MASTER THESIS

Human-centred design for sustainable behaviour change: Research, design and evaluation of a mobile application

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Abstract

In this master's thesis on design for sustainable behaviour change, two research goals are addressed. Firstly, it is investigated how to design a mobile app that encourages people to take on sustainable actions across different areas of life (e.g. nutrition, mobility, waste). Secondly, it is investigated, to what extent such an app can support people in taking on more sustainable actions. The theoretical basis is the Theory of Planned Behaviour which is used as a general framework to understand and evaluate behaviour change. The app is designed in a human-centred approach addressing the user needs of the target group of young, sustainability-minded people. The designed app assigns high control to the user and supports through the design strategies of eco-information, eco-choice, eco-feedback, eco-spur and community elements. At the core of the app are sustainability challenges in which users participate, collaborate and compete in a community environment and receive targeted, personalised feedback and tips.

In a two-weeks field study, the app is tested with 30 target users.
The analysis shows that, during the usage phase of the app, participants acted statistically significantly more sustainably with regards to the self-reported behaviours "nutrition", "tap water consumption" and "shower time" as compared to the pre-study measurement. Users' positive attitudes towards acting sustainably and their perceived behavioural control also statistically significantly increased. In particular, their awareness of potential sustainable activities to take and their knowledge about their impact on the environment increased.

Limitations of the study include the usage of non-validated questionnaires and self-reports, a small and highly homogenous test group and technological immaturities of the app that might have impacted the user experience. In the future, field studies should be expanded to more areas of life (e.g. travel, finances) and should be applied to a larger user group and over a longer period of time to investigate long-term effects of the usage of a sustainability app on behaviour change.

Acknowledgement

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Finally, I want to say thank you to Futury, the company that encouraged me to pursue the topic of design and sustainability for this master's thesis and who pushed my team and me to develop our app and business model. And, of course, a big hug and thanks go out to my team *Budge* for working together on our vision to encourage people to a more sustainable life.

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1 Introduction

Nutrition, shopping and consumption, energy and water usage patterns and mobility and travel decisions are just a few examples of daily life choices that define the degree of sustainability of our lifestyle and, in particular, our ecological footprint[1]. More and more consumers become aware of their responsibility to consume sustainably and are rethinking their lifestyle [1], [2].

At the same time, mobile-first applications supporting real-life behaviour change and habit creation are becoming more popular such as in the field of sports, nutrition or language learning. Smartphone usage in the German market reached a record-high of 73.18 million users in 2019 which amounts to more than 88% of the population [3]. In the year 2018, for the first time, more people used the internet through the smartphone (74% of internet users) as compared to the desktop (73%) [4]. For younger generations, the smartphone is of even more importance: mobile-first apps like Instagram or TikTok are highly popular and are meant to be used on the smartphone primarily. Designing a mobile app thus ensures leveraging current trends and the opportunity to be ubiquitous and accessible to the user wherever and whenever he or she desires.

This master's thesis connects the dots and explores how a mobile application designed in a human-centred way can support the challenging process of behaviour change towards more sustainable and pro-environmental behaviour. In the design process of the app, a holistic approach is taken to encourage and support sustainability-minded individuals in their sustainable behaviour change attempts across different lifestyle areas like nutrition, water usage and mobility. More concretely, the aim of the thesis is to develop a mobile app encouraging sustainable behaviour change. How might such a mobile app look like that encourages people to take on sustainable actions across different areas of life? And to what extent can this app support users in taking on more sustainable actions?

In the following sections, the researcher's motivation to write this master's thesis is explained (Section 1.1), the concrete problem statement and research objectives are presented (Section 1.2), the research questions are defined (Section 1.3), definitions for terms and concepts are given (Section 1.4) and the remaining thesis content is outlined (Section 1.5).

Part of the content of this thesis is adapted from the Research Topics report *"The user's perspective on design for sustainable behaviour change"* by Naima Volz, an internal report handed in at the University of Twente.

[1] Definitions are listed in Section 1.4.

1.1 Motivation

In this paragraph, it will be introduced why the topic of sustainability is so pressing and which role design could play to achieve more sustainable behaviour change among individuals.

In view of climate change and its consequences, the demand for sustainability and sustainable actions have gained unprecedented traction in recent years. On a societal level, the awareness and willingness to demand action from governments and the economy have gained momentum with the "Fridays for Future" school strike for the climate. At its peak in August 2018, the movement united 6 Million attendees across 4,500 locations in 150 countries to protest for climate action [5].

On a governmental level, in November 2019, the European Union presented the European Green Deal, a package of measures and policies aimed to turn Europe into the world's first climate-neutral planet by 2050. At least €1 Trillion (€1,000,000,000,000) of investments into a climate-neutral, competitive, inclusive and circular economy are to be allocated over the next 10 years towards this objective [6].

Sustainability and sustainable action[2] are required more urgently than ever as the global warming target compared to pre-industrial times lies at 1.5°C and already now, a warming of 1.0°C has been measured. The target of 1.5°C is on the one hand required as it reduces the – already dramatic – extent of climate risks compared to a 2°C global warming on parameters like extreme weather, species extinction, water availability and sea-level rise (see Figure 1) [7]. On the other hand, global warming of more than 2°C can cause so-called 'tipping points' of climate change – irreversible points of no return, causing dramatic chain reactions. A tipping point can be a small change which makes a big difference as it creates a disruptive, sudden change through breaching critical ecological thresholds [8].

[2] see section 1.4 for definitions

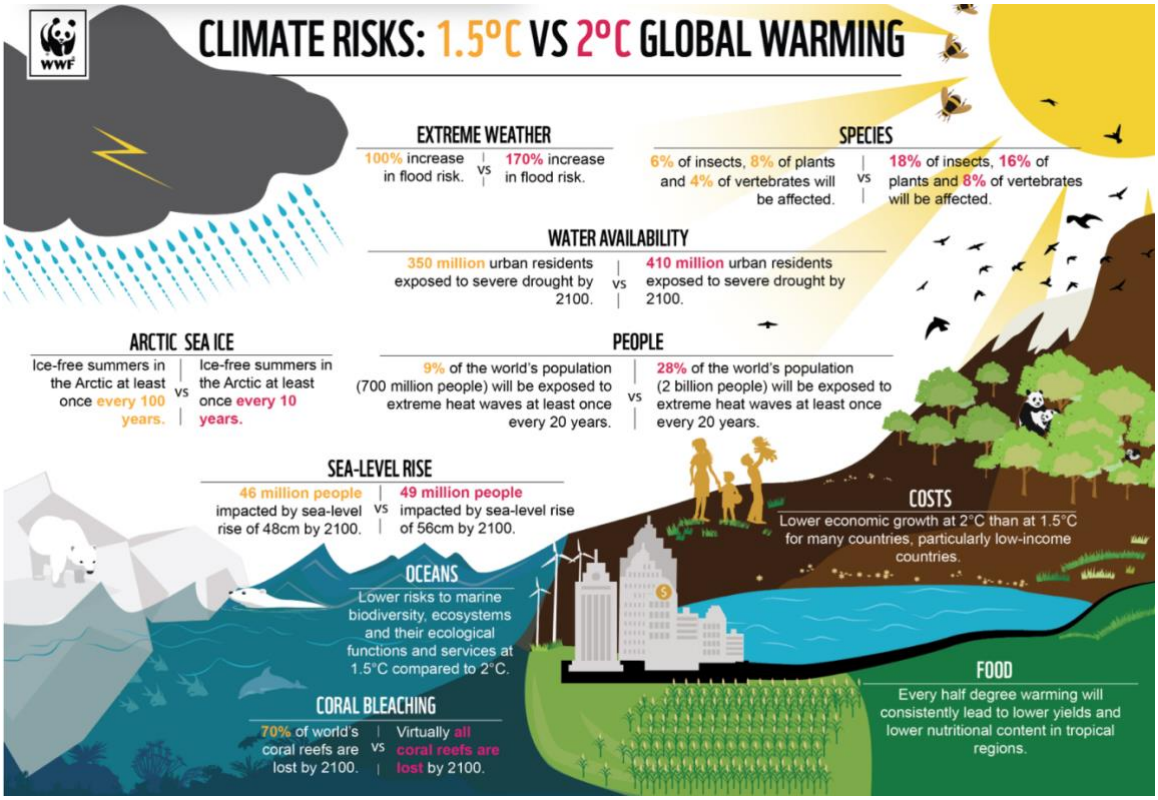

Figure 1. WWF: Climate Risks of 1.5°C compared to 2°C global warming. [7]

According to WWF, it follows that action has to be taken now by policy decision makers and individuals alike to keep the global warming target at 1.5°C:

> *"Political leadership is important. So are individual choices. Strong leadership and the right choices can lead to the necessary rapid and deep cuts to greenhouse gas emissions, which improves the chance of limiting warming to 1.5°C."* [7, p. 1]

In this master's thesis, the focus lies on the importance of *individual* choices and the support in *individual* behaviour change. The behaviour of individual consumers plays a vital role to achieve environmental sustainability as the degree of sustainability of a society is influenced by the way its citizens are purchasing, using, processing and discarding products [9], [10]. Individuals choose which products or services they buy and thus whether they contribute to less sustainable industries or business models (e.g. fuel cars) or more sustainable ones (e.g. electric cars). The way users choose to *interact* with a product or service can also have a significant impact on the climate, for example through the reduction of water usage, energy usage or choosing more sustainable mobility alternatives [11]. Concrete exemplary activities for positive individual choices are illustrated in the United Nations Environment programme's "Anatomy of Action" (Figure 2) [12]. They target food ("food"), consumption ("stuff"), mobility and travel ("move"), financials ("money") and positive activism ("fun").

