.

While their approach draws upon the relationship of practices as chronologically organized, they do not account for the key elements of a practice. Still using a following-the-actor approach, the food consumption lifecycle by Ng et al. [247] already accounts for different entry points and the repetitive nature of food consumption (see Figure 1b). The incorporation of motivational factors in FPs, as well as the utilization of tools within different practices, are an advantage of their model. Besides, the model suggests that planning is the

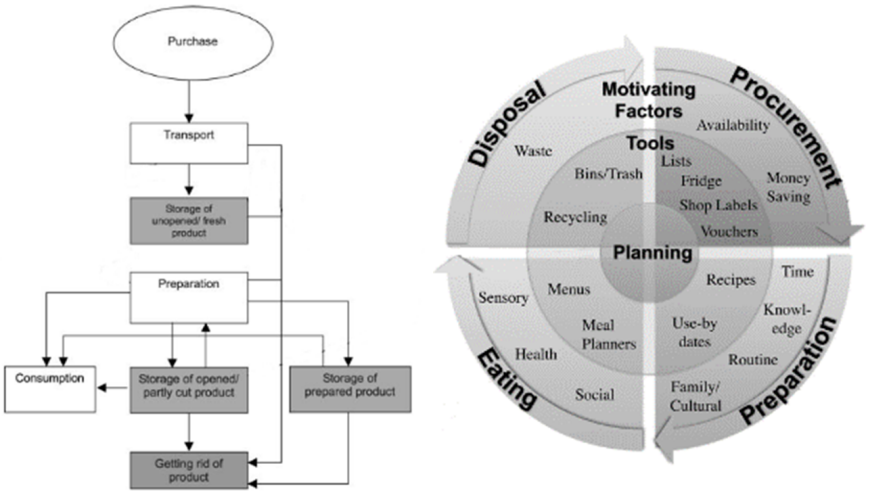

Figure 4: (Left) Linear [340] and (Right) Cyclic Practice Models [247].

underlying central practice governing all FP: from procurement to disposal. This implies an individual agency making rational decisions and thereby neglects a fundamental notion of SPT, namely that an individual merely acts as the carrier of a practice (see [279, 294]). Such a view is insufficient because it considers food waste as a planned behavior, rather than an unintended result of interconnected practices [117].

5.2.2.2 Dispersed & Integrative Practices Besides linear and cyclic approaches, Warde [364] and Ganglbauer [117] use the notion of dispersed and integrative practices, which suggest a hierarchical, tree-like structure of top- and sub-practices. Although they do not visualize their structure, their attempt aims to identify hidden interrelations and the inner logic of FP as a complex bundle. According to Ganglbauer et. al. integrative practices in the food domain are, e.g. "cooking practices and eating practices, where the embodied actions of the cook or the dinner are often habitual, informed by histories and cultures of performance, but also adapted to an unfolding social and environmental context" [117]. For Warde [364] consumption cannot be considered an integrative practice but is rather a dispersed practice that is required and entailed in most integrative practices. Ganglbauer et. al. [117] argue that food disposal, as non-consumption, is a dispersed practice as well. It is not by chance that Ganglbauer et. al. [117] do not apply a follow-the-

good-as-the-actor methodology, but use open-ended interviews to make use of people's competences to express relations among practices and to integrate experiences as well as to rank them into hierarchical order.

5.2.3 Excursus: Network Theory

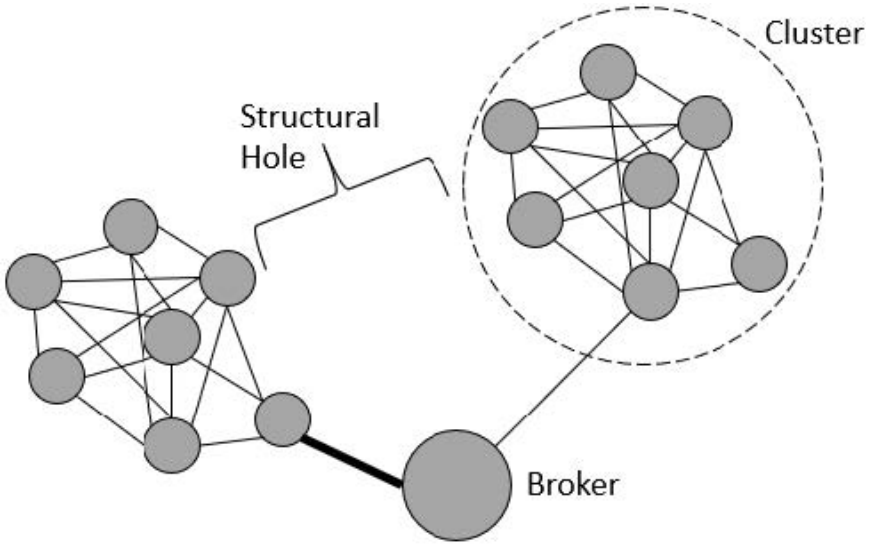

Figure 5: Simple Example Network.

Before our work continues with an explanation of how SPT and network theory relate, we briefly want to give a short introduction on basic terms from network theory based on the work of Burt [54] and Butts [55]. Figure 2 shows a simplification of a network. The grey circles are nodes, which represent entities in the network. Nodes are connected by edges, that have a varying thickness, which displays their degree of importance. The thicker they are, the more important and vice versa. When several nodes are closely interlinked with each other by edges they form a cluster. In our example network, the two clusters are connected by a node called broker, which creates a kind of bottleneck between both clusters. In this case, we can suggest that the broker has a high centrality, meaning a short average distance to all other nodes. Nodes have a 'degree', which describes the amount of edges connected to the node. For the limited connection between clusters, network theory refers to structural holes [54], where only little exchange between clusters resp. their

elements exist.

5.2.4 Social Practices as a Network

Addressing the downsides of current modeling approaches on SPT, researchers [31, 160, 161, 211] suggest a new method: The conjunction of network theory and SPT. Motivated by a deeper understanding of practices as well as the creation of models to improve the communication between engineers and sociologists [160, 161], a further discussion and refinement of their work might contain solutions for questions arising from practice-based design.

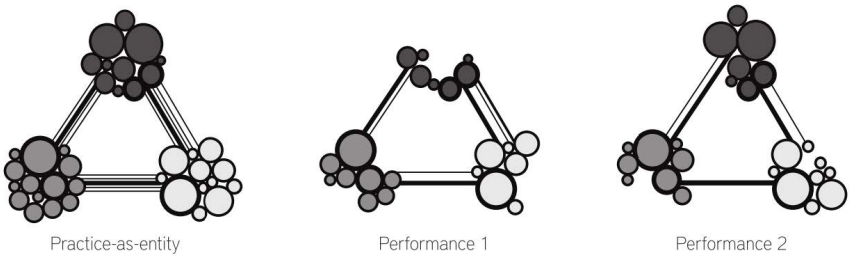

Figure 6: Adapted Practice Model by Kuijer [206].

Shove et al. [312] explore elements shared by different practices. Based on the example of driving and repairing they illustrate how masculinity is a shared element of meaning between both practices. While this perspective exemplifies the details of connections a more 'zoomed-out' perspective promises to see a network of practices forming an interconnected nexus [312]. This perspective is also shared by Nicolini [248, 249], who describes practices a forming rhizome like network structure, that is formed by connected elements, such a computer that is shared by the practice of manufacturing and using computers.

Slightly adapting the model of Shove et al. Kuijer [206] visualizes variants of practices-as-performances, that built a partial "manifestation" of the practice-as-entity. The practice-as-performance is constituted by a sub-set of elements and therefore links connecting them. Kuijer draws upon the importance of certain links, by increasing their line strength. Strength reflects the impor-

tance of a link, whereby it is stronger when the connection is observable within more performances. Similarly, the size of the bubble represents the importance of a certain element [206].

Higginson et al. [161] propose a different layout of the graph since the clustering of elements of the same type implies a certain proximity which does not necessarily exist. In their layout, the type of the element, either material, meaning or competence is given by color instead of position. To further increase the information gain by the means of visualization Higginson et al. suggest drawing the node size, based on its node degree [161].

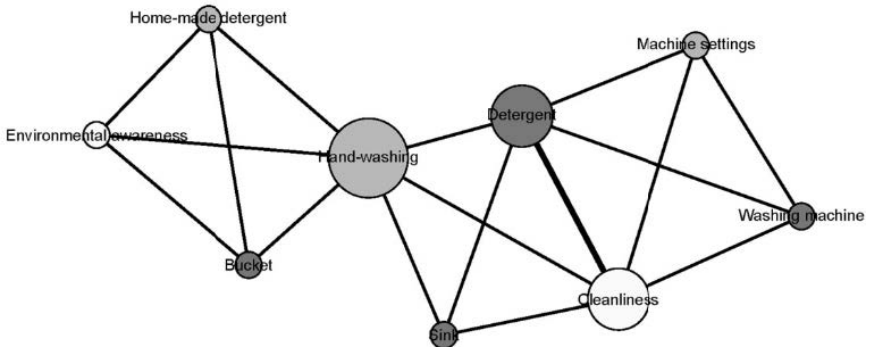

Figure 7: Example of Laundry Practices as a Network [161].

In their first work Higginson et al. [161] construct a network of a practice to identify central elements shared by the practice of doing laundry. The here investigated perspective very much refers to 'zooming in' as described by Nicolini [248]. Still, the comparison of different practices belongs to 'zooming out' for her. She 'metaphorically' highlights the importance of studying practices in detail, by recognizing the interaction of humans with artefacts, materials, and other humans. From this perspective, the 'rhizomatic nature' of practices is quite similar to Shove et al. [312]. Still, shove goes a step forward in distinguishing between elements that constitute parts of the rhizome and how they have to be connected universally.

In further research on commuting as a practice, Higginson et al. [160] take up on Shove et al.'s [312] suggestion to 'zoom out', but abandon their theoretically founded 'universal connection' phenomenon, that implies that all elements of a practice are equally connected in constituting the nexus. Hig-

ginson et. al. [160] move towards a follow-the-actor approach by chronologically connecting practices, that does not reveal hidden (inter-)connections of the nexus. However, despite these criticisms, their work provides the fundamental considerations to construct a network of practices. Therefore, there work more resembles the 'zooming out by following intermediaries' as described by Nicolini [248], that implies a stronger spatio-temporal dimension to the antecedents of practices, rather than a universal zooming out on shared elements as Shove et al. suppose [312].

In summary, we see how not different scholars attempt to operationalize the theoretical perspective on interconnected practices as network by mainly referring to Shove et al. [312]. Although there are differences in the meanings of what zooming in and out is about, we think that, in addition, to continuing to follow the path of Shove et al. [312], the work of Nicolini [248] is valuable to consider for a more nuanced understanding of perspectives.

Based on this inspirational corpus of ideas, our work tries to improve the method, adapt it towards applicability practice-centered computing and trigger design-related discussions.

5.3 Constructing a Network of Food Practices

5.3.1 Qualitative Online Survey

To construct a network of FP, we conducted an online-survey, similar to the survey of Higginson et al. [160]. We decided to follow the approach of Higginson et al. [160] in conducting a survey, as this paper mainly focuses on the operationalization of practices as a network and as the method has shown to be fruitful in their research. Still, especially in the light of ethnographic research [117, 247, 248], we believe that it is necessary to consider other, probably more detailed methods in the future. Therefore, we discuss the choice of methods in more detail in the discussion section (section 5.5).

The survey of Higginson et al. [160] was adapted to be more online and user friendly. We randomly assigned each participant to questions either about planning, procurement, storage, preparation, eating or disposal, which are

most commonly used to structure FP [32, 33, 117, 247, 340]. The questions encouraged the participants to describe the competences they use, the material context of the practice as well as the meaning of the practice. In total we asked 9 questions per practice, with 3 questions per elements category, either material, meaning or competence. For the example of cooking the questions were: "which tools / aids do you use for cooking?", "which techniques and skills do you use for cooking?" and "which (social, religious or self-defined) rules and norms influence your cooking?".

Our sample of 60 participants (10 per practice) has been recruited through an opportunistic sampling approach within the authors extended social network, to capture a variety of practices. We directly asked practitioners in our social media to participate. The resulting sample is characterized by the following socio-demographic structure:

- Age (18 – 80, Avg. 40, Std. 18.39)
- Gender (37 female and 23 male)
- Education (29 university degree, 5 trade school, 11 apprenticeship, and 15 high-school)
- Housing Situation (18 with a partner, 1 alone with children, 19 alone, 12 partner and children and 10 flat-sharing community)

The qualitative survey data were transcribed and analyzed[1] with Catma[2]. We used the practice-theoretical lens of material, competence, and meaning [311, 312] to mark the elements for our later network within the given answers. After each iteration of coding, we discussed the current coding template [202] to ensure reliability.

5.3.2 Network Construction

Analogous to the first attempt of Higginson et al. [161] we treated the occurrence of each element within the coding of the individual survey result as

[1]The elements identified in the interviews were translated from German to English. The coding was done by a native speaker based on the German original survey answers.

[2]https://catma.de/

equally important for the constitution of a practice. We followed this perspective as it is grounded on the perspective of Shove et al. [312]. Following the work of Kuijer [206], we weighted the importance of connections and elements based on their number of occurrences in the complete survey. To further explain our operationalization, we imagine the following example: A single practitioner answers that s/he for cooking uses a pan (material), his/her cooking skills (competence), and follows the meaning of health.

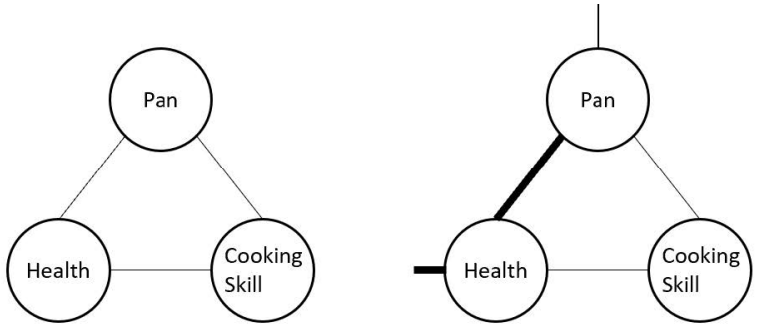

Figure 8: Example Network of Practices with Weighted Importance.

(Left) Example Network for One Practitioner; (Right) Same Example Network for Multiple Practitioners.

As Figure 5 (left) shows for this single practitioner all elements are equally connected with no specific weight for the edges. If we now add answers of other practitioners, that among other elements, name the pan and health, the weight is adjusted to highlight the importance of specific connection (see Figure 5 (right)). Analyzing our survey results, we filled out a matrix (159 elements on the x-axis and the 60 participants on the y-axis) with an one (if an element is mentioned) or a zero (if not). With the help of a Python script, we imported the results in Gephi[3], an open-source graph exploration software. This resulted in a Graph of 159 nodes (89 materials, 41 meanings, and 29 competences) with 2759 edges (weight between 22 and 1).

In line with Higginson et al. [161] we ranked the size of each node according to its degree and then applied the force atlas 2 layout, to pull highly connected elements into the center of our network and form clusters of highly interwoven elements. However, we choose a different measure of distance,

[3]https://gephi.org/

which addresses the original criticism of Higginson et. al. [161] concerning Kuijers [206] approach, that the three key elements of practice are resp. not necessarily strongly tied to themselves. While Higginson et. al. [161] solve this issue by rearranging the network with the help of a force atlas algorithm, we additionally distinguish between the elements by color, according to the respective practice that has been inquired. To distinguish between the key elements, we use 'M' to tag meaning, 'S' for material and 'C' for competence in brackets behind the name, e.g. Food (S).

5.4 Food Practices as a Network

Examining networks of practice with a theoretical focal point in mind and visualized by the means of network theory, we will interpret and discuss certain perspectives on the network of FP to define methodological capabilities and raise questions for further research.

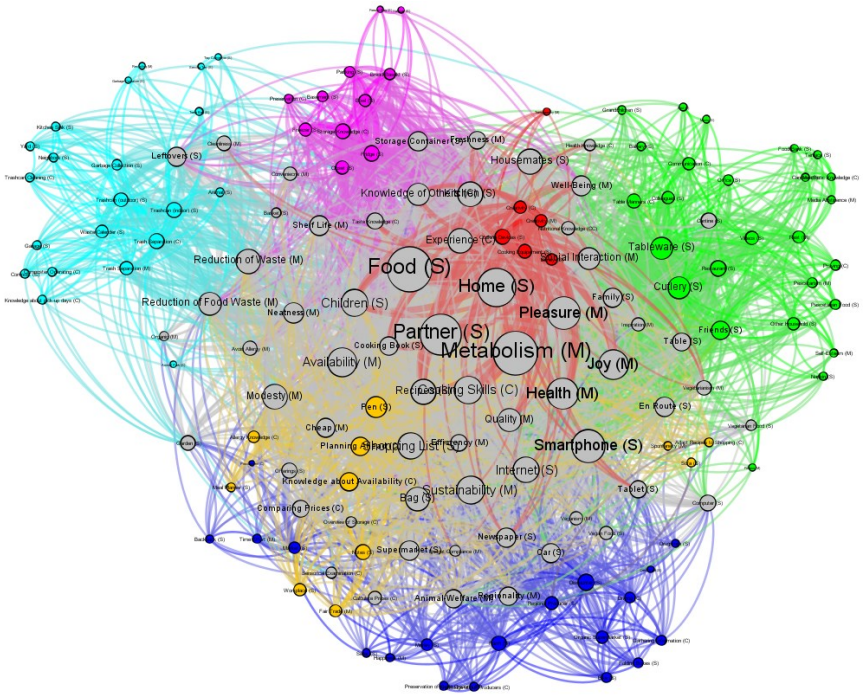

Figure 9: Network of Food Practices.

(Cyan = Disposal, Purple = Storage, Yellow = Planning, Blue = Procurement, Green = Eating, Red = Cooking, Grey = Multiple Practices)

5.4.1 Zooming Out

When 'zooming out' we are able to first identify the overall arrangement of practices, by analyzing the clusters (practices) separated by their respective color and second the central elements of the overall network. While we mainly follow the perspective of Shove et al. [312] when zooming-out as means to see the relation of practices, still, this is similar to what Nicolini describes as "Zooming out by following the relationships among practices" [248].

In Figure 6 the elements are colored according to the practice, that they constitute. When an element constitutes multiple practices, we colored it grey.

5.4.1.1 Arrangement of Clusters within the Network When observing the network of practices from a 'zoomed out' perspective, we first see how practices, given by their clusters of elements, are separated and visualized by color as a measure of distance. The practices all include several elements that are colored by their unique given color and therefore are essential to this practice only, while other elements (grey) are constitutive for several practices. With a further look at the overall arrangement of practices within the network, we can see that practices of eating (green), procurement (blue), planning (yellow) and storage (purple) group themselves around the practice of cooking (red). Besides the red elements of the cooking practice, a cluster of shared elements, strongly connected to cooking, as visualized by the edges, is located in the center. Those elements, such as Food (S), Partner (S), Metabolism (M) or Home (S) are shared by several practices. These elements are represented with the biggest nodes, based on the frequency of being mentioned. Therefore, they can be seen as central to the overall network of FP. The constitutive elements of the practice of disposal are connected to the practices of planning and storage, but in general not central within the overall network of FP.

5.4.1.2 Central Elements - Central Clusters Besides the whole cluster of elements of disposal practice, single elements of other practices are placed in the peripheral area around their respective practice. Higginson et al. [161] state within their reflection on core and peripheral elements, that "[c]entral

elements are defined as 'core' to the practice; those which appear at least once in each variant and are shared by all variants. Marginal elements are 'peripheral'; they are herein defined as those elements which are unique to a single variant. Elements that do not fall into either the 'core' or 'peripheral' groups logically form a third group, which is referred to as 'intermediary'. These elements are shared by some, but not all, variants."[161]. At this point we want to extend the corpus of analytical lenses on the network of practice, by defining central and peripheral clusters. We define central clusters as those, being 'core' to a network of practices, resp. those contributing to the overall doing of the practices. Peripheral clusters are similarly not important for the network of observed practices, in a way that the incorporated doing of several (inter-)connected practices might be possible without this specific practice (depicted as a peripheral cluster).

After describing the overall structure of the network and how clusters are arranged, as well as defining the ideas of central and peripheral clusters resp. practices, we now want to have a further look on those central grey elements, having a high node degree. While Food (S) as a central element is quite an expected result, as already mentioned by follow-the-actor approaches [247, 340], other elements such as Metabolism (M), have not been mentioned in attempts to structure FP. Especially when utilizing the lens of dispersed and integrative practices [117, 364] to interpret the importance of the cluster constituted by the central 'meaning'-elements Metabolism (M), Joy (M), Health (M) and Pleasure (M), we see the notion of consumption as a dispersed practice. Thereby consumption is not constituted by any competences, at least no competences mentioned by our participants, but the food as the material to be consumed and several meanings that are attributed to the (prospectively) consumed material by the participants.

5.4.2 Zooming In-Between

When zooming in but remaining on a perspective on the whole network of practices, to which we refer as 'zooming in-between', we are able to identify elements that connect practices and therefore function as intermediaries. This zooming on intermediaries originates from Nicolini [248] but is used in a

more immediate sense rather than overtime in our work.

5.4.2.1 Elements and their Connections From a practice-centered computing perspective, the central role of the smartphone is interesting to see (Figure 6). To follow the links of the Smartphone (S) we colored the smartphone red and its adjacent nodes pink. Other elements are dark grey. This, on the one hand, shows how many direct neighbors the smartphone has, and on the other hand how it is linked to nearly the entire network. The smartphone being centered between the practices of cooking, eating, procuring and planning, shows how digital technologies integrate whole parts of FP, by e.g. allowing to write a shopping list on the smartphone, using it whilst shopping, searching recipes on the smartphone or even using them as a starting point for planning and finally watching videos during mealtime or sharing photos of food with others.

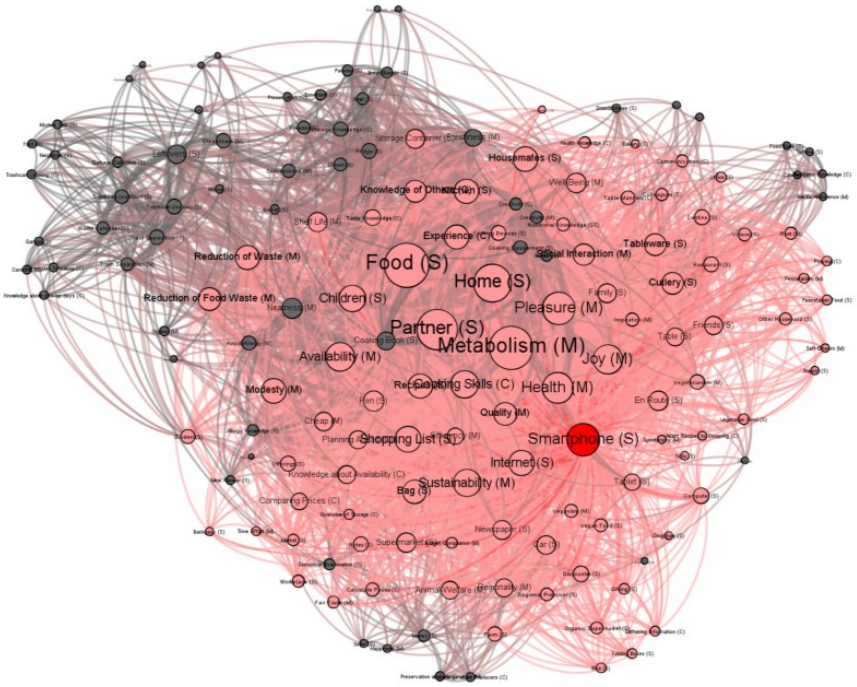

Figure 10: Smartphone Connecting Practices.

Apart from that, we see how the smartphone is not central for practices of storage and disposal yet. These practices remain excluded from data exchange,

at least from a digitally mediated data exchange, through the use of smartphones.

5.4.2.2 Practices and their Connection. When having a look at the overall arrangement of practices, the question of why disposal is not equally connected to the highly connected cluster of cooking resp. to the rest of the network arises. To answer this question, we 'zoom in-between'. By doing so we are able to reveal the links between disposal and the other practices in detail. To do so, elements only belonging to disposal are colored in light blue, elements shared with another practice are colored according to the practice (purple = storage; blue = procurement; green = eating; dark grey = multiple practices).

Although disposal practice is in general only loosely connected to the main cluster, its elements are linked to some of the central elements of FP, e.g. the food itself, the kitchen and residents of the household. Those connections are quite expected, due to shared household activities and the food, being the material that is thrown away. Similar to the element Kitchen (S), eating is connected to disposal due to the Cantina (S) as a shared location of eating and throwing away food.

Besides those obvious links, is the linkage between two thematic clusters worth having a look at. First the cluster of '(Food) Waste Reduction', constituted by elements such as Reduction of Waste (M), Reduction of Food Waste (M), Sustainability (M), Modesty (M) and Neatness (M); and second the cluster of 'Unspecific Food Competences', constituted by elements such as Experience (C), Taste Knowledge (C) and Knowledge Taught By Others (C). Those links show how disposal is, in the mind of the participants, not meant to be a part of FP, but a practice whose performance has to be minimized. However, the competences, besides Taste Knowledge (C), do not indicate a clear strategy, despite the trust in one's own experience. Taste Knowledge (C) as a competence describes the knowledge about one's own as well as flavor and ingredient preferences of others. This seems to be a method of ensuring the procurement and cooking of meals that are not in danger of being thrown away caused by the mismatch of preferences and characteristic flavors. In-

terestingly participants mentioned other skills belonging to disposal, such as the cleaning of the trash can, the knowledge about the pick-up days and the operation of a composter. While the first two and the meaning of Cleanness (M) indicate a strong connection between disposal and other cleanness-related practices, e.g. laundry practice identified by Higginson et al. [161], the operation of the composter indicates a connection to gardening.

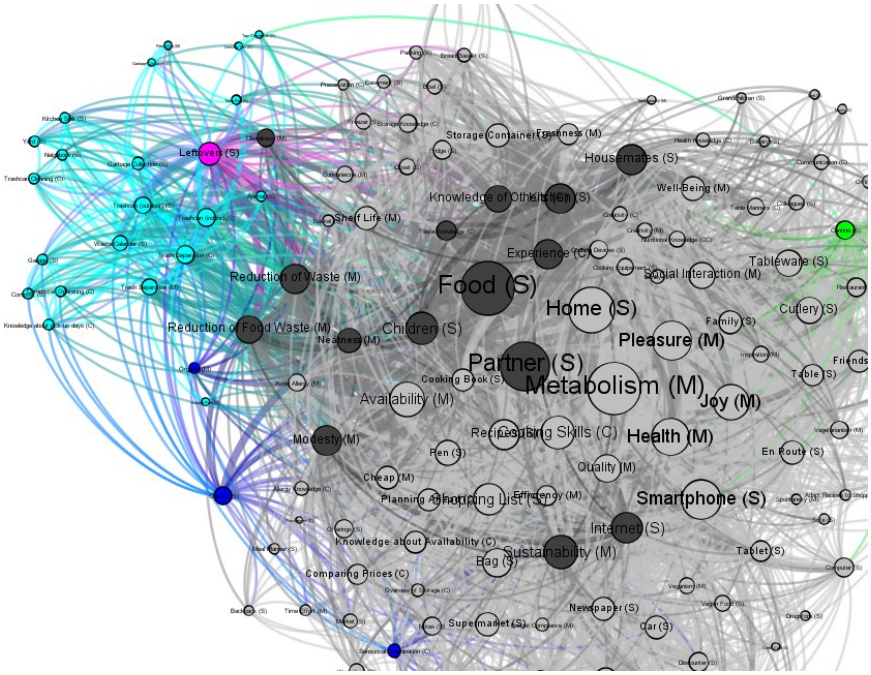

Figure 11: Zooming In-Between Disposal.

Having a look at the links towards procurement (blue elements) the connection to gardening becomes more obvious. Especially the meaning of Organic Food (M) as well as the Garden (S) as a place to procure food, show how disposal might be connected to the overall cluster in the sense of a lifecycle. However, gardening to grow one's own food is not a common practice [71]. Therefore, this connection is not strongly tying disposal to procurement. Besides Gardening (C), procurement and disposal share the competence of Sensorial Examination (C). Food is examined according to certain sensorial characteristics when being bought, but also when the decision of whether to keep or dispose of food or leftovers. Besides the dark grey elements, Leftovers (S) as an element shared with the practice of storing food, has the highest degree

(node size). This element indicates the change of perception on the food, so it becomes another material: The food which was previously integer becomes a leftover because it was once prepared and meant for eating or was partly not needed during food preparation.

5.4.3 Zooming In

When 'zooming out' we were able to recognize the central position of the cluster of elements of cooking practice. To further understand its centrality, we should 'zoom in' this cluster of practice itself to have a more detailed look. To observe a specific practice, we have chosen a coloring that fade out elements not belonging to the practice, as well as gradually coloring those elements constituting the practice according to their centrality for the practice itself (see Figure 9). This helps visualizing central elements of the overall network, based on the size of the nodes, as well as the centrality of the elements for the practice itself, based on the gradual coloring. While elements central to the overall cluster, such as Food (S), Home (S), Metabolism (M) or Partner (S), are of minor interest here. Nodes, such as Cooking Skills (C), Recipes (S) and Cooking Devices (S), as well as Cooking Equipment (S) are more interesting. Based on the coloring we can see how Cooking Skills (C), Cooking Devices (S) and Cooking Equipment (S) (small Nodes above Home) are equally colored, which means, that they are equally central for the practice of cooking, but their node size is different, which means, that they are of different importance to the overall network.

Furthermore 'zooming in' shows how Cooking Books (S) and Recipes (S), which are less central to cooking, based on our network, are central to the network of food practices. Examining their connections suggests how the knowledge about cooking, either informal or as a formalized recipe, is used during planning and procurement practices.

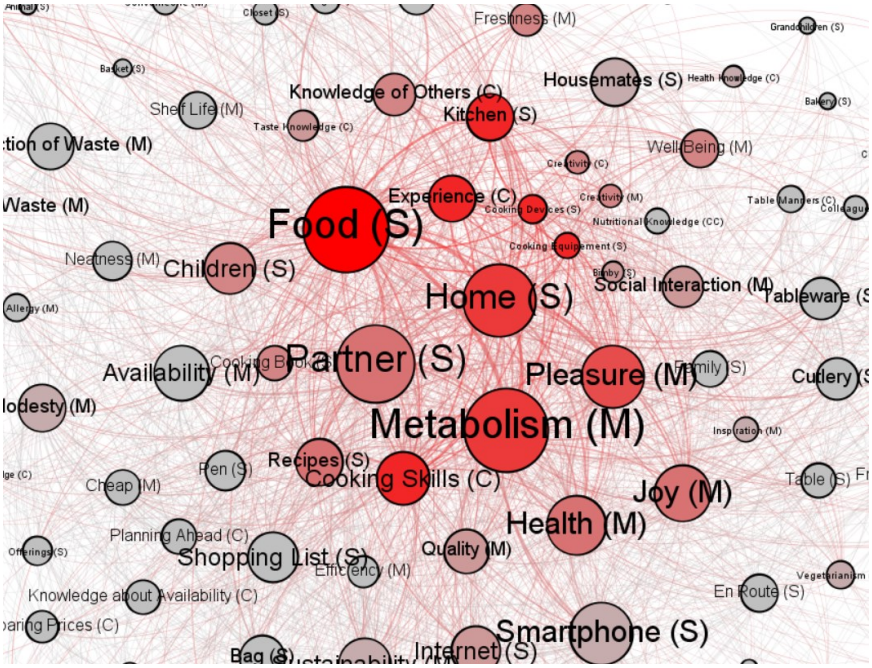

Figure 12: Zooming In Cooking.

5.5 Discussion & Critical Reflection

5.5.1 Informing Design through Networks of Practices

Our example of FP as a network as well as Higginson et al.'s [160, 161] work present the analytical capabilities of the approach to visualize practices using network theory. However, still, there is a need for discussion about how the method enhances our understanding of practices and what kind of implications resp. incentives it provides for design. We argue that networks of practices provide the means to identify opportunities for intervention as well as new methods to evaluate design, both through the visualization of static and dynamic networks of practices.

5.5.1.1 Identifying Opportunities for Intervention Our example network indicates two different opportunities for intervention: first, the identification of, what network theory calls 'structural holes' [54, 55] and second the identification of elements that are central to the overall network, meaning that they are connected to several other elements and practices.

Regarding structural holes, the food network reveals that there is a hole between the practice of procurement and the practice of disposal. While our network already indicates possible connections through Gardening (C), the practice of growing one's own food is not widespread anymore [71]. The identification of such a structural hole might provide opportunities for intervention, e.g. the (re-)introduction of a practice to fill the hole and tie practices together more strongly or implementation of other mechanisms or technologies to connect the elements of the practices through a, for the lack of a better word, broker-technology. 'Brokerage' [55] indicates the role of a certain node as a connector of different clusters. In our example, such broker-technology might e.g. connect a competence of the procurement practice, such as Sensorial Examination (C) to disposal practice, so that food is more commonly examined by the status quo of edibility and not by the narrow definitions of food regulations, e.g. the best-before date. Identifying opportunities for such brokerage might be especially valuable for technology probes [118, 171]. They could act as a means to fill the gaps and explore opportunities for a (re-)connection. While traditionally, probes focused on reflection on and changing of practices, brokerage in this sense offers a new opportunity for restructuring and recombining whole networks of practices.

In order to facilitate digital support for practices, practice-centered computing researchers can find the means to widen the field of investigation in an network-theoretical approach to everyday (food) practices especially by investigating digital artifacts (the smartphone) with regard to connected elements (competences, meanings and other materials), the connections to different practices, its comparable importance to a particular cluster and the overall network, and the relationship of these connections (interconnections). Thereby practice-centered computing research can evaluate how a design intervention can influence other elements, practices resp. their nexuses, and in particular how storage and disposal can be included in the development of integrative systems to support FP.

Regarding central elements and clusters, our network shows how central and widespread certain elements are. For example, the Smartphone (S) is connected to several practices of the FP network, expected storage and disposal practices. Similarly, Cooking Skills (C) (formal or informal), as well as the

cooking practice itself, are central to the network. The identification of such elements for intervention is quite alike to what Shove et al. call "points for intervention" [313]. These points might enable change within a network of practices, reaching more than one practice alone, but several connected practices. Within our example, an intervention focusing on the central role of Cooking Skills (C) might influence other practices next to cooking practice. Being able to cook healthier might for example lead to more healthy procurement practices. Likewise, the whole cooking practice might bring change to FP as a whole when being influenced by an intervention. However, our work provides no answer on how a change in a central practice effects the nexus of other practices.

A network of practices overcomes the focus on a particular practice (or its central element), towards "an emphasis on the interdependencies, connections and configurations that are central to the constitution, reproduction and transformation of social life"[41]. In this way, design interventions can be examined for their effects on other practices or their nexuses. Before interventions are initiated, they can be diagrammed in different network graphs representing the distinct nexuses of practices based on different intended interventions. Furthermore, the current stage of interventions, somewhere between proto-practice and practice can be analyzed. By these means, researchers and designers can discuss and evaluate design decisions.

Networks of practices can support practice-centered computing research in the development of design interventions and decisions by giving it access to previously unexposed information, in particular, to illustrate interconnections. We were able to show that a 'zooming in' is possible in the form of representing a practice within a nexus by visualizing both, the relevance of a central element for the practice and the nexus. In the 'zooming in-between' the different connections to a central element or a cluster of a practice, in our example, the smartphone or food disposal were presented. Likewise, in 'zooming out' the connection between clusters of practices become investigable. In the study of these different forms of connections, the understanding of the relationship between connections (interconnections) can be extended.

As Kuijer et al.[204] already suggest, central elements are not a 'magic bul-

let'. They bear the danger of making interventions more difficult and complex due to the need for a reconfiguration of other practices as well. In line with their considerations, networks of practices help to identify the interconnectedness of these elements and therefore raises the awareness about how difficult and complex a certain change might be as well as which practices and other elements an intervention should consider, too.

5.5.1.2 Evaluation through the Dynamics of Practice Networks Both network theory and SPT are not only interested in static representations but challenge the understanding of dynamics. This is especially interesting to understand how complexes (of practices) change [312] and how spatio-temporal patterns arise [248]. While network evolution supports the approach of Shove et al. in an analogous way, processes might be applicable for observing certain elements or clusters as they move through a network of practices. Processes are comparable to the notion of 'threading through' which is a term in an open discussion within the social sciences in order to find a theoretical framework for how "an object or a practice, can move or advance through the nexus of practices, thereby linking the practices through which they pass or to which they are connected"[169]. For the practice-centered computing community, these approaches promise to give valuable insights into the course of hardware, technical devices, and other artifacts through daily usage. An exploration and elaboration of such dynamic diagramming of networks of practices is open to future work.

While some short-term interventions allow measuring certain key-values, such as the amount of food discarded [10, 104, 105, 118] or the amount of organic food purchased [381], sustainable, long term practice change, especially when it is still in a phase of transition, requires other means for evaluation. Networks of practices allow for such evaluation of interventions, concerning the dynamic of social practices [312]. Although our work did not capture two or more different networks of FP in terms of time, that could be compared, the example of the smartphone indicates how appropriation and access of an intervention could be analyzed. Comparing a depiction of a network of food practices, captured before the invention of the smartphone, could reveal how such a widespread technology might have influenced and changed the inter-

connected FP. Further research could draw from our results by looking into the influence and change in certain clusters of practices and the rearrangement of connections between certain elements. However, as we have seen in our example, the smartphone is central, but not reaching disposal and storage practices so far. Comparing our network with another empirically captured network after a smartphone-based intervention, that focuses on storage practice, might help to understand how the practice has changed with respect to its elements and their connections. Additionally, side-effects on other practices and the overall network, as well as barriers for appropriation, can be analyzed. Having such a measure at hand might, therefore, support more sophisticated and integrated evaluations of design.

5.5.2 Gathering Data & Constructing Networks of Practices

Lastly, our work wants to critically reflect on the method of creating a network of practices from different perspectives.