Figure 2. The "Anatomy of Action" by the UN Environment Programme. Image taken from [12]

The role of design in this picture is to leverage its capabilities of supporting people or nudging them to change their behaviour. In this context, design is not about "how things look" or how the User Interface is set up, instead, it is about creating the whole user experience of a product, to design for the perception and receptions that a person experience through using or anticipating to use a certain product, system or service [13]. When applied to the context of behavioural change, design can be applied to shape or influence human behaviour for health, safety, social benefit or commercial success. It can also be applied to achieve the user's uptake of sustainable product and service innovations and behaviours [14]. Triggering such sustainable actions through design has in the past been highly beneficial for the environment (e.g. [15], [16]). More concretely, the behavioural design has supported changes in the consumer's mindset and behaviour towards more sustainability in various areas of life such as nutrition [17], [18], [19], environmental behaviour [20] and general consumption behaviour [21].

The design for sustainable behaviour approach has in the academic context mostly been applied to specific behaviours (e.g. showering) and particular devices (e.g. shower timer), but it has so far not been investigated how a single mobile application might encourage behaviour change across many areas of life (e.g. nutrition, waste, mobility) [20]. There seems to be an excellent opportunity to address large-scale sustainable behaviour change of individuals using a human-centred design approach.

While the role of design for sustainable behaviour can play a crucial role in the uptake of more sustainable actions, there are also economic initiatives emerging that are aiming to increase awareness for sustainability topics and build new innovations and solutions that support the sustainable development process. One of those initiatives is the Open Innovation program "The Mission" organised by the German company Futury[3]. Futury is an innovation and venturing platform that connects entrepreneurial talents with leading companies. The program "The Mission" is a large-scale program for a "sustainable future" that wants to bring sustainability into business in 12 different fields of the industry. One of the project teams of "The Mission", that consists of four students including me as the author of this thesis, aims to develop a business and a mobile app around "sustainable consumption" in cooperation with the corporate partners Deutsche Bank, Kaufland and Bain & Company.

The project team consists of four members. My role as the author of this thesis is Product Management and UX Design, including User Research. In more detail, I am fully and independently responsible for preparing, conducting and analysing the user interviews, user tests and questionnaires, creating personas and user journeys, content research and writing, producing wireframes and the visual design. Two team members are working on tasks that involve business development, project management, marketing and communication. The fourth team member is a developer, and his core contribution is the development of the functional high-fidelity prototype based on the wireframes (Section 3.5). Other team contributions relevant to this thesis are the research of competitor names in the sustainability sector (Section 2.3) and the assistance during qualitative interviews and synthesis in the user research process. Figure 12 visualises the whole design and development process conducted for this thesis. The process steps were all undertaken by me as the thesis researcher. The exception is the development of the high-fidelity prototype, which was programmed by the developer on the team.

The project goal for the team is to develop a mobile app from scratch that encourages the sustainable behaviour change of its users in a human-centred way. At the same time, the business idea should be backed by a viable business model. This master's thesis should, therefore, be seen as a thesis at the intersection of academic research and practical implementation through a mobile app backed by a viable business model.

[3] "The Mission" website by the company Futury: https://www.futury.eu/programs/the-mission

1.2 Research Objectives

Changing the consumer's mindset and behaviour towards more sustainability is relevant for various life areas such as nutrition [17], [18], [19], environmental behaviour [20] and general consumption behaviour [21].

As mentioned in Section 1.1, the research on achieving more sustainable behaviour through design has mostly been focused on addressing single behaviours like "showering" [22]. The research objective is to explore how a mobile app designed in a human-centred approach, can support people in making more sustainable choices and acting more sustainable *across different life areas* (e.g. nutrition, mobility and travel). It will, therefore, be investigated, to what extend one single mobile application can address different pro-environmental behaviour categories at the same time.

Academically, the objective is to investigate how an app encouraging sustainable behaviour change across different life areas should look like (addressed by RQ1). For this purpose, the app needs to target users' needs and pain points. The app should also showcase high usability and user experience. However, neither good usability nor user experience is sufficient to judge how successful an app targeting behaviour change might be. Instead, it also needs to be evaluated, to what extent the app can trigger behaviour change when used in a real-life setting (addressed by RQ2).

As stated in Section 1.1, further business objectives are guiding this thesis. The business objective is to develop a mobile application that encourages more sustainable behaviour in general and more sustainable *consumption* in particular while allowing for a *viable business model*. In an initial briefing with the stakeholders from Deutsche Bank and Kaufland, it was decided to explore the opportunity of "sustainability challenges" for the app. Sustainability challenges can be seen as similar to challenges known from the fields of sports applications (e.g. "Do 10.000 steps a day"), nutrition (e.g. "No carbs for a week"), language learning or even leisure (e.g. the "Ice-bucket challenge"). With the corporate stakeholders, it was, however, not further discussed, how these challenges should look like in detail or which further features might be required from a sustainability app.

1.3 Research Questions

Based on the problem statements and research objectives, two research questions were formulated to guide this master's thesis.

> *RQ1: How might we design a mobile app that encourages people to take on sustainable actions across different areas of life?*

Sub questions that should be answered to address Research Question 1 are the following ones:

- *Sub question 1: Which user behaviour, needs, pain points and goals should be considered in the design process?*
- *Sub question 2: Which design strategies might be appropriate when designing a mobile app that targets sustainable behaviour change across life areas.*
- *Sub question 3: Which kind of user experience, and which features should an app have that encourages people to take on sustainable actions across life areas?*

Sub-question 1 will already be answered during the Exploration phase of the user-centred design process as this is the baseline for future design decisions (see Section 3.2.3 for details). Sub question 2 and 3 will be answered in the final results for Research Question 1, which are presented in Section 5.1.

Research Question 2 evaluates how the designed mobile app can encourage users to act more sustainable in daily life:

> *RQ2: To what extent can a mobile app support people in taking on more sustainable actions across different areas of life?*

The research questions will be answered in the respective sections in the results chapter (see Chapter 5) and discussed in the discussion chapter (see Chapter 6).

1.4 Definitions

This section aims to define terms frequently used throughout the master's thesis.

Sustainability

Sustainability is a concept defined differently depending on the literature. In this thesis, the definition of sustainability is derived from the United Nations' Sustainable Development Goals (SDGs), which were adopted by all UN Member states in 2015 (see Figure 3).

Figure 3. The 17 Sustainable Development Goals defined by the UN. [23]

Sustainable development stands for development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [24, p. 1]. The objective of the SDGs is to achieve "shared prosperity in a sustainable world—a world where all people can live productive, vibrant and peaceful lives on a healthy planet" [24, p. 1]. The 17 SDGs can all be allocated around three interconnected areas that have to be harmonised to achieve sustainable development: economic growth, social inclusion and environmental protection. Sustainability refers to an inclusive, sustainable and resilient future for the planet. Additionally, it strives for a positive future for the people, too. "Sustainable actions" are mandatory to keep this planet healthy and therefore the life on it worthy for all its inhabitants.

The broader vision of this master's thesis research is to achieve environmental, social and economic sustainability and trigger behaviour change affecting all those areas. However, due to the limitations of this paper, the focus shall lie on *environmental sustainability*. The following sustainable development goals are mostly addressed: Responsible consumption and production (Goal 12) and Climate Action (Goal 13). Further impacted are the sustainability goals Life below water (Goal 14), and Life on land (Goal 15).

In the remainder of this master's thesis, the word 'sustainability' and 'environmental sustainability' shall be used interchangeably both standing for the concept of environmental sustainability. Where applicable, social and economic sustainability with be explicitly mentioned.

Ecological footprint

WWF defines the ecological footprint as "the impact of human activities measured in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated. More simply, it is the amount of the environment necessary to produce the goods and services [required] to support a particular lifestyle." [25] As such, the ecological footprint can be seen as a measure of sustainability because it makes transparent how much resources a country or human consumes as compared to how much is available and would be recovering naturally (e.g. through carbon sinks[4]).

Pro-environmental behaviour

Pro-environmental behaviour (PEB) is "behaviour that harms the environment as little as possible or even benefits the environment" [26]. Pro-environmental behaviour can be seen as the 'target behaviour' to achieve with the sustainability app. It is used interchangeably with "sustainable behaviour" in this thesis as the sustainability focus lies on environmental sustainability.

Sustainable behaviour

Sustainable behaviours are deliberate and effective actions that lead to the conservation of natural resources and social resources. As further described in [27], "it encompasses pro-ecological, frugal, altruistic and equitable behaviours. These behaviours allow the conservation of the natural environment and the protection of the integrity of society". In this thesis, the focus lies on the "conservation of natural resources" rather than social resources.

Design

In this thesis, "Design" is understood as an abbreviation for human-centred design. It entails both User Interface (UI) and User Experience Design. As such, "design" as defined in this thesis is not just about "how things look" or how the User Interface is set-up. Instead, it is about creating the whole user experience of a product, to design for "the persons' perceptions and receptions resulting from the use and/or anticipated use of a product, system or service" [13, p. 17].

[4] A carbon sink is any natural reservoir that absorbs more carbon than it releases, and thereby lowers the concentration of CO2 from the atmosphere. Globally, the two most important carbon sinks are vegetation and the ocean. [101]

Human-centred design (process)

The human-centred design process as defined by the International Organization for Standardization (ISO) [13] is a systems design and development approach focusing on the (user) interaction with the system to increase usability and user experience. In the human-centred design and development process, the user is involved throughout the whole design and development process.

User experience

The International Standard Organisation describes user experience (UX) as a "person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service". [13] Included are the users' emotions, beliefs, preferences, perceptions, psychological responses, behaviours and accomplishments.

Usability

Usability is the 'extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.' [13]

Design for sustainable behaviour (DfSB)

When design for behavioural change is applied to support the user's uptake of sustainable product and service innovations and behaviours, the design approach is described as Design for sustainable behaviour (DfSB) [28]. Design for sustainable behaviour (DfSB) is a design area which aims to influence user behaviour towards sustainable actions. As such, DfSB has strong connections to both Lockton, Harrison and Stanton's [14] "Design with Intent (DwI)" method for influencing user behaviour as well as the design for sustainability field which aims to achieve more sustainability through design.

Habit and habitual behaviour

Habit is defined as a disposition to perform a particular behaviour that is triggered by an impulse. Habitual behaviour is the learned behaviour following a given trigger, and it is "frequently repeated, has acquired a high degree of automaticity, and is cued in stable contexts" [29].
The process of breaking and forming habits plays a crucial role in behaviour change.

1.5 Thesis Outline

This master's thesis describes the research, design and evaluation process of a mobile app that aims to facilitate sustainable behaviour change. The thesis is structured into the chapters introduction (Chapter 1), background (Chapter 2), design (Chapter 3), field study set-up (Chapter 4), results (Chapter 5), discussion (Chapter 6) and conclusion (Chapter 7).

In more detail, Chapter 2 gives an overview of the literature on behaviour change (Section 2.1), design for sustainable behaviour (Section 2.2) and the state of the art of digital applications that aim to encourage sustainable behaviour change (Section 2.3).

In Chapter 3, the applied, iterative design process of the sustainability app based on the human-centred design process according to ISO (Section 3.1.1) and the design for sustainable behaviour stages "Exploration" (Section 3.2), "Generation" (Section 3.3) and "Evaluation" (Section 3.4) are described. The high-fidelity prototype is presented as the outcome of the design process in Section 3.5.

In Chapter 4, the field-study set-up is described. In the field-study, the developed high-fidelity prototype is tested for two-weeks with 30 test users. The chapter includes a general introduction of the study design and participants (Section 4.1) followed by the detailed methodological overview for Research Question 1 (Section 4.2) and Research Question 2 (Section 4.3).

In Chapter 5, the results of the different applied methodologies are introduced for Research Question 1 (Section 5.1) and Research Question 2 (Section 5.2). For Research Question 1, this includes the results of the in-depth interviews (Section 5.1.1), a post-study survey (Section 5.1.2) and the User Experience Questionnaire (UEQ) findings (Section 5.1.3). Additionally, the re-designed app is introduced as the final outcome of the design and development process during this master's thesis research (Section 5.1.4). For Research Question 2, results of the descriptive analysis and data pre-processing steps are given (Section 5.2.1), followed by the results addressing Hypothesis 1 (Section 5.2.2) and Hypotheses 2-4 (Section 5.2.3).

In Chapter 6, the results are discussed. Section 6.1 focusses on the discussion of Research Question 1 by first providing an answer attempt (Section 6.1.1) and then introducing limitations (Section 6.1.2) and future work suggestions (Section 6.1.3). In section 6.2, Research Question 2 is answered and discussed (Section 6.2.1), and the related limitations (Section 6.2.2) and suggestions for future work are explained (Section 6.2.3).

In Section 6.3, the general discussion reflects on the overall results found in this master's thesis, compares them to the literature (Section 6.3.1) and introduces overall limitations (Section 6.3.2) and future work recommendations (Section 6.3.3).

Chapter 7 draws a final conclusion.

2 Background

In this chapter, the relevant theory that serves as a baseline for the design of an app targeting sustainable behaviour change will be introduced. Firstly, an introduction to the theoretical background of behaviour change will be given (section 2.1). Secondly, the academic literature and practical examples on design for sustainable behaviour will be explained which serve as a baseline for the design strategies and principles applied in this master's thesis (section 2.2). Lastly, an overview of the business context will be given. The focus lies on companies who enable consumers to pay off their carbon-footprint and applications gamifying or rewarding sustainable behaviour change (section 2.3). Section 2.4 concludes the relevant learnings.

2.1 Theory of behaviour change

The theory of behaviour change is essential to answer both research questions. On the one hand, to answer RQ1, designing targeted digital behaviour change interventions requires theoretical knowledge about behaviour change.

On the other hand, to answer RQ2, understanding the theoretical frameworks of behaviour change is crucial. Theoretical frameworks will help to define which constructs could be measured as indicators of behaviour change. Based on these, it becomes possible to derive conclusions on whether the app impacts any of those parameters and thus can potentially have a significant impact on behaviour (change) in general.

In section 2.1.1, the Theory of Planned Behaviour will be introduced, in section 2.1.2 the role of habit and long-term behaviour change will be explained, and section 2.1.3 concludes the relevant learnings from this Section.

2.1.1 Theory of Planned Behaviour

Diverse prominent theories from sociology and psychology aim to explain behaviour and behaviour change. Popular theories are Skinner's behaviourism [30], Bandura's Social Cognitive Theory [31], [32], the Theory of Planned Behaviour introduced by Ajzen [33], the Goal-setting theory [34] and the Dual Process Theory [35].

Among those, Ajzen's [33] Theory of Planned Behaviour (TPB) is the most studied social cognition theory [36]. It is also frequently used in behaviour change research in general and research on digital behaviour change interventions in particular [37], [38], [39]. As a consequence, the Theory of Planned Behaviour will be used as a baseline theory in this paper.

The Theory of Planned Behaviour (see Figure 4) states that intention is the most important predictor of behaviour. Conscious intention to perform the behaviour, in turn, is predicted by a person's attitude, subjective norms and perceived behavioural control (PCB). "Attitude" is defined by Ajzen as the degree to which a person has a favourable or unfavourable evaluation of the relevant behaviour. Subjective norm refers to the perceived social pressure to perform or not to perform the behaviour. Lastly, "perceived behavioural control" (PCB) is defined as the perceived ease or difficulty of performing the behaviour [40]. PCB primarily refers to external and general factors that **cannot** be controlled by the individual but just be *perceived* as easier or more difficult [37].

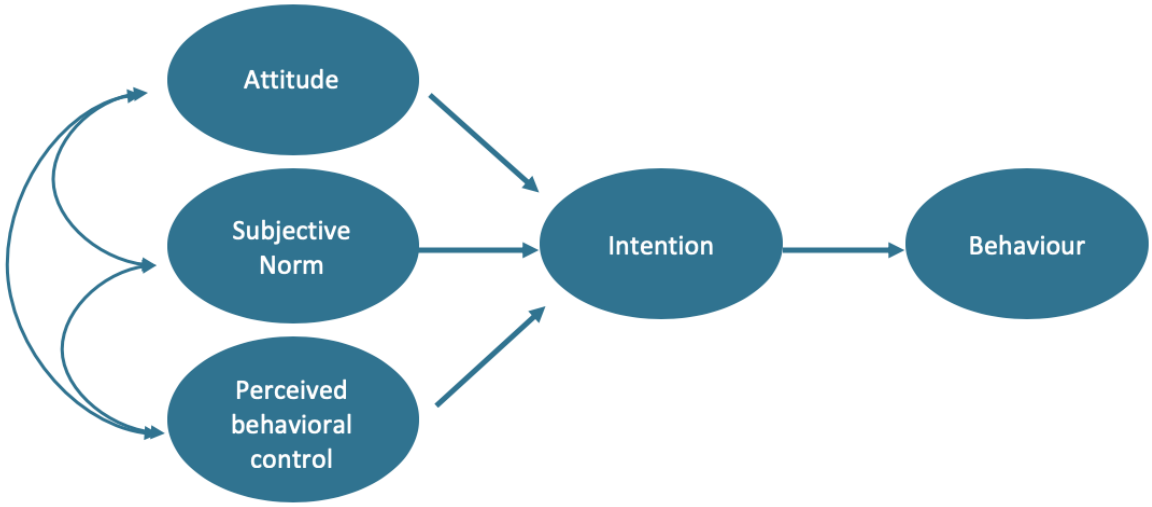

Figure 4. Visualisation of Ajzen's Theory of planned behaviour. It states that intention predicts behaviour. Intention, in turn, is predicted by attitude, subjective norms and perceived behavioural control.