5.5.2.1 Avoiding the Trap of Oversimplification Although our research, so far, presents the opportunities of this new approach from quite an optimistic point of view, networks of practices similar to any other modeling of social life may be too condensed. Any trivial representation of a nexus runs the risk of undermining the complexity of elements and their connections if these connections themselves are just another element. Schatzki debates practices cannot be modeled or simulated without jeopardizing the irreducible complexity and dynamism of social affairs [296]. Shove et al. [312] already considered the danger of their model falling "prey to the scientific urge to build simplifying, diagrammatic models of social life"[295]. Also, Higginson et. al. bring into the debate, if the approach of diagramming social practices into one graph can fall into the "trap of reducing the insights of SPT so significantly as to undermine their contribution"[160]. However, the possibility of that trap should not prevent us from researching new means to make SPT more accessible for empirical research agendas and thereby scaling up its impact on design. Shove et al. [312] argue similarly, when they state that their approach helps them to gain insights into the conceptualization of stability

and change as well as into the recursive relation of practice-as-performance and practice-as-entity. While we have not evaluated our method towards its capabilities to support insights gained in a real-life design case so far, we see from a methodological point of view how a condensed network approach supports the identification of certain characteristics of connected practices.

However, these potential benefits do not liberate us from the awareness of the boundaries and downsides of social practice modeling and the task to critically scrutinizing our own method as well as to improve it in regard to accuracy and precision. Higginson et al. argue that "thinking critically about how one might model practices and experimenting with different approaches is in itself a valuable aim"[161]. The very difference in the level of detail between Higginson et al.'s [160] work and our approach shows how little advanced the discussion about networks of practices is and how much networks of practices have to be created and analytically used to understand the capabilities and barriers of the method.

5.5.2.2 Empirically Populating a Practice Network While our work has adapted the survey of Higginson et al. [160] such that people not familiar with SPT can answer the respective questions, we have not questioned the procedure in general. This might be less important for our example network due to the methodological contribution of this paper but is a key question for the applicability of network theory in future design-oriented work.

Considering the unequal distribution of material, competences, and meanings, that have been gathered with our survey, the question of how to gather as many nodes and their connection as possible arises. While Higginson et al. [160, 161] and our work uses a qualitative survey, that needs interpretation and coding of the results to identify the elements of the network, other SPT based research uses a broad variety of methods, e.g. qualitative interviews [117] or ethnography with a sense cam [247] as well as closed-questions quantitative surveys [366]. In our view, the use of other empirical methods could also be applicable to networks of practices. However, our work does not provide an answer on which method to use to gather empirical data for the construction of a network of practices. Here, further research should focus on a better match

between the collection of data and the visualization. Using a deeper ethnographic inquiry might allow for thicker data sets and elements that remain hidden when directly asking the participants.

However, ethnographic research is time-consuming and often relies on smaller samples, and networks of practices require some kind of quantification by definition [88], e.g. to determine the edge weights before letting the layout algorithm run. Kuijer [206] already laid the basis for edge weights depending on the importance of a certain edge resp. the number of occurrence within the sample [161], but we so far do not know how big our samples need to be to identify the weights of the edges. correctly. Furthermore, the occurrence of all performances and their elements as well as their connections is a matter of quantity, if researchers want to prevent 'anomalies'. One example of such an 'anomaly' in our food network is the competence Allergy Knowledge (C) which seems to be misplaced. Although the competence could be applied in several food-related practices, such as eating, procurement, and cooking, it is, however, only present in planning practices. This 'anomaly' occurs due to our small sample size and the random assignment of the probably only allergy suffering participant to the survey on planning.

Without wanting to take up the old discussion of qualitative and quantitative research [142, 300], we still want to raise awareness about certain issues. Networks with a higher degree of detail or a more explorative character might be created by ethnographic methods, while a stronger quantification is needed for more robust networks with more causal significance. Especially when choosing smaller qualitative samples researcher should be aware of outliers and probably other yet unidentified phenomena that are not correctly visualized within such networks.

5.5.2.3 Analysis – A Matter of Distance Methodically our approach uses, in contrast to Higginson et al.[160, 161] in particular their later work, color to visualize the distance of nodes instead of reducing their connectivity. While they [160] argue that they reduced the connections, since they observed a low tendency to cluster as well as less obvious geometries, our results show that clusters and geometries of the overall network can be visualized, al-

though nodes are highly connected. From our perspective, this difference is based first on the means of visualization and second on a distinction between practice-as-entity and practice-as-performance.

Regarding the visualization, our coloring approach shows how practices are forming quite homogenous clusters, although all practices resp. clusters despite disposal are closely tied together. The introduction of the additional layer of color is however not only helping us to identify overall geometries when 'zooming out' but due to the versatility of coloring, we were able to visualize and therefore provide more detailed explanations. A gradual highlighting of nodes and edges, e.g. when 'zooming in or in-between', allows to clearly trace the connections of certain elements or the importance of a particular element for a certain practice and the network of practices as a whole. Therefore, with regard to the discussion about oversimplification, we argue that networks of practices should not simplify reality, but adapt towards the complex social life and therefore provide means that might at first glance be complex as well, but upon further observation are more helpful when researchers want to apply SPT to inform design.

Regarding the distinction between practice-as-entity and practice-as-performance, our work indicates that practices-as-performances form clusters, that represent practices-as-entities. From our perspective, the network of Higginson et al. [161] shows the same tendency to cluster, although they [160] argue that there is a low tendency. Attempting to capture different variants of laundry practice, their [161] network, visualizes different performances of doing laundry. Those performances cluster towards one entity, that then does not allow for differentiation between the different performances. Within our results, the gathered performances of one practice (e.g. cooking) form a practice-as-entity cluster as well. Within this cluster, we are not able to distinguish between the performances or 'variants' of performances as well. Here it might be interesting to see which additional measures of distance, e.g. layer of color, could visualize those categories to allow for an even more detailed 'zoom in'. Generally speaking, we disagree with Higginson et al.'s [160, 161] observation that practices do not cluster but argue for more adaption of the method towards a higher level of detail. This means that research on a practice-as-entity level needs distance measures that are less selective

than research on a practice-as-performance level within the entity clusters.

5.6 Conclusion

Adapting the approach of Higginson et al. [160, 161] our work introduces the combination of network theory and SPT to the practice-centered computing community. Furthermore, we attempted to improve the method to address, what we have identified as downsides in current approaches. Based on the constructed network of FP we identified design opportunities and benefits of an understanding of practices as interconnected networks.

Rather than focusing on practices in isolation our work indicates the chance for interventions by a focus on structural holes and central elements through what we call 'broker-technologies'. Nonetheless, we argue that this focus is not a 'magic bullet', that changes practices towards desired outcomes. However, an understanding of how practices are interconnected might support understanding barriers of intervention as well as barriers of appropriation over time.

While our work contributes to SPT based practice-centered computing research by introducing, adapting and discussing a new research method, we are aware of the still unanswered questions. Limited by a small sample of 60 participants and no application in a real design study, many of our thoughts remain theoretically and more questions arise than have been answered. We especially want to encourage researchers to contribute to the discussion about networks of practices, research methods to empirically gather elements of practices as well as to evaluate its usage in real design studies.

With our work, we intended to create a deeper understanding of the methodological capabilities of network theory applied to SPT and an understanding of practices as a network. This paper offers the potential to inspire designers and researchers to engage and contribute to the discourse about networks of practices.

6 Going Vegan: The Role(s) of ICT in Vegan Practice Transformation

Abstract

With the debate on climate change, topics of diet change and the reduction of animal products have become increasingly important in both public and academic discourses. However, sustainable ICT studies have so far focused on individual aspects, in particular investigating the criticized persuasive design approach. We argue for a broader perspective on the role(s) of ICT, one that helps in identifying opportunities to support consumer practice transformation, beyond motivational aspects. Based on retrospective interviews with 16 vegans, we argue to understand practice transformation as co-evolution of practices and ICT artefacts, as this perspective helps to understand how tensions arising from complex entanglements of practices, socio-material contexts, and communities can be resolved. Rather than a motivational process, we observe various roles of ICT artefacts co-evolving with practices: Ranging from initial irritation, to access to information about vegan practices, to the learning of vegan food literacy, to the negotiation of a vegan identity, and vegan norms at the intersection of the 'odd' and the 'norm'.

6.1 Introduction

> "A shift in the social norm of meat consumption is a transition that is repeatedly called for in climate change policy discourse. Yet this rarely sets out practically how such reduction might be achieved and, surprisingly, has yet to look to vegans as a knowledge resource." [355]

From an ecological perspective, Veganism, once considered to be something over-ethical and nearly religious, has taken on new significance as the ecological consequences of diet choice have become more apparent. Nowadays, it is acknowledged that dietary choices have significant consequences for sustainability [133, 342]. Compared to a regular omnivorous diet, veganism usu-

ally causes a much lower carbon footprint [293, 356] and is associated with health improvements [286]. Indeed, "the Intergovernmental Panel on Climate Change (IPCC) includes a policy recommendation to reduce meat consumption" [298].

This raises the question of how ICT could support the transformation of omnivorous consumer practices towards plant-based practices. Sustainable ICT research has hitherto been dominated by a 'persuasive' perspective focusing on rational [270] and sluggish consumers [110]. These approaches usually have a positive short-term impact on the motivation to change behaviors, but their long-term impact is uncertain [52, 91, 229, 301, 302]. The argument is that we need to understand, in more detail, how people construct sustainable practices themselves and how such perception is shaped by their sociomaterial environment [134, 303].

Addressing these issues, research on (non-)sustainable practices has emerged as an alternative lens [270]. This lens was applied to energy consumption (e.g., [52, 134, 301, 302, 303]), and also food waste [117], food sharing [120], and recently organic food consumption [197]. Yet, where studies on the transition to vegan practices exist, they mainly originate from social science, neglecting the role of ICT artefacts [268, 354, 356].

Research Gap: While there is a rich body of knowledge about ICT in pro-environmental behavioral change and nudging, as well studies on sustainable consumer practices in general, less is known about practice theories in action and ICT not just for motivational aspects but for the long-term transformation of consumer practices [153, 270].

It is exactly this knowledge about the complex evolution of entangled practices and the involvement of ICT artefacts that is important if design is for successfully supporting sustainable transformation [150]. However, the question of how "technology [can] promote reflection on diet [and sustainable practices] more strategically over longer periods?" remains unanswered. In light of this research gap, we address the research questions of 'How to support vegan practice transformation with ICT artefacts?' and 'How do these ICT artefacts co-evolve with practices in the transition towards vegan practices?'.

To answer these questions, we conducted a qualitative study with 16 partici-

pants, using semi-structured interviews. The focus was on vegan food practices, as food consumption is acknowledged for the high environmental impact and is more present in daily practices than buying clothes for example. Furthermore, diet is often the starting point for veganism [200]. Nonetheless, we provide related information on other consumption fields and discuss the extension of vegan design towards a broader inclusion of other consumption infrastructures. We used Shove et al.'s [311, 312] and Twine's work [355] together with work on appropriation [175, 333] as a theoretical lens to understand the role of ICT artefacts in long term sustainable practice transformation.

From this retrospective perspective on practice transformation, our findings (as summarized in Figure 13) show that rather than a motivational process, we should understand practice transformations as a co-evolution of practices and ICT artefacts. We observe co-evolving artefacts ranging from initial irritation, to access to information about vegan practices, to the learning of vegan food literacy, to the negotiation of a vegan identity, and vegan norms at the intersection of the 'odd' and the 'norm'. While our results at first sight only contribute to the study of vegan practices, we argue that co-evolution is a helpful lens to study and design for sustainable practice transformation in general, especially in the light of increasing awareness of the importance of green issues.

6.1.1 Transforming Practices and Forming New Practices

Practice-theoretically informed ICT interventions found a deeper understanding of sustainable consumption practices and the socio-material context that shapes them [179, 117, 119, 270]. This lens has been used to uncover ICT design opportunities, such as food sharing as a means to procure and dispose of food [120], studying sweet spots in consumption practices to prevent food waste [117], or opportunities for other food-related practices, such as gardening [225], foraging [68], and recently, organic food consumption [197].

Practices, in general, are understood as the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood" [278]. Beyond this rather broad definition, one

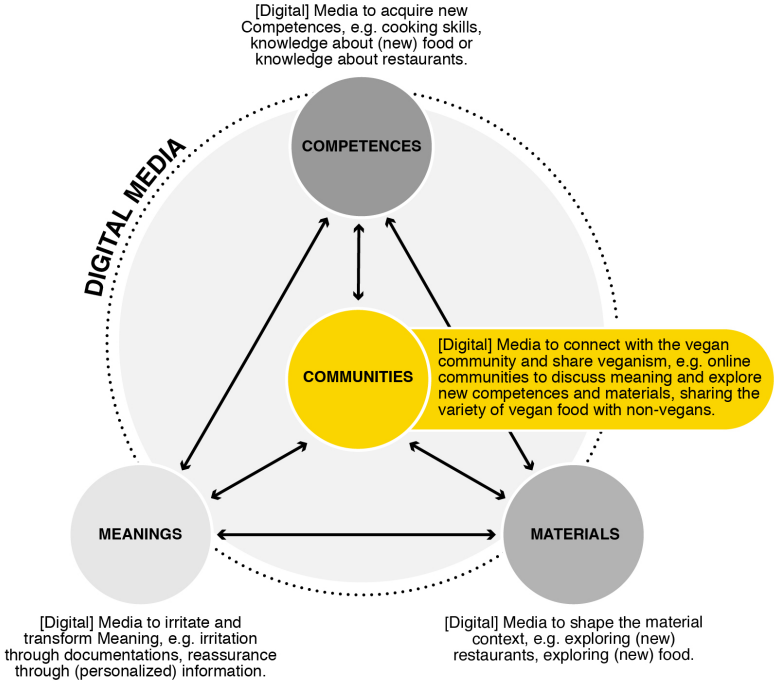

Figure 13: Summary of Going Vegan Findings.

can distinguish between materials, competences, and meanings of a practice [311, 312]. Meanings are understood as the "symbolic meanings, ideas and aspirations" [312]. It is related to what Reckwitz calls mental activities, emotions, and motivational knowledge [278]. Competences are understood as skills and know-how, practical knowledge, or techniques [312], for example, knowing how to prepare a particular recipe [344]. Lastly, Materials refers to "objects, infrastructures, tools, hardware and the body itself" [312]. They are related to Reckwitz' [278] notion that "things [... and] objects [are] necessary components of many practices".

Given this framework, the question of how to transform practices emerges. In daily consumer routines, the elements are connected stably, creating a kind of equilibrium [333]. A change of one of the elements creates an imbalance, resulting in a "crises of routine" [278]. For the resulting dynamics, Shove et al. [312] distinguish between practices, proto-practices, and ex-practices. Practices are the well-established and unconsciously performed routines. Proto-practices are practices that are not yet incorporated by the person because

relevant elements are not yet appropriated or not yet linked. In contrast, ex-practices are practices that have been abandoned because one of the links has broken [312].

Based on this understanding, interventions aim to destabilize practices and reestablish new practices. However, still due to the complex entangled nature of practices [117] and how sustainable practices are still considered as something 'odd' [150] as the benefits of "good individual choices" [117] are not always recognized equally, designing and understanding these interventions is not straightforward. As most research hitherto has studied practice from a prospective standpoint, we lack strategies on how to transform practices in the long term [74], solving the tensions arising from the entanglement of practices [117, 204] and departures from the 'norm' [77, 150]. Indeed, this problem has been seen across a range of contexts, including car-free mobility [150], simple living [141], and water-reduced bathing [204].

6.1.2 Appropriation of ICT Artefacts

Hasselqvist et al.'s [150] work on transformation towards car-free mobility practices already highlights that practice transformation comes with the appropriation of new artefacts. For example, the usage of a planning tool to find suitable routes for the new vehicle. As stressed by Stevens and Pipek [333], such making use is a dual process that changes both the object and the subject. The adoption includes acquiring new competences through informal learning, resulting in a transformation of the practice itself [92, 93]. However, it is not only the practice itself but the ecology of ICT artefacts that is dynamically adapted to the introduction of new artefacts, e.g., abandoning other artefacts or establishing of joint usage [43]. Appropriation is thus closely related to what Engeström [101, 100] calls expansive learning. Expansive learning mainly happens in the wild, where neither the learning goals nor the learning activities are defined in advance but are open-ended. It starts with the diffuse feeling of a need and the reflection of inner contradictions in the situation at hand (unsatisfactory state), followed by exploring and trying out new options and ideas (excited state) and finally finds a new equilibrium in a stable state [43].

Appropriating new artefacts and learning new practices does not happen in isolation but involves enculturation into a community of practice [61, 264, 265]. With the ongoing performance of a practice, the community implicitly communicates knowledge, values, and identities that can be learned by newcomers. Members share their commitment to the community as well as the competences, materials, and meanings, "in short a shared practice" [370]. Several studies [14, 183, 305] have demonstrated that practitioners do not need to be co-located and that newcomers can also become enculturated by participating in virtual communities of practice.

ICT artefacts play a twofold role in the process of appropriation, expansive learning, and enculturation. They are objects of appropriation [43, 333], but at the same time, they are also the medium as they support practice transformation [150].

6.1.3 Sustainable Food Consumption Practices and Veganism

Veganism includes a general exclusion of animal products, e.g., in food, cosmetics, and clothing [200]. Besides the ethical reasons cited for veganism, criticism on industrial large-scale livestock farming, health considerations, and environmental protection can be motivations for vegans [200, 356]. In particular, greenhouse gas emissions are strongly correlated with animal consumption [260, 293].

Twine [356] shows how, for diet transition, different modes of food change are entangled with the adoption of vegan practices, ranging from substitution to the exploration of new dishes and products, as well as the adaption of competences relating to the new material (food). Such change is reflected in the 'veganization' of meals with plant-based substitutes for animal products or a shift towards two-part vegetable meals instead of a tripartite arrangement around meat as the main ingredient [356]. Adopting Shove et al.'s [311, 312] practice lens, Twine [355] identifies essential elements that constitute new vegan practices. Their framework highlights the interaction of new competences, such as vegan cooking skills or knowledge about eating-out options, the new materials, e.g., the vegan food substitutes or the restaurants themselves, and the meaning of veganism in respect of pleasure, health, and/or

ethical behavior [355]. Thus, a vegan diet transition not only affects eating, but also other practices, such as cooking or buying food.

As practices should be understood within their socio-material context, it is worth broadening the scope towards the environment vegan practices are currently conducted in. In general, vegan practices, as other anti-consumer movements that deviate from regular consumption patterns, can be referred to as a niche practice. This perspective highlights the gap between regime consumption infrastructures and the needs of niche practitioners [77]. Not only from a practice-perspective but also based on the number of vegans in Germany [200] and other European countries such as the UK [356], vegans remain a niche with a little over 1 percent of the population. In other countries such as Spain or France, the number remains even lower [81].

However, the situation is changing; over recent years, a continuous rise in the number of vegans could be observed [200, 273]. This change is resembled in an increasingly growing market for vegan products and restaurants. Also, the market for media such as books is growing [273]. Here, it can be assumed that a similar trend can be observed for other media. In a similar vein, the vegan label (issued by a European Vegan NGO [273]), as well as other private labels [273], are increasingly established. For non-food consumption domains labeling is not yet widespread, but evolving [273]. However, there are various different labels, that not always follow a transparent and consumer-friendly definition of veganism, nor are all products labeled [125].

From a governmental and consumer protection perspective, this topic of regulating vegan labeling and facilitating consumer choice was neglected for a long time. Until today, there had been no governmental label and only a few years ago the German federal states agreed on a definition for the term ‘vegan’ [125]. The situation is similar on a European level, where no binding definition for vegan food exists [125]. Sustainable consumption, against the background of this market-based policy-making, is mostly treated as a consumers’ responsibility and a matter of informed choice, rather than a topic for pro-vegan or pro-environmental policy [231]. For Germany and France, consumer protection even goes in a different direction. In 2018, the German Federal Ministry of Food and Agriculture issued legislation that complicates

the naming of substitutes, e.g., 'vegan sausage' [255]. In France, we found rulings than ban 'meaty' names for substitutes [59].

Not only from a legal perspective but also from a western cultural perspective, meat consumption is traditionally understood as a symbol of prosperity and wellbeing [354]. In the media, consuming animals and speciesism is reproduced as the norm [75]. This positive perception is also reflected in the negative reactions to 'vegetarian day' policy suggestions for public canteens. In 2013, the German Green Party suggested introducing a 'vegetarian day' in German public canteens, however their idea was broadly commented by public media as "'an ideological lifestyle dictatorship' or 'a disenfranchisement of citizens'" [231]. Similar reactions to veganism were studied for UK media, that perpetuate vegan marginalization and bias [75]. Despite its positive aspects, veganism is still arguably perceived by many as somewhat abnormal and characterized by a puritanical view of life [354]. Such an attitude places vegans in the position of explaining and justifying their 'niche' practice [77] in their social environment. Various strategies can be identified as to how vegans deal with this kind of social pressure. The intentional choice of vegan partners (also called vegan sexuality [268]), for instance, aims to avoid such conflicts, at least within the partnership. There are also more inclusive behaviors such as the cooking and presentation of vegan dishes to show non-vegans the benefits that can be gained from vegan meals, attempting to trigger a change of values [354].In summary, it can be stated that vegan practices are increasingly conducted, which follows an increasingly growing market and more and more labeling of products. Still, from a governmental and a consumer protection perspective, there is no clear support for veganism and the related issue. In a similar vein, despite the growing number of vegans, practitioners remain a niche that has to justify its anti-consumerism and face social pressure.

6.2 Materials and Methods

To answer our research questions, we conducted semi-structured interviews with vegans in Germany. Our qualitative sample of 16 vegans was recruited through a snowball sampling procedure [253]. We started our recruitment

with vegans from the extended social network of the authors and social media. The main criterion for participation was the maintenance of a vegan diet (based on the participants' self-images). We explained to participants the purpose of our research and informed them about the (anonymous) storage of data on university computers and use for research only. Further, we emphasized that participation was voluntary and that they could choose at any time to discontinue. Afterward, participants gave us their informed consent. We also ensured that the sample matched the socio-demographic structure of vegans in Germany: Vegans in Germany are 80% primarily female [200], have an average age of 31 [200], tend to have a higher formal education [286], and tend to live in urban areas [286]. This tendency of vegans to be female, young, and educated is also reflected in our participant sample (see Table 1).

Our interview guideline covered the participants' vegan diet and lifestyle (e.g., duration, self-image, further dietary restrictions, motivation), reflection on artefact use alongside their dietary changes (including both artefacts still in use, but also once used), and reflection on how their practices (Planning, Procurement, Preparation, Eating, Disposal) changed in the course of going vegan.

The interviews took between 13 and 50 min (Ø: 25 min). Afterward, the interviews were transcribed and coded using Catma (CATMA—For Undogmatic Textual Markup and Analysis (https://catma.de/)). The interview data were analyzed using thematic analysis [48]. Twine's work [355] together with work on appropriation [175, 333] is used as an initial template of codes [202]. During our inductive analysis, we especially drew upon the notion of the dynamic evolution of practices [312], the importance and appropriation of artefacts as part of vegan practices, as well as the transitions implicated. After each iteration, we discussed the codes and developed themes collaboratively. Note that, for the presentation of results participants' quotes were translated to English, and location information was anonymized.

6.3 Results

6.3.1 Irritation and Reassurance

At the beginning of the vegan diet transition, the media immediately takes on an essential role in unfreezing established beliefs, meanings, and interpretation schema. While the first contact with a vegan diet is often due to exposure to documentary resources, leading to a questioning of one's diet, more critical is the role of media in establishing personal feasibility.

6.3.1.1 That is not True? Asking about reasons and drivers of the transition towards a vegan lifestyle, P1, P3, and P10 reported that the first contact was mainly by video platforms such as Netflix and YouTube.

> "There have been several, but for example the classic Netflix documentaries like Cowspiracy for example or Earthlings and on YouTube there's a lot of stuff like that ... and also channels of private people pushing stuff like that." P3

Documentaries such as Cowspiracy, Earthlings, The End of Meat, and What the Health were repeatedly mentioned in the interviews as a critical experience, e.g., by participants P3, P4, P8, and P9. Our participants found themselves confronted by such documentaries and related pro-vegan information resources serendipitously. For example, P15 could not in the first instance believe the facts shown in the documentaries and dismissed them as 'propaganda'. Such confrontation constitutes a 'friction' or 'irritation', which prompts reflection. Those terms refer to raising the self-reflection about previously unreflectively conducted practices. Where this occurred, we refer to the 'unfreezing' of practices. P4, P8, P9, and P11 also mention friends and acquaintances as triggers for questioning established food consumption practices. P14 also mentioned the importance of specific events such as the lasagna horse meat scandal in 2013 [371]. That event was his initial reason for rethinking his food consumption practices.

> "In any case, the use of media played a big role because I also

> started with it. Those were mainly videos, videos about the vegan diet from different sources that I started watching, I motivated myself with those videos at the beginning where it was still difficult for me. I watched videos and different pictures and yes, in any case, the media pushed me to go on, and yes I gathered further information from the media about how a healthy vegan lifestyle can be maintained." P1

P1's quote shows that various sources of information were used not only to validate the given information, but also to obtain even more details about the general feasibility of the diet. Hence, videos, which are, for example, accessed via YouTube, played an important role as did traditional print media. Indeed, the initial confrontation with health and livestock farming issues (especially animal suffering and dying) was frequently followed by a more intense encounter and exploration.

6.3.1.2 Does Veganism Work for Me? In addition to the motivation mentioned by participant P1, the acquisition of nutritional skills and knowledge surrounding the maintenance of a vegan lifestyle also played an important role. P7 described how she received hints from YouTubers on nutrition and dietary supplementation, which reassured her, both about the feasibility and about the existence of a broader community. Besides the rather general information about the feasibility of a vegan diet, there was a demand for nutritional information. That information was gathered from YouTube, where different channels provide information that can be accumulated and measured by personal experience with a vegan diet. Another mode was mentioned by participant P12, who read books to triangulate information sources, thus aiming to make sense of the need for nutrients alongside the characteristics of food items.

> "I think that it is difficult with your nutrients because as a vegan you have to make sure that you have all the nutrients and so on and it is also not necessarily so good to take vitamin B12, I mean continuously. It is excreted by the body. But it is not good to

> consume a permanent oversupply of it. I think I have no concrete idea, but I think that the nutrient thing, that it is important, because it is ultimately about your health. And you have to be reminded regularly that you have to do a blood test, that you just know if something is missing in your diet. I think that would be helpful, but I don't have a specific approach." P13

P13's example shows her high degree of uncertainty regarding the correct amount of vitamins, especially vitamin B12, which is probably one of the most critical nutrients when maintaining a vegan diet since it only rarely occurs in plant-based food [201]. She explained how a blood test once a year ensures that the vegan diet meets bodily needs. This uncertainty demonstrates a desire for tailored and personalized information about one's diet and whether the dietary needs in question are being met.

> "Just to get a balanced diet. For example, beans, berries, other fruits and then it says how many portions you need. Then there are the vegetables. Other vegetables. Greens or what's it called, cabbage, beans. Or just nuts. Whole grain, grain, water, sports. Vitamin B12. Vitamin D, water. And so on and so forth. I've tried that before, for a while. Well, that's not so comprehensive now, it's just an approximation, for example: One serving is 60g hummus. Zack. That's it. When you've eaten that, you tick it off. Exactly here you have to eat three portions a day. Zack. Here you need one portion, how many berries are here, for example, frozen or fresh—60 g. It's just so coarse. A rough guideline, so that you stop, yes." P15

Instead of blood tests, 6 of our 16 participants started to use diet trackers. Those tools helped them, especially at the beginning of their transition, to increase their awareness about what food to eat in which amounts, but also to prove the feasibility of their diet to themselves. Nonetheless, the use of those devices was relatively brief for some participants due to the substantial effort required to track the food intake. Participants P7, P9, and P10 explained how

they stopped using diet trackers because of the high workload entailed. Participant P15 stated that he stopped tracking and now "really hates" it, because it was "time-consuming", although he admitted that a tracker could support "rough guidelines" for one's nutrition.

Some participants seemed to dive straight into the vegan diet, while others described a step-by-step approach. P1 explained that she adopted a vegan lifestyle "from one day to another" and that she had never dealt with a vegan diet before. Therefore, she did not eat a balanced diet for the first month but acquired insights into "how such a healthy, vegan lifestyle can work out" by watching videos. Participant P11 began her vegan diet with a "vegan week", in which she made explicit and conscious choices every day, all geared to getting better informed about how a vegan perspective is constituted. During that time, she discovered a website by PETA ZWEI and signed up for 30 days of "vegan kick-start" in which she was supported by the organization. P11 found it helpful to get an organization newsletter every 2–3 days that she could respond to as well as a personal contact, to whom she could address questions.

6.3.2 Learning New Competences and Exploring Materiality

Once our participants had abandoned their former diet, they faced several practical problems. Restaurants and cafés are not necessarily vegan-friendly or beloved treats and recipes might include non-vegan ingredients. (Digital) media played a critical role in acquiring practical knowledge and exploring food, especially where to find it, answering questions such as the following.

6.3.2.1 Where can I Eat Vegan Food? As a result of the change in diet, many previously visited restaurants were no longer suitable for the new vegans. To find more options, our participants used various websites, apps, and blogs (e.g., from PETA). Further sources for help were acquaintances and friends (P3, P11).

> "In fact, over the Internet. I don't know, I sat down and googled for some time. Vegan restaurants in (big city) and surroundings

> and there are actually unbelievable many in (big city)." P1

The quote shows how P1 rediscovered her environment with the help of Google and how she was surprised about how many vegan options there were in her neighborhood. Eight of the 16 participants used HappyCow or Vanilla Bean, which offer information created by other users and show different vegan options on a map. They use these apps to find vegan or vegan-friendly restaurants and cafés. Even so, they highlighted that they now primarily used these apps in foreign places.

> "Yes, definitely. That's HappyCow, I own the free version and especially when I'm traveling, or when I'm in a city where I don't know any vegan places." P11

This seems to be a general pattern for using such apps and websites: After the initial exploration of the surrounding neighborhood in the city of residence, regular use decreases over time. As the degree of familiarity with these features of the locality increased, the information provided by these apps was internalized. Apps of this kind continue to be used, unsurprisingly, when visiting unfamiliar locations.

A little surprising was that our participants did not use the resources of this kind to find vegan-friendly stores and supermarkets. Instead, the participants mostly continue to shop for their vegan foods in regular chain-supermarkets as well as known organic supermarkets. Only P5 stated that she occasionally bought special vegan food online.

6.3.2.2 What can I Eat? In much the same way, the material quality of food was also rediscovered in vegan practices.

> "I think CodeCheck definitely, that was a big thing for me, that I could always scan the... this barcode then and then it was in there whether it is vegan or whether it is maybe vegan or was tested on animals. That was a super big help, but after a while it is marginalized, because then I knew what is vegan and meanwhile

> it's everywhere anyway. That means the time helped me there also a little bit." P11

Participant P11 described the difficulty of a transition from relatively carefree shopping to shopping or consumption with a more considered approach to the ingredients and properties of the food. Participants P3, P4, and P7 also described how artefacts, especially CodeCheck, helped in gathering further information about the product. However, according to nine participants, an initial assessment here is also possible by simply looking at the ingredients and allergens of a product, or solely at vegan-trade-signs. However, the former is not always valid because, as participant P3 stated, some products use flavoring substances, e.g., lard in potato chips, that is not declared in the ingredient list.

> "You learn so much from the ingredients and then you've looked at the product 5 times, then you know what's in there, it's vegan and it's okay. Or with things like marzipan, you look on the ingredients list one time and then you eat it all the time. Just because there's a label, no just because there's no label on it doesn't mean it's not vegan. You have to pay attention to the ingredients and eventually you know it by heart." P13

Similarly, to exploring food ingredients 5 participants explained how they try to reduce leather and animal fibers when buying clothes. While these participants did not report on any ICT support for checking the material of clothing or showing plant-based clothing stores, trade-signs and material lists are a good starting point for the purchase decision.

This information also has a direct effect on food- or product-specific knowledge in the sense of a competence, which is sufficient for most consumption situations, so that the medium subsequently loses its significance for daily practice, as the example of participant P13 shows. However, five participants explained that media such as CodeCheck or Google were still used in situations of uncertainty, e.g., when buying an unfamiliar product.

6.3.2.3 What can I Make from My New Food? Participants described how they needed information on how to prepare vegetables as well as how to include them into dishes. This information was usually accessed by simply searching the internet for recipes or specific tutorials on how to prepare the vegetable as well as looking at vegan cookbooks.

> "Yeah. Also. Within the last year, after I started to eat vegan, I've learned about so many new vegetables that I simply got to know, which I did not know before. You always see the whole variety of vegetables, but how can I prepare this at all. That wasn't even clear to me. Meanwhile, I know how to do it, so I do it gladly, really. Vegetables that I have never processed or never bought. That I see now so ok it is just the season and then I like to buy it and then I look online. What can I do with it at all and then. Partly the meal I cook depends on the vegetables I buy. So, I've always been experimental about what I do with all that stuff." P5

The example of participant P5 shows how this additional mode of food exploration is supported by (digital) media. She explained how she discovered a whole new variety of vegetables that were previously not included in her diet.

Besides the exploration of new vegetable possibilities, dishes, in general, seem to be transformed from a three-part meal towards a two-part meal, as Twine [356] already mentions in his work. This change was described by participants P7, P8, and P11. They explained how they usually cook some source of carbohydrate, e.g., potatoes or rice and some vegetables with it. P11 further highlighted beans as an addition to the vegetables.

> "But if I have a special idea, for example, I wanted to bake a banana bread then I just google "banana bread vegan" and click on any recipe from a blog, those are mostly blogs I didn't know." P8

When it comes to the 'veganization' of formerly known dishes, the internet is, as the examples of participant P8, P10, P12, and P16 show, a good source

for recipes. The internet provides enormous variety and, moreover, a variety that is coded to vegan interests. Participant P10 explained how he searched the internet for recipes of beloved childhood meals and inspiring meals from restaurants to 'veganize' them by finding a vegan version of the recipe. The same applies for inspiration for more complex weekend dishes or dishes prepared for friends or family. To prepare them, special vegan blogs, Google, Instagram, or YouTube cooking channels are visited to get some inspiration, as seven of our participants explained. P5 described how she, at first, had difficulties in making use of the whole variety of vegan recipes. Thereby, they had some "trusted" blogs, from which they get, from their perspective, healthy recipes, as participants P8 and P10 state. An additional mode of inspiration and food exploration is, of course, the usage of vegan-style cookbooks as several participants explain, e.g., P11.

6.3.3 Community and Sharing Veganism

Prior work [268, 354] already highlights how vegans negotiate and exchange the experiences of their diet with other vegans but also with the omnivorous majority. Since our participants were often the only vegans in their circle of acquaintances, artefacts helped them to connect with other vegans, but also to share and negotiate their practices with others.

6.3.3.1 Connecting with Other Vegans With the transition to a vegan diet, media, especially social media such as Facebook, are used to make contact with like-minded people. As six participants show, this contact can take place on a purely digital, passive basis, in the sense of receiving information about offers of local supermarkets, inspiration, or recipes. Participant P11, however, often asked questions and engaged in exchanges, as the Facebook group was seen as a place of mutual understanding, where vegans are safe from being "flamed by somebody". Understanding and security were also taken up by participants P1 and P7 in the context of finding a vegan community. The reasons were the annoying questions about their diet or the lack of understanding on the part of non-vegan people.

> "I'm also a member of a vegan [Facebook] community. (big city) vegan, that's the name. There you sometimes get a notification when a new restaurant opens or when there are special offers or something like that." P14

Besides the example of participant P14, participant P11 mentioned how she learned new cooking skills and formerly unknown ingredients from such a group, e.g., making macarons with aquafaba (liquid remaining after chickpea cooking) as a substitute for eggs. At this point, interestingly, the aforementioned vegan groups have a strong local connection, usually containing the city or region name as well as some sort of vegan identifier. Besides the names, the content of these groups is also tied to the local context at least to some extent. While nutritional information is universally valid, information about restaurants and retailers is only of value for the local community. Furthermore, food infrastructures participants reported on various other consumption infrastructures that are exchanged in the community. These range from clothing stores, locations of leather-free furniture, or shoes without an animal-based glue. At this point, the variety of consumption infrastructure resembles veganism if often not only a matter of food consumption, but is also entangled with various other consumption practices, for which we yet found no ICT designs, but the appropriation of social media to exchange such information.

However, this exchange was not always successfully established, as participant P6 explained. She described how she tried to join an online community but found it difficult to get in touch with the other vegans. This difficulty is primarily because—despite the perceived expectation of non-vegans—being a 'member' is not always straightforward. Where membership of such online groups is successfully established, it is sometimes used to establish 'offline' contact.

> "Yeah, so that is just called vegan regulars' table ah and there was. I was once joining such a running group the somehow called good night running group or something like that. And there you always meet at full moon here at (locality) and run five kilometers or so

> and then make a donation for some animal welfare project. And there were mostly vegans, too." P7

The example of participant P7 shows that regulars' tables are often formed, which put a stronger focus on face-to-face exchange and information retrieval. Apart from this, however, there are also people meeting for other leisure activities, such as the good night running group, a run against animal suffering. In this respect, the media has less of an informative function but more of a mediating role, which enables people to find like-minded people who, for instance, share similar eating habits.

6.3.3.2 Sharing Veganism Within "the mode of performing veganism in a demonstrative manner that draws omnivores or vegetarians into the sensual experience of vegan food"[354], participant P8, as well as six other participants, explained how pictures of home-made vegan food were shared, as were photos of food from restaurants via Instagram to a broader public or with friends via messengers such as WhatsApp. The example of P8 shows how she hoped that the sharing of the sensual experience through the visual representation of her food motivated others to try a vegan diet. However, the sharing of food experiences was not always tied to a sense of motivating or persuading others to change their diet. Participant P10 explained how she uses pictures and recipes to "break with prejudices" about her vegan diet.

> "I think subconsciously, one has always a little bit of hope that one can maybe motivate someone to try it for themselves. And because I maybe want to show the people that vegan food can be totally great and doesn't mean abandoning anything." P8

The quote from P8 shows her desire to share the perceived positive characteristics of vegan dishes and diet. Similarly, Participant P5 started her own Instagram account to share pictures of her vegan food. She explained that the ongoing questions "what can you still eat?" motivated her to share the variety of food that she consumes. She and participant P7 argued that they got positive reactions and significant interest from their audience who, they

suggested, are often astonished by the fact that the meal was made without animal products and even that friends sometimes stated that they wished they could eat the food as well. In the circle of friends and acquaintances, however, food was not exclusively shared via digital media in the form of pictures. Six participants also described how they made a special effort when they cooked for others to improve the sensual experience of the prepared dishes.