Armitage's and Conner's review [37] on the Theory of Planned Behaviour shows that it can explain changes in behaviour and intention well. The predictor variables *attitude*, *subjective norm* and *perceived behavioural control* accounted for 27% of the variance observed in the dependent variable "behaviour" and 39% of the variance observed in the dependent variable "intention". Also, the perceived behavioural control (PCB) construct explains a significant amount of variation in intention and behaviour. However, the subjective norm construct has found to be only a weak predictor on intention [37]. In the context of sustainable behaviour, the significant findings were replicated supporting the Theory of Planned Behaviour.

The different factors in the model and their implication on predicting sustainable behaviour change will be outlined next.

Attitude

In the context of sustainable behaviour, attitudes are individuals' favourable or unfavourable evaluations [40] of sustainable behaviours. An item measuring attitude in this context could, for instance, be the following statement: *"It is important to me that I follow a sustainable lifestyle."*

Various studies showed that *positive attitudes* towards sustainable actions (e.g. "being vegetarian") correlate positively with the *intentions* to perform the behaviour (e.g. "consume vegetarian food"). Research, for instance, showed that positive views on organic food predicted the intention to purchase such products [38] [39]. Similar findings were established for the consumers' intention to buy sustainable beverage packaging [41] and practising "green", environmental-conscious, tourism (e.g. [42], [43]).

Subjective Norm

Subjective norms in the sustainability context refer to the existence of more or less "perceived social pressure to perform or not to perform" [40] certain actions. An example survey item is the following statement: *"People whose opinions I value would prefer that I purchase green products"* [44].

A significant impact of subjective norms on intention has been shown in various contexts such as technology-use intention [45], organic food purchase intention [38] [39], green hotel revisit intention [43] and environmental conscious consumption [46], [47]. However, there were contradictory results in the literature on the role of subjective norms. In Paul et al.'s study [44] on green purchase intention, subjective norms were not found to be a significant predictor.

Perceived behavioural control (PCB)

Perceived behavioural control (PCB) in the context of sustainable behaviour describes the perceived ease or difficulty of performing sustainable action [40]. In other words, it asks, to what extent a person experiences obstacles or hurdles. An example questionnaire item would be the following statement: *"There are enough sustainable products and services offered."*

PCB positively predicts intention to sustainable actions as shown by several studies. Research has, for instance, been performed in the context of recycling [48], green hotels [43], organic foods [49] and green consumer products [47]. Additionally, Paul et al.'s [44] research on green purchase intention found significant results for PCB in the prediction of green purchase intentions.

2.1.2 Habit and long-term behaviour change

Habit is defined as a disposition to perform a specific behaviour that is triggered by an impulse. Habits are essential to our everyday life. According to a study conducted by Wood et. al [50], participants on average reported that 43% of their behaviour is performed most days in similar contexts with greater automaticity than other behaviours: it is habitual. Habitual *behaviour* is defined as the learned behaviour following a given trigger, and it is "frequently repeated, has acquired a high degree of automaticity, and is cued in stable contexts" [51, p. 374]. Diverse behaviour relevant to sustainability is habitual as well, such as nutrition [17] environmental behaviour [20] and general consumption behaviour. An example of a general consumption habit is that over time, consumers are more likely to purchase similar products from similar vendors, for example, clothes.

As shown, habits are relevant for explaining and thus changing pro-environmental behaviour. Nevertheless, addressing habits is out of scope for this master's thesis because they establish and change over the *long-term*. It is not possible to measure whether habit change is caused by using the application as the user interaction phase of the study is too short and habitual behaviour needs to be assessed over a more extended period of time. As a consequence, RQ2 will not consider habit or the individuals' habit strength. Nevertheless, the theoretical findings on how to break habits can be used to inform the app design strategies.

As discussed in section 2.1.1, the TPB can predict behaviour reasonably well in some cases. However, this is not true for all types of behaviour and context. There are other parameters involved in the prediction of behaviour. This is underlined by the fact that a larger change in intention only causes a smaller change in behaviour. When strong habits are involved, a so-called "intention-behaviour gap" between what people *intend* to do and what they *actually* display as behaviour can be observed [52]. In simple terms, people are more likely to have the intention to "take the bicycle to work" than they are to show the actual behaviour of picking up the bicycle and cycling to the office.

According to Pinder et al. [53], reasons for the intention-behaviour-gap in the TPB model are that the theory omits essential factors relevant to predict behavioural change, for example, habits and emotion. Webb and Sheeran [52] investigated this further. In their meta-analysis of 47 studies, they found that changing intention does not necessarily lead to changing behaviour when a habitual behaviour had already been established. For instance, if a person has the habit of taking the car to work, it will be difficult to change that habit even if the intention "cycling" appears.

Webb and Sheeran [52] also found that the new behaviour was more likely to be performed when the past behaviour was infrequent or was in an unstable context. For instance, the commuting

behaviour might not be habitual when one has just started a new job. Then, the new routine of "cycling to work" would be more likely to be performed.

For the development of a sustainability app addressing behaviour change, the persistence of habits can pose both a challenge as well as an opportunity: Once established, habitual behaviour which may be less sustainable (e.g. heavy meat consumption, commuting by car, taking long showers) is hard to change even when a person has the intention to do so. On the other hand, the opportunity of the persistence of habits lies in the formation of "positive" sustainability habits. Once formed, sustainable habits can then potentially have long-lasting behavioural effects [54]. They can act as the "default" behaviour when people are not able or willing to make conscious, active decisions about how to act [55]. For instance, if the new habit of "cycling to work" instead of "taking the car" has been formed, this new behaviour is more likely to persist even during challenging periods such as rainy or cold seasons.

2.1.3 Conclusion

Section 2.1.1 has shown, that the Theory of Planned Behaviour can partially explain sustainable behaviour through intention and its predictors attitudes, perceived behavioural control and social norm. For answering the Research Question 2 of the master's thesis, one measure to consider is thus the following: To what extent does the interaction with the sustainability app lead to a positive change in attitude, in behavioural control and in the intention to act sustainably?

There are two relevant conclusions about the importance of habits for designing a sustainability app that targets behaviour change. First, techniques from design for sustainable behaviour change (see Section 2.2.2) that consider the need for breaking old habits should be applied. Secondly, the application should encourage and support users in building new, more sustainable habits. For these approaches, previously successful strategies should be used. In the following section, some of these strategies from the research on design for sustainable behaviour change will be introduced.

2.2 Design and Sustainability

In this thesis, beyond just changing behaviour, this behaviour change should positively impact sustainability. The relevant design research field to look at in more detail is thus the field of *Design for Sustainability*, a design discipline aiming at leveraging design for sustainable development. In section 2.2.1, "Design for sustainability" will be briefly introduced with a focus on "Design for sustainable behaviour (DfSB)" (2.2.2) which is the most relevant design research area for this master's thesis. The mentioned research fields are crucial as they introduce concepts, design strategies and successful methodologies to achieve sustainable behaviour change through design which can be applied for the design of the sustainability app in this thesis.

2.2.1 Design for sustainability

Design for sustainability is a sub-discipline of design that can be defined as "a design practice, education and research that, in one way or another, contributes to sustainable development" [56, p. 103]. Design for sustainability can trigger and support innovation, influence materials, products, product-service systems, social organisations, socio-technical systems and ultimately individual and societal behaviour and habits [28].

Early approaches of design for sustainability dating back to the 1990s, namely Green Design and Product Eco-design, have mainly focused on redesigning individual products, on making the whole product lifecycle more sustainable and on extending the lifespan of products. Examples of successful strategies are the reduction of the general usage of material, the replacement of harmful with non-hazardous material and achieving increased recyclability of products [28, p. 12]

Further design for sustainability strategies involve the so-called emotionally durable design (EDD) which aims to increase the emotional connection between a user and the product to delay the product redundancy perceived by the consumer and consequentially the decision of product replacement [57]. Successful design strategies in EDD include the launch of highly unique products such limited series productions, the involvement of the user in customization and co-design activities, and the designing of products that are adaptable or allow capturing memories.

Besides these Design for Sustainability approaches, there are many more diverse approaches such as cradle-to-cradle design, biomimicry design and product-service-system design for sustainability. These approaches are mainly relevant for the design of physical products or spaces, rather than software applications. They can be reviewed in Ceschin and Gaziulusoy's (2020) book on design for sustainability [28, pp. 53,63,73].

In the approaches explained so far, there is the perhaps most obvious phase of the product lifecycle missing: The actual phase of user interaction with the product - the usage and

consumption phase of products and services. Surprisingly, addressing the usage phase with design has started to emerge as a research area only from 2005 onwards [28] and has gained more traction with the work of Tang & Bhamra [58] and Lilley [11], among others. Lilley found that the way users interact with a product or service has a significant impact on the climate [11]. Further research suggests that impacting user behaviour and the way users interact with products and services could be highly beneficial for the environment [15], [16]. As an example, the user's interaction style with products that consume energy largely determines the total energy consumption of the product [59]. Another example is the ECO Mode in cars which is designed to support drivers achieving an eco-friendlier driving style. The overall impact of such cars on the climate will only be improved if the user actually uses the ECO Mode and adjusts the driving style - the behaviour - towards environmental consciousness. Beyond designing the ECO Mode and its features, design for sustainability thus also needs to consider ways to encourage the user to drive in the ECO Mode as frequent as possible.

2.2.2 Design for sustainable behaviour

In view of the enormous potential impact that users can have through their behavioural choices, there is also a tremendous opportunity for products and services that are designed in ways that actually engage users to take on such sustainable actions. As a design for behavioural change approach, this research field has strong connections to Lockton, Harrison and Stanton's [14] "Design with Intent (DwI)" method for influencing user behaviour. This method aims to shape or influence human behaviour for health, safety, social benefit as well as commercial success. When this method is applied to support the user's uptake of sustainable product and service innovations and behaviours, the design approach is described as Design for sustainable behaviour (DfSB) [28].

Design for sustainable behaviour has started to emerge as a research field from 2005 onwards [28] and various approaches, guidelines and tools have been derived and applied. Niedderer et al. [60] identified four basic goals researchers aim to achieve across this vast literature:

1. Make it easier for people to adopt the desired behaviour
2. Make it harder to perform an undesired behaviour
3. Make people want the desired behaviour
4. Make people not want undesired behaviour

In this master's thesis, the focus will lie on the first and third research approaches which aim to support people in *adopting* the desired behaviour of more sustainable actions and make people *want* this desired behaviour.

Coskun et al. [61] provide an extensive literature review on the current state of design research for sustainable behaviour change. The researchers analysed 70 peer-reviewed research papers

published between 2002 and 2014. Coskun et al. [61] use a simple framework to guide the DfSB process, which will also be applied for the design process in this thesis. The process follows a structure typical for the human-centred design process (see 1.4 for a definition): Coskun et al. suggest splitting the process into the following stages: "Exploration", "Generation" and "Evaluation" (see Figure 5). The stages can be further distributed into smaller sections. In the Exploration stage, the designer should choose a target behaviour or product (e.g. household water consumption or "shower") and next select a target user to address (e.g. university students or families). Then, design opportunities for behaviour change are identified, which may support the establishment of the target behaviour for the target user segment. The identification of such opportunities can be carried out, for instance, through observations, interviews or targeted quantitative surveys.

In the Generation phase, suitable design techniques are chosen (see below for further explanations), and concrete ideas are generated based on the design techniques.

In the Evaluation stage, the selected product or service concepts are prototyped and evaluated with the target users. Notably, the design process is iterative, which means that after the evaluation of the prototype, the new learnings from testing with users will be applied. This could, for instance, mean that new design techniques or ideas are chosen or that the existing prototype is iterated and further improved to suit the user's needs and goals.

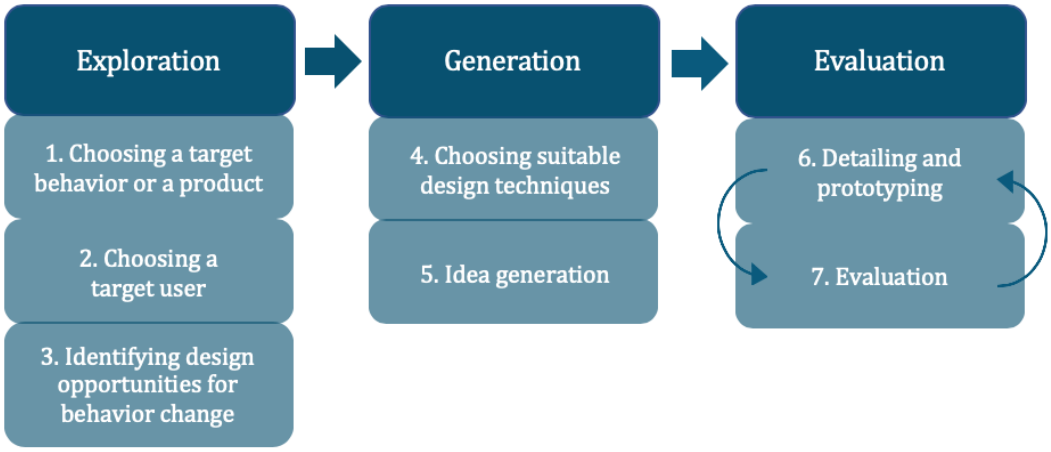

Figure 5. The process of design for sustainable behaviour after Coskun et al. [61] consists of the three phases exploration, generation and evaluation which are common for the human-centred design process.

Coskun et al. [61] analysed previous research on design for sustainable behaviour based on the framework above. Their structured analysis allowed the researchers to identify successful strategies as well as existing discrepancies and research gaps.

In the following paragraphs, findings across the design for sustainable behaviour workflow will be summarised to inform focus areas for this master's thesis' design process as well as concrete design techniques that have proven effective in past studies.

Choosing a target behaviour or product

Coskun et al. [61] identified that, across empirical studies, the most cited target behaviours to be changed were electricity consumption (in 34 of 70 studies) and water consumption (in 5 studies). Other behaviours like paper consumption, making repairs to already owned products, purchasing more sustainable clothing, mobile phone use in social contexts and various other environmental behaviours were only investigated once or twice. It seems that no study has so far investigated behaviour change interventions across different areas of life areas such as nutrition, consumption mobility and travel. Instead, the focus was usually on one behaviour, product or service.

Interestingly, the reasoning for choosing a certain consumption area and behaviour to address was oftentimes not explained in the empirical studies. This unsystematic approach is problematic according to the researchers: It leads to a lack of focus on high-impact opportunities for designing for sustainability [61]. According to [62], a good approach to address this shortcoming is to identify such design opportunities by observing the user's consumption behaviour and then identify the highest impact behaviour to address for targeted design interventions.

Choosing a target user

The target users of design for sustainable behaviour interventions in the 42 empirical studies investigated by Coskun et al. were either individuals (28 persons) or families and households (14 users). The users were selected based on age and, in some cases, based on being a student. However, it is worthwhile to mention that in only 24 of the studies, the users' attitudes towards pro-environmental behaviour or their environmental concern was considered. When it was considered, the focus was usually lying on people scoring higher on these factors, thus being more open towards sustainable behaviour and more concerned about the environment. The preference for "pro-environmental" users might have a drawback. These users might already display an above-average sustainable mindset and behaviour. Targeting to improve their behaviour might not have such a significant impact. It might thus be more indicate to change the behaviour of people with a negative attitude towards sustainable behaviour and a low environmental concern [63], [64].

However, it could be argued that the focus on people open to pro-environmental behaviour and high concern for the environment could also be more effective. This target group has a positive attitude and might be more willing to start acting or changing their behaviour. The Theory of Planned Behaviour (2.1) has found a positive correlation between positive attitudes, intention and ultimately, behaviour. For people scoring higher on pro-environmental attitudes, the interventions might be more effective as they have a higher motivation and intention to change their behaviour.

Identifying design opportunities for behaviour change

According to Coskun et al. [22], there is a lack of systematic approach when it comes to identifying concrete design opportunities for behaviour change. Nevertheless, a few researchers did suggest more systematic approaches: Clear et al. [62] suggest observing the behaviour (e.g. nutrition) and then select the activity likely to be most harmful for the environment (e.g. eating beef). The objective should then be to target this concrete behaviour with design.

A different approach could be to understand user pain points associated with the different activities to identify where and how design could support best. Across research, one common hurdle in taking up sustainable behaviour was, for instance, the invisibility of energy or water as a resource (e.g. [65]). A second common barrier was the perceived difficulty in changing habits and the resulting delay of such change [65]. Lastly, the lack of awareness on the consequences of an action were identified as common difficulties (e.g. [65]). Defining a good design opportunity could thus also be supported by an in-depth understanding of the user's current behaviour, their needs, objectives and pain points.