> "I think only once, when I was at the Christmas market, there at a vegan food truck and then I just posted a picture, but under the cloak of 'Christmas market' and not with the tag 'vegan'." P11

The desire to promote veganism is not universal. The example of participant P11 shows that not all participants share their vegan diet via Instagram with the public. While in the beginning, she wanted to convince people within her family and friends that they should reduce the share of meat within their diet, she nowadays shares her experiences without a specific reference to veganism. Thus, the "cloak of Christmas market" allows her to share the experience without explicitly telling a broader public about the details of her diet and therefore aligning with the (omnivorous) majority's narrative interests.

6.4 Discussion

While prior research studied the role of artefacts for changing entangled practices from a prospective perspective [117, 204], our research provides insights on how vegan practices and artefacts co-evolve from a retrospective perspective.

In contrast to TTM [269], co-evolution is not a stepwise process, but requires multiple iterations of learning, exploring, and adjusting practices in a dialectic relationship with artefacts. However, there seems to be some 'unfreezing' of change, as an initial step in triggering the "crises of routine" [278], that creates the need for new artefactual use [43] and a desire to rethink practices [312]. From there on, a continuous, iterative learning of practices and adapting of artefacts begins, with a constant tinkering as new issues arise. Eventually, co-evolution will come to a new 'more' stable and satisfactory state, where

vegans become comfortable with their status and familiar with the various sources that enable this stability. Nevertheless, this has to be achieved in a context where veganism is still regarded as 'odd', at least by some. Negotiating the relationship with more 'normal' practices is a constant challenge.

This view draws on prior research [117, 150, 204] that highlights the evolutionary nature of practice transformation as well as research on dynamic artefact ecologies [43, 185], that shows the interrelationship and changing nature of artefacts. However, our work adds to this perspective, by arguing that artefact ecologies and practices should be understood in their mutual relationship manifested as a co-evolution, rather than individually, when designing for sustainable practice transformation. This co-evolution is presented in Figure 14.

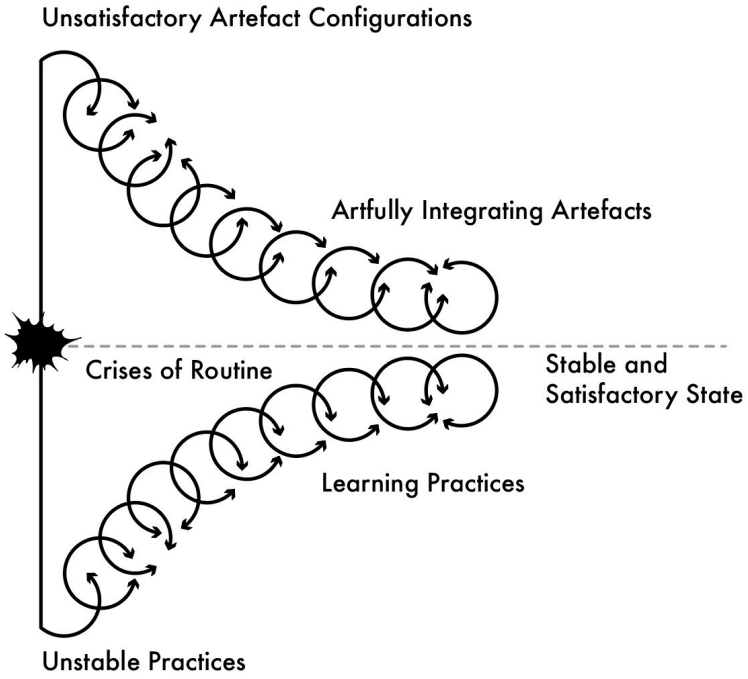

Figure 14: Co-Evolving Practices and Artifacts (inspired by [218]).

From this perspective, artefact ecologies are not only dynamic [43] as new resources are found, but are also adaptive to the changing needs as people 'become' vegan. This is redolent of Becker's[30] famous paper on marijuana use, where he demonstrates the cultural practices required to become a com-

petent user.

6.4.1 Co-Evolution from a Perspective of Practices

From a perspective of evolving vegan practices, meanings, competences, materials [355, 356], and communities [268, 354] are underpinned by a dynamic ecology of artefacts contributing to the incorporation of elements and a progressive stabilization of use.

For meaning, the role of artefacts slightly shifts with the evolution of vegan practices. With the initial confrontation, we observed that artefacts helped to unfreeze the existing, routinized non-vegan practices by questioning established beliefs, views, and meanings. There are some parallels with persuasive approaches [381], even if none of the participants mentioned the use of persuasive and gamified technologies, e.g., eco-feedback to motivate and sustain diet-change. Instead, we observed something that could be called persuasive rhetoric. For instance, documentaries about veganism use persuasive rhetoric to raise people's awareness about veganism and confront viewers with the negative effects of meat consumption and livestock farming. To validate the information seen in documentaries, our participants were making use of different information sources. For instance, some participants used diet trackers or medical tests to verify information consumed or practices explored. In particular, the reassurance of the personal feasibility of the diet went hand in hand with testing to understand what veganism means for oneself and one's body.

Overall, we saw that the old interpretation schema is not suddenly and entirely replaced by a new one. Instead, meaning shifts over time. Most participants did not have a complete commitment to veganism as an alternative diet in the beginning but proved the feasibility and practicability of veganism with their ongoing evolutionary practices. When stabilizing, reflection turned to moral commitment, exhibited in various forms of sharing meaning with vegans as well as non-vegans.

For materials, we can distinguish between two mutually related areas: First, the materiality of practices, including physical performances, tools used,

goods, infrastructures, etc., and second, how such materiality becomes relevant to practice.

For the first, we observed, in keeping with Twine [356], how some participants changed their diet patterns by substituting non-vegan products to veganize recipes and changed from the tripartite structure towards meals that consisted of vegetables and carbohydrates only. Our participants also abandoned a variety of practices involving certain materials such as visiting non-vegan restaurants and buying non-vegan food. For the second, our study reveals that artefacts help to compensate such loss by supporting the exploration of potential new materials, such as providing access to unknown vegetables, substitution recipes, or raising awareness of vegan-friendly restaurants.

For competences, as outlined by Twine [355, 356], we also observed that a change of competence was linked to and mediated by changed material use. Vegan newcomers must acquire new competences in many areas, such as finding and preparing appropriate food, appropriating existing vegan infrastructures, such as vegan-friendly restaurants in their neighborhood, or figuring out how to make use of online recipe databases. Additionally, appropriate behaviors and actions must be learned and explored, e.g., how to stay politely when the own practice is commented by others or how to offer food to non-vegans without being the 'killjoy' [354]. Here, artefacts do not only serve as an 'awareness' tool, but also help people to incorporate new elements into their practice. They not only provide facts and information about veganism, but also what Pipek [263] calls appropriation support. For instance, cooking videos show how to perform practices such as substituting eggs when baking macarons.

For communities, artefacts play an important role in connecting vegan newcomers and experienced practitioners either online or (less often) offline. Vegans are sometimes confronted with the reaction by an omnivorous norm, ranging from the merely unhelpful to offensive reactions [354]. Against this background, it is not surprising that social and symbolic support becomes important. Our participants actively searched for like-minded people as they presented a kind of safe space to develop and try out a new vegan identity and role model. They actively oriented to the presentation of their lifestyle as

'valued'. However, as noted by Warde [365], such communities do not just provide symbolic support, but constantly negotiate rules and norms towards a mutual understanding of how the practice has to be adequately performed.

In contrast to this inner orientation, prior research [141, 150] pinpoints the co-existence and tension of 'norm' and 'odd' practices. Our study shows that the two are linked in a dialogic relationship. Our participants, as newcomers to vegan practices, negotiate meanings and share knowledge and positive experience with their omnivorous families and friends. Similar to the conflicts and justification strategies (see [268, 354]), presenting perceived advantages of the new, vegan diet seems to be aimed towards decreasing prejudice and exploring ways to co-exist, e.g., cooking for both vegan and non-vegan guests.

6.4.2 Co-Evolution from a Perspective of ICT Artefacts

We can observe how the composition of the artefact ecology changes with the ongoing incorporation of practices, enabling iterative learning steps that then cause a reconfiguration of artefacts.

Artefacts as irritation and reassurance tools are important especially at the beginning of practice transformation, as they trigger "crises of routine" [278] by productive confrontation [333], for example when challenging existing beliefs about one's diet when watching documentaries or reading about a food scandal. This irritation leads to a tension that unfreezes existing convictions and dismantles existing linkages between the practice elements, preparing the ground for the emergence of new proto-practices (see [312]). Still, the reconfiguration of the artefact ecology with such media in use does not automatically lead to a practice transformation. At this point, either new artefacts need to be iteratively incorporated or artefacts need to be used in different ways as new practices evolve.

However, from time to time, tools to reassure become important again. This is similar to Engeström's cycle of expansive learning [101, 100]. In our results, this is shown in the notion of 'reflecting on the process' by vegans, providing reassurance e.g., when identifying new meals as sufficiently nutritious by means of diet trackers or reflecting on diet change in more general terms by

blood tests after a certain time.

Artefacts as information and learning tools play an essential role in recreating new linkages by exploring a 'vegan' material environment as well as supporting knowledge and competence building. Foundation for this exploration, is visibility of practices and the entangled infrastructures, that would otherwise remain hidden within an omnivorous practice regime. As the example of restaurant search shows, applications and information sources, such as HappyCow, are intensively used in the early evolution of vegan practices, but their use diminishes over time. Similarly, learning recipes or scanning food becomes less important when competences and materials are incorporated, and practices stabilize.

Although certain artefacts seem to decrease in importance with developing environmental familiarity, they re-emerge into the ecology when traveling to an unknown location or stumbling upon a new product when grocery shopping.

Artefacts as communication tools connect vegan newcomers with an (online) community of practice. For example, when tensions with the omnivorous 'norm' practices arise, communication tools provide a means for reassurance and defensive strategy. They also provide for more active use, such as exchange about new food, restaurants, or preparation techniques. While communication was mostly online, some communities' activities shift to the 'offline world'. In those cases, communication tools enable the formation of an offline community, but once friendships and regular meetings are established, it became less important.

From a more general perspective, the artefact ecology shifts in very contingent ways. Use can be thought of as a kind of "bricolage"—tinkering, exploration, and reassurance, characterized by discontinuities and situational factors. This bricolage has been demonstrated in other contexts [6, 333], sometimes referred to as artful integration [337, 338], or creative consumption [69, 164]. Thereby, change to the ecology of ICT artefacts follows the logic of making vegan practices and practice transformation more convenient. In the beginning, it is the lack of routinization that is supported by ICT, while in later transformation, convenience is provided by again incorporating tools to deal

with unusual situations. Still, convenience and the usage of ICT cannot be understood as a luxury problem but as a support of fundamental daily routines and the satisfaction of basic needs when infrastructures and practice elements are invisible. Based on early work on veganism [215], we assume that a lack of such visibility induced by technology would raise the perception of barriers to vegan practices as opportunities, e.g., in the neighborhood, would remain invisible. From a practice theoretical perspective on the technologies, this goes along with media as part of practice, to change meanings, learn competences, explore materials, and enculturate into communities [355]. These different role(s) that are part of practice [355] and their iterative contribution are in contrast to motivational design research that aimed to motivate rational consumers with enough motivational and informational resources [52, 270]. Still, motivation is one aspect of practices, as the documentaries that accompany early vegan practice transformation show. However, these just provide some basic torque for transformation that would quickly decrease if the appropriation of a socio-materiality would be difficult.

CodeCheck, for example, was not designed for vegans. Still, it has become common practice in vegan communities to use it as a tool to determine more details about product ingredients and to avoid unintentionally buying and eating non-vegan food. The search for vegan-friendly restaurants presents another example of such creative consumption: There are specifically designed apps such as VanillaBean or HappyCow for this purpose. However, we also observed that participants adopt appropriate filtering strategies to obtain information about vegan restaurants when using Google and/or Google Maps. In addition, single artefacts are used in combination to support the evolution of practice transformation, as the reflection of the new vegan cooking practices by means of diet tracking shows.

6.4.3 Designing for Co-Evolution of Vegan Practices

Our research uncovered the use of various ICT artefacts along with the practice transformation of Going Vegan, still, there are several blind spots in current design to be addressed by future research and design. Although we argue that no single ICT design transforms practices like a 'magic-bullet', novel and

vegan sensitive design could contribute to small steps towards vegan practices and the appropriation of such.

Designing for Value Tensions between Livestock Farming and Consumed Reality: By now design research focused on small changes of practices, e.g., by encouraging organic food consumption [197] or reducing food waste [117]. Often these studies aim to raise awareness about the lived reality of consumption and the therefrom caused environmental impacts [153]. For veganism, to the best of our knowledge, no such study was conducted [153]. While our research observed value tensions between the realities of livestock farming and consumer values, as well as information on perceived barriers of change, to cause reflection on consumption patterns, it remains unclear how to successfully design for encouraging (more) plant-based consumption. An interesting approach is the various challenges, e.g., Veganuary (https://uk.veganuary.com/). However, also linking effects of own consumption patterns to the conditions of livestock farming, environmental, and health impacts might be promising. At this point, tying up to previous work on visualizing organic food consumption [197] shows paths for awareness-raising designs. Still, vegan design needs supply-chain information, e.g., place of origin, living conditions, and transport conditions. Furthermore, how to communicate and design such information remains an open gap between research on vegan practices and environmental psychology.

Designing for Visibility of Consumption Infrastructures: While our research observed various tools to increase visibility and learning of consumption infrastructures, these still only cover restaurants and supermarket food. To facilitate practice change, future design should focus on other infrastructures, such as clothing and cosmetics or furniture. Thereby, it is not only about the products, but also entangled services, such as hairdressers that offer plant-based cosmetics or clothing companies that do not test their colors on animals. Given that our research mainly focused on food, future design research first needs to understand the visibility and perception of such infrastructures, especially against the background of satisfying the basic needs of daily life. Indeed, recent work on the practice of food teaming shows how a perspective on consumption infrastructures, their perception, substitution, and visibility is helpful to inform design [272].

Designing for Tradeoffs with Family and Friends: Having discussed the idea of more infrastructure aware design, still, it remains open how to bridge the gap between expectations of family and friends ant their practice [354] e.g., on what a proper eating-out location is and one that is vegan friendly. By now, there are apps such a HappyCow for vegans and tools such as FourSquare or TripAdvisor that are used by regime practitioners. Bringing both ICT designs together to allow finding places, where vegans and their family and friends are satisfied, should be addressed in future research. More strongly including the making of trade-offs in such filtering and search mechanisms for infrastructures could reduce social tensions, decrease the perception of vegans as killjoys, and finally facilitate diffusion as barriers between practices are reduced.

Designing for Label and Ingredient Transparency: Against the background of missing European or national issued legislation on a consumer-friendly definition of vegan products and labels [125], future design should research current efforts of vegans to check and discuss ingredients, in particular with apps such as CodeCheck, to provide a transparent and unique interface for checking vegan qualities of products. An additional feature of this could be the inclusion of social, information e.g., vegan negotiations in social media about products. Bridging social information on products, ingredients tables, producer information, and transparent label information together could be an improvement of current services. Also, non-food products should be included in the related databases, as this is currently a blind-spot.

Designing for Learning Taste and Substitution: A particular blind-spot of current vegan design is substitution and the learning of new tastes. Already in the 1950s, Becker [30] showed how learning new practices comes with the learning of taste. In addition, Twine [356] also observed how vegan practitioners over time transition from an omnivorous regime taste to a celebration of plant-based foods. However, design does not yet support such iterative exploration of vegan foods. Recommender systems, although yet not designed for special diet requirements [346], offer the technological foundations to understand current consumption and recommend foods for the future. Therefore, future research should bridge the gap between the basic ideas of self-actualization and sustainable consumption in recommender systems and the

process of learning new tastes. Here, it could be tied up to and extended on research that already explored recommendations based on flavor components [8]. For example, recommendations could start with substitutes that fit into beloved recipes and taste like meat, e.g., supermarket burger substitutes and then gradually shift and prepare towards pulses, tofu, and other vegan options. With such mechanisms, not only taste, but also competences, could be learned over time.

6.4.4 Designing for Co-Evolution of Sustainable Practices

Veganism might appear to be a somewhat narrow focus of interest, but we want to argue that it forms part of a developing, and increasingly important nexus of practices associated with 'green consumerism' and even 'anti-consumption' [38]. As we have seen, veganism is associated with complex and co-evolving practices and artefacts. An understanding of these new constellations from a more general perspective should bring attention to the same co-evolution if we are to design for sustainable practice formation in general. For other practices associated with green consumption [117, 150], designing for change might require the same understanding of many learning iterations co-evolving with artefacts and how they integrate with emerging communities of practice.

Designing for Crises of Routine: As most of our participants highlighted a specific event or documentary that caused a "crises of routine" [278], persuasive design and gamification still might play an important role, as a starting point for co-evolution. Although these approaches are critiqued for not considering the socio-material context [134, 303], we observed that triggering initial change is often a function of 'awareness prompting'. That is, exposure to documentary and other formats can trigger this crisis of routine. Certainly, initial triggers of one kind or another seem to play an important role. The routines of Hasselqvist et al.'s [150] participants, for example, were brought into crises by challenging them to not use their cars anymore. How best to incorporate such triggers into design is an open question, since there will be ethical and other issues to contend with, as we cannot simply adopt showing slaughterhouse content. Persuasive design might, at these early stages, remain

a viable proposition.

Designing for Iterative Learning of Practices: Once change is initiated, rather than designing for practice transformation as 'absolute change', we should focus on smaller iterations of learning the materials and competences for the new practice, as an appropriation of niche infrastructures. This involves exploring the infrastructure of restaurants and stores nearby, learning which ingredients are vegan, and building new cooking competences. However, evolving knowledge and competences change use, as with the restaurant tools we describe above. Similar evolutions can be seen with the move to car-free mobility [150], where appropriate travel planning tools are appropriated, used, and then abandoned. Another element of this process is the monitoring or tracking behavior as a reflection on the process that we observed with diet trackers and is also highlighted in other research [117].

Designing for Artful Integration and Alignment: However, what is currently evident is that there is no integrated provision for these heterogeneous practices, nor for different learning strategies. Multiple artefacts exist and are used but no current facility exists for integrating them. This is similar to the work of Ganglbauer et al. [117] who show that changing food-wasting practices needs multiple interventions. Therefore, design should be flexible enough to be abandoned, recombined, and used in completely different ways, in short enabling artful integration by the users. On the other hand, designers can use the dialectic relationship with tools to resolve tensions arising from the entanglement of practices, e.g., diet trackers to change the meaning of vegan meals and recipes to learn the necessary competences to, in short, align the appropriation of artefacts and the learning of practices.

Designing for Tension between the Odd and the Norm: Design should be sensitive about the niche existence of practices and the difficulty arising from being perceived as the "odd" [150], "going against the [...] society" [141] or the "killjoy" [354]. Therefore, rather than breaking all ties to the 'norm' practice and its community, design should reconcile both, e.g., designing for 'veganization' of meals in omnivorous recipe apps, rather than directly providing completely new and unfamiliar recipes. This is similar to Hasselqvist et al. [150] who already suggest including sustainable modes of traffic in reg-

ular planning tools, creating visibility of alternatives, rather than providing for separate and already decided use. In addition, it is exactly this tension that causes some instability of niche practice even after most of the learning has happened. Here, design can play distinct roles, on the one hand by creating safe spaces for the community, allowing for support, reinforcement [141]. and temporary withdrawal, and on the other hand, allowing for productive exchange between the different communities. Both artefact usages have been observed in our study, with participants using online groups to be not exposed to commenting by the 'norm' and at the same time sharing pictures of vegan meals to create visibility for their 'niche' and decrease prejudice.

Co-Designing with Practitioners: Lastly, we want to reflect on the retrospective perspective of our research and the reflection on ICT usage along the practitioners' transformation journeys. For this purpose, we want to come back to the quote we used at the beginning of this paper: "Yet this rarely sets out practically how such reduction might be achieved and, surprisingly, has yet to look to vegans as a knowledge resource." [355]. While the idea of studying practices [117, 153, 270] and involving practitioners [280] is not a new one, often the starting point of design is the research of unsustainable practices. This usually leads to designs that just cover the first iterations of change, such as increasing the motivation of consumers or raising awareness about their unsustainability [153, 270]. At this point, we do not want to argue that unsustainable practitioners should not be included in the co-design process, but that complementing design ideas with success stories and the experiences of already sustainable practitioners will allow for a more nuanced understanding of barriers of transformation, ICT designs that are practice-proven, and blind-spots in the ICT ecology.

6.5 Conclusions

Our research uncovered how vegan practices and the usage of ICT artefacts co-evolve. While our results at first sight only contribute to the study of vegan practices, we argue that co-evolution is a helpful lens to study and design for sustainable practice transformation in general. From this perspective, the role of persuasive design and gamification should be reconceptualized as a trigger

for the "crises of routine" and reassurance when doubts arise. Understanding the role of different artefacts in knowledge and competence acquisition, and in supporting membership of evolving communities of practice, we suggest, has been under-rehearsed and will require ever more attention as sustainability becomes part of the mainstream agenda. Furthermore, we argue design should focus on the border between the 'norm' and the 'odd' to foster learning, exchange, and to support the negotiation of elements. Finally, we discussed how a retrospective perspective and learning from success stories complements practice research to inform design. For veganism, in particular, we formulate paths for future design and research:

1. Designing for Value Tensions between Livestock Farming and Consumed Reality, to encourage plant-based consumption practices and raises awareness about the gap between values and consumed reality.

2. Designing for Visibility of Consumption Infrastructures, that make vegan-friendly infrastructures and therefore vegan materiality visible, not only for restaurants and food but also for clothing, cosmetics, and various other services of daily life.

3. Designing for Tradeoffs with Family and Friends, to allow bridging that gap between omnivorous and vegan practices, such that leisure time activities and shared usage of infrastructures is facilitated.

4. Designing for Label and Ingredient Transparency, to support easy access to the information on vegan qualities of products and its labels against the background of social meanings of what veganism is about.

5. Designing for Learning Taste and Substitution, to support the exploration of vegan substitutes, recommend new foods with awareness to the practitioners' taste, and iteratively support the acceptance of vegan foods especially protein sources and the learning of related competences.

Reflecting on current ICT designs and the needs of the community, it is worth mentioning that a focus on food practices is a good starting point, as most participants' individual transformation journeys started from food practices.

However, with the ongoing transformation questions of veganism and the relation to other consumption domains arose, such as clothing and even furniture. Therefore, design should broaden the perspective and besides food encourage a holistic perspective on veganism and related designs. Still, detailed investigation into design ideas and the related practice(s) is needed to sharpen the ideas presented here.

Our results are limited by the fact that we interviewed vegans, who successfully managed to undergo a practice transition. Therefore, in future work, it will be interesting to focus on participants who are either still uncertain about their diet change or who attempted unsuccessfully to transform their practices., e.g., through the absence of technology. At this point, it is of particular interest to quantify the impact of ICT in future work. Furthermore, the absence of elderly people, who might have different artefact ecologies, and the small sample size, limits our work. The elderly group, given demographic change, should not be underestimated when aiming for sustainable transformation. Also, for the background of quantifying the impact of ICT for practice change, recruiting a representative and bigger sample should be addressed in future research.

In light of the urgent need to transform our (diet) practices [133, 342], our work contributes to both theory and ICT design: Regarding theory building, our findings shed light on the transformation of consumer practices by making aware about the co-evolutionary process of using ICT artefacts in making consumer practices vegan and in general more sustainable. Our study uncovered common patterns of self-reflection, learning, and enculturation together with the adoption of new goods and infrastructures and how this transformation is accompanied by ICT. Regarding ICT design, we inform to broaden the scope of ICT to go beyond persuasion. We aim to inspire designers to develop interventions that support a shift towards more vegan and other sustainable consumption practices.

No.	Age	Gender	Education	Job	Household	Residence
P1	17	Female	Student (High-school)		With Family	Suburban
P2	17	Female	Student (High-school)		With Family	Rural
P3	21	Female	Student (Bachelor)		Flat Sharing	Urban
P4	21	Female	Student (Bachelor)	Translator	Flat Sharing	Urban
P5	22	Female	Student (Bachelor)	Assistant in Finance	Flat Sharing	Urban
P6	22	Female	University Degree		Alone	Urban
P7	23	Female	Apprentice-ship	Laboratory Assistant	Alone	Suburban
P8	25	Female	University Degree		Alone	Urban
P9	26	Female	University Degree	Job seeking	Alone / With Family	Urban / Rural
P10	26	Female	University Degree	Assistant	Flat Sharing	Urban
P11	27	Female	University Degree	HR-Manager	Alone	Urban
P12	29	Female	University Degree	Public Servant + Sports Teacher	With Partner	Urban
P13	26	Male	Student (Bachelor)		Alone	Urban
P14	28	Male	University Degree	Commercial Clerk	Alone	Urban
P15	29	Male	Apprentice-ship	Accounting Clerk	Alone	Urban
P16	31	Male	Apprentice-ship	Mid-Level Employee	With Partner	Rural

Table 1: Participants Going Vegan.

7 Going Car-free: Investigating Mobility Practice Transformations and the Role of ICT

Abstract

With the debates on climate change and sustainability, a reduction of the share of cars in the modal split has become increasingly prevalent in both public and academic discourse. Besides some motivational approaches, there is a lack of ICT artifacts that successfully raise the ability of consumers to adopt sustainable mobility patterns. To further understand the requirements and the design of these artifacts within everyday mobility adopted a practice-lens. This lens is helpful to get a broader perspective on the use of ICT artifacts along consumers' transformational journey towards sustainable mobility practices. Based on 12 retrospective interviews with car-free mobility consumers, we argue that artifacts should not be viewed as 'magic-bullet' solutions but should accompany the complex transformation of practices in multifaceted ways. Moreover, we highlight in particular the difficulties of appropriating shared infrastructures and aligning own practices with them. This opens up a design space to provide more support for these kinds of material-interactions, to provide access to consumption infrastructures and make them usable, rather than leaving consumers alone with increased motivation.

7.1 Introduction

Against the background of climate change and common transport-related problems such as noise, congestion, and air pollution, a change in the nature and extent of car use is necessary [150]. Although the private car offers high flexibility and comfort [314], it is rather unsustainable compared to public transport alternatives [376, 127].

However, according to Kemp and van Lente [199] changing consumption patterns towards such sustainable modes "include[s] two challenges: on the one hand a long-term change to various technologies and infrastructures, while on the other hand ensuring that consumer criteria change in the same move". The

development of new infrastructures and technologies related to low-emission vehicles and sustainable modes of transport is an ongoing challenge addressed by various parties. However, supporting consumers to change their consumption practices is an often overlooked challenge [199].

Research already explored such transformations of consumption practices for other domains [356] and highlighted the opportunities of ICT to support consumers [213]. For mobility, such a practice-based HCI focus is missing. Here, "research on mobility and transport has been dominated by a focus on the automobile" [130] or the use of a motivational lens [12]. For public transport, there is very little ethnographic research on ICT use in HCI, according to Wulf et al. [377]. Therefore, there is a lack of an understanding of how ICT artifacts can facilitate and simplify more sustainable mobility practices beyond motivational aspects only.

Research Gap: Designing artifacts to support the transformation of consumers' practices and the adoption of new modes of transport, requires a more nuanced understanding of consumer trajectories. Therefore, we address the research question of *"How consumers appropriate car-free multimodal mobility practices and which role ICT artifacts play?"*.

To answer this research question, we conducted a qualitative study with 12 participants using semi-structured interviews. The focus was on consumers' narratives about their car-free practice transformation journey and the associated ICT use. Similar to other other research on sustainable practices, we interviewed consumers who had already changed their habits as a source of knowledge about the difficulties and how they have addressed them [213]. We used as a practice-theoretical lens [102] to understand the role of ICTs and their relationships with infrastructures and practices.

From this retrospective perspective, our findings show how the appropriation of sustainable mobility practices comes with a tinkering into new practices rather than a motivational process only. Participants use ICT artifacts that mediate between their own practices and the inherit schedule of the infrastructures they use. This perspective on sustainable practices contributes to the design of ICT artifacts, by, on the one hand, presenting the dynamic needs of consumers for infrastructure-related practices that can be addressed by de-

signers, but, on the other hand, also by critically reflecting on the role of ICT and the boundaries of design solutions.

7.2 Related Work

7.2.1 From Car Dependency to Multimodal Mobility

One of the main drivers of consumption related carbon emissions is transport. It is responsible for about one third of the energy consumption in western societies [116]. Especially private motorized transport plays a particularly problematic role [238]. In contrast to public transport and shared mobility, the private car is less environmentally friendly and less resource-efficient [127]. Nonetheless, the car is still the number one mode of transport and it is even considered to be growing in ownership [376].

The car plays an important role in the modal split of many people because it offers a certain freedom. Urry [358] stated that a large part of social life would even not be possible without the flexibility of the car and its 24-hour availability. The modal split describes the extent to which certain modes of transport are used. In the context of personal mobility, it can be considered equivalent to the individual choice of transport mode. It therefore provides information about consumers' mobility behavior from an abstract perspective on their daily mobility patterns [276].

To be able to address traffic-related problems, the share of motorized individual transport in the modal split must be reduced [127]. In this context, multimodality means the use of several modes of transport for daily mobility. In order to close this gap, the integration of innovative mobility services, such as public bicycle sharing, into traditional public transport is an important step towards promoting multimodal practices. After all, such practices are only possible if appropriate alternatives to the private car are available. Through this integration, traditional public transport gains flexibility and attractiveness, which are traditionally understood as motivators for car-dependent mobility [314]. For sustainable mobility, it is therefore crucial to promote walking, cycling and public transport, and to avoid or limit motorized private transport wherever possible.

7.2.2 Designing ICT for Sustainable Mobility

Over the past decade, HCI research has increasingly focused on the provision and consumption of mobility services [223]. "However, for various reasons, research has been dominated by the car"[130]. Although others modes have received less attention, we find research on public transport [360], walking [374], cycling [281], and car or ride-sharing [49]. Nevertheless, studies on ICT and public transport are still rare [377].

Within this research, *persuasive design* to motivate consumers has been one of the dominant themes. In particular, various prototypes were used to stimulate and motivate sustainable mobility with eco-visualizations, social comparison, and emotional appeals [12]. These attempts to promote sustainable consumption [87] primarily rely on theories of environmental psychology [115], as well as gamification and persuasiveness [110]. Nevertheless, the focus on motivation has been criticized for having positive short-term impact on behavior change motivation, but no long-term impact [52, 91, 229, 301, 302]. Along with this critique, research on eco-feedback concludes that it needs to be incorporated into multimodal travel planning and that access to and use of infrastructure is a practical difficulty that is not solved with higher motivation and can even be demotivating [65, 64, 233, 329]. In short, there is a lack of ICT artifacts that successfully support the simplicity and ability to conduct new behaviors [109].

To overcome this focus on rational consumers that just need to have enough motivation and more broadly consider ability factors [109], sustainable consumption studies in HCI have used a practice lens [233, 150, 149, 329]. Still, the settings were rather limited by the provision of electric vehicles in urban areas [150], or the provision of a planning platform for the specific group of elderly consumers [329, 234]. Moreover, it lacks a multimodal and public transport perspective [377] that develops an understanding of the role of ICT artifacts and their design.

7.2.3 Theoretical Framing

To give greater attention to the ability and simplicity factors that facilitate sustainable routines [109], this research adopts a practice lens that "increase[s] the understanding of the complexity of what influences how we do things and to create support for more sustainable practices"[150].

Practices are the "routinized way in which bodies are moved, objects are handled, subjects are treated, things are described and the world is understood" [278]. They exist in a context of materials, competences, and meanings [311, 312]. Meanings are the "symbolic meanings, ideas and aspirations"[312], e.g. the perception of biking as healthy [150]. Competences are skills and know-how, practical knowledge, or techniques needed [312], e.g. knowing the city or which train to catch [150]. Lastly, materials are all "objects, infrastructures, tools, hardware and the body itself" [312], e.g. the train, the station or the phone to buy a ticket. In HCI, this lens has been adapted to understand the relationship between infrastructures (shared materials) and ICT artifacts (near/owned material) [102]. Infrastructures can, thereby, be seen as the "entirety of devices, tools, technologies, standards, conventions, and protocols on which [...] the collective rely to carry out the tasks and achieve the goals assigned" [266]. From a consumption perspective, this entails the production and distribution mechanisms of consumable goods, that are shaped by shared usage but not steered and controlled by individual consumers [102]. Such mechanisms entail, e.g., the public transport-system, streets and shared vehicles.

Given the question of how mobility practices transform to a more sustainable state, we have to consider the dynamics of practices as well. In daily consumption routines, the elements are stably connected, creating a kind of equilibrium [333]. Still, an imbalance or "crisis of routine" [278] could lead to a dynamic that comes with the appropriation of (proto-) practices and their respective elements [312]. In the course of dynamic practices, the near materiality of the ICT artifact is also dynamic [43], e.g., the acquisition of new artifacts for new situations or the abandonment of artifacts after the practice has stabilized [213]. In this sense, it begins with an unsatisfactory state, followed by exploration and testing of new options and ideas (excited state), and

finally a new equilibrium in a stable state [43].

7.3 Interview Study

In line with the research question, the goal of our interview study was to understand consumers' car-free practices and the supporting role of ICT artifacts. A particular focus was on comparing different stages of the transformation of mobility practices.

We, therefore, conducted and analyzed 12 (P1-12) interviews (24 - 74 min.) with consumers. The sample was recruited using a snowball sampling approach [253], starting from contacts in the authors' extended social network. The final selection criterion, in terms of purposive sampling [343], was the renunciation of prior car use. This approach did not aim for a representative sample, but rather a broad and diverse sample in terms of mobility practices, life situations, and personal experiences with practice transformation. This diversity is reflected in the selection of participants (see Table 7.3). Our sample includes participants living in rural, suburban, urban, and metropolitan areas. In addition, motivations for adopting a multimodal practice range from leaving home, migrating to Germany, moving to another city, and environmental reasons.

The semi-structured interviews [20] followed an interview guideline that covered (1) the participants' reasons for car abandonment, (2) their current mobility practices, and (3) the transformation of their practices, and (4) the appropriation of ICT for both current and transforming mobility practices. All interviews were transcribed and analysis was conducted by two researchers using the inductive approach of thematic analysis. As an initial template for coding [202], we used the differentiation between pre-, on- and post-trip practices [282, 203] and the simplified action-theoretically informed constructs of stable practices and unstable practices [43]. After coding, the codes were consolidated and the themes were developed collaboratively to achieve a mutual understanding of the material.

No.	Age	Gender	Education	Residence	Time Car-Free	Modes
P1	25	f	University Degree	Urban	6 years	bike; train
P2	24	m	University Degree	Sub-Urban	few months	bike; bus; train
P3	24	m	University Degree	Urban	3 years	bus; tram
P4	38	m	University Degree	Metropolitan	15 months	bus; train; taxi
P5	23	f	University Degree	Urban	4 years	bus; train; tram
P6	54	f	Middle School	Urban	since 1987	bus; train
P7	25	m	University Degree	Sub Urban/Rural	3 years	bike; bus; train
P8	28	m	University Degree	Metropolitan	2 years	bus; train
P9	30	f	University Degree	Rural	8 years	bus; train; taxi; ride-sharing
P10	32	f	University Degree	Rural	1 year	bus; train
P11	24	f	University Degree	Urban	4 years	bus; train
P12	20	f	High School	Urban	2 years	bus; train

Table 2: Participants Going Car-Free.

7.4 Results

Our 12 participants were either car owners or had access to a car in their family. Accordingly, it can be said of all participants that they were socialized with individual motorized transport practices and carried them out for a certain phase of their lives. Thus, at the beginning of our study, the question arose how a change from car-oriented practices to multimodal practices occurred.

Unlike the change of other practices [213], there was no careful tinkering into the new practices. Instead, all participants faced the challenge of adopting new practices from one day to the next due to a change in the personal situation. Examples of this are moving to a bicycle-friendly or a car-hostile city (P1, P2, P9), their own car breaking down (P4, P7), moving to another country (P8, P10) or even the fear of driving after an accident (P6) or due to a lack of routine (P12). In addition to these disruptive events as a crises of their routines, there are also participants who no longer own a car for financial reasons. It can thus be stated that a change of practice is enforced by a disruptive event, rather than influenced by ICT.

Over the course of practice transformation, consumers appropriated additional meanings. For example, the advantages of car-free mobility, e.g. the possibility of sports and leisure activities (P1, P8, P10), independence from one mode of transport (P1, P10), cost and time savings (P2, P3, P5, P7, P11), environmental protection (P3, P6, P7, P11), efficient use of time (P4, P5, P9) and freedom from car-related worries (P2, P12) come to the fore. Similar meanings are also found in research on small electric vehicle practices [150].

> I think it's really important. I mean, you always have your phone with you or you always have a piece of technology with you to check the best route, to check the schedule, to check different things. –P10

While ICT does not play a role as a trigger in our sample, the role of ICT increases with finding oneself in an unsatisfactory state, given by disturbed routines. Thus, participants used artifacts to re-establish stable routines. In the following, we look at the establishment of new routines in the pre-, on- and post-trip practices. In contrast to previous research [329, 234, 150], the focus is on ICT artifacts (near materiality) and infrastructures (e.g. public transport, bicycle lanes, etc.) in relation to the practice transformation. From an analytical point of view, we further distinguish between artifacts that are used to re-stabilize practices, e.g. at the beginning of practice transformation, and artifacts that well established in stable multimodal mobility practices.

7.4.1 Pre-Trip: From Planning Trips to Synchronizing with Infrastructures

7.4.1.1 Planning the Unseen At the beginning of the practice transformation, our participants were confronted with a new uncertainty caused by the lack of knowledge about alternative mobility infrastructures.

While the previous use of the car was perceived as something familiar and simple, the new uncertainty had to be resolved by planning the trips in more detail.