Choosing suitable design techniques

At this stage, suitable design techniques could be chosen from a plethora of possible options. Coskun et al. [22] summarised the most common strategies applied in empirical studies as follows: "informing about environmental problems, offering advice on environmental problems, providing a choice to action these problems, providing feedback on behavioural impact, setting goals for being more sustainable, ensuring commitment to be sustainable, engaging in sustainable behaviours by appealing emotions, steering behaviour through affordances and constraints, rewarding sustainable behaviours, comparing one's performance with others, making sustainable behaviours easier to do, constraining unsustainable behaviours through technical intervention and intelligent products that automate sustainable behaviours." Among these strategies the by far most frequently applied strategy was feedback (33 times) followed by rewards (7), providing information about environmental problems and suggestions to overcome them (4), communication through social networks (4), behaviour steering (3), intelligent products (2) and goal setting (1). These strategies can, of course, also be combined in one intervention.

Various researches have attempted to structure these many available strategies into frameworks. However, no leading framework has been established yet which would have been widely accepted across researchers. Realising the need to find a common language and methodology for design for sustainable behaviour, De Medeiros et al. [66] summarised and evaluated the existing frameworks.

Based on their learnings from different frameworks, De Medeiros et al. [66] furthermore developed a "decision support diagram to promote sustainable behaviour" (Figure 6) which consists of four phases: (1) user analysis; (2) level of user or product control; (3) strategy definition; and (4) incorporate strategies to the product. These phases will next be explained in more detail as they are crucial to guide the design of the mobile application in this master's thesis.

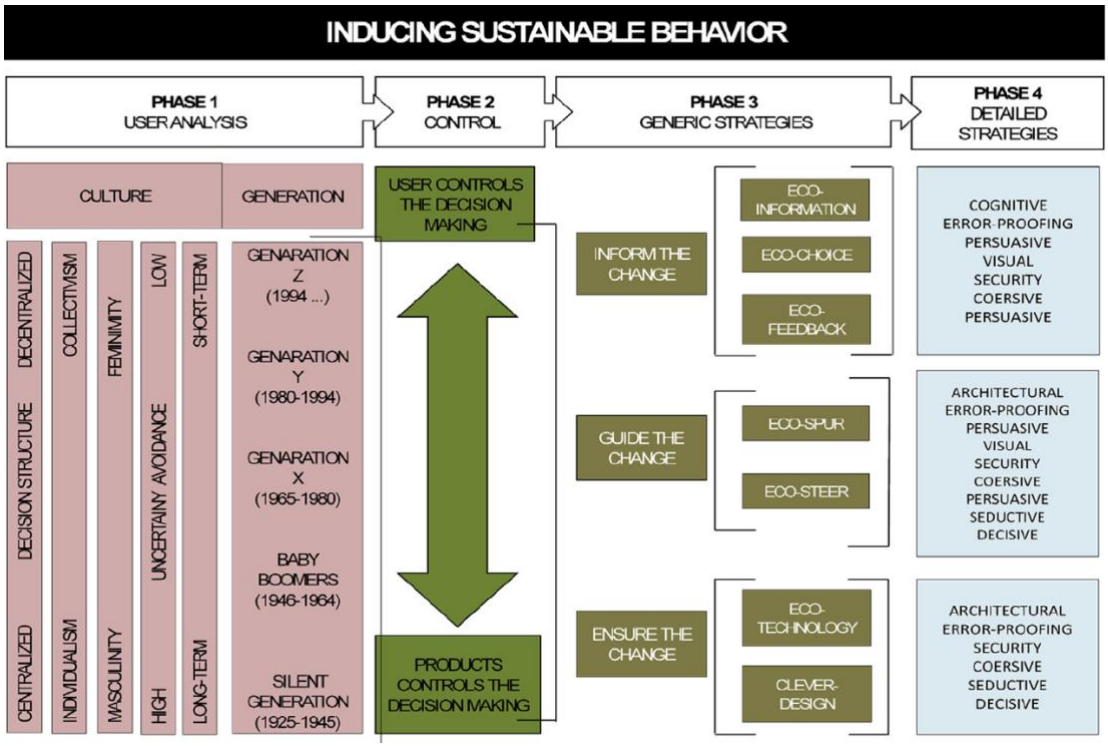

Figure 6. De Medeiro et al.'s [66] "Decision support diagram to promote sustainable behaviour". It has been developed for designers to guide the process of designing for sustainable behaviour change based on the broad exiting literature. A designer has to go through the process of user analysis (Phase 1), control (Phase 2), generic design strategies (Phase 3) and detailed strategies (Phase 4) to choose suitable design techniques for the respective product or service development

Phase 1

The analysis stage of the user type overlaps with the *Exploration* phase of the structure followed in this thesis. For user analysis, De Medeiros et al. [66] emphasize the importance of culture and generation for choosing appropriate design techniques. The aspect of culture, due to limited scope, will not be considered in this master's thesis. However, the age and thus, generation will be considered as a relevant parameter when designing a mobile app targeting sustainable behaviour change.

Phase 2

In Phase 2, the designer has to establish how much control of the product or service usage shall be allocated to the user vs the product or to a combination of both along a continuum [11], [67], [68]. An example of a design solution with high product control would be a technology that automatically switches off the air conditioner when the user opens the window to avoid the user's "mistake" of wasting energy. A mixture of both product and user control, could, for instance, be

the implementation of an eco-friendly pre-setting for a washing machine. As users are more likely to follow the pre-settings, the user's sustainable behaviour is partially controlled by the product – however, with the user having the option to change the pre-settings to a normal laundry setting. Lastly, there is, for example high control allocated to the user when a product informs about the water usage while showering. The user is then informed about the environmental impact but can freely decide whether to act upon it or not.

As an indicator to decide which control focus is most appropriate, Zachrisson and Boks [69] suggest that more control should be given to the user if the desired behaviour aligns with the user's beliefs, attitudes and intentions. The other way around, the author argues that the breaking of a negative behaviour or habit can be initiated by making the habit strange to do or impossible and this way assign the control to the product (as in the air conditioning example above).

Phase 3

In Phase 3, the decision for generic strategies is made. These generic strategies are clustered into "inform the change", "guide the change" and "ensure the change" (Table 1). Generally, eco-information, eco-choice and eco-feedback are appropriate strategies to inform change. Eco-spur and eco-steer are most relevant to guide and maintain on-going change. Lastly, eco-technology and clever design are most relevant to ensure change. Table 1 shows an overview of these approaches after Tang & Bhamra [59], [67] and defines them further.

Table 1. Detailed design strategies to "Inform", "guide" and "maintain the change" following Tang & Bhamra [59], [67]

Inform the change	**Eco-information:** Design-oriented education	**What?** Makes consumables visible, understandable and accessible **Why?** Inspire consumers to reflect upon their use of resources **Examples?** Encourage user to interact with resource use e.g. energy-generating bicycle pedals
	Eco-choice: Design-oriented empowerment	**What?** Encourage the user's thoughts on consumption **Why?** Enable them to take responsibility for their actions **Examples?** Provide consumers with options for sustainable use and develop sustainable product
	Eco-feedback: Design oriented links to environmentally responsible action	**What?** Inform on what users are doing with real-time feedback **Why?** Support in socially responsible decisions **Examples?** Diverse feedback mechanisms in the kitchen
Guide the change	**Eco-spur**	**What?** Rewarding incentive and penalty **Why?** Encourage more sustainable behaviour through rewarding "good" behaviour and "punishing" bad one **Examples?**
	Eco-steer	**What?** Limit the use of environmentally undesirable habits and encourage sustainable ones

		Why? Make it easier for users to pick the 'easy route' **Examples?** Make the positive habits easier to get done and the negative habits more difficult e.g. with regards to energy usage
Ensure the change	**Eco-technology**	**What?** Make existing use habits impossible or very difficult or automatically control user behaviour **Why?** Restrict users from acting un-sustainable; or 'protect' users from errors causing environmental damage **Examples?** new materials; renewable energy resource; new technology such as advanced computing and science technology
	Clever design	**What?** Innovative product design allowing the user to automatically act more sustainable without realising it or changing their habits **Why?** Reduces environmental impacts while not depending on user to be willing or able to change current behaviour **Examples?** Integration of toilet and washbasin – re-use water for handwash automatically to flush toilet

Phase 4

The detailed strategies introduced in phase 4 are mainly based on Lockton et al.'s "Design with intent" [14] method and as such are not specific for sustainable behaviour change. The strategies are not specific for a particular control distribution and they can also be combined for the same product design. As such, these detailed strategies already seem too theoretical and narrow to guide the app development for this master's thesis.

Conclusion: Choosing suitable design techniques

Choosing suitable design techniques for sustainable behaviour change is non-trivial, as many frameworks have been developed which have not yet been evaluated in-depth. Nevertheless, phases 2 which indicates the control distribution of the product or service, as well as Phase 3 which provides general strategies to inform, guide and maintain the change, are useful for the app design and development process. At the same time, the choice of suitable design techniques should not be over-engineered during the first iterations, as the following stages of prototyping and user evaluation should demonstrate, which strategies are worth being implemented in the product to trigger sustainable behaviour.

Idea Generation

The purpose of idea generation in the context of design for sustainable behaviour is to connect specific design strategies to ideation. However, very few studies investigated this topic. The studies that did implement specific ideation that goes beyond general "brainstorming" methods showed that this approach could be beneficial [61]. An example of such ideation tools is Lockton's Design with Intent toolkit. [14]

Prototyping and Evaluation

In the phase of evaluating the impact that a product or prototype has on encouraging the target behaviour, several interesting findings have been derived from empirical studies. Coskun et al. [61] summarise that many users would find it difficult to interpret consumption data and translate this data into concrete actions for their daily life. Also, users preferred feedback with personal, comparative, comprehensive, visually appealing, specific and entertaining elements. When target users were presented with ambient and iconic representations of their consumption data to reduce their consumption, this feedback proved more effective compared to numerical data and representations [61]. Interestingly, no common set for evaluating whether a chosen strategy has proven successful or not has been identified so far. As of the current research knowledge, it is not possible to say what makes certain strategies or features more or less effective in changing behaviour. Thus, it is also not possible to choose very specific strategies based on their success in the past, as these success metrics have not been identified yet [61].

In the evaluation stage, it also becomes obvious that few studies investigated the long-term effect of sustainable behaviour change interventions. Only 2 of the 42 empirical studies which Coskun et al. [61] analysed, investigated whether behaviour change persisted over time. These studies yielded contradictory results. It was found that engagement might decrease over time with the novelty effect of a new product reducing [22], [70]. For the design of interventions, it is thus important to implement different techniques and also vary them overtime to keep the users engaged and interested in the product or service.

2.2.3 Conclusion

The previous sections on design for sustainability and design for sustainable behaviour have provided insight into the design process to implement when developing products and solutions encouraging sustainable behaviour change across different areas of life. The design for sustainable behaviour process consists of the three phases *exploration, generation* and *evaluation*.

In the exploration phase target users and design opportunities will be identified. The target users and design opportunities to address with an intervention should be those, that promise the highest impact opportunity for achieving more sustainability. For this mobile application, the

most promising target users are likely to be tech-savvy, sustainability-minded individuals. Regarding the selection of design opportunities, as argued above, no study has so far investigated behaviour change interventions across lifestyle areas such as nutrition, consumption, mobility and travel. Instead, the focus was usually on one behaviour, product or service. This thesis will focus on addressing different behaviours and lifestyle areas with one single mobile application.

In the generation phase different design for sustainable behaviour strategies are employed to prototype or develop the product. Design strategies like eco-choice, eco-information, eco-feedback, eco-steer, eco-spur, eco-technology and clever design can be applied.

In the last phase, the evaluation phase, the product is tested with target users in an iterative way. In previous evaluations with users, specific strategies have been found to work well: personal, comparative, comprehensive, visually appealing, specific and entertaining feedback and providing support for the user to interpret consumption data and translating it into concrete actions for daily life. For results that are more likely to last long-term, it should also be kept in mind that the variety of different intervention techniques is required to keep users engaged over time.

2.3 State of the Art

In this section, a number of digital applications on the market that are encouraging sustainable behaviour change are analysed. Common approaches across businesses are identified to further inform the design of the mobile app in this master's thesis.

2.3.1 Paying off the carbon-footprint

Several apps aim at encouraging its users to pay off their calculated CO2 footprint. These apps work via estimating or calculating the CO2 footprint of the user's lifestyle. Next, they offer the user a payment scheme for paying off the caused CO2 footprint. The effect of their CO2 offsets is visualised through tangible images such as trees planted, or long-haul flights saved.
The design strategies used are mostly *eco-information* and *eco-feedback.*

Ecologi is a mobile application that allows its users to purchase a subscription to offset their CO2 footprint [71]. Users pay a subscription fee to pay for real trees being planted in supported ecological projects. The user's impact and "their" trees planted are visualised in the left two screens in Figure 7. The second right screen shows a tangible visualisation by comparing the removed CO2 to the amount of equivalent long-haul flights. Lastly, there is a section in which users can set lifestyle goals such as "shopping locally" or "using public transport" (right screen). The goals are presented as a checklist that users can tick off once.

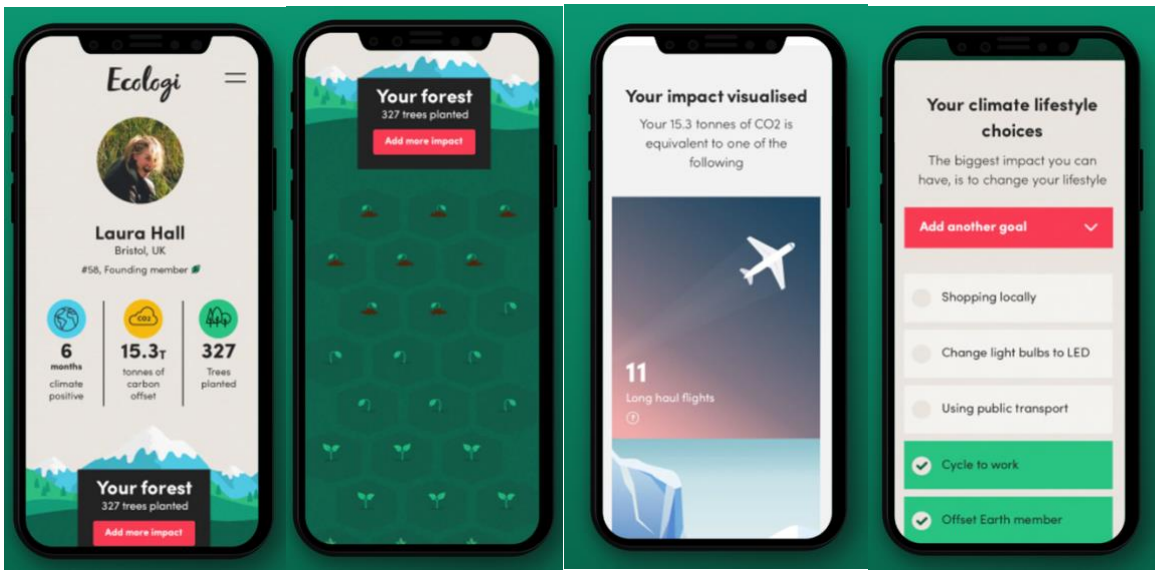

Figure 7. Screens of the Ecologi app. It focuses on off-setting the climate footprint by planting trees [71]

The app **Klima** (Figure 8) is currently still under development and promises to *"make it easy to calculate your footprint and understand the climate impact of your lifestyle."* Based on the climate impact of the lifestyle, users would then be able to financially support *"science-backed projects that remove or prevent the same emissions elsewhere"*. [72, p. 1]

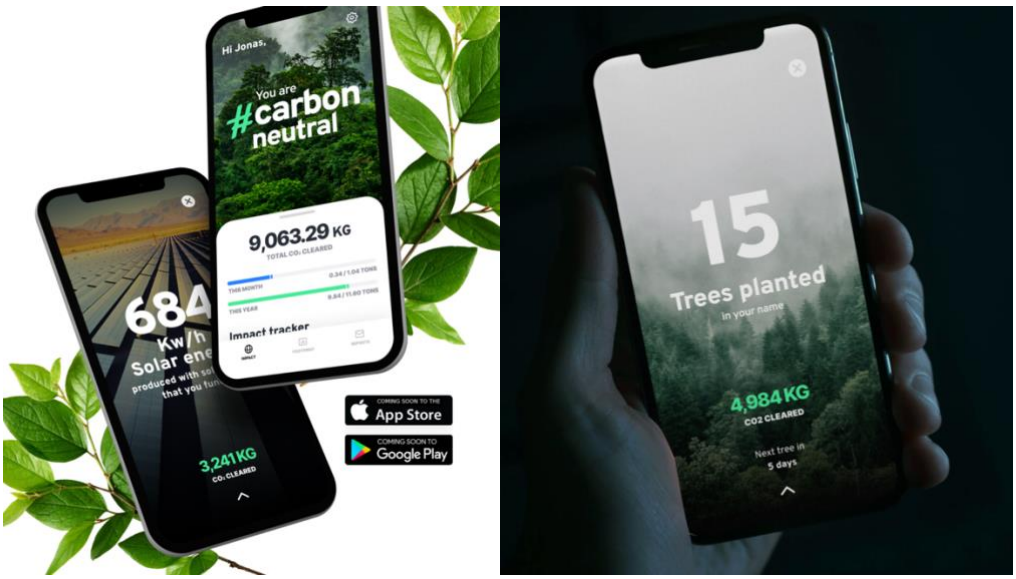

Figure 8. Impressions of the currently still developed app "Klima"

There are also several apps aiming to quantify the impact of business operations on the climate to encourage management boards to create more sustainable business practices and processes. Ecologi and Klima are available for private and business users, too. Further examples of such business solutions are Plan A earth [73] and Wespire, an employee engagement platform covering sustainability as one of several topics [74].