> ”If I wanted to go somewhere, I could just get in my car, look at the GPS and go where I want to go. Now I have to look on the timetable to see, ok, at what time I can go, [...] I wanted to be there at 10, so I have to take the train earlier. [...] what time is the last train or what time do I have to be back so I don’t miss the train. So I have to be really conscious with the time.” –P10

The planning practices themselves are strongly interwoven with the appropriation and use of new technologies. It is noticeable that mainly the smartphone and partly also a computer are used for planning. Also, Google Maps is one of the most frequently used tools. In addition to information about the available modes of transport, other factors are also included into the planning process. P2, for example, also takes the difference in altitude into account for trips for which a bicycle would in principle be an option.

> ”If I’m about to do something new now, [...] I would just look on Google Maps on my phone, where is that, or look on my laptop, where is the address?” –P2

Although technology provides access to multimodal planning and connecting of different mobility infrastructures, participants faced the problem of not finding the best solution directly. This problem seems to be caused by the technologies themselves. For example most apps do not take into account that taking a bike on a train ride could be faster than the subsequent bus. Other

issues, arise from non-transparent pricing models, which need workarounds and explorative tactics to find the best price.

> ”And then I found a solution, but somehow I also tried out different things. First I tried [...] Bicycles that you can just rent [...] That was better [...] But somehow still not so optimal [...] And then I finally found out that you [...] can take your bike on the train for free. [...] And that is now the perfect solution for me to get there quickly. But it took a while to find this solution.” –P1

But it is not just infrastructures and modes that need to be explored. Especially in the early stage of practice transformation, participants reported exploring and trying out different apps and technologies to find a suitable solution that worked for them and their information needs. Thereby, they reported that local apps, in particular, often provide better information, such as live transit schedules or the locations of sharing vehicles, while other apps provide a broader overview of cross-regional traveling.

> ”I also downloaded the [local mobility app] [...], but I’ve deleted it again because I use this [other local mobility app] and it basically has the same functions. And why should I have two of the same apps on my phone?” –P6

7.4.1.2 Daily Synchronization However, all of this effort and exploration is not necessary in the long-term. Once multimodal practices become more stable, e.g. routinely conducted trips and the corresponding infrastructures are better known, participants did not need to use the artifacts that intensively.

However, the technological solution and the corresponding competencies to find a possible connection of modes to get from A to B, once appropriated, remained an integral part of their mobility practices. Although usage generally decreased, new situations, e.g., destination not yet reached, again create some type of instability that needs to be resolved through these technologies and competencies.

> ”So if I’m looking for an unknown route now, I still check busliniensuche.de to see if there’s somehow a bus that goes there cheaply and in a reasonable time.” –P11

But similar to the initial trigger of practice transformation, major life changes, such as moving to a new neighborhood or starting a new job, can cause a new instability that requires reflection and application of well-learned patterns to re-stabilize the own mobility routines.

In addition to this repetition of learning about infrastructures, the issue of synchronizing one’s schedule and practices with the infrastructure’s schedule emerges in long-term pre-trip practices. Here, our participants explained how they learned the departure and arrival times of their most frequently used modes and adjusted their routines to fit the schedule.

> Somehow I adjust my timetable, my own timetable to the bus timetable. And that has affected my life, [...] it’s just not spontaneous.” –P8

This synchronization with the timetable goes hand in hand with another phenomenon, the use of apps to check whether the train or bus is on time. Most participants reported that even though they know the lines very well, they often check the live schedule if they need to hurry to miss the bus, or stay inside a little longer to not wait in the cold.

> ”Most of the time you don’t have to wait that long, but I often check Quando or other apps to see when the bus is coming and it it leaves on time, and it happened to me so many times that the bus has even arrived too early.” –P3

> ”I usually activate this reminder function, so that you are notified when the train is delayed.” –P11

Again, our participants shared how they tried different solutions to have the best synchronization experience. Through trial and error, they tried different

apps to see how up-to-date the data really is and how well the technology actually reflects the infrastructure. Still, a compromise had to be made between artifacts that aggregate multiple transport services but often lack real-time information, and detailed information provided by region-specific artifacts.

> ”In city C, I used the [local mobility app], [...] because it was somehow more accurate than the DeutscheBahn app. So for cities it’s maybe even better to use their own app because they can provide even better data and not all of them have forwarded that to the DB app.” –P7

Once matching artifacts are appropriated, they remain an integral part of consumers’ multimodal practices. But of course, the need for synchronization depends strongly on the chosen modes. In a situation where they use their bicycle, which can still be considered an individual mode of transport, there is less need to synchronize with the infrastructure. Still, for bicycle trips routines need to be aligned with the weather or the amount of traffic, which requires completely different apps.

7.4.2 On-Trip: From Continuous Optimization to Enjoyment and Efficiency

7.4.2.1 Continuous Orientation and Optimization Especially at the beginning of practice transformations, but also in uncertain new situations, our participants show a high need for information about the currently used mode of transport, even on-trip. When the environment is unfamiliar or the mode of transport seems slower than expected, participants reported using the service provider’s app to check for punctuality. They also look for alternatives if they guarantee a faster or safer arrival. This can be seen as a repeated synchronization with the infrastructure.

> ”To see when the next one is leaving or simply to have alternative routes suggested to me, if the app then tells me that the bus is canceled, then the app can also tell you how you could [...] get there after all.” –P5

Similar to daily synchronization, the use of artifacts is highly dependent on the chosen modes. When biking or walking, there are obviously far fewer opportunities to use ICT. In this sense, technology use for these more individual modes of transport is mostly limited to navigation.

> ”I then usually go to satellite and zoom in a bit closer and then look at some of the surroundings and then look at anchor points where I basically have to search for. [...] I recently had to walk from work to another practice and didn’t know one hundred percent how to get through the side streets. So I used Google Maps, for example, and then I sort of walked according to Google Maps. I use that, too, but otherwise I wouldn’t know what to do to get to the [local destination] [...] Yes, well, I also use the train app.” –P6

But again, the interaction between the technology (near materiality) and the infrastructure is prevalent. Our participants chose the technology that provides the appropriate level of detail and features for navigating the mode. This is particularly interesting because it is the technologies that include a wide variety of modes that lack a certain level of information for specific modes. For example, while Google Maps provides a good overview of the entire route, navigation with a bicycle requires different apps that provide more detailed bicycle maps.

> ”I sometimes do not use Google Maps, but another map, MapsME it is called, because the bike paths were still somehow better shown or drawn.” –P1

7.4.2.2 Time Exploitation and Enjoyment In the long term, uncertainty decreases as our participants reported being more aware of schedules and alternatives and simply becoming more comfortable using different modes of transport. Therefore, exploitation of time, efficiency, and enjoyment become more important within the ecology of artifacts used on-trip. Nevertheless, some participants have developed a routine of checking live information at least once.

> ”So I definitely look at it at least once before I get on the train, because a lot can change. And the station usually has the most up-to-date information.” –P11

However, this established routine is not only used to check the infrastructure's schedule, but also to reach the subsequent modes of transport. This can be done, as the example of P10 shows, through a simple communication via messenger or call to ensure a certain synchronicity, but also checking one's own location to get off at the right stop or to reach subsequent modes in time and space.

> ”I would just text the person that I'm there and where we're going to meet. And sometimes if you're not sure where you are, because for me it's like I'm traveling there for the first time, so then I make sure I'm in the right city or where I'm going, for example, I look around to see if there's some kind of signal. Or I even look in Google Maps to see if I'm at the right stop.” –P10

In addition to these routines, which are still predominantly focused on the functionality of the transport infrastructure, the participants also explained how a certain routine emerged over time and the use of travel time came to the fore as a new space that can be shaped. On the one hand, this shows, from a practice-theoretical perspective, how the new modes of transport are also gradually seen as an opportunity for more leisure time. On the other hand, the design of this new time is as different as the participants and the modes they use. For example, they reported that they use the time to rest, to consume media, but also to study or work.

> ”Play games, listen to music, read. Work. I think I forgot to mention working, because it's often the case that you do have something that you can do on the laptop. It's just not as effective as at home, i have to admit. But I used to watch movies from time to time, but I haven't done that for a few years now.” –P2

This involves adapting the ecology of artifacts to the particular mode and the established routines. Specifically, our participants reported exploring which

applications can be used without an internet connection (offline mode) if their route passes through an area with low internet coverage or only use certain features of their applications. Participants also reported preparing accordingly, such as downloading content for later consumption.

> ”With Spotify, it’s just my previously downloaded playlists that I listen to, in Netflix then also only the downloaded stuff, because for this my network flat is not enough [...] WhatsApp just write messages, also no video calls or so, simply because the connection would be too bad for that.” –P5

Similarly, some participants explained how they chose to refrain from certain activities because their chosen mode of transport does not provide the necessary infrastructure in terms of WiFi or charging options. While routines and artifacts are mostly aligned with the infrastructure in use, in some cases participants also report choosing a different mode of transport and making trade-offs between how they can use their time and how fast, comfortable, or expensive the mode is.

> ”I think it’s stupid that train don’t have WiFi, which means you can’t work there well. [...] When I really find a cheaper train, that’s mostly such train. And sometimes I decide against it when I really want to work on something, but I’m prevented from doing because they don’t have WiFi.” –P7

7.4.3 Post-Trip: From Reflection on Practices to Routinized Non-Usage

7.4.3.1 Optimizing Practices and Improving Infrastructures Even for post-trip practices, our participants reported using artifacts to predominantly stabilize their practices. Optimizing the route previously taken and comparing the recommendation or time predictions of the travel planning systems with the real travel time arose as an important theme, especially in early practice transformation.

> ”If you have the navigation that you want to be guided from A to B, then you can track, for example, how long it took me to get there by bike. I sometimes find that quite interesting, especially if it’s a new route, because then I can also estimate for the future, okay I need 20 minutes to get there.” –P1

The example of P1 shows how the participants, depending on the mode, compared the planned travel time with the actual time. This optimization approach for one’s own routines is explained by the fact that one can better estimate the time needed to travel either earlier or later. Such optimization is not limited to bike rides or walks, but also to transfer times between bus rides, where the consumer might get an earlier ride because the app underestimates the walking speed.

In addition to optimizing their own routines, by reflecting on their own use of infrastructures, some participants began to optimize the infrastructure themselves. This optimization is sometimes focused towards the digital infrastructures, such as OpenStreetMap, where they record their trips or label roads, such that other consumers have access to better data and route recommendations.

> ”I came across OpenStreetMap at that time through my dad, because he also liked to enter data there, so when he made bicycle tours, where no one has entered that there is a bike path and has taken the GPS data, [...] which was then recorded on this map, okay there is a bike path. I thought that was cool because it was somehow filled in by the people and because it also took into account all those little paths that maybe only the people who live in the place know.” –P1

Besides, participants tried to share their experiences and optimize the physical infrastructures. For example, they went to demonstrations for better bike lanes after realizing that certain areas are dangerous or do not provide good riding conditions. Other examples include writing letters of complaint about certain bus routes, their service or the schedule.

7.4.3.2 Routinized Non-Usage Since post-trip ICT usage itself is less prominent, it plays a marginal role for stable practices in the long term. Most of our participants reported that they are just happy to have arrived at their destination without uncertainty and that they already used their smartphone or computer a lot during the trip.

> "I'm usually glad when I've arrived, especially after longer trips, you're glad when you've arrived and can do the other stuff." –P2

Still, there are situations where they want or even need to check for bonus programs or travel-related news, such as upcoming constructions. But non-use of artifacts remains the majority case for the post-trip practices.

> "What I might check is the rail bonus status later to see if it's enough for a free ride again." –P10

7.5 Discussion

To answer our research question, we discuss our findings from two perspectives. First, from a theoretical perspective that sheds light on the appropriation of sustainable mobility practices by consumers and the respective role of ICT. Second, building on this understanding, we discuss design implications that put a different focus on the design for sustainable mobility practices.

7.5.1 Practice Transformation as Mediating between Practices and Infrastructures

At the beginning of our participants' practice transformations, a change in their personal situation or a breakdown in their mobility infrastructure forces them to rethink their mobility practices. For our participants, the obvious outcome was to give up their cars and adopt multimodal mobility practices. This immediate change is quite similar to Hasselqvist et al.'s [150] experiments, but consumers still gave up motorized personal transport completely. Interestingly, while in other transformations of consumer practices [213] media

and ICT triggered the questioning of infrastructures and practices, in mobility it seems that — speaking with a practice-lens in mind — transformation is triggered by a change in the material context, e.g., moving to a new city or abandoning the car, rather than by a change in meanings.

While the motivational aspects of persuasive design [110] are a major focus of HCI research on sustainable mobility, it does only play a small role in our sample. Of course, we cannot draw broader conclusions about all consumers due to our sample size, but nonetheless, motivation tends to come from material change. Nonetheless, there seems to be an initial meaning that changed and influenced the decision even before the material change that initiates the moment of transformation. This meaning is, for example, the high price of a car or the inflexibility in finding a parking space. In addition, this meaning changes and stabilizes as the transformation progresses towards other perspectives, e.g. the environmental benefit. Here, despite the observed non-use of motivational design, this branch of ICT could play its role in practice transformation, e.g., preparing consumers for a transformation decision when the material context provides an opportunity. Moreover, to stabilize practices and support sustainable practice transformation, persuasive features could provide information to develop new positive meanings.

Given the material-focused initiation of practice transformation, the simplification of the interplay of technologies and infrastructures was much more prevalent in our sample. This, as our results show, is not just a matter of planning the routes to take, but an ongoing synchronization of practices and infrastructures. While planning has already been observed by Hasselqvist et al. [150] and Stein et al. [329], our research emphasizes that multimodal practices require not just planning but also information about the interconnectivity of modes, their schedules, and real-time information. This need for information exists not only before the trip, but also on-trip, e.g. when changing the mode. Given this perspective, a main lever to facilitate multimodal mobility is ICT, which supports consumers in connecting to, appropriating and using the infrastructure, in short, getting familiar with the new material that suddenly became part of mobility practices without adapting the other elements, neither skills, nor meanings, nor other materials.

This observed role of ICT use is not just an intermaterial relationship between ICT and infrastructures, but is highly related to the acquisition of knowledge about infrastructures. This knowledge acquisition is reflected in the decreasing need for planning, but constant synchronization to deal with everyday problems before and during the trip. Moreover, ICT is even used for learning about the infrastructure in the post-trip phase, e.g., reflecting on the duration of different mode combinations. But the appropriation of the various ICT solutions is also accompanied by learning about their use, the data they provide, and tinkering with a useful ecology of artifacts that fits the ecology of the multimodal infrastructures. In this sense, access to infrastructures proved to be the more relevant issue, as current ICT designs hardly support consumers in accessing infrastructures, but in contrast make it more difficult for them, as mobility modes are interconnected while ICT remains isolated.

Lastly, ICT plays an important role in the use of additional travel time. Although this role seems quite trivial at first, it should not be underestimated when designing ICT. Behind this are the different needs of consumers and their desire for efficient use of time and space when traveling [332]. Furthermore, the ability to use time in the intended way even shapes meanings toward sustainable mobility, as a way to travel and have an enjoyable and/or efficiently used time.

7.5.2 Implications for Design

Reflecting on our research, we will discuss the design implications for supporting multimodal practice transformation using ICT from different perspectives in light of our empirical findings.

7.5.2.1 Motivation beyond Instability Given the initiation of a practice change motivated by a changing material context, it appears that current persuasive design approaches, that strongly focus on motivational aspects, are either not prevalent in the actual app offering or simply play a marginal role for mobility consumption. Nevertheless, in our view, there is room for such motivational approaches. While they may not be well suited to address initial instability in practices, motivational artifacts could prepare consumers for

infrastructural and material changes when they are in their work routines, so that the decision in these cases is in favor of alternative modes. In addition, (eco-)feedback technologies could help shape meanings even after consumers have started their multimodal journey, i.e., the design could help them see how long it actually takes them to travel a distance, how much workout or time in the fresh air they spend, how much money they saved, or even how much extra work they were able to do. As our results show, these meanings form slowly with stabilizing routines, but given the sample, we still do not know how many consumers reverse their change for lack of positive meanings toward their new situation. Moreover, motivational approaches could encourage the sharing of data and the active participation in shaping the sustainable infrastructure, as seen in 7.4.3.1.

7.5.2.2 Facilitating Multimodal Infrastructure Access Although one can identify sweet spots for the use of motivational artifacts, the main issue is access to and connected use of infrastructures. Current designs force consumers to plan their trips by combining different apps, measuring their walking/biking times between different steps of their trip, and summarizing to find a suitable multimodal trip on their own. In this context, it is particularly important to ensure a region-specific adaption of ICT to be able to support mobility practices in line with local conditions. Local information and integration of all mobility services in the region can provide a platform. This integration should also include new shared mobility services that can complement existing services to solve problems such as the last mile or switching between modes. Here, consumer-centric design approaches could facilitate infrastructure appropriation by supporting trip planning in a personalized way. Personalization here refers to one's own capabilities, tickets, and needs for time use. Helpful information could be, e.g., network coverage along the route, the availability of WiFi in a train, or seat occupancy.

7.5.2.3 Pro-Active Infrastructure Synchronization In addition to planning, synchronization the own practices and their schedules with the infrastructure turned out to be an issue, even for long-term routine multimodal mobility users. To the best of our knowledge, this synchronization has not been

the focus of design approaches to support multimodal mobility users. Even in the wild, we observe that it is the consumers who actively check the status of the infrastructure pre-, on- and even post-trip. Here, a more proactive design approach could support consumers to travel more comfortably and waste less time waiting for public transport or get information about weather conditions for the whole trip. It is especially important to not only provide the real-time information pro-actively, but to assist in finding alternative routes that consider the proprieties of the consumer's practices.

7.5.2.4 Data Sharing Beyond Regional and Modal Borders While infrastructure access requires smart design concepts from a consumer-centric perspective, the backend of such technologies must enable data sharing and processing across regional or modal mobility service boundaries. Currently, different mobility providers are rather reluctant to share their data. As a result, consumers need different apps for different information, ranging from real-time information about bus delays to comprehensive information about how their bus connects with the train in the next city. The situation is even more complex when it comes to integrating novel mobility services from the shared mobility context into practices. Accordingly, ICT should rely on shared data to support better planning and access to infrastructure so that searching for and selecting the right information is not a burden on consumers. Moreover, such data sharing could facilitate planning by providers themselves to offer better and more coordinated services to their customers.

7.5.3 Critical Reflection on the Scope of ICT

In addition to the implications presented for the design of ICT to support the appropriation of multimodal mobility practices and the corresponding infrastructures, we want to use the space to reflect on the scope of ICT itself. Sustainable ICT design has been criticized for conforming to the neoliberal agenda that places the burden of transforming society toward sustainability on consumers [91]. However, it must be admitted that the presented roles of ICT and the corresponding implications are mostly focused on consumers and thus create expectations for their behavior and practices. On the one hand, such an

approach is necessary given the urgent need to rapidly reduce our environmental impact. On the other hand, at least the providers of mobility services would also need to change some of their practices, such as sharing data, providing real-time information, facilitating bicycle trips to catch a train, or providing more consumer-oriented services. Nonetheless, we want to emphasize that consumers and providers are not the only actors in this process and that ICT is not a 'magic bullet'. As our results show, ICT can facilitate multimodal mobility, but providers still need to optimize and expand their offerings, and likewise policymakers need to support such forms of mobility [233]. Local authorities could address this on a higher level, since they do not primarily pursue their own economic interests but instead seek to improve mobility as a whole. Public digital mobility infrastructure could promote the emergence of both novel mobility services and new types of providers, also in suburban and less densely populated areas.

Still more and better information and increased connectivity with infrastructures, could facilitate consumers' political participation and allow them to practice some power over policymakers and providers [233].

7.6 Conclusion

In this paper, we presented an interview study with 12 car-free mobility consumers who changed their mobility consumption practices. By analyzing the data from a practice-theoretical lens, we show how ICT mediates and simplifies the interaction between practices and infrastructures. This is defined by different modes of planning, synchronization, and optimization of use, and even optimization of the infrastructures themselves. Based on these results, we contribute to HCI research by discussing a nuanced understanding about the transformation of mobility practices and the role of ICT artifacts in particular for the use of shared infrastructures [102], which is currently lacking [377] but important to better support sustainable practices rather than leaving consumers alone after having increasing their motivation [213, 150].

Still, our research is limited by the sample selection for two reasons. First, our sample is rather young, although it reflects the trend of young adults aban-

doning their cars. This raises the need for broader generalization with other age groups, as they might have different ICT preferences and usage patterns. And second, by interviewing ”survivors” of practice transformation, we can only suggest that ICT plays an important role in individual journeys based on consistent reports, but cannot show that its absence makes a difference. Future research should, therefore, focus on a broader sample as well as the (non-)appropriation of ICT and its influence on the practice transformation. Moreover, our research only emphasizes future design, but does not provide and evaluate any instance of a solution yet. Therefore, in future research we need to focus on prototyping the consumer-facing artifact as well as the back-end that enables collaboration and organization of mobility providers.

8 Comparative Summary of Findings

The previously presented sections have taken an isolated perspective on the research question RQ1. For this reason, we will summarize the results of the three studies comparatively in the following to more broadly consider the role of ICT in sustainable consumption practice transformation. Moreover, abstract implications for design will be developed, partly taken up by the design and evaluation sections in part III.

8.1 ICT Artifacts and the Elements of Sustainable Consumption Practices

In the following, we will shortly summarize and compare the previous studies' results to understand better how ICT artifacts relate to the elements of consumption practices throughout the practice transformation.

8.1.1 Meanings

In the sense of a combined consideration that follows the logic of practice transformations, the question of meanings and motives arises. This is especially interesting to propose a practice-based perspective on the large number of studies that use psychological theories and the corresponding design artifacts to increase consumers' motivation. Therefore, in the following, the focus will be on shortly summarizing and comparing the appropriation of meanings, their development over time, their persistence, and the respective connection to ICT artifacts. The comparison is based on specific phenomena observed at least in one of the studies. Each of these observations is summarized and compared in one particular paragraph.

Initial Motivation: In both studies, section 6 and 7, the participants explained how the sustainable practice transformation started initially.

For the vegan practice transformation, ICT artifacts are essential in motivating consumers. Thereby, we could not observe technologies such as eco-feedback but persuasive media such as online videos or documentaries. In addition,

real-world events, e.g., a public scandal, triggered an initial rethinking. These artifacts have in common the impact, which is described as ”traumatic” or ”shocking.” In this respect, they have a persuasive effect or use persuasive mechanisms but have little in common with the mechanisms of known design approaches.

For the presented use case of mobility, in contrast, quite different mechanisms were observed. Although there also seems to be an appropriation of meanings that are positive towards multi-modal/car-free sustainable mobility practices, these do not automatically lead to a transformation of practices. Presumably, this appropriation of meanings is also influenced by a general societal or media sentiment. However, they do not immediately trigger a change due to the embedding in the socio-material context of the practitioners and the inertia of practices [211, 212]. Although this appropriation can be considered the start of the practice transformation, a further acceleration only starts when the material context (place of residence, near materials such as the car, or infrastructures such as the train) also changes. Possibly this can be explained by the high financial value of a car, which impedes an arbitrary exchange of the mode of transport for most consumers. This is quite different compared to the frequent acquisition of food.

In summary, it can be shown that specific influences on the meanings are a typical pattern to trigger or at least prepare a transformation of consumption practices. However, depending on the embedding of practices in shared contexts and personal situations [102], there seems to be certain inertia in consumption practices. Accordingly, the intense focus on persuasive design does not solve the problems of consumption practice transformations alone. Still, it should not be underestimated to create a positive attitude and a fundamental motivation.

Development and Stabilization of Meanings: Again, in both studies, an interconnection or relationship of meanings and ICT artifacts could be observed in the mid- to long-term practice transformation.

For vegan practices, it is crucial to mention that the participants described a high initial motivation for change but do not appropriate a new practice overnight. This careful approach also comes with a reconsideration of mean-

ings, a development, and appropriation of new meanings as well as their stabilization, e.g., perceiving animal welfare not just as an initial shocker based on a documentary but stabilizing the ethics behind it. This careful tinkering into new practices is accompanied by quantified-self technologies, such as diet tracking and learning artifacts. These, for example, helped to check if the facts about the new diet are reflected in everyday life and if the diet suits the personal situation. While this can be understood as an additional development, reassurance, and long-term stabilization of the meanings, it should not be understood as a permanent usage of the artifact but rather a fluctuating reassurance from time to time.

Also, for mobility practices, a form of reassurance and adaptation of additional meanings can be observed. This is reflected in the evolving meanings throughout the practice transformation, e.g., sustainability as a positive understanding of the car-free practices evolved as an additional justification of the own practices. From an artifact perspective, again, quantified-self tools, e.g., recording of bicycle rides, calculation of savings, or self-perception (e.g., more opportunities to be in the fresh air or more time for work/learning), function as an artifact that is directly connected to the meanings of the practices.

In summary, once practice transformation gains a certain momentum, artifacts support the reassurance, development, and stabilization of meanings. Although our sample shows a bias due to the focus on the ”winners of the practice transformation” and no statements can be made on the statistical influence of these artifacts on the success of transformation, this type of technology nevertheless seems to play a role in the transformation from the subjective perception of the participants.

8.1.2 Materials and Infrastructures

As indicated in various observations of the previous studies, the material context, that is, near materials and infrastructures [102], plays a significant role in transforming consumption practices. For example, a change in the material setup of consumption practices can cause enough momentum to accelerate the practice transformation, or barriers [215] are overcome as relevant infrastructures allow for a less uncomfortable deviation from the regime's path. A

disadvantage of this perspective is that no change can be made in the shared material context [102] in terms of the actual physical setup from an ICT design perspective. Nevertheless, implications for the role of ICT as an enabler and facilitator of infrastructure and material access can be derived from a combined consideration of the previous studies. This offers a perspective to complement earlier approaches to the action phase of behavior change, such as those anchored in the TTM [269], with a practice-theoretical perspective on ICT artifacts. Therefore, in the following, the focus will be on shortly summarizing and comparing the appropriation of materials and infrastructures and the respective connection to ICT artifacts. Again, the comparison is based on specific phenomena observed, at least in one of the studies. Each of these observations is summarized and compared in a specific paragraph.

Discovering the Niche: In both studies, section 6 and 7, the participants explained how they dealt with finding themselves in a situation of unknown materials and infrastructures.

Coming from a situation where most food items were edible for our consumers, they found themselves in a situation where the niche items and infrastructures, e.g., restaurants, were hidden within the market presence of the omnivorous regime practices. To deal with this situation, we observed that the participants used a variety of artifacts to get access to niche materials and infrastructures. This is particularly evident in ICT artifacts such as the various apps for filtering and searching for vegan restaurants, which have become an established part of the practice. Moreover, CodeCheck and other apps for checking nutrients or ingredients of food items can be named here. Those artifacts can be understood as recommending Systems in the sense of the given definition in section 2.3. Where such systems to interact with the material context are missing, online groups as a form of social recommendation can be mentioned here as a substitute.

The use of material-focused artifacts is also evident in sustainable mobility practices. Apps are used to access infrastructures, e.g., the public transport infrastructure. This can be seen in route recommendations via the app of the local transport company, but also in apps that help to plan routes for bike trips. Again, recommending Systems or Recommender Systems are evident

in finding the right infrastructure to be consumed. Furthermore, ICT artifacts are used to link different infrastructures with each other. Sometimes this is done by using just one app, but in some cases, infrastructures must also be combined manually over multiple applications. This is especially evident for inter-modal trips, where various mobility infrastructures from different providers are used but not connected.

In summary, the patterns of appropriating new consumption practices are relatively similar in terms of infrastructures and materials. Consumers use a variety of artifacts to make the often opaque and complex infrastructures of everyday life accessible and usable, e.g., supermarkets with 40,000 products or bus stops with a multitude of lines and irregular intervals. This seems to be a general problem, as various identified barriers are often material in nature [215]. A lot of the artifacts can be considered recommending or even Recommender Systems. For those, the underlying mechanism of, e.g., route planning and restaurant search can be seen as analogous since the core is about finding a consumption infrastructure or material through search and filter mechanisms. Still, the setup of the material context is different for both practices. While the mobility practices mainly deal with infrastructures, the focus of vegan practices is very much material-focused.

Adapting to the Niche Infrastructure: The phenomenon of adaption to the niche infrastructure or synchronizing the own practices with the infrastructure was unique for car-free practices (see section 7). Still, as we will show in this comparison, other sustainable practices might bear such a phenomenon.

Within car-free practices, the participants explained how they try to schedule their appointments to match the stopping times of buses and trains. Such synchronization becomes relevant as the schedule and also unavoidable delays are not necessarily aligned with their appointments and plans. In this sense, the material is not just appropriated but requires constant rearrangement of the practice, thus creating ongoing momentum on a micro-level.

At first glance, this only occurs in mobility practices. However, the synchronization with the supermarket offerings can also be seen as an analogous phenomenon. This can be observed, for example, in the use of online groups to find out whether a particular product is available in a store. Depending on

such inquiries, other meals are cooked, or a slight detour for the shopping trip is needed.

In summary, this phenomenon can, again, be observed in both practice transformation journeys. However, presumably due to the stronger infrastructural focus of mobility practices, it is more important and thus more prevalent in the sample.

Stabilizing a Niche Material Context: It is essential to emphasize that throughout practice transformations, the patterns of artifact usage change in a similar way in both empirical studies.

In the beginning, for vegan practice transformation, artifacts are used intensively to explore materials and infrastructures. But over time, once access to infrastructures and materials is established, the recommendations do not have to be retrieved from the system repeatedly. Thus, long-term use is limited to exceptional situations such as traveling or purchasing unknown food items, as consumers lack information about the materials for these situations.

For mobility, especially at the beginning, when the infrastructures are still unknown and opaque, there is a strong reliance on route recommendations. In the course of the practice transformation, the practitioners learn about the departure times of the trains and buses and their routes, such that usage is only necessary in exceptional cases, e.g., a trip to new friends or a schedule change.

In summary, both domains show pretty similar patterns. In the course of the practice transformation, the practitioners learn about materials and infrastructures and their specifics, such as departure times or opening hours. In this sense, the arrangement of the niche materials is stabilized. But given the definition of a niche, it remains a small space surrounded by the regime. Therefore, new stabilization and support are needed once leaving the own stable context.

8.1.3 Competencies

Lastly, competencies, as the remaining practice-theoretical element, need to be considered. As already indicated in the previous section, an important dif-

ference between food and mobility practices is grounded in the configuration of the material context. In line with this observation and the strong reliance of food practices on near materials, the vegan practice transformation seems to be more strongly linked to the appropriation of new competencies compared to the car-free practices. In the following, however, the parallels, but also the differences, are highlighted by comparing the role of competencies and the associated ICT artifacts. This again offers a perspective to complement previous approaches to the action phase of behavior change, such as those anchored in the TTM [269]. The comparison is based on specific phenomena observed at least in one of the studies. Each of these observations is summarized and compared in one particular paragraph.

Learning about Infrastructures and Materials: In both empirical studies, the appropriation of infrastructures and materials was strongly linked to the learning about these. Such learning was prevalent in the interview data itself but also in the usage patterns of the described artifacts.

For vegan practices, the learning of infrastructures and materials can be seen in the usage of artifacts, such as the restaurant apps or CodeCheck. These are not only used for infrastructure access, but as Twine [356] has already noted, they are used for learning about infrastructures and materials. Recommendations are learned, and consequently, they are available as competence or knowledge about the infrastructure or the material. Such learning was also evident in the learning about the public transport routes and schedules as part of the infrastructure. First, they are reliant on information and recommendations coming from an artifact. In the long-term, however, the frequently traveled routes are learned, such that the usage of the artifact is replaced by competence.

For food consumption, competencies are also needed for the preparation or eating. Again, ICT artifacts play a significant role as a learning tool, which is evident in recipe websites, cooking tutorials, and similar artifacts, that help to appropriate the needed competence. Unlike food, however, for car-free practices, no such artifacts are used. It seems that this is caused by the difference between mobility and food infrastructures. For food, the infrastructure provides a material that needs to be prepared for consumption. In contrast,

for mobility, the infrastructures can be used without any preparation. At this point, we do not want to underestimate knowledge and competencies to use, e.g., a bus, but still, this knowledge seems to be available more broadly.

In summary, both domains share some features of competence appropriation that are supported by ICT artifacts. While both consumption journeys come with a strong reliance on information and recommendation that is, over time, replaced by competencies, the object of consumption seems to determine the need for further preparational knowledge.

Learning about ICT Artifacts: A phenomenon that might easily be underestimated is the need for learning about the ICT artifacts themselves. These artifacts are also an object of consumption in the sense of the given definition in section 2.2.

For the vegan practice transformation, consumers explained how they started using different apps but also learned properly search for vegan restaurants on Google. Such learning about the artifacts can be considered a necessary competence, enabling any further consumption. Such learning was also observed for car-free practices. Our participants explained how they even tried several apps, learned about their features, and selected the most appropriate app for their use case. Indeed, such competencies are supported by the general knowledge about the usage of a smartphone or computer. However, still, as the data shows, consumers face various barriers when it comes to using those specific apps.

In summary, the competencies needed for using the consumption support artifacts should not be underestimated, as they are part of both consumption journies. Especially from a UX and usability perspective, designers should consider an easy to user interface as well as supporting functions that require little learning about the app itself.

Enculturation and Learning how to behave: The last phenomenon that was observed in both studies is the enculturation into and learning about the culture of niche consumers. This is quite similar to the learning of competencies and the enculturation as observed by Becker [30], who described how consumers adapt to a marijuana users' culture, the symbols, and their actions.

For vegan practices, mainly social media was observed to be used to start discussions with other vegans, e.g., about how to deal with omnivorous friends or to learn about the positive experience of certain foods. Although consumers did not necessarily become friends with other consumers from their local niche, they at least found a place to exchange cultural means.

For car-free practices, in contrast, there are no indications of an ICT usage for enculturation into a mobility culture. However, we observed the participation in demonstrations for which we can assume a specific culture. This particular branch of mobility culture, however, can be considered a minority or niche within the niche. Therefore, it remains unclear why such enculturation is the case for vegan practices and not for multi-modal practices. It can be assumed that the difference between norm and niche [77] plays a decisive role in the need for such competencies.

In summary, the enculturation into a consumption culture via online groups and other artifacts was only apparent for food practices. However, as described, we can assume that the political niche of car-free mobility practices also comes with a specific culture. Nonetheless, the topic of enculturation should not be underestimated when designing for sustainable consumption. The community is described as crucial for the vegan practitioners to strengthen their own well-being and deal with regime consumers.

8.2 Preliminary Design Implications

To support the appropriation of sustainable consumption practices and easy access to the relevant consumption infrastructures, we derived design implications from comparing the practice transformations of the two application domains. The implications outlined below guide our design-case studies presented in the following part of this thesis. The design implications are formulated in general terms for consumption as a broad field and adapted and refined in the subsequent studies. Moreover, it is worth mentioning that, in line with the focus of this thesis, the following implications are focusing on artifacts, in general, and recommending Systems primarily. This class is to motivate the focus once more of interest, as the respective artifacts are already used in the

observed practice transformations, especially for the material and competence interactions.

- **Create Access to Consumption Infrastructures and Materials:** In line with the observations of the three previous studies, an essential issue of sustainable consumption practice transformation seems to be the appropriation of new infrastructures and materials. This appropriation can be understood as including new elements into the network of their practices. These elements, thereby, need to match all practices that used the ex-elements that needed to be abandoned, e.g., the car or meat. Having observed this, artifacts, e.g., Recommender Systems, should support consumers in accessing their alternative or niche infrastructures and materials. These usually remain distributed, hidden, and hard to access based on their low visibility within the regime's dominance. Therefore, those systems need to establish mechanisms to filter them from the regime's infrastructures and increase visibility.

- **Facilitate the Learning about the Usage of Infrastructures and Materials:** Quite similar to the above implication, those artifacts should enable the consumers to learn about the infrastructures and the materials. Although this means that in the long-term, consumers would not need the artifacts anymore or at least less often, learning about infrastructures makes the conduction of practices easier and reduces effort. Therefore, they should provide a certain kind of transparency and give broad information. This can either be expressed through learning the schedule of public transport or by highlighting which ingredients are vegan-friendly, rather than just suggesting the item. Also interesting are the different values and implications of the consumed good or service. Consumers want to make their own deliberate decisions rather than being forced to what is the 'right' infrastructure. In addition, to these general implications for veganism, more detailed recipes and inspiration become relevant as materials often need to be brought into a consumption-ready state.

- **Decrease the Perception of Barriers and Increase the Perception of Alternative Materials and Infrastructures:** In line with the different

values and implications of the materials or the infrastructures, the Systems should provide means to compare different offerings. Therefore, it is crucial to not just recommend the one best option but allow for an individualization rather than an enforced normative understanding of why and how consumers should consume those. This is important against the background of the different motives and journeys, but also to continuously provide motivators and possibilities to adapt to new perspectives and meanings. In this sense, the artifacts should be as flexible and personalizable as the transformation journeys are. Also, the artifacts must be embedded in the context of practices, which means that availability, personal schedules, budget, impairments, goals, or restrictions should be considered.

Part III

Designing Infrastructure Recommender Systems for Sustainable Consumption Practices

9 Introduction

While part II provided a broader overview of ICT artifacts for sustainable practice transformations, in line with the research questions RQ2, this part focuses on recommending and Recommender Systems as an essential type of artifacts that fosters material/infrastructure interactions.

- *RQ2.1:* How do consumers interact with infrastructures mediated by ICT, and which design opportunities and requirements for sustainable infrastructure Recommender Systems result from this?
- *RQ2.2:* How do consumers use and appropriate Recommender Systems for sustainable Infrastructure consumption, and which potential do they have for practice transformation?

Thereby, this part takes up the preliminary design considerations. However, it has to be noted that the studies of part II and part III were conducted independently. Still, the design studies reflect the same design considerations and, thus, match with the previous studies in the sense of a joint consideration in this thesis.

Again focusing on the results of the previous part, it was shown that alternative or niche consumption infrastructures are hard to access as they are somewhat invisible, follow their own logic, and/or consumers are not skilled in using them. Moreover, compared to regime consumption infrastructures, they are less comfortable, require more effort from the consumers, and seem more pricey. This perception was already described by Prost et al. [272], who highlight the competitive advantage of supermarkets. Similar observations were made for mobility, where alternative services come with a feeling of less autonomy and freedom [234]. Prior research [156, 195, 180] already engaged in studying Recommender Systems to support sustainable, critical, or ethical consumption. But still, those systems are instead designed and evaluated from a psychological perspective [180]. In line with the practice-based Computing approach of this thesis, the goal is to co-design such systems and evaluate them in real-world settings to show the capabilities and boundaries for supporting sustainable consumption.

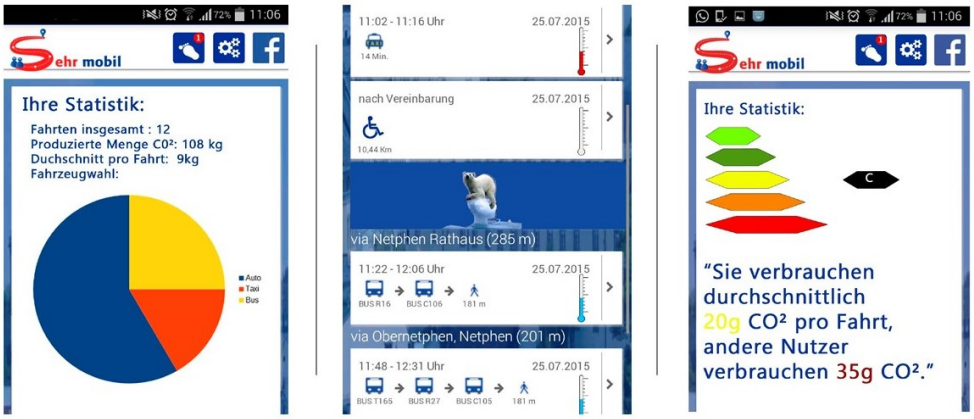

Figure 15: Impressions of the EcoMobil Concept [232].

Against this background, section 10 shows a design case study on food consumption. Based on an empirical pre-study, a Recommender System is designed and evaluated in a real-world trial. Similarly, section 11 introduces the design case study for the domain of mobility. While the first study focuses on personalization and inclusion of ethical values as means to reflect those within food choices, the second study focuses on supporting decision-making utilizing an eco-feedback approach that is included in a Route Recommender System. The respective design approach of the artifact is explained in more detail in the paper of Meurer et al. [232]. There it can be seen that the focus is on giving decision information, decision assistance, and affection [180] along with the recommendation, while the recommendation itself remains unchanged. As figure 15 shows, the app concept relies on enhancing the recommendations with eco-relevant information, social comparison, and personalized statistics.

Finally, in section 12, the insights are shortly compared and summarized from a practice-theoretical perspective (similar to section 8.1). This summary prepares for the next part – the discussion. Here, the practice-theoretical results and design implications are discussed in more detail against the background of the research questions and the existing literature.

10 Buying the 'Right' Thing: Designing Food Recommender Systems with Critical Consumers

Abstract

Critical consumerism is complex as ethical values are difficult to negotiate, appropriate products are hard to find, and product information is overwhelming. Although recommender systems offer solutions to reduce such complexity, current designs are not appropriate for niche practices and use non-personalized intransparent ethics. To support critical consumption, we conducted a design case study on a personalized food recommender system. Therefore, we first conducted an empirical pre-study with 24 consumers to understand value negotiations and current practices, co-designed the recommender system, and finally evaluated it in a real-world trial with ten consumers. Our findings show how recommender systems can support the negotiation of ethical values within the context of consumption practices, reduce the complexity of finding products and stores, and strengthen consumers. In addition to providing implications for the design to support critical consumption practices, we critically reflect on the scope of such recommender systems and its appropriation.

10.1 Introduction

> "The notions of 'critical/political/ethical consumer' and 'critical/political/ethical consumerism' play an increasingly important role in discussions on how to bring about a sustainable development in a market driven economy [139, 349, 335]."[129]

From an ecological and social perspective, critical consumerism[4] has taken on a new significance as the consequences of food consumption choices have become more apparent. Critical consumers, as diverse as this group is, address

[4]We refer to critical/political/ethical consumers as critical consumers.

various environmental or social issues of the food system, e.g. a reduction of meat, fair trade, or organic food [129]. Addressing these issues, prior HCI research suggests to "support planning and shopping by making information accessible and visible" and considering "costs, sustainable, ethical, and health" values in design [117]. Thereby, according to Håkansson et al. [141], design needs to support the personalization of what are the 'right' values, rather than enforce a normative understanding.

Such design, however, needs to support consumers within the complexity of practices that are entangled with cultural aspects and personal situations, e.g. budget, allergies and surrounding infrastructures with different stores and ten thousands of products [259, 60, 129]. This burdens consumers with making decisions with conflicting values and under information overload [129].

Reducing information overload and finding matching products is usually addressed by recommender systems (RecSys). Current systems are, however, designed from a vendor perspective to motivate and nudge more consumption [317, 132], rather than to engage and support critical consumption. And even 'independent' RecSys that are presumed to support consumers, turn out to be driven by market interests [80, 195]. Also in academia, food RecSys neglect the complexity and diversity of diets and practices, e.g. they do not work well for vegan or vegetarian diets [346], as they focus on popular food rather than niches and do not take the implications, e.g. allergies or values, into account. Moreover, they reinforce current behavior, instead of allowing for exploration and setting new goals [324], and rely on intransparent ethics [195]. Resulting from this, there is a **research gap** in the question of how personalized food RecSys can be designed and used to support critical consumers in realizing their complex values, ethics, and restrictions [195].

In light of this research gap, this design case study [379] aims to combine both, the discourse of sustainable food practices and personalized food RecSys, by examining how critical consumers can be supported by a personalized RecSys and how such a system should be designed to appropriately to consider their values, restrictions and situations. Based on the literature review to frame the research focus (Section 10.2), we conducted a pre-study with 24 consumers to understand their current consumption practices and present

first considerations for the design (Section 10.3). The challenges and requirements identified in this study were addressed in a co-creation workshop that supported and inspired the development of F-RS4CC, our knowledge-based **F**ood **R**ecommender **S**ystem for **C**ritical **C**onsumers, which is presented in Section 10.4. Finally, in Section 10.5, we present the evaluation of F-RS4CC with ten consumers. The focus of the study was not on technical accuracy, but practical requirements, appropriation, and the scope of the approach.

The contribution of our research is twofold. First, we contribute to food RecSys by designing and evaluating our prototype and showing how to bring in personalized values and context information. Thereby, the evaluation shows how future design needs to go beyond ethical values and incorporate settings for the personal situation and allow for different complexities of profiles. From a sustainable food practice perspective, our results contribute by showing how food RecSys can indeed reduce complexity but are limited in regard to everyday usage as consumers' shopping planning turned out to be informed by an established set of products rather than new explorations. Still, in new situations, consumers found the prototype helpful to support new situations.

10.2 Related Work

10.2.1 Critical/Political/Ethical Consumerism

The nexus around critical consumerism is often defined as ethical-value-driven and more conscious consumption practices that consider the broader implications of own consumption. While this nexus of critical, ethical, and political consumption is often used without any exclusive definition, it mostly refers "to the conscious choices implied in attempting to connect values and actions in the market-place"[129] and "may be seen as a form of political, or extra-parliamentary participation"[129] in the food system.

Critical consumerism typically addresses personal concerns, such as health, and broader altruistic values "such as human rights or work rights, [...] use of scarce resources, environmental impact, climate change, animal welfare, and politics, such as perceived social irresponsibility"[129]. However, bringing values into action is quite difficult. Consumers face the challenge of balanc-

ing their often numerous ethical values and restrictions against the offering of their surrounding markets and the available budget, gain practical knowledge about products, and resist unplanned shopping desires [60]. From a practice-theoretical perspective, the transition from unconscious consumption practices to critical consumption practices can be seen as a learning of new competencies, exploration of new products and stores, and negotiation and appropriation of values [355, 213].

Although one individual consumer might not change the whole food system, consumers aim to diffuse change into society by sharing practices and the meanings of alternative consumption [192, 292]. This participation and its expected influence on the food system are criticized by some researchers as the political dimension is considered an expression of legislative weakness in neo-liberalism [29] and consumers might be disenchanted about the effect of their consumption [129]. Others [237, 334], however, see it as complementing legislation by low-threshold and non-bureaucratic market participation, which allows even groups with little legislative power to shape the food system.

Supporting the planning of shopping is seen as a major opportunity to bring critical consumer values into action [60, 117]. Thereby, previous research found that consumers use various information resources to inform their consumption decisions [257, 213]. However, this is challenging as products are not properly labeled, information is not given, and appropriate products are invisible within the nearly infinite number of products and stores [213].

10.2.2 HCI to Buy the 'Right' Things

Closely related to critical consumerism, Prost et al.[270] introduced the concept of food democracy. This concept entails going a step beyond the neoliberal roles of consumers and producers and start building on alternative food systems, e.g. urban gardens or consumer co-operatives, that compete with the current system. Still, as not everybody can participate in alternative food systems and systems may co-exist [270, 144], "we also need to acknowledge and design with (or around) already existing food infrastructures with competing interests and values"[272]. Supermarkets, as "the visible end of the corporate food infrastructure and their hegemony [are] prevalent through their ef-

ficiency, pervasiveness, and in many cases, aggressively cheap pricing"[272]. Addressing those infrastructures, Ganglbauer et al. [117] suggest to "support planning and shopping by making information accessible and visible" [117]. In doing so, design should consider "costs, sustainable, ethical, and health" [117] values in a personalized rather than normative way [141]. This entails not only the values but also the cultural background of the consumers or their personal situation, such as budget, available stores, and products [259, 129]. Moreover, Parker and Grinter [259] conclude that future design should "provide insight into how users can eat healthfully given their cultural, local and temporal reality". Towards this end, HCI has been researching the support of buying the 'right' food from different perspectives.

For healthy food, research [190] focused on reducing the complexity of nutritional features by introducing more simple indicators. To support in-store decision making and searching for healthy alternatives, Ahn et al. [7] introduced an augmented reality prototype that successfully reduced the search time during shopping. Further research [283] introduced systems to reflect on consumption patterns and track health-related goals of past purchase decisions during shopping, but also at home.

Similarly, for sustainable purchases, research focused on in-store decision making and reflection on consumption patterns to bridge the intention-behavior gap [306]. Some research [191, 36] engaged in decision support during shopping. Their research used the opportunities of scanning products with the shopping cart and visualizing simple information on regionality or organic quality with LEDs. The display allowed for comparison with other consumers. Likewise, Herbig et al. [156] designed and evaluated a mobile app to in-store, scan and assess products. They highlight the importance of trustworthy data and customization towards their understandings of sustainability. Still, scanning products in the store is assessed as a tedious task that needs to be reduced. Besides, research[197] used digital receipts to allow participants to reflect on their organic consumption patterns. Reflection here proved to increase organic food consumption.

While the presented research focused on motivational aspects and in-store assessment, research on critical consumption highlights the importance of

planning [60] as well as the exploration of products and retailers that sell the appropriate products [213]. Regarding this, Clear et al. [73] suppose to support purchase planning by showing sustainability information right behind the selected item in the shopping list. A broader evaluation of the approach is missing.

10.2.3 Food Recommender Systems

To reduce information overload and filter for appropriate products and stores, RecSys offer a well-known solution, as they are already adopted by millions of users and allow for real-time information access at any time [195, 98].

According to Tran et al. [345] there are four types of food RecSys. The first type gives recommendations of recipes or products based on similarity to consumer preferences [113, 147, 95, 345]. Type two integrates the recommendations of (health) professionals and their assessments [357, 1]. While type three represents a link between the food preferences of individual consumers and nutritional recommendations [98], type four generates recommendations for consumer groups, e.g. a family or group of peers [96, 345].

Within these attempts, mostly content-based, collaborative filtering or hybrid approaches were used for food recommendations [345, 350]. Thus, recommendations are mostly based on popularity or similarity of food. Based on this dominant approach, food RecSys do not work well for critical consumer practices, e.g. recommending vegan food [346]. While this approach ensures broad acceptance of the recommendation, the recommended foods are rather unhealthy and unsustainable [324, 347, 348].

Due to the outlined issues, current approaches start to reexplore the opportunities of knowledge-based approaches where the aim is to recommend food based on a holistic user profile that includes individual health conditions [244]. However, there is still a gap in research on food RecSys that consider the preferences of individual consumers in a profile [345] and bring personalized critical consumer values and ethics into action [195].

Regarding this, Karpati et al. [195] found that there are already some food RecSys available that use ethical concepts. However, those are non-

personalized, which means that consumers are only able to find the 'right' product if they share the value set of the RecSys provider. For those services, ethical guidelines, algorithms, and the underlying business model are often intransparent [80, 195]. Therefore, they [195] argue for research on RecSys that allow for personalization of ethical values and consideration of consumers' needs for transparency and trust.

10.3 Empirical Pre-Study: Understanding Critical Consumer Practices

The objective of our empirical pre-study is to understand the diversity of critical consumer practices, current approaches to finding appropriate products, and potentials of a food RecSys to support planning and exploration.

We therefore conducted and analyzed 24 (PS1-24) interviews (avg. 26 min) with critical consumers. The sample has been recruited with a snowball sampling approach, starting from contacts to critical consumers from prior studies. In taking such an approach, we were not aiming for a representative sample, but a broad and diverse sample regarding critical consumer practices, values, and combination of values and other restrictions. For example, our sample covers vegetarians, vegans, allergies, political boycott, religious restrictions, diet (low-carb, low-sugar), sustainable/organic and plastic/packaging reduced consumption practices. The sample is characterized by 9 male and 15 female participants, aged between 21 and 35. The education ranges from apprenticeship to a university degree. Living conditions range from alone to living with a family.

The semi-structured interviews [20] followed an interview guideline that covered the participant's food consumption practices, including their ethical values and restrictions, issues of critical consumerism, and their current efforts to purchase decisions. All interviews were transcribed and the analysis was conducted by two researchers following the inductive approach of thematic analysis [48]. After coding, codes were consolidated and themes were collaboratively developed by the group of authors towards a mutual understanding of the material.

10.3.1 Critical Consumerism

Our participants' perceptions of their consumption were as diverse and ambiguous as the definitions of critical consumption in the literature. Some identified themselves with role models, such as vegetarian, vegan, or political consumer, while others loosely describe their restrictions and considered (ethical) values.

> "I use the word vegan or would describe myself that way because it is easier. But actually I pay attention to consumption. Consumption is a crucial point for me, because for me every purchase is a ballot. I am actively influencing our economy with it." – PS11(26,m)

However, none of our participants was just committed to one restriction or value. In particular, we found various examples, where participants described their consumerism as evolving from one direction towards the negotiation of different goals and ethical stances. For example, veganism to minimalism (PS7(26,f)), religious to political boycott (PS15(29,f)), food to whole lifestyle (PS14(31,m)), or sustainability to political boycott (PS16(35,m)). Thereby, the goals do not necessarily have to be altruistic ones, but complexity can arise from additional personal goals as well, e.g. reducing calories (PS20(30,m)), allergies (PS18(26,f)), keto-diet (PS22(26,m)), reduction of ingredients suspected of being carcinogenic (PS17(25,m)), or health reasons (PS16(35,m)).

> "So for many people it is only vegan eating or clothing, for me it actually means the complete lifestyle [...] I'm really trying to keep the whole lifestyle completely free of suffering and I try to extend it to things like not shopping at H&M or Primark, trying to buy organic, as environmentally friendly and free of suffering, also for humans." – PS9(27,f)

In a broader reflection on the political or economic aspects of their consumption, our participants expressed ambiguous feelings. The perspective, thereby, ranged from having high market power and that every consumption matters,

to little power for individual consumers, but mass matters, and finally to rejection of power, but an emphasis on being at peace with oneself and own values.

> "I don't know if I'm making a mark with this but I believe that the crowd can make a mark by buying certain products less, so a single one probably won't make any difference but in masses you can make a difference" – PS15(29,f)

10.3.2 Complexity & Effort of Critical Consumerism

Participants described their practices as associated with various efforts and complexities that need to be resolved. Although, most participants explained that their consumption practices become more convenient and easy over time, e.g. when they found new 'basic' products that match their needs. Nevertheless, in uncertain situations, e.g. facing new products or moving, new complexity arises.

> "The problem is the everyday life. Everything I just said [about my consumption] sounds very good and idealistic. But in the end you are only human. And that is really exhausting. Personally I find it very exhausting to go through it all time. If something slips in between, I am not so strict. [...] Of course it is easier than before, but if you want to go away or eat something else." – PS11(26,m)

Thereby, the complexity arises from various issues that are entangled with the situation of the consumers. Participants articulated how they try to find products that best match their values, but still, trade-offs have to be made between different values as there is no 'right' thing. In some cases, there is even no product that fully matches their requirements, at least from perception.

> "For a long time I thought, [...] organic is good, but when I get it sold in cardboard and plastic, I start to have doubts and think

> 'hmm, then I'd better buy the normal ones that are on the shelf without packaging, regardless of whether they say 'organic' or not, because that's part of the deal for me. One tries to see the whole thing and not just trust on some label" – PS24(30,m)

Moreover, not all products are available at a single retailer or even retailers nearby. Although most of our participants explained how they usually purchase products at bigger retail stores, even those do not have all the products they need. Therefore, another problem arises from getting an first overview of the offerings of different stores, and second, managing shopping trips that include multiple stores.

> "Sometimes I think my life is a bit too hectic to think about it. I would really need an afternoon, okay I'll go to the zero waste store and buy this and that. The problem is that sometimes some things are used up faster than others, which means I buy it on demand. And so it is hard for me to say okay, I am gonna go to the zero waste store again. Exactly because this convenience factor is essential for me and that I am looking for which store is close." – PS8(26,f)

The field of tension between products, stores, and ethical values is further influenced by the personal situation. On the one side, consumers already struggle to weigh the properties of the food, as the above examples of PS24 shows. On the other side, time in everyday life, financial capabilities or simply the distance to the next store add tension. Accordingly, this tension in everyday life can sometimes not be resolved in favor of the value-matching product, but the given situation. For example, the budget especially concerned the students in our sample, but also unemployed or low-income consumers. They describe organic and unpackaged products as more expensive than regular products and therefore, not in scope of every shopping trip.

> "This week I bought in the organic supermarket for a lot of money. 50 euros. Then I know the next few weeks I should perhaps not necessarily go out to eat and that I should not go to the

> organic supermarket again. Then I go for example, to a discounter and just buy the basics and try to cook more for me." – PS8(26,f)

Furthermore, family, roommates, or partners are a factor that adds effort to food purchase. Besides, friends are mentioned, e.g. when the participants invite for dinner. At this point, the own consumption needs to be aligned with that of other consumers. Thereby, these can also have their ethical values that are not necessarily compatible with the participant's values.

> "I'm not always strict on it, because I can't have so much influence on it. I am just one person and most people, for example, my family, they consume exactly what I partly avoid." – PS19(27,f)

10.3.3 Current Approach to Purchase & Planning

To cope with the complexities, consumers developed certain strategies to buy the 'right' thing. Thereby, the acquisition of food information turned out to be an important issue. This includes certain ingredients, labels, and sources for further checking of the quality, impacts, and values of the products. In this manner, participants describe how they use various labels, e.g. the vegan, organic, or fair-trade label. In addition, for unlabeled products, the ingredient list is checked for allergens and unwanted ingredients.

> "I look at the product and there is often also the vegan label on it and otherwise I look exactly at the ingredients. I think I've probably googled some ingredients, but usually I look at what's inside, because I have to do it due to my allergies." – PS10(29,f)

Sometimes, however, consumers face the challenges of not understanding or recognizing ingredient names, finding no label or certain information is hidden or not provided, e.g. the carbon footprint or ingredients summarized as 'natural flavoring'. For this reason, most of them established strategies to check the product. A tool repeatedly mentioned is CodeCheck, an app to scan the product's barcode and access data about ingredients, qualities, and the

assessment of other consumers. Another approach is using lists of websites, googling the ingredients, or asking peers offline or in social media.

> "I google sometimes, whether something is not marked with a vegan label, whether it is vegan, for example, such a cereal. Or for example Peta, they sometimes have lists. Or CodeCheck, if there are any hints." – PS5(23,f)

Against this background, most consumers explained how they established a set of 'basic' products to reduce the tedious checking-effort in everyday shopping. Despite this set, some participants, however, address the value of pleasure and the joy of exploring new products. They do not see their consumption as a limitation, but as room for new explorations.

> "For me it is not a renunciation, but actually an enrichment, because I have been cooking much more diverse since then. And yes, I do not eat dairy products and eggs anymore, but otherwise I like to cook a lot and very much and I also attach importance to good food. I like to eat." – PS2(21,f)

Exploration, however, is associated with again negotiating values and checking products. Common sources of inspiration, such as leaflets or advertisements are not relevant for critical consumer practices, as they address regular consumers and often do not promote appropriate products or give the necessary information. Here, our participants explained how they join online communities, where other critical consumers post messages about newly explored products, answer questions about products, or just help with finding retailers that offer certain products nearby.

> "I'm in a Facebook group that's called 'vegan action' where people post discounts from different supermarkets or shops and that's sometimes very useful." – PS6(25,f)

10.3.4 Considerations for Designing Recommender Systems for Critical Consumer Practices

To support planning grocery shopping and easy access to relevant information and products, we derived design implications from the literature study and our complementary interviews. The main implications that guided the development of our prototype are outlined in the following.

- **Support Planning and Product Exploration:** In line with prior research [60, 213], the support of planning and exploration activities for critical consumers turned out to be a critical issue to be addressed by our prototype. Consumers can not make use of traditional leaflets and have to cross-validate information about products. Supporting with information and appropriate product recommendations before a purchase can provide means to reduce the effort of critical consumer practices.

- **Personalized Profiles:** Critical consumers are not a homogeneous group nor is it easy for individuals to describe their preferences as they are usually multifaceted [129, 60]. Furthermore, consumer practices underlie a transition, e.g. from vegetarian practices to vegan ones [213, 355]. Therefore, our RecSys approach should support the negotiation and exploration of values and restrictions and allow for personalized changes in the value arrangement [156]. Here, a knowledge-based approach might be appropriate to capture the complexity and flexibility of practices [244] while allowing for the ethical autonomy of the consumers [195].

- **Well-known Role-Models to Reduce Complexity:** Although not all consumers identify as well-known types of consumers or role models (e.g. vegan), the design should use such framing to give guidance for less experienced consumers and reduce the complexity of the system itself. Such role-model approaches to consumption patterns relate to the interview study were consumers explained that their approach is for example, veganism plus additional restrictions and ethical values.

- **Considering the Context of Practices:** A critical point for consump-

tion practices beyond their ethical and altruistic stance is their embedding into the personal situation of the practitioner. Thereby, the approach needs to consider the context as given by the household of the consumer, available retailers, and financial capabilities[17]. Furthermore, personal goals and restrictions, e.g. allergies, need to be considered.

10.4 Development of F-RS4CC

To support the exploration of new products and planning practices, we developed F-RS4CC as a cross-platform application. The design was accompanied by a co-creation workshop (approx. 3h) with ten participants. Again, they covered a wide range of consumer practices and values. To document the workshop we took notes on the discussions and explanations and took pictures of the paper prototypes. The consumers were between the ages of 23 and 57 (six males and four females).

The co-creation workshop focused on understanding the consumers' approach to bring their values into action. In particular, we aimed to understand the requirements for the UI, abstract ideas of how a RecSys should filter and rank the products, and which input they want/need to provide. Therefore, the workshop was organized along (1) a welcoming and problem introduction, (2) creative phase to sketch and discuss the profile UI, (3) discussion of its influence on the ranking, (4) creative phase to sketch and discuss the shopping list UI, and (5) reflection on additional factors, e.g. food sharing, and conclusion. Although the participants were critical consumers themselves, we provided personas and purchase scenarios [250] (inspired from the pre-study), to allow for participation without self-disclosure in the group, e.g. of allergies or diseases. For the creative phases, we provided standard materials, such as paper, pens, and scissors. Moreover, example product data (name, ingredients, labels, and nutrition table) and printed food labels and symbols were available for both the sketches and the discussions.

Inspired by the consumer concepts, we designed the final prototype. In the following, we present the overall workflow (see Figure 16) of F-RS4CC and

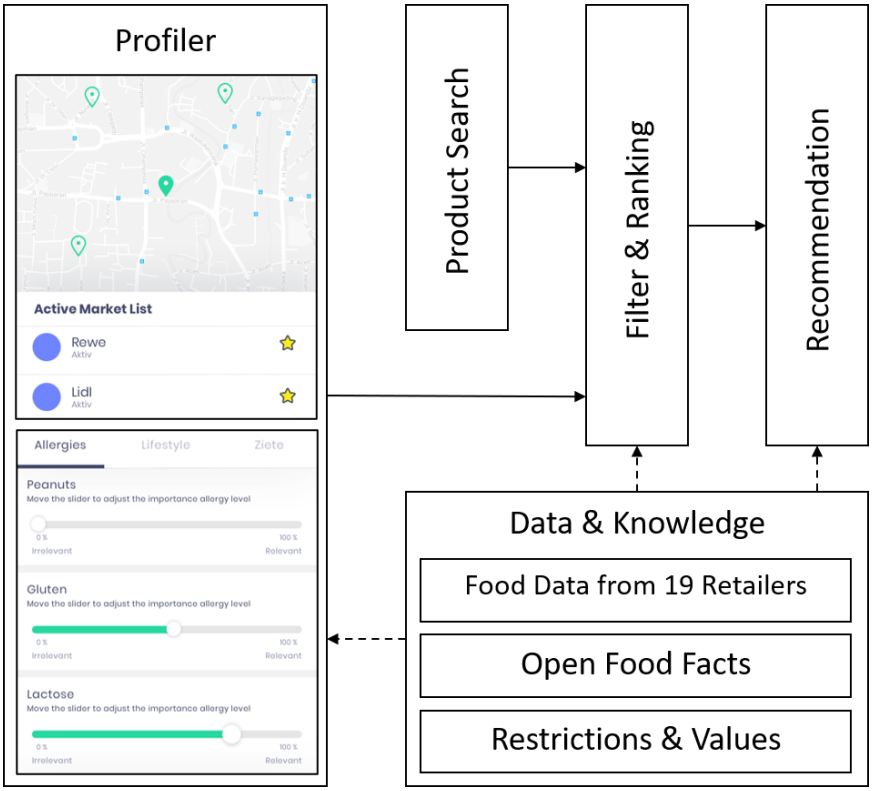

Figure 16: Workflow of F-RS4CC.

give an overview of the different functions.

10.4.1 Workflow & Data Sources

The employed recommendation approach can be classified as a knowledge-based RecSys [5], as it exploits knowledge about food products, nutritional values, ingredients, labels, and environmental knowledge to identify the most suitable foods. In line with prior research [244], the recommendation is based on three main components: A profiler, a filter, and a ranking. Furthermore, we added a search and a shopping list to allow for bringing recommendations into action.

Our prototype uses data from 19 participating local retailers including supermarkets, full-organic shops, zero waste shop, and directly selling farmers. The data from these markets consists of their products and the related master data that usually contains the product name, category, ingredients, and nu-

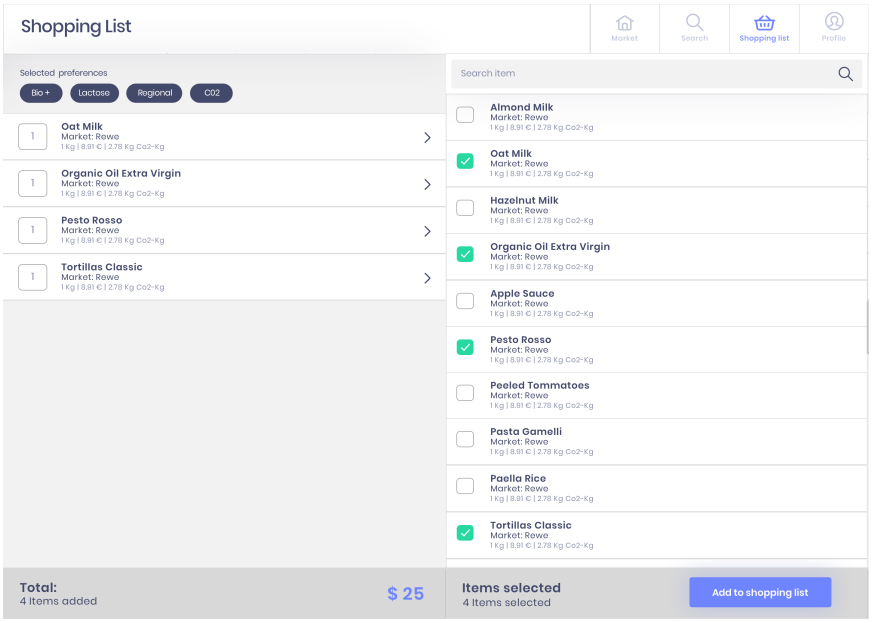

Figure 17: Search, Recommendation & Shopping List.

tritional values. Furthermore, we complemented the product data with data from Open Food Facts[5], a collaborative platform that adds carbon footprint, nutritional assessment, labels, and user-based assessment of food characteristics (e.g. vegan). Therefore, we mapped the products based on their Global Trade Item Number. Moreover, food knowledge is provided in the form of rules about restrictions and ethical values that are mirrored in the properties of the food.

10.4.2 Profiler

The consumer initiates the F-RS4CC by setting up a profile that consists of two parts:

Restrictions & Values: Core to the prototype is the profile setup with critical consumer values and restrictions to infer matching food recommendations. As shown in Figure 16 (Profiler, lower screen), we broadly differentiate between allergies, altruistic, and personal goals. The allergies section consists of declarable allergens plus some additional allergens, such as apples, that came

[5]https://world.openfoodfacts.org/

Table 3: Example Rules of F-RS4CC.

Rule-Name	Formalization
Vegan	Has a vegan-label or does not contain milk, butter, meat, ...
Boycott Nestle	Is not produced by nestle or one of its subsidiaries
Low Carb	$\leq$ 20% of carbs in the nutrition table

up during the pre-study or workshop. The altruistic section, for example, includes settings such as vegan, organic, or Nestle boycott. Personal goals, for example, consist of cost-saving, low-carb, or reduction of carcinogenic additives. Overall, the system provides more than 20 different settings.

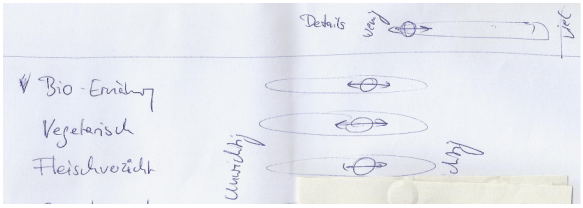

Figure 18: Conceptualization of Sliders during the Workshop.

Each of these settings is based on food knowledge that is formalized as a rule to filter and rank the food products (Examples are given in Table 3). From a user perspective, each rule consists of a slider that allows for weighting each rule between Off (0%) and On (100%). Besides the ranking, for some rules, such as allergens the On-Setting has an additional filter function that filters out foods with respective ingredients completely. This is indicated in the UI as a subtext within the rule-UI-element, e.g. 'All non-vegan products are filtered out'.

This design decision is based on a deeper discussion in the co-creation workshop, where the participants tried to sketch a UI for the profiler (e.g. see Figure 18). First attempts focused on binary decisions, e.g. Do you have a soy allergy? - Yes/No. However, it became apparent that many rules can not be seen as binary restrictions but that trade-offs and rankings between different

rules exist. For example, for some products, consumers search for the vegan-as-possible recommendation, but would still eat the vegetarian one as long as it is organic. For allergy sufferers or strict political consumers, allergies or the boycott of certain companies need to be binary options. The current design, therefore, combines both the trade-off and clear restrictions.

Locations & Markets: As shown in Figure 16 (Profiler, upper screen), the consumer is shown all participating markets on a map. Here, the consumer can explore new markets and select the ones s/he is frequently visiting, e.g. in a certain radius around the neighborhood. In this sense, the selection of markets provides an additional filter criterion, as it allows to restrict the markets, e.g. to only buy from fully organic retailers or local farmers.

The selection of markets within the profiler also arose as a topic during the co-creation workshop, as the selection of markets can also support critical consumerism. For example, by supporting small retailers only or to simply account for everyday practices, such as reaching all stores by foot.

10.4.3 Filter & Ranking

The filter & ranking is executed based on the profile setup. This part of the application is based on food knowledge (see Table 3), product data from the retailers combined with Open Food Facts, and the search.

Search: Usually, knowledge-based RecSys are designed for shopping infrequent items, e.g. a new TV [5]. However, for purchasing food, it is necessary to not just get the recommendation based on the current offering of the markets, but search for specific products and get a ranked list of those, e.g. 'burger patties'. Therefore, our design makes use of a search that is matched with the product name and category. This search can be seen as a pre-filter of the items to be recommended.

Filter: Whenever certain rules, such as allergies, are set to 100% they are used as a binary filter to completely remove certain products from the recommendation candidates. As explained earlier, this need for strict filtering arose from the workshop. A further filter is based on the market selection, where only products available at those markets are included.

Ranking: After filtering and searching, the candidate set of food items is still large for most of the products. Furthermore, certain values (with a weight ¿0% and ¡100%) have not been considered by now. Therefore, based on a score for each candidate food, a ranked list of recommendations is created.

$$score(f,P,C) = \sum_{p \in P} i_p * ruleScore(f, r_p, C) \tag{10.1}$$

Thereby, the ranking is based on the $score(f,P,C)$, which denotes the overall ranking score for a food item f, the profile P and a candidate set of food items C. P is a set of all rules with i_p as the weight between 0 and 1 and r_p as the rule.

$ruleScore(f,r_p,C)$ is defined as a function of r_p that assigns a float value between -1 and 1, depending on the food item in relation to the other candidate food items. Some rules, e.g. allergies, allow for binary classification only. For those, the function either assigns 1, does not contain allergen, or -1 contains an allergen. For 'linear' rules such as carbon footprint reduction, all candidate items $c \in C$ are mapped to a value range between 1 and -1. Each item f is assigned a value between 1 and -1 according to its relation to the other candidates. Based on each score(f, P, C), food candidates are sorted in descending order to create the final ranking.

10.4.4 Food Recommendation & Shopping List

Once the list of food items is sorted, it is shown to the user (see Figure 17). Here, the products on top are the most appropriate products according to the profile. Each product is represented by its name, the price, its carbon footprint, various labels depending on the selected rules (e.g. lactose-free or not), and the selling retailer. Labels are used to sensitize consumers if the rule is not set as a binary filter but a weighted factor among others. When clicking on products, they are transferred to the shopping list. Furthermore, users can open a pop-up with more detailed product information.

In addition, the UI contains the search bar and a quick overview of the profile settings and the resulting ranking of the rules according to the assigned weights (see dark blue boxes in Figure 17). Regarding this workshop partic-

ipants demanded certain transparency about the current profile settings when receiving their recommendations.

10.5 Evaluation: Understanding the Design & Appropriation of F-RS4CC in Use

The objective of the evaluation was to discuss the design of the prototype with a focus on the profile setup, the recommendation itself, and further improvements and directions for design. Furthermore, we aimed to understand the usage and appropriation of F-RS4CC in everyday critical consumer practices.

Therefore, we conducted pre-interviews (avg. 37 min) to understand the current practices of the participants and their first assessment of the prototype, followed by a usage phase (avg. 2 months), and post-interviews (avg. 27 min) that focused on their experience, appropriation, and design issues.

Ten participants (E1-10) took part in the evaluation study. The sample was recruited with a snowball sampling approach, from the network of the pre-study. Again, the focus was on recruiting a sample with a variety of consumption practices, values, and restrictions. Moreover, we focused on diverse housing situations ranging from living alone, to flat-sharing to families with children. The sample is characterized by 6 male and 4 female participants, aged between 24 and 45. The education ranges from apprenticeship to university degree.

Both interview studies followed a semi-structured interview guideline. We transcribed the interviews and analyzed them following the inductive approach of thematic analysis [48]. The thematic analysis[48] focused on understanding the appropriation of the prototype, changes in their consumption practices, and design issues with an emphasis on the recommendation including the profile and the food knowledge. After coding, the themes were collaboratively developed by the group of authors towards a mutual understanding of the material.

10.5.1 Exploring Products & Reflection on Action

In general, the prototype was well received by the participants. They especially liked the inclusion of so many local markets and the long list of products. Here, in particular, the filtering and ranking according to the own settings were assessed as a positive concept.

However, what quickly became apparent was that the participants did not appropriate the prototype as part of their planning in the sense that they search for products, transfer them to the shopping list, and execute this planned behavior. Although five participants reported on trying to use the tool as a shopping list, they quickly returned to their established mode of purchase, which was either no shopping list at all, especially for younger consumers, a paper-based list, or the established tool within the household, e.g. a collaborative list that was shared with the partner.

> "I use a shopping list app on Android where my wife and I put in our shopping needs, I sort into several lists sorted by the shop where we buy." – E8(32,m)

Regarding this, most participants explained how product research and informing about new products is something completely different than writing a shopping list. Moreover, consumers explained how they have established a set of 'basic' products for their daily shopping. Those products meet their restrictions and ethical values, such that they do not need to start product research every time.

> "For example I sit at the table, make myself lunch or breakfast and notice "oh, the liverwurst is slowly running out" and then it's just easy to take the mobile out of my pocket, write liverwurst on it and put the mobile back in my pocket. That is also important that I do not want to start a product research at that moment." – E5(45,m)

However, participants used our F-RS4CC prototype as a tool to explore and research new products. Thereby, it was especially valued how the prototype

offers the chance to easily find new products that match the own set of values and restrictions.

> "So still I find it good to look for new vegan burgers, here I'm doing it right now. Organic veggie burger for 2,99. I do not know it yet, why I do not know it yet." – E4(32,m)

In this context, some participants compared the tool to a search engine that reduces the effort of searching for food and checking its characteristics by having a personalized profile.

> "I have to think about it, I mean, you know it a little bit from search engines, filtering can make your work incredibly easier when you know exactly what you want and what you don't want." – E1(24,f)

Reflecting on the influence on their consumption, some participants explained how they stopped buying certain products when they became aware that there are better alternatives or the product does not match their preferences. Others explained how the application rose their awareness for certain filters that they were not able to apply by their current approach. For example, the carbon footprint, besides some other factors, was repeatedly mentioned to be a factor that was added to their practices as the information was made available by F-RS4CC. Here, the reduced effort of gaining information was mentioned as a main driver for the exploration of products and profile settings.

> "I think I planned my shopping more consciously than when I normally just made a list with my roommates, because I think more consciously when you see the CO2." – E7(32,m)

10.5.2 Consolidating Infrastructures

Besides the food, some participants used the prototype to explore and consolidate the local consumption infrastructure, in the sense of finding stores that

offer appropriate products or discover formerly unknown stores. For example, the local farmers market was an option that a lot of consumers did not know before their usage experience.

> "Yes, I think it helps you that it helps you to discover products that you didn't know so much about before, or perhaps to get to know shops, for example, the Birchfarm, which is present in the program, and otherwise you would not know about it." – E10(30,f)

In this context, participants reflected on their experience of becoming critical consumers and changing their practices. Some participants explained how such a tool would have helped them in their early exploration of alternative consumption infrastructures. E9(26,f) further explained how even in new situations, such as moving to a new city, the exploration of shopping infrastructures is valuable, as it allows for a quick and easy overview of appropriate products and markets in the neighborhood.

> "Especially at the beginning or when I move somewhere, it would save me having to search everywhere, who sells this specific product I need right now, that would be cool, that would help me and of course, it would also save me a lot of work, because I wouldn't have to read all the labels in all the supermarkets to find out what it is right now, where it was produced and under what conditions." – E9(26,f)

Still, it was criticized that the current implementation of retailers as binary filters does not account for purchase practices. While participants, in general, appreciated the possibility to select nearby markets in a radius, they articulated the requirement of prioritizing the stores. The main reason mentioned was more efficiency during purchase and a reduction of time and kilometers traveled.

> "Which would also be good, would be a sorting [...] if you know that you go to one store, you can prioritize it in the product search that you don't have to drive to another store." – E7(32,m)

10.5.3 Reliability of Data & Definitions

Speaking about the recommendation itself, participants raised our awareness about the reliability of the data and the underlying food knowledge and algorithms.

A particular issue was wrongly labeled data that resulted in unwanted recommendations. While one might think that this only arises from the data provided by the Open Food Facts Community, it was also caused by retailers' data. One example of such recommendation was given by participant E5(45,m) who found chocolates that were labeled as regional when searching for sweets.

> "I just noticed, there is a lot of regional chocolate. For category regional? The supermarket has indicated this, which means that you have to check the data of the supermarket. Who knows where they get it from, you have to find out more about it." – E5(45,m)

A further issue came along with the rules themselves. Although we added a short explanation text for each profile setting, some rules were intransparent for the consumers. For example, 'organic+'(extended organic condition with better husbandry conditions) was not known by most of them. They wondered about the underlying definitions in contrast to regular organic food. Moreover, some participants recognized some minor bugs that led to wrong recommendations. This was, for example, based on ingredients that were not properly recognized.

> "We had the problem that despite my preference "vegetarian" with a 1 I was still shown some meat products, or convenience products containing meat." – E10(30,f)

Overall, wrong recommendations and wrongly labeled data were perceived as decreasing the trust in the recommendations. Reliability was particularly important in the field of tension between ethics, values, and restrictions, as participants neither want to consume products that cause an allergic reaction

nor do they want to eat, for example, products that contain animal products if they follow a strict vegan diet.

> "The database would have to be really complete, because as soon as I have the feeling that there is a gap somewhere in the database, then it loses some kind of credibility, which I would accept once or twice but then I would say 'oh no, I can't trust that'" – E4(32,m)

10.5.4 From Complex Rules to Customized Rules

Along with wrong recommendations, non-reliable data, and trust, the rules themselves were discussed in more detail. From an overall perspective, they were assessed as comprehensive and interesting to experiment with. Even though, for allergy sufferers, some special allergies could be included. For four consumers, the set up of a profile bears a certain complexity as there is too much to consider and think about when negotiating and weighing the settings.

For some consumers, the provided rules did not offer enough flexibility and room for their own settings beyond common categories and role models. They formulated the requirement to manipulate or develop their own rules. One such example was given by participant E9(26,f) who explained how for allergies some consumers have different levels of sensitivity, e.g. in grams per 100 grams of product. Similarly, this ratio was discussed for low-carb. A further example is veganism, where two participants mentioned the requirement to in detail modify rules, e.g. such that honey is not considered to violate it, as this reflects their unique approach to consumption.

> "That you can configure the filters by yourself, or a separate filter that somehow says it is vegan certified, the other one is vegan but has honey or other things in it, or it is vegan by recipe but not certified." – E6(29,m)

During the interviews, the topic of collaborative food knowledge and the sharing of modified rules were also discussed. While most of the participants

articulate more collaborative access to the profile and the list, some participants go a step further and would be interested in outsourcing and sharing of knowledge. For example, E7(32,m) explained how rules and even profiles, created by certain organizations such as Greenpeace would help with decision making. One such rule was already included in the form of the Utopia list of suspicious additives[6]. Here, two participants criticized that they do not know the organization and their assessment of ingredients, which decreases trust.

> "Utopia is unknown to me, I don't know which list is behind it." – E5(45,m)

While in general participants appreciated our knowledge-based approach, four participants explained how additional information on item similarity or even community-based approaches might contribute to better choices. For example, E4(32,m) explained how he bought newly explored vegan burgers that tasted awful. Additional information about how others liked this burger patty or how it tastes similar to products he likes would have helped him.

> "I recently bought vegan burgers [...], they were terrible. I could have skipped them if someone had commented on the taste." – E4(32,m)

10.6 Discussion

Reflecting on our research, we will discuss the preliminary design implications against the background of our evaluation from different perspectives to more precisely formulate implications for design and research.

10.6.1 Establishing a Set of Products, rather than Planning

Based on the literature research and our pre-study we expected our participants to appropriate the prototype for their planning practices. However, as it turned out, planning is completely different from exploring a new set of

[6] https://utopia.de/ratgeber/lebensmittel-zusatzstoffe-e-nummern-liste/

products or giving the established set of products an update. In this sense, our research confirms prior research [156, 213] that already lines out that consumers do not use in-store information at every shopping trip, but establish a set of frequently bought products.

Still, our results imply the explorative aspects of the design to enable more easy access to appropriate food, retailers that sell them, and the underlying information. Here, especially the combination of stores as purchase infrastructures and the food they offer helps with the arrangement of a new product set during sustainable practice transition. This set itself can be seen as a plan that is repeatedly performed [60]. This supports the assumption [213] to more strongly support the search for niche products in dominant consumption infrastructures. In this sense, design should not just address the 'What to buy?' as approached by prior HCI prototypes, but also the 'Where to buy?' as they are closely entangled. Reflecting on the dominant in-store [156, 36, 191] and motivational approaches [197, 381, 191], our research shows how transparent and personalized food RecSys support practices beyond single retailers and shopping trips by addressing the complexity of finding and establishing appropriate products and filtering information, in short, strengthen and protect critical consumers.

10.6.2 From Ethical Profiles to Practice-based Profiles with Ethics

'Where to buy?' was just one aspect that raised our awareness for the embedding of our approach into the context of practices. Furthermore, the pre-study showed how consumers, besides ethical values, need to consider a variety of factors, such as the nearby stores and their available products, their family, their budget, and allergic restrictions, to find the 'right' product. Although current food RecSys start (re-)exploring the capabilities of knowledge-based [244] and ethical approaches [195] to more holistically consider consumers, supporting critical consumerism is still a major gap in the RecSys literature [345, 195]. Especially as the profiles only focus on narrow aspects such as health [244] or sustainability [195] rather than consumption practices in their diversity and complexity.

Here, our research contributes by presenting the design of a personalized

food RecSys that allows for a flexible setup of a profile that considers personal goals, altruistic values, allergic restrictions, and personal situation e.g. through the selection of nearby markets and the option to search for products that make trade-offs between budget and ethical values. To the best of our knowledge, this is the first food RecSys with a personalized profile including ethics [195] and practice-oriented options. On the one hand, this is in line with research [156, 195] on sustainable in-store assessment that already emphasizes flexible definition and weighting of values, on the other hand, it enhances the implications by more strongly highlighting to account for including practices and their context rather than ethics and sustainability, only.

10.6.3 Different Complexities of Profiles

Moreover, our evaluation showed an emerging design space between personalized profiles that go beyond role models, the easy usage of such role models, and shared profiles and knowledge that is created by organizations and/or other users. This design space directly relates to the work of Herbig et al. [156] that also found a certain need for democratization of profiles. While for some consumers such outsourcing of the profile to trusted institutions and role models might make it easier to set up the profile, others even demand more detailed options for personalization. For those consumers, role models, such as 'vegan' provide a general direction but do not allow for an adjustment towards their own consumption patterns.

Against this background, our results sensitize us for the requirement of a flexible profile that makes use of both institutionalized and shared profiles and rules but also room for in deep personalization that allows for modification or creation of rules and subrules, e.g. incorporating own definitions of what veganism is about. Here, further engaging in end-user development [220] of such RecSys could be an interesting perspective to engage in. This resembles the heterogeneity of the critical consumer group [129] and that they can not be simply subsumed under umbrella terms such as sustainable consumers or even more detailed terms such as political consumers in terms of design.

10.6.4 Towards Open and Reliable Data and Algorithms

Although not in the scope of our prototype, the evaluation showed how reliable and open data and algorithms are important for trust and appropriation of ICT to support critical consumer practices. In particular, in the sensitive field of consumption, consumers demand certain reliability, especially if they have certain restrictions or take their ethical choices seriously. Interestingly, it was not always the crowd-sourced data from Open Food Facts but data from the participating markets themselves which led to wrong recommendations. Thus, we want to highlight the importance of thinking beyond the scope of technology design but demand a policy that forces producers to pass reliable data to consumers such that they can make reliable decisions as already called for by Stevens et al. [331].

From an algorithm perspective, consumer protection organizations already criticized that even supposedly consumer-friendly third parties do not have transparent algorithms and it remains unclear how they recommend items [80, 195]. Also, our results show how consumers want to understand the food knowledge in detail and how the system creates the recommendation. This is important if the profiler makes use of outsourced food knowledge. Therefore, future designs should not only use open and reliable data but also open and transparent algorithms that allow to understand why a certain product matches the profile.

10.6.5 Critical Reflection on the Scope of Recommender Systems

Besides the presented implications for designing RecSys to support critical consumer practices, we want to use the space to reflect on the approach itself. In line with the critique on the neo-liberal agenda that burdens consumers with the transformation of the society towards sustainability [29, 129], our system does not account for the responsibility of other agents such as producers or the government. However, the urgent need to quickly reduce our environmental impact from our perspective needs a multifaceted strategy that exercises power towards policymakers and strengthens consumers that already attempt to make sustainable consumption decisions.

Here, the scope is limited when it comes to motivating consumers. However, it addresses the difficulties of motivated consumers, as outlined by prior research [213], in the sense of supporting the exploration of products and consumption infrastructures. Addressing those issues appropriately contributes to an ongoing practice transition rather than leaving consumers alone with the difficulties of practice change once they are motivated.

Moreover, thinking such systems from a broader perspective that goes along with open data and algorithms might contribute to more consumer protection and power towards the producers that nowadays benefit from informational asymmetries [195]. In particular, the increased awareness about consumption infrastructures could help with the articulation of requirements towards producers and policy-makers [233].

10.7 Conclusion

The literature- and the pre-study sensitized us to various aspects of the design of a RecSys for critical consumers. We developed a prototype that allows for setting up a profile that not just considers the complexity and diversity of critical consumer practices but also tries to incorporate the context of practices by inducing holistic aspects of diet restrictions, personal goals, markets, and budgets. From our evaluation, we found how such an approach addresses typical issues of critical consumers that have difficulty finding appropriate products within the diversity of products and retailers. Still, our implications needed to be revised to some extent after the evaluation as, for example, planning did not turn out to be the practice where we can support consumers, but rather we should focus on exploration and reflection as a separate activity. In addition, future research and design should not only use complex profiles to personalize 'what is the right thing' but allow for considering the personal situation. Furthermore, profiles need to be understood as having different complexities for different consumers while some find it appropriate to user role models such as 'vegan' or use outsource knowledge to institutions, others require deep personalization and modification. Lastly, especially when outsourcing, reliable and open data and algorithms are needed to strengthen the position of consumers.

Overall, the results contribute by designing and evaluating one of the first (see [195]), personalized food RecSys that brings in critical consumer values and by reporting on the requirements, appropriation, and scope of food RecSys beyond stimulating consumption as a means to support consumer protection and grant access to distributed and complex consumption infrastructures and products.

Given our definition of critical consumption and the related participant sampling, our results are clearly limited to a Western context, where, e.g. veganism is not the norm but a critical minority leading the way towards the important reduction of animal production consumption [192]. In other cultural contexts, low consumption of animal products might be the norm based on other cultural values [290] or poverty. Although our prototype accounts for price-value trade-offs, precarity is a factor that needs more consideration, even in Western contexts, as not all people can afford products that are in line with their values or can only afford environmentally sustainable products, which then finds no acknowledgment in the sense of critical sacrifice. In this sense, the theoretical lens itself can be seen as a privileged Western perspective [57].

While the results clearly support the approach of a RecSys to support exploration and reflection, a long-term study with more participants would be necessary to understand the influence on consumption practices. In addition, the focus of this study should be on consumers that have not already established some set of products and explored markets, but consumers that are in a more early phase of their practice transition. Moreover, our research touches various topics such as shared, personalized, or institutionalized food knowledge that was not implemented in our prototype. Here, more research is needed on the collaborative or End-User Development aspects of how one can make its own rules.

11 Opportunities for Sustainable Mobility: Re-thinking Eco-feedback from a Citizen's Perspective

Abstract

In developed nations, a growing emphasis is being placed on the promotion of sustainable behaviours amongst individuals, or 'citizen-consumers'. In HCI, various eco-feedback tools have been designed as persuasive instruments, with a strong normative appeal geared to encouraging citizens to conduct a more sustainable mobility. However, many critiques have been formulated regarding this 'paternalistic' stance. In this paper, we switched the perspective from a designer's to a citizen's point of view and explored how people would use eco-feedback tools to support sustainable mobility in their city. In the study, we conducted 14 interviews with citizens who had used eco-feedback previously. The findings indicate new starting points that could inform future eco-feedback tools. These encompass: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) the scope for participation and the sharing of responsibility between citizens and municipal city services.

11.1 Introduction

Throughout the western world, a (neo-) liberal agenda has arguably been placing a greater burden upon individuals as 'citizen-consumers' to both consume for the sake of the market whilst accepting responsibility for the sustainability of their actions [72]. Private transportation currently accounts for about a quarter of global CO2 emissions. Given current trends, this value is set to increase by roughly 50% between now and the year 2030 [24, 23]. Hence, studies have shown that even small changes in people's individual behaviour can lead to significant reductions in carbon emissions [162, 291]. For example, Divetz et al. [84] estimated that "the adoption of easily implementable actions on a household level (e.g., changing one's driving behaviour by slower

acceleration and adhering to speed limits) can save 123 million metric tons of carbon per year, a figure that equals 8.4% of the EU's national carbon emissions". As individual behaviour can have such a significant impact on sustainability, eco-feedback tools to encourage sustainable behaviours amongst citizen-consumers have become very popular in HCI research [87, 52, 111].

In general terms, eco-feedback has some similarity to the quantified self-movement as it uses mobile phone data (MPD) to close the 'attitude-behaviour gap' [178] by motivating behaviour change. Hence, eco-feedback tools are less about the health of an individual and more about promoting a sustainable lifestyle. However, measures aimed at changing individual behaviour can face very low levels of uptake, complex constraints and even resistance [240]. Critiques of these approaches often point to the normative stance of assuming sustainable mobility is the only 'good' mobility, which risks being unintentionally paternalistic and behaviouristic [168, 52].

In this paper, we aim to challenge the normative top-down pressure upon citizen-consumers to adopt more sustainable mobility practices. Instead, we chose to examine the perspective of citizen-consumers themselves and explore what it would take for ecofeedback tools to support their own interests. To this end, we conducted an interview study with 14 citizens in a medium-sized city in Germany. To ground the study in their own everyday practices, we used an eco-feedback tool as a probe that captured their daily mobility habits and their sustainable character. In this way we sought to make them familiar with eco-feedback technologies and to elicit their reflections upon their limitations and the possibilities to support an eco-friendlier mobility.

The study showed, in accordance with the literature, that eco-feedback tools with a strong normative positioning can easily be perceived as restricted. We found that such a stance was not always compatible with individual mobility situations, needs and local mobility resources. In particular, we found a range of limiting factors as well as a number of possibilities for design that might have the potential to either lower or raise the acceptance of eco-feedback tools. Design in this space, it would seem, needs to find ways to: (1) support citizen's understanding of how sustainable mobility is measured and monitored; (2) respect individual mobility situations and preferences; and (3)

support participation and shared responsibilities between citizens and municipal city services.

11.2 Related Work

Over the last decade the sustainable HCI community has seen papers presenting interactive technologies that variously aim to support, inspire or persuade people to adopt pro-environmental behaviours (e.g. [39, 87, 262, 91]). A central feature of them has been the provision of eco-feedback, which has become an increasingly active field of research in its own right (cf. [87, 109]). A core assumption here is that the right kind of information about one's behaviour and its environmental effects will encourage more environmentally-friendly and sustainable habits [115]. Over recent years, the concept of eco-feedback has increasingly entered people's homes, addressing their recycling habits [341], their food consumption [381] and their electricity consumption [261, 336].

Several kinds of persuasive strategies, relating to private transportation, have also been developed. An early example was the work of Froehlich et al. [114]. They aimed to influence individual mobility behaviour through 'emotional' feedback. This was symbolized by the fate of a polar bear, visualized as a virtual pet standing on an ice floe. Others have used 'gamification' to make the desired behavior more enjoyable and to sustain the interaction by challenging users to compete with each other, e.g. EcoPath [289] or the Green Daily Guide [40]. 'Socially normative' feedback approaches that seek to motivate users through comparisons or rankings, have also been used. These are often embedded in social networks such as Facebook to show rewards for fulfilling sustainability challenges, like the platform Tripzoom [181, 50, 116]. An extended version of this can be found in MatkaHupi [186], which aimed to stimulate users through personalized challenges. Finally, 'awareness-related' eco-feedback approaches aim to catch user's attention by using different means of information visualization and route recommendations [321]. Examples here include the Quantified Traveler [178] or EcoMobil [232], both of which are good examples of providing users with detailed information about their mobility behaviour and personal eco-footprint.

Although, there are some indications that persuasive ICT can have a positive effect upon sustainable behaviour, long term evaluations in real-life settings are missing. Furthermore, persuasive approaches have recently been subjected to fundamental critique (see, for example, [168, 52]). This critique hinges upon issues such as "turning the problems of environmentalism into questions of personal moral choice" [20 p. 8], focusing too much on individual consumers [87] and using persuasive technologies that have a narrow focus on individual behaviours [52]. The same authors instead see opportunities to support environmental movements [91], address things at a collective, regional or national level [87] and shift the focus from behaviours to practices [52]. In particular, these critiques seek to address what is seen as a patriarchal top-down perspective regarding how sustainable mobility should be pursued, ignoring the fact that daily mobility habits have often developed over lengthy periods of time and are deeply rooted in everyday routines and situated reasoning.

Against this, some work has highlighted the importance of daily habits in relation to everyday mobility choices and has suggested that just providing information about alternatives may not be enough for people to change their habits [150, 27]. In this regard, some studies have noted the importance of travel context and have shown fundamental differences in transport preferences between everyday, leisure and holiday mobilities [26, 254]. Many studies also indicate the importance of attitudes and lifestyle choices [23]. Thus, it has been suggested that travel planning tools should provide not only information about the time and cost of different alternatives, but also about convenience, comfort and privacy [70, 329]. There is also a strand of work that considers the importance of values. Egbue and Long [94], for instance, have shown that values relating to sustainability and the environmental benefits of electric vehicles (EVs) have a major influence on EV adoption, but also that these values can be deemed less important than cost and performance. Some have also suggested a need to focus on sustainable values that extend beyond the design of technology itself and into the design of the physical infrastructure [367]. There is also commentary upon the impact of other environmental factors, such as the weather [271] and uneven distribution of transportation access [23, 235].

It can already be seen just from this overview of the literature that many more factors influence upon the adoption of sustainable mobility practices than those currently being addressed by eco-feedback tools. Often, such tools neglect the complex interplay of how mobility is entwined with social practices and personal preferences, e.g.: how practices of (un)sustainable mobility are related to others; the structure and organization of physical environments; and how solutions for sustainable mobility are supported by the local infrastructure.

To tackle these challenges, we suggest a change in perspective. Instead of using a top-down persuasive approach, dictating what sustainable mobility should look like and how citizens should behave, we questioned how citizens would adapt eco-feedback tools to support sustainable mobility practices promoted in their city. Here, the goal was to examine the limitations and potential for eco-feedback tools to sustain a more environmentally sound mobility in cities. Thus, a special focus was placed on the use of MPD as a central element of feedback tools in general.

11.3 Methods

To explore the above issues, we conducted interviews with 14 citizens. Within these interviews we aimed to explore the potential of eco-feedback tools while addressing the interviewees "as analysists of their own and others' practices" [51]. Mobility practices exhibit people's orientation towards what Tuan [351] calls a *sense of place*. This can be defined in the following way:

> "[A]sense of place is inevitably dual in nature, involving both an interpretive perspective on the environment and an emotional reaction to the environment .... A sense of place involves a personal orientation towards place, in which one's understanding of place and one's feelings about place become fused in the context of environmental meaning"

Thus, one's orientation towards a sense of place is constituted in and through the act of moving in space. Note that mobility practices are not only shaped

by given infrastructures, but also shaped by people's interactions and movements. Exploring mobility as a practice therefore means exploring people's spatial movements and experiences [182, 258]. To ground this endeavour, we followed the example of [235] and recorded people's spatial journeys, enriching geo-location data with users' qualitative reports of their own personal experiences.

In this case, we used an eco-feedback prototype to track daily mobility activities. The tool functioned as a probe to show the interviewees a practical example of how MPD might be collected and visualized. The prototype itself provided an outline of users' journeys and associated modes of transport. We recorded the movements of all interviewees over a set period prior to the actual interviews. During that time, we gave the interviewees time to think about the limitations and potential of the prototype and how they would like to enhance, modify and elaborate on such a tool. The goal was to offer a creative incentive for the articulation of new ideas and social innovations [363]. To that end, the prototype offered some simple visualizations to sensitize them to the possibilities of MPD selection and how it might be visualized (see Figure 1).

As we wanted to engage with 'ordinary' citizens, we had to allow for a potentially very broad target group, which had to be rendered manageable in some way. One strategy was to interview only people who were individually or jointly responsible for the organization of mobility in their household. We also paid attention to acquiring a broad spread across gender, age, type of household, rural or urban place of abode and preferred means of transport. A detailed overview of the chosen participants is provided in Table 1. We selected a total of 14 participants, living in a medium-sized German town. People were recruited using local organizations that were related to activities such as sports, computer clubs, a local citizen's forum and through personal acquaintance. All of them, regardless of age, had sophisticated smartphone skills. They were also all genuinely interested in the topic of sustainable mobility and were open-minded regarding the use of new media and MPD. Participation was on a voluntary basis and they were not offered any financial reward.

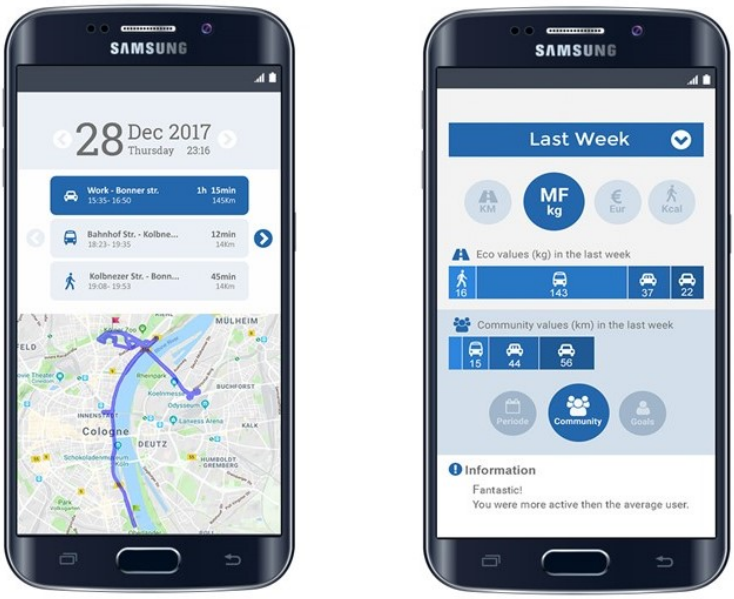

Figure 19: Collected Travel Information (left) and Sustainability Measurements (right).

These designs were subsequently slightly modified to improve readability.

The study began with a kick-off meeting where we introduced the study procedure and installed the prototype on the participants' own smartphones. From then on, we passively recorded their daily mobility for a period of about four weeks. During this period, participants were able to inspect the visualizations of their mobility behaviour (Figure 1), as well as adjust wrongly classified modes of transport, to ensure the stored information was accurate. Afterwards, we conducted individual interviews at the participants' homes. The interviews were divided into three sections: First, we asked them about their mobility background, previous mobility experiences and their personal mobility biography. Descriptions were elicited through questions such as: *"I am interested in your personal experiences as a mobile person and mobility participant. Perhaps you can start by telling me about the time when you moved out of your parents' house and then, had to decide for yourself about your mobility and how it continued until today."* Secondly, once the interviewee had arrived at the present, s/he was asked to look specifically at some of the recorded instances of mobility in their data: *"It would be great if you could report in more detail about the concrete mobility situations that were recorded, the mobility modes you used, the way you organized your travel and why you decided to do it that way."* Thirdly, we asked the interviewees about shortcomings and opportunities of the eco-feedback tool in more detail: *"Lastly, we want to ask you about your experiences of using this tool, the limitations and potentials. If you imagine a complete re-design what characteristics would be important for you to foster sustainable mobility in your city?"* During the interviews, we aimed to secure an open narrative to gain individual insights. The interviewers relied on reflective questioning and probing, prompting participants to provide additional detail, clarifications and explications. The interviews lasted for between 30 and 90 minutes, were transcribed and anonymized, then analysed.

Analysis was based on a reconstructive, documentary approach [44]. We started the process by subjecting some cases to intensive examination, while other cases were only used to provide supplementary material. Relatively quickly, it became apparent that some interviews documented concrete potential for how eco-feedback tools could be developed further from a citizen's perspective. Other cases gave less information, depending on the nature of the

questions and the willingness, knowledgeability and enthusiasm of the participants. The analysis process itself was carried out in three steps: First of all, sections were selected in which theoretically interesting aspects and the subjective relevance systems of the interviewees emerged with particular clarity. These sections were examined with regard to "what" was said and they were 'immanently' or thematically annotated. In the second step, we sought to reconstruct the frame in which a topic was dealt with. At this point, the focus was no longer on "what" but rather on "how" interviewees talked about a particular topic. Finally, depending on how the limitations of eco-feedback tools and ideas for their development had been handled in concrete statements, they were compared and contrasted to other statements in the material to formulate concrete themes. In the end, we arrived at three main themes, which are presented below.

No.	Age	Gender	Household	Residence	Transport
#1	28	m	SH	urban	PT; B; W
#2	24	f	SA	rural	C
#3	44	f	SH	rural	C
#4	60	f	FH	urban	C; W
#5	64	m	FH	rural	C; PT
#6	55	m	FH+2	rural	C; W
#7	21	m	SA	urban	PT; W
#8	32	f	SH	urban	C; PT; W; B
#9	61	m	FH+1	rural	C; eB
#10	71	m	FH	rural	C; W
#11	24	f	SA	urban	PT
#12	43	f	FH+2	urban	C; PT; W
#13	34	f	FH+3	rural	C
#14	67	m	SH	urban	C; PT; eB; W

Table 4: Participants Opportunities for Sustainable Mobility.

(SH = single household; FH = family household no children; FH+n = family household with n children; SA = shared apartment; C = car; PT = public transportation; B = biking; eB = electric bike; W = walking).

11.4 Findings

The analysis showed clearly that, although all participants spoke at some point during their interviews about the positive value of sustainability, the value was not considered a driving factor in and for the organization of their daily journeys. Moreover, we found that daily mobility was deeply rooted in everyday practices that often conflicted with what one might understand as sustainability. In accordance with other studies mentioned above, eco-feedback that aims to persuade people towards more sustainable mobility was mostly regarded as too far removed from people's actual mobility needs, individual situations and available resources. However, aside from these limitations, the interviewees also mentioned other concerns (or themes) that they felt eco-feedback tools needed to address. These themes encompassed: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) supporting participation and the sharing of responsibility between citizens and municipal city services.

11.4.1 Measuring and monitoring

This theme relates to the expressed wish of many participants to understand sustainable mobility better in general and individual sustainable mobility in particular. Although, most participants obtained information about sustainable mobility from the daily news (via print, online media or the television), ways to measure, monitor or define sustainable mobility had not previously been encountered by many participants. We also found that participants lacked any point of reference to get a better understanding of their own sustainability behavior. These points are discussed in more detail below.

11.4.1.1 Measuring sustainability mobility The interviewees often expressed uncertainty about the units adopted to measure sustainable mobility in a quantitative manner. Some participants even stated that they felt "insecure" (#11), "irritated" (#14) or even "helpless" (#7) when trying to understand how the CO2 balance for their everyday mobility was measured. Mrs.

Brown (#12) expressed it like this:

> "When I throw garbage on the roadside, I can directly SEE that my behavior is causing pollution. That is different with my mobility. / Interviewer: Why, why do think so? / Because It is harder to see a direct effect of my behavior. [...]. A plastic bag is a plastic bag, but 53 grams of CO2 is (pause) I think we have still so much to learn about how our environment is affected by our daily mobility."

Her explanation shows that she lacked ways of making CO2 pollution more directly accountable in experiential terms. However, some felt they needed more detailed information about the exact calculation of CO2 values per mode of transport and how the guiding values were calculated. The units of measurement for CO2 in kg often remained only abstract values that were difficult to understand. Mrs. Henry, (#3) was particularly explicit on this point:

> "The first-time hearing of kg it didn't ring a bell. I always have thought it's just blown out and that it doesn't have any weight. For me 1kg conforms to 1kg flour. So, one can't imagine that easily."

This quote is an example of how difficult understanding measurements of sustainable mobility can be for a non-expert. If the participants were not used to reading the measuring units they had problems understanding the balance sheet of CO2.

We also found that participants struggled to interpret their data in a qualitative way. For instance, knowing whether your own CO2 values were high or low was articulated as quite difficult by most interviewees. So, Mr. Edward (#10) asked:

> "I know how much or little 100 Euro is, but I have no clue how much or little 1kg CO2 is. What does make sense in that case?"

To illustrate his difficulty, he compared CO2 with money and argued that he is used to understanding the value of money, but understanding CO2 values is something new for him. While we are used to putting a value to money, we have never learned to value CO2 balances and to experience it as a kind of 'lived' data rather than abstract information. Many insecurities about how to handle environmental data, it would seem, are due to a lack of knowledge, proper information and practical experience.

11.4.1.2 Monitoring sustainable mobility Another important aspect was the monitoring of sustainable mobility. In the prototype we used a benchmark that raised for many participants the question of how sustainable mobility was defined. Mrs. Brown (#12), for instance, asked:

> "Who is actually defining that benchmark? I mean is it an official one? I really would like to know where these values come from. [...] Also, I wonder what happens when my CO2 consumption level is below or above the benchmark."

These questions address critical points, such as the lack of an official benchmark for sustainable mobility. For our prototype we decided to use data from our project partner, the Wuppertal Institute for Climate, Energy and Resources, who developed the sustainable backpack.[7] Its underlying model is built upon the level of CO2 consumption per person required to stay below the world climate goal of less than 2°C of global warming. Of course, private mobility is only one factor in the model out of many others that might cause global warming, including housing, household consumption and nutrition or taking holidays. Thus, the benchmark for sustainable mobility can only be understood as an average proportion of CO2. Further, positive incentives for sustainable mobility were requested by many of the participants (#3, #6 and #13). Mr. Mahoney (#4), for instance, said:

> „It would be great to see the effects of our mobility behaviour. I mean does the effort make any difference, and if so, in what way?

[7] ttps://www.ressourcen-rechner.de/?lang=en

> It would be great to see if it raises the air quality or has any other advantages."

In this example, Mr. Mahoney is not talking about just a data visualization of CO2 consumption, but rather about effects that might be experienced in the real world, such as the local air quality. Mrs. Adams also had an interest in more local environmental awareness functions. She asked

> "can we see its effects on the local pollution load?"

While sustainability is often discussed at a global scale, Mr. Mahoney and Mrs. Adams questioned if the effects could be shown at a local level. Citizens might be emotionally motivated by local environmental data that is close to their homes, work or schools. This renders the data less abstract and more open to direct experience. So, just making monitoring models more transparent might not be enough. The model also needs to be grounded in local and tangible experiences that can encourage citizens towards eco-friendlier behaviour and that can provide concrete incentives to proceed in certain ways.

On the other hand, we did also encounter examples of people who valued the opportunity to monitor their mobility behaviour in terms of sustainability. The following example comes from a married couple, Mr. and Mrs. Garcia (#9), who were living in the countryside. Mrs. Garcia first of all said to her husband:

> "in principle you cannot change anything on your mobility practices. He replied: Yes, but I find it meaningful to raise awareness about this, although it does not change anything or cannot change anything. [...] But basically, when I am concerned with it and when I am using it, it stays in my mind. [...] You will not think about your transport mode every trip, but the attitude may change. Thinking about the environment and how you can influence it, even with limited possibilities. And for this it is good to have such an app, where I can see how many resources have been used, just to be a little bit more aware that my behaviour is actually causing effects."

Mr. Garcia began by agreeing with his wife that confronting his own habits with sustainability measures was unlikely to cause direct behavioural change. Nevertheless, he saw a potential in eco-feedback tools to make himself more aware of his own behaviour. During the interviews, other participants also saw some benefit in behaviour monitoring, even if they did not intend to change their behaviour because of it. These participants positively valued the learning effects derived from using the prototype because it helped them to get a better understanding and awareness of how mobility could affect the environment.

We also found that people appreciated being able to assess their mobility data by means of comparison. The prototype we developed supported making a comparison between people's own data and the data for an average user. This was described as being helpful for developing a better sense of the import of their own mobility behaviour. So, Mr. Taylor (#14) noted that a comparison with his own behaviour had led to a more critical review of his own practices:

> "I first took a look at the distances and then I focused on my car usage in relation to the others and so I figured out something interesting, look at the kilogram-section." Interviewer: "right, you are ahead there, because the other users drive their car mostly with two passengers. They have more kilometres, but are eco-friendlier because of that." Mr. Taylor: "yeah, exactly. The others covered a longer distance but cause less CO2, because they travelled together. You have to learn to understand it."

It is important to stress that this new insight did not necessarily mean Mr. Taylor would then change his practices. What the data does show, however, is that feedback about one's own behaviour can be an opportunity to question old habits. Thus, Mr. Garcia (#9) was surprised that he walked less than the average person and this made him consider walking more often. Similarly, Mrs. Henry (#3) was very surprised when she and her husband realized the enormous impact on their sustainability values caused by their holiday trips with a camping car. The couple were enjoying their retirement by taking regular longer trips away, but this had increased their regular CO2 rates by a factor of 32 in comparison to a normal week. Again, these new perspectives

on old habits are by no means a driver for behavioural change or giving up on pleasurable practices.

So, monitoring does not automatically lead to behavioural change. It can, in some cases, sensitize people to what more sustainable mobility might involve for them, thus giving them the means to engage in active and informed reasoning about it. However, in other cases it can lead to frustration and even rejection. In all cases it was important to the participants that their individual mobility situation be considered, as different people have different opportunities to make their mobility more sustainable.

11.4.2 Individual mobility situations and preferences

When examining the issues regarding measurement and monitoring, we found that, from the participants' perspective, it was very important that the specificities of managing their own individual mobility be recognized and respected. However, general monitoring processes and rhetoric often clashed with these desires, as we discuss in more detail below.

11.4.2.1 Individual mobility needs Many participants reported that fitting their mobility routine to their personal needs was of the utmost importance. We identified several different concerns and ideas about what optimal mobility might look like, e.g.: a car's luggage compartment allowing for the easy packing of sports bags or groceries (#2); using rail services to commute because it allows one to "sit in the train and get work done" (#1); using public transport to get to the city centre (#14) because you "don't need to care about parking. That saves stress and money". These different rationales are highly indicative of how people arrange and chose modes of transport that fit neatly to their lifestyle and cause a minimum of disruption or hassle. Certain modes of transport were also regarded as being healthier than others. Thus, Mrs. Evans (#8) commented:

> „A heathy mobility for me means to leave the car once in a while, even if it is less comfortable. Shopping by foot can be a great training (laughter)."

So, driving can be replaced by walking to achieve a healthier mobility, even if it is perceived as less comfortable or as an 'effort'. 'Healthy' mobility, then, is a disciplinary practice that needs to be actively pursued and valued. However, sustainable mobility does not always go hand in hand with other priorities in people's lives.

Thus, we found a couple of examples where sustainable mobility was characterized as a 'luxury', because it can result in higher mobility costs in terms of flexibility and money. Mr. White (#6) was particularly concerned about issues of flexibility with regard to sustainable transport options:

> "At the moment, I am unfortunately dependent on the car because I have to do a lot of trips and I'm not able to ride the bike anymore. That isn't changeable. Based on my inner attitude everything should be eco-friendlier. But if I am pressurized and have to be fast and precise, I take the car. To be honest, sustainability is more like a luxury topic for me, of course it is nice to care about the environment and everything, but it should be possible, too. Maybe I'm the wrong person. I'm not a benchmark for sustainable living".

For Mr. White riding a bike and using public transport do not meet his need to be "fast and precise". Although, he emphasizes his positive attitude towards sustainable living, he excludes himself from the moral imperative by saying "I'm not a benchmark". This illustrates the trade-off between wanting to be sustainable and having to pay for it with a form of mobility that is deemed infeasible. Others, were concerned about the trade-off between sustainable mobility and the high monetary cost of public transport. In particular, they did not see the sense of buying bus or train tickets when they already had a car in their garage. In this situation, bus or train tickets were described as a "cost on the top" (#3) or as "extra costs" (#13) in addition to the high maintenance cost of cars. Together, these examples show the extent to which personal pressures and preferences shape whether people will choose more sustainable modes of transport. Not only do individual perceptions of sustainable mobility vary greatly according to different perceived needs, but also it is clear that general monitoring processes fail to address the individual logics of mobility.

11.4.2.2 Respecting individual mobility needs When we took a more detailed look at the concrete monitoring data produced during the trial, many participants felt that the monitoring process did not do justice to their individual mobility behaviour. In this regard, Mrs. Adams (#13) claimed that there was little opportunity to change her mobility towards more sustainable modes of transport. So, the monitoring did not result in a behaviour change but rather "frustration":

> "I know that I need to drive more than other people, like those who live in the city. I need my car for everything. I cannot avoid it. So, I do not really want to know how sustainable I am. I know that I'm not. But I do not drive around unnecessarily, just the bare necessities. All the same it is."

Note, here how she expressed a preference for not receiving eco-feedback about her lifestyle. This is not a preference for ignorance exactly. She says that she is already aware that her behaviour is not very sustainable. Instead, she does not want to be continually reminded and called to account for something that she feels powerless to change. When assessing whether their own mobility behaviour was sustainable or unsustainable, we found that many participants tended to perceive their consumption in terms of being either 'necessary' or 'unnecessary / wasteful'. In this regard, Mrs. Brown (#12) said:

> "I'm always on the run and without my car I would be totally lost". Interviewer: "Can you explain that in more detail?" Mrs. Brown: "Well, that's what I NEED. I need to be quick and flexible to manage everything [...] I have to be mobile to go to work, to go shopping and to take care of my family. I'm always saying 'I'm the taxi for my children' (laughing). [...] That is just the really basic."

Mrs. Brown used to live with her family in the city centre with relatively good public transport access and with many places in reach. Despite this, she still preferred to use a car rather than public transport to manage the different needs of her family. The expression "that's what I NEED" shows her sense

of car-based mobility being the only thing flexible enough to meet with the diverse requirements of her family. Somewhat differently, Mr. Davis (#6), a father of a teenage girl who lived with his family in a rural area, described sustainable mobility behaviour as the prevention of what he considered to be unnecessary or 'waste':

> "Sustainability is very important to me [...] I really try to do it as well as possible. [He elaborates further examples regarding how sustainability is integrated into his daily e.g. not buying plastic bags]. It was always important to me that I do not drive around un-necessarily and waste any money. I don't drive around just for fun, or have a big car, just because I could. No. I orientate my mobility on what is really necessary."

He made it clear that sustainability was an important value in his life, which, for him, meant paying close attention to his personal mobility habits. The over-riding orientation, here, was to only consume as much as was absolutely necessary. This focus on 'waste' drove a perceived need to organize transportation more efficiently, but not necessarily more sustainably. What might be argued to be 'enough' or 'efficient' is subject to enormous variation and can highly differ from person to person, according to individual values, needs, contexts and the local accessibility of different modes of transport. It can also be subject to the situated vagaries of dealing with whatever needs to be dealt with here and now. Although, most of the interviewees expressed positive views regarding the value of sustainable mobility, they were also more than capable of providing good accounts for why they conducted their mobility in the way they did. This is something that needs to be respected rather than set aside.

11.4.3 Shared responsibilites

According to different circumstances, needs and available infrastructure, the interviewees had different kinds of mobility lifestyles. As we have seen above, there is not always a choice when it comes to mobility behaviour. Another important outcome of this is that people do not always feel completely

responsible for their choices and the environmental impact of those choices. However, people are still willing to take on some measure of responsibility. But they feel that local mobility suppliers and local municipal city services should take on some responsibility, too.

11.4.3.1 Individual responsibility While many participants did not see much opportunity to change their daily mobility habits, they were more than ready to support new mobility services aimed at developing more sustainable mobility. Mr. Mahoney (#4), who lived in a more rural region, said:

> "To establish a more sustainable mobility I think that sharing opportunities offer a nice opportunity. If some offer would be close by, I think I would consider if we really need two cars in our family, or if we could replace one because I use it only occasionally."

Thus, car-sharing services were viewed as a potential opportunity for some participants to scale down their individual car use. Related forms of sharing such as ridesharing turned out to be relevant here, too. Mr. Taylor (#14) commented:

> "If I would know, I could help my neighbours with a lift, I would immediately offer a ride. That is what I understood under a local solidarity. I think that would improve the quality of a neighbourhood [...] and that also accounts for a sustainable mobility, right?".

So, offers of sharing could play a part in fostering the formation of a local community identity where part of it is bound up with a collective responsibility for the environment.

Many interviewees expressed the view that sustainable mobility is the shared responsibility of the local community, rather than about individual effort: "It is a shared effort, not an individual duty" (#3). However, characterizing attention to sustainability as a 'duty' has certain connotations. It implies seeing it as a personal burden, that is easier to bear when the weight is distributed

across a number of shoulders. Others argued that collective attention to sustainable mobility is more efficient (#12):

> „I alone, I don't think that it makes a big difference at all and I don't think it is my duty alone. It's a collaborative responsibility and I'd like to see how OUR actions have an impact."

This statement makes it clear that people may think their own impact would be quite low, whilst a joint effort might result in more visible change. Another participant expressed it as a feeling of being part of a community of fate. This was clearly articulated by Mrs. Adams (#13), a mother of two young children

> "I really would like to know what all of us could achieve together to improve our environmental situation [. . .] this needs to be considered for our kids, too".

Here, sustainable mobility is seen as a collective achievement. In contrast to the previous example, it is not expressed as a collective burden, but as a shared experience ("achieve together"). This is more about an investment in the future and, indeed, later in the interview she refers to a collective responsibility to care for the future of the "kids".

11.4.3.2 Responsibility of the city Some interviewees expressed a view that caring about sustainable mobility and environmental pollution was being pushed too much onto individual citizen-consumers. This was expressed by Mrs. Williams (#12). She vented her frustration as follows:

> "Phew! I'm a little torn, because I think that everybody has to do something to make a change, but sometimes I feel that the individual hasn't the ability to do so. Actually, I guess this is because sustainability isn't applied in the big wide world. We're always thrown back to ourselves [...] but I'm just a small cog in a big wheel [...] I mean, what's the point of me walking more, but the car industry is developing stronger motors on and on. I reject

> that, I say, no, I do not want to take that pressure; you should start on a large scale. That's far more efficient, instead of me, average citizen, starting small."

In this quote, the overall political system is criticized for not providing a more environmentally-friendly infrastructure that might then facilitate sustainable mobility on an individual scale. Mrs. Williams expressed a need for concrete action to be taken by industrial operators and political decision makers to provide sustainable transport options, thus effectively calling them to account for their inaction. In this regard, Mrs. Evans (#8) wished that the local mobility situation would be taken more seriously by the city services:

> "If they would know how my daily mobility looks like, they would not ask me to take the bus or to ride a bike".
>
> Also Mrs. Davis (#6) stated: "I wish I could clarify my mobility situation so that people know how desperate the public transportation is. Maybe then something would happen, maybe then they would come up with something. (pause)."

In both of these quotes the interviewees express a desire that their individual issues and concerns might be recognized by the authorities, who were considered to be better-placed to do something about it. There is a demand for what Iris Young calls 'political responsibility' [380]. This concept captures the sense of actors not being solely responsible for issues they have not caused directly through their actions, but where there is a sense of co-responsibility because everyone is structurally entangled in their formation. Responsibility, in this case, is not tied to a question of whom to blame, but rather where the obligations lie.

11.5 Discussion

In the above results, we identified three key themes that capture both the limitations and the potential of eco-feedback tools from a citizen's perspective.

These encompass: (1) better information regarding how sustainable mobility is measured and monitored; (2) respect for individual mobility situations and preferences; and (3) support of participation and shared responsibility between citizens and municipal city services.

While a lot of research has already pointed to the limitations that attach to reinforcing unsustainable norms, presuming rationality [52], or taking a paternalistic perspective [382], less work has examined what other kinds of potential may reside within an eco-feedback approach. An exception here is work that addresses the potential for rendering sustainable behaviour more accountable [303]. However, similar studies on eco-feedback systems that aim to support sustainable mobility are lacking. To address this gap, we argue that understanding how eco-feedback tools are engaged with from a citizen's point of view provides a new perspective on the potential of eco-feedback and how it might encourage more environmentally-friendly mobility. In the following we suggest some of the possibilities that were motivated by our analysis.

11.5.1 Understandable and accessible information

Our findings showed that the interviewees were more interested in understanding and learning about sustainable mobility than they were in being confronted with abstract values that did not make concrete sense to them. They all had an interest in information related to sustainable mobility. Most of them were well-informed by the media about topics such as environmental pollution, electric vehicles, new mobility services like car sharing and the more general situation regarding mobility in German cities. However, many of them also expressed uncertainty regarding their own competence and skill to make informed judgements about whether specific forms of mobility were more or less sustainable. When it came to concrete statements about sustainable mobility, their judgements were often quite programmatic and abstract, such as: 'cycling is sustainable' or 'driving is unsustainable'. Although, these statements are not necessarily wrong, they do not capture a very detailed understanding of what sustainable mobility might entail.

Even though many participants struggled to understand the abstract aspects of

measuring and monitoring sustainable mobility, they were nevertheless interested in such things. In particular, they wanted to understand how sustainable mobility could be distinguished from unsustainable mobility. However, not every user wants to invest significant effort and time in understanding detailed and complex background information. An official model could help to foster trust in the reliability of monitoring. This model should be easy to understand and accessible to everyone. It would help if information such as the fact that benchmarks are based on keeping an individual citizen's CO2 output below a certain value was better promoted. This could be done in schools, at the workplace, by municipal city services and by other organizations, but also in the different applications that aim to support sustainable mobility.

An important point to mention here is that knowledge and information about how to interpret mobility data should not be simply used for persuasion but rather to support users in developing a better awareness of the consequences of their actions and of the character of environmental pollution in general. In this regard, this study can be thought of as an example of an induced learning process on mobility data related to sustainability. Such learning processes need to be further fostered in different social settings such as, again, schools and workplaces, and in public settings, cars, at train stations and, of course, in the media.

11.5.2 Balancing the tensions between individual needs and monitoring

During the interviews we found that transformations of mobility routines were often associated with life-changing events. For instance, becoming a parent had led, in one case, to a new way of thinking about mobility (#6). Getting a new job caused new mobility demands in two cases (#8; #12). We also found that mobility requirements needed to be re-organized in the course of a separation (#12) and, in two cases, when people met new partners (#8; #6). Interviewees reported having somehow 'slipped into' new ways of proceeding with their daily mobility as a result of changes in their living circumstances. This underscores the strong connection between mobility habits and the evolving character of everyday routines that have developed over the course of people's lives: e.g. decisions about where to live, where to work, how to organize the

household and its relationship with the outside world; how and with whom leisure time is to be spent; how the grocery shopping is to be done; how to travel to work, and so on. In every case, there are preferred modes of transport that are reasoned about in relation to the particular situation. Changes in one's social environment often (perhaps inevitably) induce processes of self-reflection and behaviour change.

Thus, the provision of information should go beyond abstract sustainability goals that might be considered unachievable, unrealistic or patronizing. Instead, on the basis of our findings we feel that it is important to understand and appreciate daily mobility as it is: a set of practices that have to fulfil different needs and serve different values that might even seem to contradict the broader aims of sustainability. It is unreasonable to expect that users will simply change mobility routines that have evolved over extended periods of time. Intertwined with this is the fact that, where practices are sustainable, they, too, have developed over the longer term. This rather conflicts with persuasive eco-feedback approaches [178, 13] that assume that just providing the feedback will result in change. The findings also indicate that eco-feedback needs to be provided in a 'safe' and 'protected' space that provides room for (self-) reflection and learning about one's own mobility habits and the effects they may have upon the local environment and community. Thus, the key thing is to support awareness of one's own behaviour that does not simply position it as 'right' or 'wrong', but that rather respects evolved practices, even if the overall goal is to overcome unsustainable mobility practices in the long run. Thus, design needs to reflect on the tensions between enforcing values and respecting the freedom of users [89] and find more effective ways of balancing the two.

We also found that mobility planning ICTs might offer a vehicle for supporting individual mobility in more sustainable ways. In the interviews, we often found a preference to own and use a car. There are clearly situations where a car is the fastest option for getting from one place to another. Using public transport or bikes is often also characterized as a hassle. Time, as in the number of minutes it will take to do something, is typically foregrounded in travel planning tools [23, 150]. However, when optimizing primarily for time, other preferences that can play an important role in sustainable mobility are often

neglected. Hence, the interviewees mentioned other, subtler, criteria, e.g.: getting physical exercise and being outdoors in the fresh air and sunlight; being with the family without having to focus on driving; sitting face-to-face and talking while travelling; taking a scenic route that can only be tackled by bike; getting to know the city better; getting some work done on the train; or travelling in a less stressful fashion.

These are all opportunities for ICT and travel services. As Hasselqvist et al. [150] put it: "Currently, travel planning tools do not suggest that replacing a 20-minutes car trip with a 40-minutes bike ride will amount to "winning" 40 minutes of exercise, sunlight or increased knowledge of the city, rather than just "losing" 20 minutes in the car." As convenience has been identified as an important factor for transportation choices [318], these kinds of benefits should be highlighted in the design of travel planners. There are examples of dedicated travel planners for electric bikes that, for example, take weather conditions into account. There might also be possibilities to enhance positive experiences of sustainable transport by linking travel planning tools to other services, such as fitness tools or time reporting systems at workplaces when people are working on the train. Ridesharing among colleagues can also augment opportunities for 'chats in the hall and whilst making coffee' that are important for informal exchange. We believe that designers need to become more aware of this tension between the traditional understandings of optimization and sustainability that reside in many tools and the ways people reason about the conduct of their lives and the travel choices they are making.

11.5.3 Collective responsibilities vs. individual pressure

Finally, the data showed that sustainable mobility was often deemed to be something that should be a collective achievement of the members of a local community who share a local interest in living in an environmentally healthy city. Thus, many participants felt, that it was not their duty alone to care about sustainable mobility. To address this issue workplaces, schools and sports teams could work as creators and facilitators of such norm-challenging (digital) communities. These are places that naturally create communities that go "beyond the individual" and that might endorse knowledge exchange,

combined with an offer of alternative mobility services. This could include joint bike maintenance, the provision of light electric vehicle leasing contracts by workplaces, ride-sharing stations and support, or car-sharing opportunities. This, in turn, could lead to more discussion about transport and might support an increasing acceptance of alternative modes of transport [28].

A further possibility is to enhance eco-feedback tools by having visualizations that show environmental wellbeing or pollution as a collective achievement or that promote challenges that will increase awareness about what is achievable in a local community. Greater awareness of local conditions on the part of municipal city services might also be further developed and local municipal services could be addressed as relevant stakeholders. By extension, eco-feedback tools could foster mutual exchange between a wide variety of stakeholder groups and encourage mutual learning and participative innovation processes.

A further matter worth reflection is the presence of evidence that suggests that the strong drive towards individualism in a number of countries in recent decades, with a concomitant erosion of a sense of community, has led to a certain fatigue with the sense of individual responsibility this instils. This may be leading to a growing social need for ways to escape this pressure, reflected in there being a higher demand for communalization in cities [359, 19]. This, too, may represent an opportunity for developing ICT that articulates community focus around matters such as sustainability, enabling people to not only 'share' but to demonstrate that they 'care' and that they hold each other accountable for caring [19]. This would bring together the above propositions, perhaps at a platform level, and provide a way of reconciling a number of different and pressing issues at the same time.

11.6 Conclusion

In this paper, we have presented an interview-based study where 14 participants used an eco-feedback probe to reflect upon their daily mobility habits and sustainable mobility. We applied a citizen's perspective to study the limitations and potential of eco-feedback for the support of sustainable mobility in

cities. We believe that the perspective of citizens is important to move beyond gross normative appeals (e.g. 'be sustainable!') towards something that is embedded in people's real experiences of having to move around in the world. The points we have identified can be collected under more general themes that may inspire designers concerned with sustainable mobility. First of all, and to re-iterate what others have also said, there is a need to design with a focus that goes beyond measurement and towards supporting an understanding of the effects of sustainable or unsustainable mobility. Secondly, we see opportunities in designing for alternatives to resource optimization and monitoring, by examining other values that are important for sustainable practices that bring a different understanding to a specific situation. Thirdly, we see potential in dispensing with promoting just individual responsibility for sustainable mobility and providing, instead, a way in which different stakeholder groups might participate in and collaborate around processes of mutual learning and innovation. Lastly, this study itself has sought to provide a positive example of how a citizen's perspective might be applied to sustainable HCI in ways that might inform and inspire the design of digital services that could support a more grounded transition towards sustainable mobility practices.

A limitation of this study is clearly that the selection of the participants was by no means representative. This applies also to the chosen city and the specific economic, political and legal environment within which the study was pursued. Every city has its own characteristics regarding its infrastructure, topographic landscape and history of supporting sustainable mobility practices (or not). It is important to continue this kind of work across a range of different communities around the world. There is also a need for studies of how sustainable mobility is negotiated and organized in the micro-economies of households and other lifeworld contexts, such as in partnership relationships, parent-child relationships and in companies.

12 Comparative Summary of Findings

The previously presented sections have taken an isolated perspective on the research question RQ2. For this reason, we will summarize the results of the two studies comparatively in the following to more broadly consider the role of Recommender Systems in sustainable consumption practice transformation. By researching the design of a Food Recommender System for critical consumers (section 10) as well as an eco-feedback enhanced route Recommender System for sustainable mobility (section 11), the research questions RQ2 are addressed from different perspectives. Thereby, the studies cover a broad range of mechanisms. In the food design case study (section 10), the recommendation is altered by changing decision information and decision structure. The mobility design case study (section 11) uses information, decision assistance, and decision affection, depending on the consumers' choices. In the following, both case studies are compared from a practice-theoretical perspective inspired by the network-theoretical accounts, as presented in section 5. Therefore, the relation of the prototypes to materials and infrastructures and the connected meanings and competencies is discussed. Moreover, the preliminary design implications from section 8 are discussed against the comparative findings.

12.1 Materials & Infrastructures

Given this chapter's material and infrastructural focus, the design implications derived from part II, and the focus on Recommender Systems, discussing these practice elements is undoubtedly the most obvious starting point. Therefore, in the following, the focus will be on shortly summarizing and comparing the relation of Recommender Systems and materials as well as infrastructures, the appropriation over time, and the long-term patterns. The comparison, as similarly seen in section 8, is based on specific phenomena that were observed at least in one of the studies. Each of these observations is summarized and compared in one particular paragraph.

Complex Infrastructures: In line with the previous studies presented in part II, the use of recommending Systems is prevalent in the appropriation of com-

plex consumption infrastructures for both consumption fields.

Food infrastructures consist of restaurants and retailers. For restaurants finding the infrastructure itself is problematic, and for retailers the complexity comes with the thousands of products offered. In both cases, the niche is covered by the omnipresence of the regime. To deal with this complexity, consumers explain in section 10 how they use different recommending Systems, e.g., various apps, to get information about the infrastructure. As already described in section 6 those artifacts have their own co-evolving appropriation patterns — once the relevant materials and infrastructures are appropriated as part of the consumption practice, no further search is needed, and the artifact's relevance diminishes. The patterns of the Recommender Systems prototype are pretty similar. The participants describe that the prototype would have been very helpful, especially at the beginning of the practice transformation or changing personal situations. In the long-term, however, the artifact is not required anymore as materials and infrastructures can be consumed without a need for planning, search, or information. Still, it is worth mentioning that a particular explorative use could be observed. While it is usually tricky for niche consumers to explore new items beyond their routine, such an artifact allows for more hedonism and joy.

As section 11 does not cover an empirical pre-study that describes the artifact usage of consumers, we will shortly reflect on section 7. The complexity of mobility infrastructures results in two main issues, the invisibility of relevant routes and their diversity when combining different modes. Again, especially at the beginning of the practice transformation, consumers face the need for searching the proper infrastructure for the current trip. Over time, platforms and schedules are learned by heart and can just be used. In contrast to the food use case, suitable infrastructures were not always prevalent for the participating consumers in section 11. Thus, even the best artifact would not be able to support their appropriation. Given this, appropriation of the artifacts and the infrastructure underlay a different pattern that is instead characterized by a co-evolving non-use. Nonetheless, the participants emphasize that planning and searching for alternative modes of transport offer a great opportunity for sustainable mobility.

In summary, the consumers of both cases face the challenge of appropriating complex infrastructures to pursue sustainable consumption practices. While the broad comparison of artifacts shows quite similar patterns, the patterns for the specific artifacts of sections 10 and 11 are different due to the availability of infrastructures. Still, an interesting pattern is worth mentioning at this point. The co-evolving appropriation of artifacts seems to go along with a transformation in infrastructure interaction. While infrastructures and materials, in the beginning, resemble shopping goods (see [165]) that require more effort of comparison, over time, they become convenience goods (see [165]) that can be bought conveniently without comparison and search needed.

Near Material Replacement: Taking up the similarities to convenience and shopping goods, we want to highlight a specific phenomenon that was prevalent in section 11 but also 7 — Consumers owning a car tend to not immediately replace their vehicle and pursue a sustainable practice, although they are motivated for change.

Such reliance on the car and stiffness of practices is mainly explained by the lack of appropriate infrastructures and the need for flexibility and autonomy. Besides that, the lens of convenience and shopping goods [165] might add to an explanation. First, cars are shopping goods that come with high costs and effort for the acquisition. Once the car is part of the near-material context of the consumer, its usage comes with rather convenience good characteristics, the car is ready at hand, and price comparisons decrease to the minimum of checking the gas prices now and then. Appropriating public transport, from this perspective, comes with the effort of using a shopping good that is much more complex and comes with the cost and effort of selling a (new) car. For food, in contrast, a convenience good that is owned for a short time before metabolic consumption is exchanged for a shopping good, but other than higher effort in comparison, no costs need to be paid for replacing the good.

Practice-Material/Infrastructure-Fit: Again inspired by the characteristics of convenience and shopping goods, a further phenomenon is observed in both studies.

In section 10 consumers explained how different proprieties of their personal

situation and practices affect the search for infrastructures and materials. The recommendations must match the other elements in the network of elements that constitutes their practices to use that metaphor from section 5. This is, for example, the way they drive to work, their personal values, or their monetary budget.

Similarly, consumers in section 11 explained how the artifact offers an excellent opportunity for planning but that the public transport must better suit their needs. Especially in rural and suburban areas, the residence of many participants, there is often only a sparsely developed infrastructure available that does not match their own schedule or destinations, e.g., the workplace. Caused by this, the participants do not see themselves in a position to conduct sustainable mobility practices. Still, they also do not see themselves as responsible for the lack of the necessary, suitable infrastructures.

In this sense, Recommender Systems allow for a search and filtering for matching infrastructures and materials. In other words, they support the search for a shopping good with properties that match the consumer's practices. This understanding places the designers of such systems in the position of mirroring practices in profiles. Nevertheless, from a critical perspective on the design approach, it must be noted that the artifacts do not create new physical infrastructures. Accordingly, other actors, e.g., politics or companies, are asked to make these infrastructures and provide the corresponding data for supportive Recommender Systems and other recommending Systems.

12.2 Meanings connected to Materials & Infrastructures

Given the interconnectedness of practices and the network formed by their elements, it is worth broadening the scope beyond materials and infrastructures as the element mainly connected to Recommender Systems. Therefore, in this section, the focus will be on meanings and their relation to Recommender Systems. These meanings are entangled with the materials as a focal point of this part. Again, this section will shortly summarize and compare both design case studies along specific phenomena presented in their own paragraph.

Understanding Barriers: In both studies, the phenomenon of changing per-

ceptions of the material barriers to transforming practices was influenced by the information and recommendations given by the Recommender System.

Within section 10, consumers explained how such an artifact would have supported them in the early transformation of their consumption practices material context rearrangement would have been of less effort. While the search for appropriate food was connected with higher effort, less pleasure, and more substantial reliance on the offered brands, the prototype, and other artifacts, helped positively influence this perception. In this sense, providing an overview of the material opportunities of the niche decreases the negative perception of barriers (see [215]). Beyond this, even positive associations and strengthened, for example, explorative and hedonistic aspects of consumption came to the foreground.

Similarly, the mobility design case study also shows how the information given by the system shapes the perception and understanding of the practice itself in relation to the material context. In this study, however, only a few (subjectively appropriate) infrastructures were available to the consumers, while at the same time, the unsustainable aspects of their car-based mobility were highlighted. Finding themselves within such a situation that comes with an overview of public transport and sustainability measures, consumers felt powerless. Thus the negative meanings connected to the infrastructure became more prevalent. Nonetheless, participants also saw a chance to connect sustainable mobility recommendations with personal goals, e.g., walking to work to get extra exercise. Thus, raising positive aspects also shows positive design potential in this study.

Both studies show how even a material perspective on consumption is entangled with experiences and meanings. Such a perspective on the negative and positive experiences in consumption is also highlighted by Hasselqvist et al. [150]. They emphasize the potential for designers to shape such experiences with niche practices. Making the niche material context accessible, thus, comes with both chances and risks. Especially complementary motivational design features can even create stronger feelings of powerlessness. In those cases, meanings can create emotional barriers to material shifts and thus, slow down or stop the whole transformation. On the other hand, there

is the potential to positively influence the understanding of the niche material context, e.g., increasing the hedonistic aspects or supporting personal goals.

Beyond Normative Meanings of (Sustainable) Consumption: Taking up the discussion on experiences with infrastructures and materials, it was shortly mentioned above that those understandings are pretty subjective and shaped by the personal situation. In this paragraph, we want to engage in this phenomenon in more detail, as it was also prevalent in both studies.

For the Food Recommender Systems, the personalization of recommendations and the consideration of the personal values, restrictions, and situations was one of the main design features. While designing this feature and during the evaluation, a certain conflict between the normative understanding imposed by the design and the subjective and personal experiences came to the foreground. Thereby, the set of values and the respective importance is unique for each consumer, but also the interpretation of each value itself. For example, for some consumers, sustainability is expressed by vegan and plastic-free food, while for others, organic and cheap food allows them to be economically and ecologically sustainable. Similarly, the example of veganism shows how some consumers include or exclude honey from this definition.

Within section 11, personalization of goals and information was the main design feature, in contrast to changing the ranking of the recommendation. The design goal was to increase motivation through social comparison, normative as well as personalized goals, while at the same time allowing for information about public transport in the area. Based on the evaluation of the artifact, however, it turned out that the normative goals are not understandable and hardly aligned with the consumption practices. Even though the participants strove for more sustainable mobility, the imposed understanding did not consider their personal interpretation of what sustainable mobility is. Similarly, social comparison is connected with the perception of varying personal situations and thus a situation in which specific contexts are rewarded or punished against normative sustainable goals. In contrast, the personalizable goals, such as fitness or finance, were perceived as an opportunity for approaching an own understanding of sustainable mobility.

In summary, the comparison shows how meanings turn out to be a critical

element connected to the material context. While normative goals indeed describe an ecologically sustainable future, they are not necessarily aligned with personal understandings of such sustainability. In other words, a narrow focus on normative ecological sustainability comes with less emphasis on social and economic sustainability on a personal level. Consumers again felt powerless and demotivated to pursue change, while at the same time, more freedom in their own definitions can foster self-determination and motivation. This is in line with the call of Karpati et al. [195], who highlight the need for personalization, no matter whether the personalization is incorporated into Decision Assistance [180] or into the ranking [180].

Appropriating New Meanings: Lastly, we want to discuss a phenomenon that is positively associated with a provision of a variety of meanings that the consumers can choose from. For this, the participants of section 10 explained how the system provided them with new understandings and values that can be appropriated.

The food Recommender Systems provides not just an overview of niche materials and infrastructures but also values that can be tied to those. For example, the importance of the carbon footprint for their consumption practices became more important for some participants once they could retrieve such information. Similarly, evolving meanings were observed in the pre-study, e.g., consumers appropriating meanings to transform from organic to vegan, or from vegan to plastic-free diets. This once more shows a particular dynamic that should also be considered.

Similarly, section 11 shows how the provision of information comes with new meanings for the sustainability of the current car-based practice, although no observable change in the behavior was initiated. Also, for section 7, the data shows how consumers appropriate sustainability as a meaning a specific time after they started to conduct car-free practices.

12.3 Competencies connected to Materials & Infrastructures

Again, this section aims to broaden the perspective by summarizing and discussing the results of the previous studies from the standpoint of competencies. These competencies are entangled with the materials as a focal point of this part. Again, this section will shortly summarize and compare both design case studies along specific phenomena that are presented in their own paragraph.

Mapping Appropriate Materials & Infrastructures: In both consumption fields, the phenomenon of exploring and mapping the material context of the consumption practices turned out to be part of the appropriation of the Recommender Systems. Consumers do not rely on such systems in the long term, but with the co-evolving appropriation of the artifact and the materials themselves, their existence as part of the niche is learned.

For food practices, section 10 and section 6, from the last part, show how consumers who face the need for a niche without knowing the niche start using various artifacts to explore and appropriate the material context. In the long-term, the location of restaurants, appropriate items in the supermarket as well as other materials are learned by heart and can be consumed without further search and information (also see the above discussion on consumption and shopping goods). Only when the local niche is left, for example, when visiting a new city, the artifact is again needed to retrieve the relevant information.

For mobility practices, the patterns are quite different. While in section 11 the consumers quickly learned about the non-existence of appropriate materials and thus the irrelevancy of new search attempts, section 7 highlights the learning of schedules, routes, and stations more strongly. Again, participants explained how the artifact loses relevance for their regular routes, e.g., driving to work.

In summary, we see how, from a competence perspective, consumers explore and appropriate the niche with the help of artifacts. While the knowledge, in the sense of competence, is first owned by the artifact, over time, it diffuses to the consumers. This knowledge or competence about the context then al-

lows for habitual consumption. This state can be referred to as a stable state (see [43]) of consumption practices, where the network elements remain in a balance. Again, a certain instability needs to be equalized with the help of the artifact's knowledge, e.g., in new situations.

Learning about the Properties of Materials & Infrastructures: Tied to the above phenomenon of learning about infrastructures and materials as part of the appropriation of both the artifact and the elements themselves, we want to discuss the competencies acquired about values, properties, and measures around consumption. This phenomenon, again, was apparent in both studies of this part.

Within the Food Recommender System study, it became apparent that the transformation of consumption practices and the artifact confronts the consumers with a lack of knowledge that is specifically needed for the niche. For example, consumers needed to learn about specific ingredients that suit their diet, the meaning of labels, and even filters implemented in the artifact. While the latter can certainly be understood as a design flaw that poses an additional challenge for consumers, the learning about the materials themselves can be seen as an essential engagement with the niche. The competencies that are acquired by using the artifact, again, allow for retrieval of the information even outside the artifact context, but also for more appropriate and informed consumption decisions.

Similarly, for the mobility consumers in section 11, unfamiliar measurement units for mobility behaviors make it difficult to understand sustainable visualizations and recommendations. In particular, the participants explain how the Material Footprint but also Carbon Footprint are challenging to assess in relation to their own mobility habits. Again, this can be seen as a lack of explanation within the system and too many competencies required for using the system. The comparison of the artifacts' modes should give a clear indication of favorable options. It is difficult to weigh sustainability with the other properties and personal goals, such as finding a trade-off between time and ecological sustainability. Still, over time the competencies for assessing transport modes increase, such that consumers can engage in a fruitful discussion. Such learning supports not only the research of the artifact or political

articulation but also the selection of appropriate modes for the right situation.

In summary, both studies highlight the need and the opportunities for a well-designed artifact for learning the measurement units of sustainable consumption. Besides the positive aspect of more informed decisions, strengthening competencies supports the self-protection of the consumer against faulty promises. From a broader perspective on artifact-related competencies, the studies show how consumers, to articulate their consumption preferences and goals fully, need to have specific competencies upfront already. In this sense, knowledge about the consumption field and the artifact are mutually related and can thus be seen as co-evolving competencies. From a design perspective, it is, therefore, a mixed blessing. On the one hand, the artifact triggers the learning, but on the other hand, a lack of competence complicates usage and even demotivates.

Learning to Articulate Consumer & Political Needs: Taking up the discussions about competencies and the related strengthening of the consumers, both studies report on discussions of market power, responsibility, and politics. With the ongoing learning about the niche, consumers acquire competencies that shape their understanding and their ability to assess their own capabilities as well as demands towards production and policy.

The pre-study in section 10 reports on the varying perception of the own market power, for example, the exercise of power then boycotting a specific brand. This perspective was not shared by all participants and was critically discussed. While not necessarily strengthening the market power of critical consumption behaviors, the artifact allowed the participants to have a broader overview of the available goods on the market that suit their preferences. In some instances, consumption according to their personal needs and goals was not supported by the items available or within their price range. For example, often organic products are packed with plastic, according to the observation of some participants. Thus reducing plastic while at the same time reducing the use of chemicals is problematic. From this perspective, the overview supports consumers in learning about their own opportunities while at the same time allowing for an articulation of responsibilities, e.g., producers to offer organic and plastic-free produce.

Similarly, participants of section 11 found themselves in a situation where, especially in the rural areas, the artifact could not provide any meaningful alternative to the usage of the car. Nonetheless, the participants highlighted the positive aspects of such information and discussed their responsibilities. The artifact, thus, supported a specific relief of the own ecological conscience. Moreover, the responsibilities of other stakeholders, such as public transport providers and policymakers, were discussed. Such articulation competence, enabled by the artifact, can be understood as an essential competence of citizen-consumers.

Summarizing this phenomenon for both studies, quite similar patterns can be observed. With more competencies and market overview, consumers understood the opportunities and barriers to self-driven sustainable consumption attempts. At the same time, more powerful stakeholders come to the foreground as enablers for change. This sheds light on all the recommending artifacts, as also observed in part 2.2, as instruments of consumer protection and access to market knowledge. This even relates to classical economic theories of informed decisions, as consumers are able to compare and understand the offerings. Still, this comparison should not be exaggerated. We see how consumers reach the barriers of their capabilities on the market and how other stakeholders would need to adapt to lower those barriers.

Part IV

Research Outcome

13 Discussion

In the previous parts of this thesis, a comparative summary of the results of the individual studies was given (see sections 8 & 12). This section aims to take up those results and discuss them against the background of the research questions and existing literature.

- *RQ1 'Transformation towards Sustainable Consumption Practices':*
  - *RQ1.1:* How do consumers appropriate sustainable practices and the respective elements?
  - *RQ1.2:* How do consumers use and appropriate ICT artifacts to gain access to practice elements, especially infrastructures?
- *RQ2 'Recommender Systems for Sustainable Infrastructure Consumption*
  - *RQ2.1:* How do consumers interact with infrastructures mediated by ICT, and which design opportunities and requirements for sustainable infrastructure Recommender Systems result from this?
  - *RQ2.2:* How do consumers use and appropriate Recommender Systems for sustainable Infrastructure consumption, and which potential do they have for practice transformation?

As already outlined in part I the research questions are mutually related, and all presented studies contribute to answering both research questions. Still, in the discussion, we aim to provide a clearer perspective on those questions by discussing the topics of the respective subsections. Moreover, this discussion includes a reflection on the methodological approach of this thesis and the lessons learned for Practice-based Computing research.

13.1 ICT Supported Consumption Practice Transformation

In the following, with a focus on RQ1, we aim to discuss the different roles of ICT artifacts for sustainable practice transformations uncovered in the re-

search of this thesis. Moreover, the focus is on the co-evolutionary nature of appropriating artifacts and practices.

13.1.1 The Role(s) of ICT in Sustainable Consumption Practice Transformation

The empirical pre-studies (sections 6 & 7) show how consumers use different artifacts throughout their consumption practice transformation. Based on the comparative perspective on artifacts and their relation to the practice elements (see section 8, the artifacts can be analytically categorized into four roles. Those are presented and discussed in the following.

13.1.1.1 Artifacts to Irritate and Reassure This role of artifacts primarily relates to the meanings of consumption practices. Representative artifacts of this role are found in the persuasive media that initially triggers the vegan practice transformation, but also artifacts that accompany the appropriation of new practices for a longer time. The latter is, for example, evident in diet tracking artifacts to reassure oneself that the new consumption patterns are suitable, as well as mobility tracking artifacts to track the benefits of the new consumption patterns, e.g., saving money or improving the own fitness routine. In their entirety, this class of artifacts, no matter if it initiates the practice transformation or accompanies the same, is quite similar to the various motivational design approaches found in the literature (see, e.g., [110, 115]).

Still, those current motivational design approaches usually rely on the idea that consumers lack the right motivation to change their behavior or appropriate new practices. This differs from the observed functions of these artifacts. While they are clearly to bring up the transformation to speed, they can only be understood in relation to the remaining practice context. This is especially shown in the comparison of section 6 and section 7. For the vegan practice transformation, persuasive media was prevalent as a trigger of a “crises of routine” [278] by productive confrontation [333], for example, when challenging existing beliefs about one’s diet when watching documentaries or reading about a food scandal. In contrast, nothing comparable was observed for mobility practices, where the transformation was initiated by

breakdowns of the near material, e.g., the car, or a change in infrastructures, e.g., when moving to a new city. We can explain such difference with the inertia emanating from an element such as the car in the network of practices.

Taking up both examples, we can identify the "crises of routine" [278]. However, it remains an open question why consumers decide to take up this crisis and productively start appropriating new practices rather than just figuring out ways to fix their infrastructure or material problems. One explanation for this, especially for the mobility example, is that at this point of infrastructuring [266, 224], the consumers have already appropriated various meanings of multi-modal proto-practices (see [312]) but are stuck in their (old) practices from a material perspective. Given this lens, it is logical to assume that persuasive media, e.g., TV shows discussing climate change and individual opportunities, already triggered the appropriation of new meanings without the consumer noticing it.

So far, the discussion has focused on the initiation of the practice transformation only. Still, as this research shows, not all meanings are ready at hand with the first doubt, reflection, or productive encounter with new information. On the contrary, consumers constantly appropriate new meanings in relation to their practices until a stable state is reached. Also, this stable state is probably somewhat an analytical term than the actual stability of the world view of human beings. The appropriation of new meanings, as already highlighted by previous research [150, 30, 355], comes with the appropriation and usage of artifacts to reassure new consumption practices and constantly reflect on the transformation. This is, for example, evident in the use of diet trackers to ensure the nutritional sufficiency of a vegan diet or the use of tracking tools to measure the real-time saving of the bike ride. Such repetition of reflection on the own action is quite similar to Engeström's cycle of expansive learning [101, 100].

13.1.1.2 Artifacts to Access and Inform about Infrastructures and Materials This role of artifacts relates to the material context as mentioned above. For mobility practices, this context emanates certain inertia to the network of practices and thus is a barrier to transformation. It is evident in the

various artifacts in both studies (section 6 and section 7). This role is fulfilled by artifacts that grant access to infrastructures by informing about the availability, location, or schedule and providing search and recommendation features. This is quite similar to the definition of recommending Systems as given in section 2.3. Examples are (vegan) Food Recommender Systems [195], e.g., to search restaurants, or travel planning tools [157], e.g., to find a bus from the local public transport provider.

In contrast to traditional Recommender and recommending System approaches that focus on nudging more consumption, the observed artifacts support and, in the case of the presented design case studies (section 10 and section 11), even 'nudge' better or less consumption, e.g., a reduced carbon footprint. This is in line with the research surveyed by Jesse et al. [180]. From a practice perspective [312, 102, 212], this consumption is enabled by the appropriation of materials and infrastructures that would have remained inaccessible without the support of the artifacts. Inaccessibility, in this case, results from the characteristics of a niche that is hidden within the dominance of the regime and the lack of information about the niche itself. This focus on the niche is, for example, evident in the use of vegan-specific artifacts for restaurants or local apps to get better transport options.

A further differentiation worth highlighting is based on the mobility and food consumption's material and infrastructural focus. While Recommender Systems often focus on shopping goods [165], the focus shifts towards convenience goods for this research. This comes with a temporal shift of the good itself. While at first, the niche good can be considered a shopping good that is hard to find, assess, and finally consume, over time, the artifact-based information supports the convenience factor of the good and thus changes its perception.

Taking up the idea of changing perceptions of the good from a shopping good to a convenience good, it is shown how the recommendation and search results are, over time, not needed anymore as the good is consumed without additional effort. From a practice perspective, the argument is that the material/infrastructure becomes a part of the stable nexus of the consumption practice. The artifact thus supports the process of stabilization and appropria-

tion. Still, for mobility practices, the results show how due to the schedule and potential delays of public transport, a certain instability remains that is counteracted with the artifacts even in the long term. This is evident in the synchronization and live updates that most travel planners/recommenders provide. At first sight, this synchronization was only apparent in mobility practices. But also, for veganism, we saw pretty similar phenomena — for example, the usage of online communities to query the availability of products in a specific supermarket.

Moreover, the design case study in section 10 showed how infrastructures are synchronized with the mobility patterns, e.g., when consumers try to buy in a store that they can reach on their route home from work. From a network perspective, niche practices are sometimes never stable. They require constant synchronization and alignment of practices, e.g., transport from work with the shopping routine or the bus schedule with the dinner appointment [63].

13.1.1.3 Artifacts to Learn about Infrastructures and Materials In the previous paragraph, the appropriation of artifacts to access infrastructures was already discussed. These artifacts overlap strongly with the here presented role, as they enable learning about the material and infrastructural context of the consumption practice — once the context is explored and learned, the use of the artifact decreases to special occasions. But besides this aspect of learning, artifacts were observed that more strongly reflect the learning of skills and competencies. They cannot be categorized into a specific class of information systems but cover a wide variety — for example, recipe apps to learn how to cook tofu or blogs and videos on the internet to learn about consumption-related skills.

Based on the comparison of food and mobility practices (see section 8), we noticed that learning was most evident in food practices, where the handling of the material, the food, itself was learned. The explanation could be that supermarkets were used before going vegan. Thus the infrastructure is already well known. Similarly, public transport is often the only available transport mode for underage people and, therefore, an infrastructure already used before switching to a car. This argument is supported by other research that fo-

cuses on other infrastructures, e.g., electric vehicles [150], food sharing [120], or food teams [272], where the infrastructure differs more strongly, and thus new competencies are needed.

As indicated, learning new competencies and the respective appropriation of artifacts are more intensely focused on materials. In this research, such appropriation of competencies to handle materials was only evident in food practices. For example, in the learning with recipes. Consumers tried to learn how to deal with previously unknown food that is now part of their vegan diets, such as tofu or aquafaba. Such competence appropriation is also observed by Twine et al. [356]. While no such learning was observed for the mobility domain, one can imagine how, e.g., a consumer new to commuting by bike needs to watch tutorials to fix the bike or learn about what to wear in cold and wet weather conditions.

13.1.1.4 Artifacts to Communicate with other Practitioners The last role of artifacts that we want to discuss is related to online groups and the direct communication with other practitioners. While all the other artifacts open the door to the world of the niche practice and allow the consumer to appropriate the relevant elements, this role focuses on more direct communication and the enculturation [30] to the niche community. Still, such communities substitute a multitude of artifacts by getting recommendations from the peers, learning their skills, or engaging in collective action [120]. Those artifacts are prevalent in various online communities, e.g., on Facebook. They are founded and maintained by the consumers themselves.

Again, such online communities of practice [370] are primarily prevalent in the research on vegan practices (see section 6). The study participants described how they used such a community to discuss tensions with members of the omnivorous regime [77, 354] or as a communication artifact to provide reassurance and defensive strategy. While communication mainly was online, some communities' activities shifted to the 'offline world'. In those cases, communication tools enable the formation of an offline community, but once friendships and regular meetings are established, they became less important. For the mobility study (section 7), we find little evidence for such community

exchange, for example, in the organization and visit of bike demonstrations as a form of consumer action. We can assume that such protests are also organized via social media to reach the whole niche.

Nonetheless, there was no evidence for enculturation [30] or clashes with regime practitioners [77, 354] broadly discussed in online communities. At this point, we can just assume why the need and thus the appropriation of such artifacts is different for both consumption fields. One explanation certainly ties to the explanation already given for learning artifacts — while public transport is part of the mobility socialization of most people, veganism is entirely new for most consumers. This leads to a greater distance between the regime and the niche, which causes more tensions and, therefore, a more significant need for enculturation in a reassuring and supporting community.

13.1.2 Co-Evolutionary Appropriation of Sustainable Consumption Practices and Artifacts

In the previous section, the main focus was on the roles of artifacts. The discussion introduced the temporal appropriation patterns of artifacts alongside the appropriation of new consumption practices. Those temporal patterns are taken up in this section and discussed in light of a co-evolving network of practices and ecology of artifacts.

The appropriation of artifacts and, thus, the artifact ecology shifts throughout the consumption practice transformations. This was observed for both consumption fields, mobility, and food. In the beginning, the encounter with a trigger or the lack of routinization creates an imbalance in the network of practices. A thereon following appropriation and usage of artifacts bridges between unstable and stable practices by helping to appropriate the relevant elements into the network. For the example of materials, this can be observed by the transformation of shopping goods into convenience goods, while at the same time, Recommender Systems become less important and used. In the latter course of the practice transformation, the artifact is primarily used to resolve minor instabilities, e.g., when visiting a new city to find the right bus or the matching restaurant.

This co-evolution, however, should not be understood as a goal-directed appropriation of both the artifact and the practice element but as a kind of "bricolage"—tinkering, exploration, and reassurance, characterized by discontinuities and situational factors. This bricolage has been demonstrated in other contexts [6, 333], sometimes referred to as artful integration of artifacts [337, 338] or creative consumption [69, 164]. Change to the ecology of artifacts [43] follows the logic of making consumption practices and practice transformations more convenient, either from a material, competence, or meaning perspective.

With such understanding in mind, it becomes pretty clear that it is neither the immediate transformation that is described by a rational consumer stance [143] nor is there a clear motivation and action phase as assumed by research on the TTM [269]. Rather, it is a fluctuating co-evaluation between dynamic practices [312] and artifact ecologies [43] that can be observed. Nonetheless, the co-evolution comes with some fix-points that provide orientation for designers and researchers. Those, to some extent, account for the perspective of other theories that, e.g., narrowly focus on consumers' motivation.

The usage of *artifacts to irritate and reassure* marks one such point. Their use can mark the 'start' of a consumption practice transformation. Thereby, those are not consciously appropriated with a motivation for change in mind but suddenly appear to be part of practices, e.g., by getting the recommendation of friends to watch a documentary. Besides these nameable (from a participant's perspective) events, there might also be some sort of creeping into practices that is not even recognized by the consumers. For example, for the mobility practices (see section 7), we can assume that global media trends and changing meanings on society's level set a fundamental motivation for change that enables the continuance of the transformation. Accordingly, we can name this motivational point that comes with the appropriation of meanings a 'starter'. But still, this point can not be understood without its dependencies and barriers that make the practice network inert. In other words, even great motivation does not necessarily mark a natural starting point, as the car dependency in the mobility studies (see section 7 and section 11) shows. Here, an external 'energy' is needed to unfreeze change [269, 229], such as the breakdown of the own car.

Artifacts to access and inform about infrastructures and materials and *artifacts to learn about infrastructures and materials* usually become part of transforming practices once change unfreezes and the network is, thus, unstable. With this, a phase of immediate abandonment of old infrastructures and materials and the appropriation of new infrastructures and materials starts. This goes hand in hand with the appropriation of required competencies strongly tied to the consumable good. From a first view, this seems to be quite similar to the action phase of the TTM [269, 229]. However, due to the fluctuating usage patterns of the respective tools — high dependency at the beginning and infrequent usage later on — there is no defined end to this phase. The phase and the artifact usage fade out in a co-evolving manner, but in exceptional situations, it flares up again. This is related to Prost et al. [272], who highlight that alternative practices are less comfortable and constantly compete with norm infrastructures [77]. For this reason, new material elements and the respective competencies need to be appropriated in every moment of slight instability, such as traveling, as the more visible and dominant norm infrastructures cannot be used anymore.

Finally, for *artifacts to communicate with other practitioners*, we can observe quite different patterns. On the one hand, enculturation [30] into a consumption community turned out to be primarily a special case for vegan practices. Therefore, some consumers never use the respective artifacts. Nonetheless, there seem to be two patterns: The first pattern comes with enculturation and using the 'services' of the community in early practice transformation, but as being part of the community does not always work for the consumers, it fades out again. In this case, consumers often remain a passive part of the community and just consume the newest recommendations and discussions. For the second pattern, the usage intensity increases over time. For example, when consumers start to engage in infrastructuring activities of the community, such as bike demonstrations.

13.2 Recommender Systems Supported Consumption Practice Transformation

In this thesis, Recommender Systems take on a distinct role, as the two design case studies (see section 10 & 11) use such a prototype. Therefore, from a critical perspective, one might ask if this focus is justified and what role Recommender Systems and even recommending Systems play in consumption practice transformations. In line with this perspective, we will discuss those artifacts and their relation to the consumption practice transformation more deeply in this section. Moreover, design implications are discussed to guide future research and design.

13.2.1 The Role of Recommender Systems in Consumption Practice Transformation

From a critical perspective, one might question the focus on Recommender Systems and recommending Systems of this thesis. Therefore, in the following, we will discuss the role of these artifacts in more detail against the background of their role within the consumption practice transformation.

Following the argumentation of a co-evolving dynamic artifact ecology and a mutually connected dynamic practice network, as discussed earlier, no artifact role, nor a single artifact, seems to play a distinct role. In contrast, a bricolage [6, 333], artful integration [337, 338], or creative consumption [69, 164] are characterized by an appropriation according to the need of the current situation. From this stance, the argument is that each artifact resolves a tension, helps to overcome a barrier, or provides new practice elements — in short plays a distinct role in the ongoing consumption practice transformation. Without persuasive media, no initial motivation, without competencies, no vegan cooking, and without communities, no enduring of the tension between niche and norm practices. These dependencies are also reflected in typical barriers of consumption practice transformations, where no clear distinction can be made concerning the importance of their temporal occurrence [215, 66].

On the other hand, for the observed consumption fields, *artifacts to access*

and inform about infrastructures and materials are one of the main similarities between both fields, as discussed in section 13.1.1. Both Recommender and recommending Systems are the most prevalent representatives of this role of artifacts. This rather pragmatic perspective uncovers how the appropriation of infrastructures and materials is a common feature in consumption practice transformation that comes with similar appropriation patterns. This is quite intuitive as definitions of consumption often focus on the material/infrastructural side of consumption, e.g., as shown by Evans [103].

Given those arguments, we can at least state that from a material perspective, those artifacts play an essential yet crucial role. Still, they are worthless without artifacts more strongly connected to the other elements. This is an important issue when understanding practices as an evolving network. The appropriation or abandonment of one element causes instability that requires other elements to follow until the entire network is stabilized again. Thus, the dependencies on other artifacts and elements only allow for one answer — those artifacts are more important and less important at the same time; a hierarchy of artifacts is only temporal, e.g., for a particular state of the network.

Still, we want to highlight some key features of these artifacts to understand their role better:

Recommender Systems, other than their traditional intention suggests, do not necessarily support rational consumers in making better choices or nudge consumers [180] but support the negotiation between practices and material contexts. Of course, this perspective emphasizes the bounding of practices to a specific personal situation and context, which is shared with other practitioners and can hardly be influenced by a rational actor alone [102]. In this context, the notions of 'niche' and 'regime' [123, 124, 77] become important. From an economic perspective [15, 90], the regime creates a path-dependent context as it provides more comfortable, economically cheaper, and more accessible infrastructures [316, 272]. This dependency is quite challenging to resolve. For example, the car is still the most comfortable mode of transport for rural areas (see section 11), or it is full of effort to find the 'right' food items in overwhelmingly large stores (see section 10). Here, Recommender Systems offer an opportunity to find the best-matching niche-infrastructures

and niche material within the path-dependency of the regime. While food consumers, for example, scan all products in a store to establish a new routine (usage of a recommending System), a traditional Recommender System approach allows them to more easily get an overview of the context they have to perform their practices in. In this sense, this approach not just gains access to niche infrastructures and materials but also supports a decrease in the perception of the connected barriers.

Still, it is essential to mention that the above perspective assumes that suitable niches are available, either physically or in the scope of the artifact, e.g., the data. If not, the artifact can obviously not recommend any niche infrastructure or material that matches the consumer's practices. From an infrastructuring perspective [193, 353, 266], this can be the starting point of a broader engagement in making niche infrastructures visible and accessible to others. For example, when bike lanes are not recommended in a travel planning app, some consumers start adding the missing data (see section 7. Also, the open data used for the prototype in section 10 resembles how consumers create their own data pool as part of their consumption infrastructure.

From a broader perspective, those artifacts, with their search and filtering mechanisms, contribute to more consumer protection and a shift of power from the producers that benefit from informational asymmetries toward the consumers [195]. They provide an overview of the market and its barriers and support the learning about infrastructures and materials by providing information alongside the results. Even in the case of non-availability of infrastructure, they increase the awareness about this lack of appropriate options that could help with articulating requirements towards producers and policymakers [233].

In summary, Recommender Systems play an important, yet not outstanding, role in the multi-faceted interaction with the materials and infrastructures to be consumed. This not just allows for routinization of practices but also a strengthening of the connection to meanings and competencies, as summarized in section 12. Still, consumption practice transformation goes beyond the access to and the learning about materials and infrastructures, but the enculturation into the community of practitioners [30], the learning of necessary

competencies [117], and the appropriation of new meanings [205], or a reflection on the own position in the society [141].

13.2.2 Designing Recommender Systems to 'Routinize' Sustainable Consumption

The following focuses on the evaluated prototypes (see sections 10 and 11) and the respective implications for designing Recommender Systems to 'routinize' sustainable consumption practices. The term 'routinize' should offer a different perspective to the current academic discourses around 'nudging' with Recommender Systems, see, e.g., Jesse et al.[180]. In contrast to this discourse, the focus on routines uncovers new potentials of Recommender Systems from a practice-theoretical perspective. This perspective, as discussed before, keeps the material focus but more strongly emphasizes the ties to other practice elements.

13.2.2.1 Establishing Routines rather than In-Situ Decision-Making

Previous research [36, 191] on recommending Systems for sustainable consumption focused on supporting in-situ decision-making. This perspective is, however, completely different from the usage in the design case studies. This is, on the one hand, due to the lack of infrastructure, which makes decision-making quite difficult. On the other hand, the observations confirm prior research [156, 213] that already highlights the appropriation of recommending Systems to establish a set of well-known and frequently consumed materials and infrastructures — in short, convenience goods, not shopping goods. Against this background, Recommender Systems should focus on approaches that allow for early recommendation support rather than creating new dependencies using methods prone to the cold-start problem (see [239, 35]). The goals must be a holistic understanding of consumption and the consumers' needs and goals [244, 195]. Based on this, consumers can develop a new routine. Such routine can, thereby, be seen as a kind of plan that becomes part of practices and is executed repeatedly. Such a perspective on planning contrasts with approaches that highlight (new) planning before every consumption as the foremost opportunity [60].

To support routinized usage of those plans, a certain synchronization support is needed, e.g., when products are missing or trains are delayed. In those situations, alternative recommendations or information must be provided. In this sense, design should not just address the 'What to Consume?', but also 'When to Consume?' and 'What else to Consume?' as they are closely entangled. Here, in particular, more long-term mechanisms are needed that, first, consider niche practices and, second, understand the transformation journey to give recommendations for the next step, rather than creating dependencies. Both are pretty difficult issues, as collaborative and content-based filtering methods emphasize the regime due to their need for data and inner logic [346]. Moreover, the monitoring and recommendation of items along a consumption journey is still a new topic [16].

13.2.2.2 Practice-based Profiles for Recommendations and Motivators

'What to Consume?' is entangled with the personal situation of the consumers and their practices. This is in contrast to a narrow sustainability perspective that focuses on reducing carbon emissions only. Those narrow and normative sustainability goals might be harmful once they are "considered unachievable, unrealistic or patronizing" [233]. In this sense, the niche should not be adopted as a new regime that takes autonomy away from the consumers. Instead, we should offer new opportunities by at the same time respecting current practices and balancing both [89]. Finally, practices should be taken as they are, although this might contradict sustainability goals. Not all consumers have the opportunities to appropriate more sustainable infrastructures.

The entanglement of Recommender Systems with practices as the foundation for recommendations entails a holistic perspective that attempts to understand the consumers and their personal situations and long-term goals [195, 244]. Current approaches focus too much on the rationale behind consumption rather than the socio-material context. For food, besides ethical values, the systems need to consider various factors, such as the nearby stores and their available products, the family, the budget, and allergic restrictions. For mobility, there are pretty similar perspectives, e.g., fitness or outdoor activity needs, the schedule, the budget as well as the living situation. Such consideration, as the comparison of both studies shows, is necessary for the different Rec-

ommender Systems approaches to support sustainable consumption [180], the ranking of items and motivators, and information visualization.

13.2.2.3 Facilitate Learning with Accessible Information Moreover, our results emphasize how Recommender Systems can facilitate learning about the infrastructures, materials, and entangled values and properties. Our participants (sections 10 and 11) were particularly interested in the measurement of sustainable consumption and the related options in the prototypes. Although all consumers had some knowledge about sustainability, it turned out that some properties are hard to understand. For example, carbon emissions are a well-known unit, but still, it was hard to weigh their importance. Moreover, the algorithms of both prototypes were perceived as non-transparent when it came to measuring sustainability. Thus, designers should use transparent and learnable mechanisms and units rather than repeating the current non-transparent approaches [195].

Moreover, to support learning and transformative developments through the usage of such prototypes, consumers should be more involved in defining the necessary units and algorithms. This design space directly relates to the work of Herbig et al. [156], which also found a particular need for the democratization of profiles. While for some consumers, it is just fine to pass this work on to a trusted organization, others want to understand and manipulate the details. Engaging in end-user development [220] of such Recommender Systems could be an interesting perspective. Accessibility, therefore, entails two perspectives, accessing information in the sense of understanding and accessing information as having the opportunity to look behind the curtains of the system and change its underlying assumptions.

13.2.2.4 Towards Open and Reliable Data and Algorithms Although not in the main scope of our research, the evaluations showed how reliable and open data and algorithms are essential for trust and the appropriation of artifacts to support consumption practices. First, open data is needed to get reliable and transparent data on the properties of the different items, e.g., food or bus trips. For the prototypes, the studies (see sections 10 and 11) needed

to rely on crowdsourced data or data from third-party institutions that do not necessarily reflect the actual infrastructures, e.g., when changes occur to the infrastructure, or it is not represented by an average. Therefore, we want to highlight the necessity for open data of goods and services. This goes beyond the scope of technology design but demands a policy that forces producers and service providers to pass reliable data to consumers such that they can make reliable decisions, as already called for by Stevens et al. [331]. The same applies to algorithms, which should be transparent such that market manipulation is prevented. This is repeatedly called for by consumer protection, as consumers need to understand why specific recommendations were made [80, 195].

A further perspective, especially for decision-makers and consumers, is the sharing of local data — for example, data on the local food sourcing opportunities, environmental pollution, or collective achievements. By providing and sharing such data with the producers and service providers, a ”mutual exchange between a wide variety of stakeholder groups [...] [and] participative innovation processes”[233] could be fostered.

13.2.2.5 Recommender Systems between Collective and Individual Responsibility Besides the presented implications for designing Recommender Systems to support sustainable practices transformations, we want to take up the critical perspective of both design case studies. ”In line with the critique on the neo-liberal agenda that burdens consumers with the transformation of the society towards sustainability [29, 129], our system does not account for the responsibility of other agents such as producers or the government”[214]. In line with this, consumers of both design case studies expressed mixed feelings about their responsibility for transforming society and the market. This was, in particular, evident in the mobility case (section 11), where participants hardly saw any opportunity to appropriate sustainable practices. Here, other stakeholders are requested to provide those opportunities.

Thinking such systems from a broader perspective, which entails open data exchange between stakeholders, the democratization of algorithms, and more

community engagement, could offer not just a small contribution to a multi-faceted strategy to cope with environmental problems but support the collective articulation of transformational needs. ”This [...] may represent an opportunity for developing ICT that articulates community focus around matters such as sustainability, enabling people to not only ‘share’ but to demonstrate that they ‘care’ and that they hold each other accountable for caring [19]”[233].

13.3 Methodological Reflection

In this last section of the discussion, the methodological approach will be in focus. This is necessary as the selection of methods in the different studies, as well as the interpretative focus on practices as networks of personal and shared elements, has a particular influence on the results.

13.3.1 Narrative Interviews to Reflect on Consumption Practice Transformation

While most sustainability research in Information Systems and HCI focuses on unsustainable practices to derive meaningful design requirements, this thesis adapts retrospective interviews. This perspective was already applied by Twine [355], who researched the vegan practice transformation from such a retrospective perspective. Also, Hasselqvist et al. [150] deviate from the known scheme by following consumers through their simulated journey.

This methodological approach, nonetheless if it follows the journey or focuses on retrospective experiences, has one main advantage: It enables the researcher to get a holistic overview of transforming consumption practices, rather than limiting the perspective to the narrow view of unsustainable consumers. In light of this dominant empirical approach, it is not surprising that persuasive design and gamification are still popular approaches, although their long-term influence is relatively small [52, 91, 229, 301, 302]. The ordinary consumers interviewed for such research are usually easy to access as a sample, and an increased motivation can be measured after a certain period of time. Nonetheless, such research neglects the continuous co-evolution of

practice transformations and leaves consumers unobserved and alone with the other practical challenges. Here, taking a retrospective perspective uncovers the next steps along the journey and reveals the requirements for artifact support after the change is unfrozen.

Still, retrospective interviews need to be critically assessed and analyzed, as the consumers need to report on an extended period and a complex journey. Therefore, not all details might be ready at hand during the interview, arrangements of practice might be transfigured, or experiences may be influenced by community stories. Taking such a perspective, therefore, comes with a lack of data quality and reliability that should be considered. An alternative would be the experiment conducted by Hasselqvist et al. [150]. However, simulating a journey is, on the one hand, very time-consuming and, on the other hand, yields the danger of manipulating the journey through the experimental setup.

13.3.2 Network Metaphor

Another methodological, or somewhat analytical decision to be considered, is the use of the network metaphor for consumption practices, as introduced in section 5. This metaphor and the respective operationalization as a model is based on the research of Shove et al. [312], Nicolini [248] as well as Higginson et al. [160, 161]. This lens also comes with its unique advantages and disadvantages.

On the one hand, using a network metaphor supported the empirical research in section 6 and section 7 by allowing to focus on the dynamics [312] as well as the unique elements of practices and their relation to the artifacts. But also, for the later design case studies, a focus on network elements supported the comparison of the two prototypes by allowing to bring the themes to a common level of abstraction. On the other hand, this perspective and the rather detached perspective on the themes might be less intuitive for the reader of this thesis. Moreover, as already considered by Schatzki [295], such a lens might lead to too simplistic models of social life and practices. Such simplification comes with potentially less focus on connections and broader themes. Still, “thinking critically about how one might model practices and experimenting with different approaches is in itself a valuable aim”[161], which

supports the design practice itself. In line with this statement, we can only emphasize that this lens on practices has been beneficial to this work and has allowed us to gain our own understanding of the issues.

Regarding the design of the Recommender Systems prototypes, the similarity between items in the Recommender Systems world and materials in the practice world is quite apparent. Thereby, the recommendation of these items is directly related to the identified opportunities for design (see section 5) in the form of 'structural holes' [54, 55] and central-connecting elements. The prototypes as a central artifact on the smartphone support the appropriation of new elements that fill those gaps and thus stabilize the network. Besides the design itself, the lens also supported the evaluation. The network metaphor emphasized: "interdependencies, connections and configurations that are central to the constitution, reproduction, and transformation of social life"[41]. In this way, the lens helped to understand the broader implications of the prototypes for (re-)configuring not just the material context but its connection and dependence on meanings and competencies.

13.3.3 Studying Appropriation of Artifacts in Consumption Practice Transformation

Lastly, the focus is on studying appropriation in the two presented design case studies (see section 10 & 11). Studying the appropriation of artifacts to understand their suitability and usefulness in everyday practices is a well-known and often used lens [333]. Still, for consumption practices, we recognized some issues during the reflection on the conducted studies.

Foremost, consumption practices, with their different values, restrictions, goals, and personal situations, are complex and diverse. Given this observation, it seems that a prototype, as well as the sample of participants, can hardly account for such diversity. This was prevalent during the design phase, where inclusion of all requirements and a consideration of all perspectives was time-consuming and just not realizable for any of the two prototypes. In particular, when the goal is to provide a personalized experience with the artifact and holistically consider the properties of the consumers' practices, any shortcut taken or any simplification endangers the appropriation due to a

mismatch. Still, for reflection and productive conversation about the artifact, such mismatch does not seem to be a barrier. Nonetheless, it is a factor to consider for future research on consumption practices and practice-sensitive data-driven prototypes — design simplifies practices, quite similar to the network metaphor, and thus cannot fully account for those.

From another perspective, it is the sample itself that is quite difficult to recruit. As argued, practice transformation is a complex co-evolution of practices and artifacts. Therefore, each artifact plays a distinct role that complements the current state of the practice network throughout the transformation. Thus, the selected sample might not have established a need for the artifact or already resolved the tension that the artifact is meant to resolve and therefore responded with little demand. Such a difficulty or even trap of sampling is observable for the two design case studies. In the mobility context (section 2.2 the samples' practices are still stable with the car in the center, which is a barrier to unfreezing change.

Similarly, for the food context (section 10), the selected evaluation sample already engaged in critical consumer practices and thus established new material routines. Therefore, the need for such an artifact was limited as it did not fully complement the current state of practices. Still, both studies showed that fruitful conversation and reflection are possible. But based on the current perspective and knowledge about practice transformations, a more sensitive sample selection procedure could have contributed to better results and a more nuanced reflection on appropriation over time.

14 Conclusion

14.1 Summary of the Thesis

This thesis contributes to sustainable design, especially the design of sustainable recommendations, by researching the transformations of everyday consumption practices. Against this background, this thesis is split into four parts:

Part I introduces the basic motivation, concepts, and methods of this thesis. In section 1 we introduced the basic motivation for sustainable consumption practices against the practical problem of climate change and broader sustainability issues. Moreover, we focused on explaining how the three fields of Consumer Informatics, Recommender Systems, and Practice-based Computing are entangled in the research of this thesis. In line with these fields, section 2 introduces the relevant context of this thesis and provides an overview of the state-of-the-art research in these fields. Thereby, we focused on practice theories as the theoretical foundation of this thesis, sustainable consumption, and Recommender Systems to support sustainable consumption. Lastly, section 3 provides an overview of the research framework used as well as introduces the specific research activities for empirical pre-studies, the technology design phases as well as the evaluations. Moreover, the subsequent parts and chapters are mapped to the research questions and the phases of the research framework *design case study*.

Part II presents one of the main parts of this thesis and directly refers to the empirical pre-study phase of the design case study framework. Here, we present three research papers that lay the empirical foundations as well as theoretical perspectives for the subsequent studies. The focus of section 5 is on a theoretical understanding of the dynamics and interconnections of consumption practices. This lens is helpful to develop further an analytical understanding of how consumers appropriate consumption practices in the subsequent sections 6 and 7. Thereby, section 6 picks up the perspective of vegans and investigates their consumption practice transformation and the respective role(s) of ICT artifacts.

Similarly, section 7 uses the network theoretical perspective on consumption practices to examine the role(s) of ICT artifacts in multi-modal mobility practices and their appropriation. To not just provide a narrow perspective on the individual consumption practices but compare the findings towards a more generalized understanding of how consumers appropriate sustainable consumption practices, we discuss the similarities and differences in section 8. Here, the focus is on using the network theoretically informed idea of practices to find a common language between both studies and allow for an in-depth understanding of how elements are appropriated, substituted, interconnected, and dynamically changing.

Part III presents the second central part of this thesis and directly refers to the technology design as well as evaluation phases of the design case study framework. In this part, the theoretical as well as empirical perspectives of the previous part, are taken up to design and evaluate two recommender system prototypes. Section 10 deals with the design and evaluation of a Food Recommender System that considers the ethical implications of food consumption, as well as considers the properties of consumer practices more broadly. Taking up a different approach of 'nudging' in Recommender Systems (see 2.3 for more details) section 11 presents the evaluation of the EcoMobil prototype. Here, eco-feedback mechanisms are incorporated into the design of a multi-modal Mobility Recommender System. Again, the results of both studies are compared from a practice theoretical perspective that highlights the interconnections and network-like structure of consumption practices (section 12. Here, we draw on the connections of material elements (near materials and shared materials [infrastructures]) with other elements. Here, the Recommender Systems are considered a mediator of such relations.

Finally, this part, **part IV** of this thesis, discusses the overall design case study approach of this thesis. Here the focus is on *ICT Supported Consumption Practice Transformation*, *Recommender Systems Supported Consumption Practice Transformation*, and a *Methodological Reflection*. Moreover, this conclusion belongs to the part.

14.2 Contributions

Now that we have provided a short summary of the chapters of this thesis, we want to refer to the areas of contribution as introduced in section 1.2 and reflect on the contributions of this thesis. Thereby, the three fields are examined separately. However, given their entangled nature, the main contribution of this thesis lies in the combined perspective of the three fields.

In **Practice-based Computing**, in particular, those studies focusing on consumption practices, the focus is usually on researching unsustainable practices to derive implications for the design of artifacts (see, e.g., [117, 141, 329, 301]). This perspective, however, does usually consider re-configurations of practices, but lacks a perspective that provides an overview about the practice transformation from end-to-end. Here, this thesis makes two contributions. First, an empirical contribution by providing an ethnographic reconstruction of practice transformation journeys as well as an understanding of requirements (sections 6 & 7) and an evaluation of the designed artifacts (sections 10 & 11). Moreover, the ethnographic reconstruction is adapted from social sciences (see, e.g., [356]) and adapted to be used within HCI/IS research, making it a methodological contribution. From a theoretical/methodological perspective, also the use of computational methods (network theories), see section 5, to visualize and understand practices can be seen as such a contribution.

Regarding **Recommender Systems**, this thesis does not contribute by presenting completely new algorithms that provide better results in experimental settings, nor does it aim for such a contribution. The empirical contribution lies in the understanding of Recommender Systems to support consumption practices with a Practice-based Computing lens in mind. Here, the thesis directly refers to the nudging mechanisms [180] commonly used in Recommender Systems research to promote sustainable consumption. On the one hand, this thesis shows that from a practice theoretical perspective, such systems can play an essential role in the appropriation of the often material-focused consumption practices. On the other hand, it shows how nudging itself is limited by the broader material context and its complexity. This perspective, especially, has not been considered by Recommender Systems

research so far, as the focus is somewhat more experimental than grounded in real-life scenarios. On a more detailed level, both artifacts contribute by providing implications and critical discussions about the design of personalization [195] and practice-consideration in Recommender Systems for the ranking of items itself (section 10) and supportive visualizations (section 11) that help consumers make sense of the presented items.

Consumer Informatics is an emerging field of research that is closely connected to Consumer Sciences and Information Systems [372]. The underlying premise of this field is that the pervasive nature of artifacts does transform not only the industry but also private households and their consumption practices [330]. While Consumer Informatics aims to understand this transformation holistically, a particular focus is on digitally-enabled sustainable practices and the consumer-centric design of digital artifacts to support these [330]. Here this thesis makes a twofold contribution. First, by focusing on the transformation of consumption practices, especially by uncovering the role(s) of artifacts for sustainable food and mobility practices, this thesis contributes to understanding these digitized consumption realms. In this context, the consumer-oriented lens shows that many assumptions of intervention-oriented IS/HCI focused on the wrong problems and left consumers alone with the difficulties of learning new practices and accessing appropriate infrastructures. In addition, the design focus of this research, which is reflected in the two design case studies, contributes by presenting the requirements of consumers on designing Recommender Systems that support sustainable practices. Although the design focus is narrowly focused on Recommender Systems, the results are generalizable towards the design of other consumption support artifacts. Besides these empirical/artifact contributions to the field of Consumer Informatics, the adapted methods contribute to the methodological development of the field. This is, for example, done by adopting narrative retrospective interviews (see, e.g., Twine [356]) that have previously been used in consumer research. This thesis adopts this method not just to derive an understanding of the role of artifacts but to gather requirements for the design of consumer-centric artifacts.

14.3 Limitations & Future Work

Limitations of this thesis arise from several factors. In the following, we critically reflect on those to further discuss how the results of this thesis should and can be understood. Moreover, those limitations exemplify the need for future research.

14.3.1 Qualitative Research Paradigm

As already discussed in section 3, this thesis follows a qualitative research paradigm. On the one hand, such a paradigm and the respective research activities were chosen to overcome the paradox of consumer-centered design, as they support the articulation of requirements for design and understanding the appropriation of practices in more detail. On the other hand, using such activities is in contrast to any confirmatory stance as it is used for the evaluation of late prototypes or to measure specific questions such as usability or energy savings. Given this, this thesis can not make any statements about the general validity of requirements for practice transformations, nor does it provide a representative overview of consumers. Still, given the number of interviews [138], we can assume that the variety of themes identified and presented gives a broad overview of designing for sustainable consumption practices. This overview accounts for the diversity of practices and raises awareness of the design space and possible solutions. Nonetheless, future research should take up those exploratory qualitative results and confirm the observed patterns more broadly. For example, quantitative surveys could help to understand the patterns of artifact usage along practice transformations and explain their influence on the appropriation of sustainable consumption practices.

14.3.2 Sampling Approach

Besides the research paradigm as the overall scheme of conducting this thesis, single research activities and their unique decisions limit this research. Although there are probably multiple smaller decisions that affected the out-

come of this thesis, we want to focus on one main problem — the sampling of participants. This issue was already discussed in section 13.3.3.

The pre-studies in sections 6 and 7 sampling approach focused on consumers who successfully conducted their practice transformation. This approach, on the one hand, has the advantage that the consumers can oversee the entire transformation journey and, therefore, can provide a broad understanding of the difficulties, artifact usage, and other experiences. On the other hand, specific events may have already been forgotten, patterns might be transfigured, or explanations are given based on community narratives. While this is not necessarily problematic and can be understood as a feature of the subjective reconstruction of practice transformations, we should keep this in mind when making sense of the results.

For the evaluation of the artifacts in sections 10 and 11 a quite similar issue arises. Here, the difficulty was to evaluate the prototypes with consumers that reached the right 'stage' of the practice transformation. Although the term stage might be misleading, as we prefer the description of a dynamically co-evolving network, it helps to understand how consumers might not yet need an artifact (probably the case for section 11, or do not need the artifact anymore (see section 10). Given this understanding, we see how difficult it might be to find the right participants for such a complex transformation of consumption practices. Still, consumers were able to reflect on the artifacts fruitfully.

Summarizing both 'timing' issues, it seems that taking an approach that follows the consumers on their transformation journey (see, e.g., [150]) might be better suited for this particular theoretical lens. Still, this comes with the effort of continuously observing consumers such that the timing problem decreases as much as possible. Moreover, a contradiction arises as the design should be based on the experiences of sustainable consumers as they provide better accounts for upcoming difficulties, while the evaluation should be continuous. Bringing both approaches into one research project seems nearly impossible, given time and budget restrictions. Therefore, more research on how to research practice transformations and evaluate artifacts within such context is needed.

14.3.3 Designed Artifacts

Lastly, a limitation of this research arises from the selection of artifacts and the chosen design focuses.

First, this thesis is limited by the focus on Recommender Systems, although we elaborated on their role in materially-shaped practices and recommendations as one significant commonality of consumption practices. Still, the results of part II could have been analyzed towards design implications for designing consumer communities or motivational approaches. Given this narrow focus on specific artifacts in the later design (part III), future research should take up the results of part II and more strongly investigate what we can learn for the design of other ICT artifacts within the different role(s) researched.

Second, the focus on Recommender Systems itself is limited by the fact that not all approaches to nudge or support sustainable consumption could be implemented, given their sheer number (see Jesse et al. [180]). Within the research, we came up with the used approaches by co-designing the artifacts with consumers who are experts in their own practices but have limited knowledge about the psychological effects of such design, their evaluation in prior research, or all technical opportunities arising from new data-driven approaches. For this reason, the results are rather selective and cannot be generalized to all Recommender Systems approaches. Nonetheless, we want to highlight how both approaches cover the most common abstract types of promoting sustainable consumption and reflect the requirements of the participating consumer. Still, designing other approaches with consumers and evaluating them in practice-based settings might contribute to even better designs and a Recommender Systems design theory at the interaction of the technology and practice theories that goes beyond optimization and psychological approaches.

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