2.3.2 Gamifying or rewarding sustainable behaviour

Several mobile apps on the market aim to gamify or reward sustainable behaviour change. Among those apps are Joulebug, Oroeco, Ducky and Green Redeem. In these apps, users are offered "sustainable activities" that they can take to gain points in the app. The financial gains and assumed CO2 saved is also listed. The app thus uses strategies of *eco-information* to inform on the impact of specific actions and recommend alternative activities to take; *eco-feedback* when analysing the climate impact of the individuals and *eco-steer* through gamifying and rewarding with in-app points. *Eco-steer* through rewarding "right" behaviours has also found to be crucial by Green Redeem, a company applying sustainable behaviour change to the B2B sector. Additionally, the *"Social"* element can be seen across solutions: Users collaborate and can compare themselves with users in the app and beyond.

In **Oroeco** (Figure 9), users can track their monthly climate impact from different sources (e.g. move, live and eat) and compare it to the American average. Users are besides offered concrete "ideas" to reduce their climate impact, such as "eat vegetarian" or "recycle". For these activities, the app displays the economic effect and expected carbon dioxide emission. On the right image, users get more details on a particular action and can then "take the activity" which tracks it and impacts the total impact compared to the average American. When taking an activity, it is unclear for which timeframe the tracking takes place, i.e. whether it is for one day or "forever".

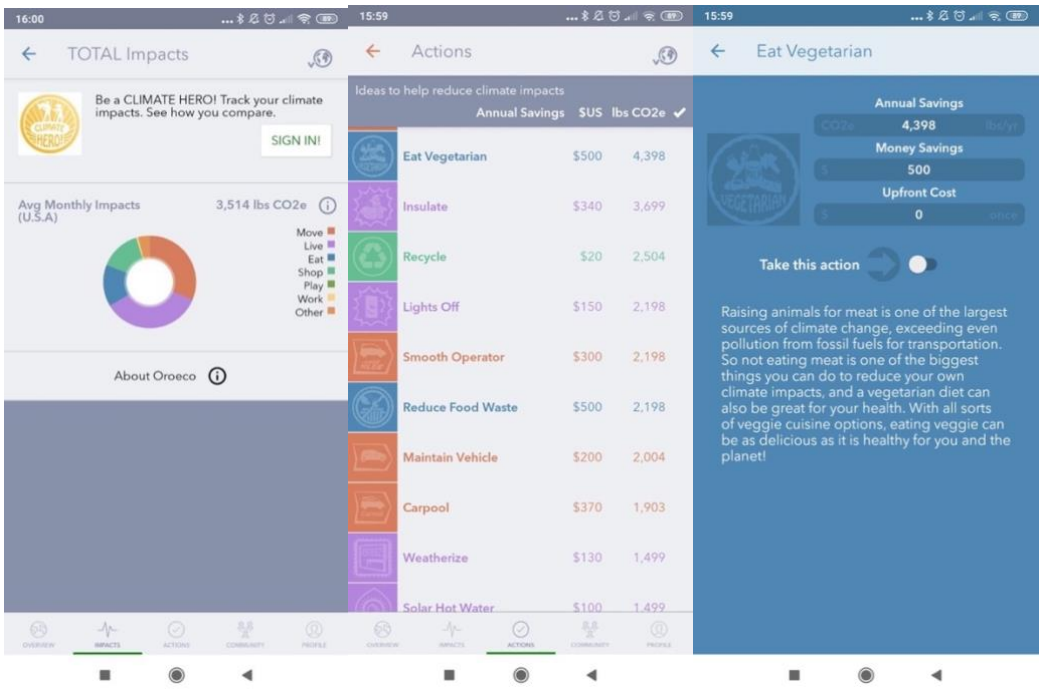

Figure 9. Impressions of the app Oroeco

The mobile app **Joulebug** offers activities to take, too. The activities are displayed in categories such as waste, transportation or food & drink. Interestingly, the names of the activities are creative, making use of a compelling naming such as "easy rider" or "blazing saddles" (left screen). Compared to Oroeco, the tracking timeframe is very fine-grained: Users need to "buzz" which means that they have to tap a button once they have done an activity (second left screen). A sharper focus thus lies on gamification as users have to repeatedly come back to the app to "buzz" and collect points. The app also offers global challenges (right screen) and comparisons against other app users (second right screen).

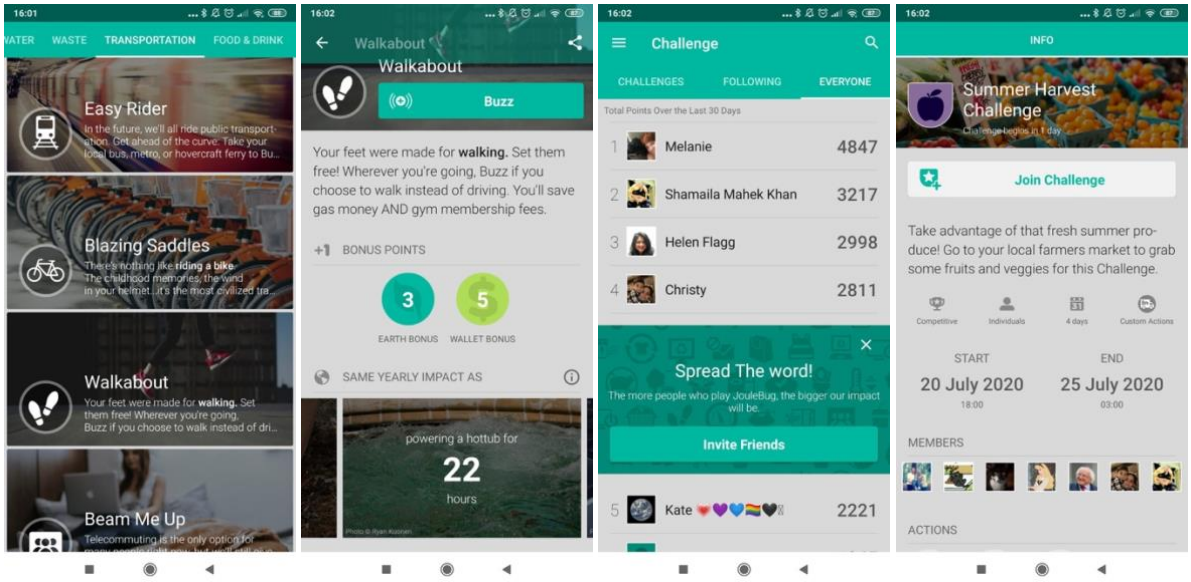

Figure 10. Impressions of the app Joulebug. It uses catchy vocabulary, challenges, points and social competition for gamification

Further apps aiming to gamify sustainable behaviour change are Ducky [75] and Green Redeem [76]. Both solutions target the B2B sector. Green Redeem states to *"help you to engage with your target audience and change their behaviour"* which might be businesses, schools or even cities. Interestingly, the app has identified four steps to encourage behaviour change across the target audience: Create a community, engage them behind a cause through tailored content, reward the right behaviours and repeat the activities to make the change habitual. These four steps are covering the topics of *eco-information*, *eco-steer* and *social* well.

2.3.3 Conclusion

The market research of mobile apps encouraging sustainable behaviour change has shown that there are already several apps available that are addressing sustainable behaviour change across life areas. Several apps aim to promote sustainable actions by informing about them and rewarding them. Other apps allow the user to pay off their expected or their measured CO2 footprint.

In these apps, mostly the design strategies of *eco-information* and *eco-feedback* are applied. Additionally, the apps allow for *social* comparison or competition around sustainable activities. The strategy *eco-steer* is applied through in-app points, leader boards and rewards.

3 Design

In this chapter, the design process of the sustainability app based on the human-centred design process according to ISO (section 3.1.1) and the design for sustainable behaviour stages "Exploration" (section 3.2), "Generation" (section 3.3) and "Evaluation" (section 3.4) are described. The outcome of this design process will be a mobile app that can be used to encourage people to take on sustainable actions across life areas. This high-fidelity prototype will be presented in section 3.5. A conclusion of the design process and final designs with an outlook to further evaluation steps will be discussed in section 3.6.

3.1 Methods

This section will introduce the different stages of app design and development that was conducted for this thesis. Firstly, the basics of human-centred design will be explained (section 3.1.1); then, an overview of all methods and the research process to design the app will be introduced (section 3.1.2).

3.1.1 The human-centred design process according to ISO

As previously described, the human-centred design process according to the International Organization for Standardization (ISO) [13] is a systems design and development approach focusing on the user interaction with the system to increase usability and user experience. In the human-centred design and development process (Figure 11), the user is involved throughout the whole design and development process.

First, the user and the context of use need to be understood and translated into user requirements. Design solutions and prototypes are developed and continuously tested in user-centred evaluations. Based on user evaluations and new learnings, the product can be redefined and retested with users until the designed solution meets the user requirements. These iterations are very typical for the human-centred design process as "the most appropriate design for an interactive system cannot typically be achieved without iteration" [13, p. 21]. The focus on the user and other involved stakeholders in the design process has many advantages such as creating solutions that are easier to understand and use, improving the user experience, providing a competitive advantage through a better brand image and ensuring higher productivity of users.

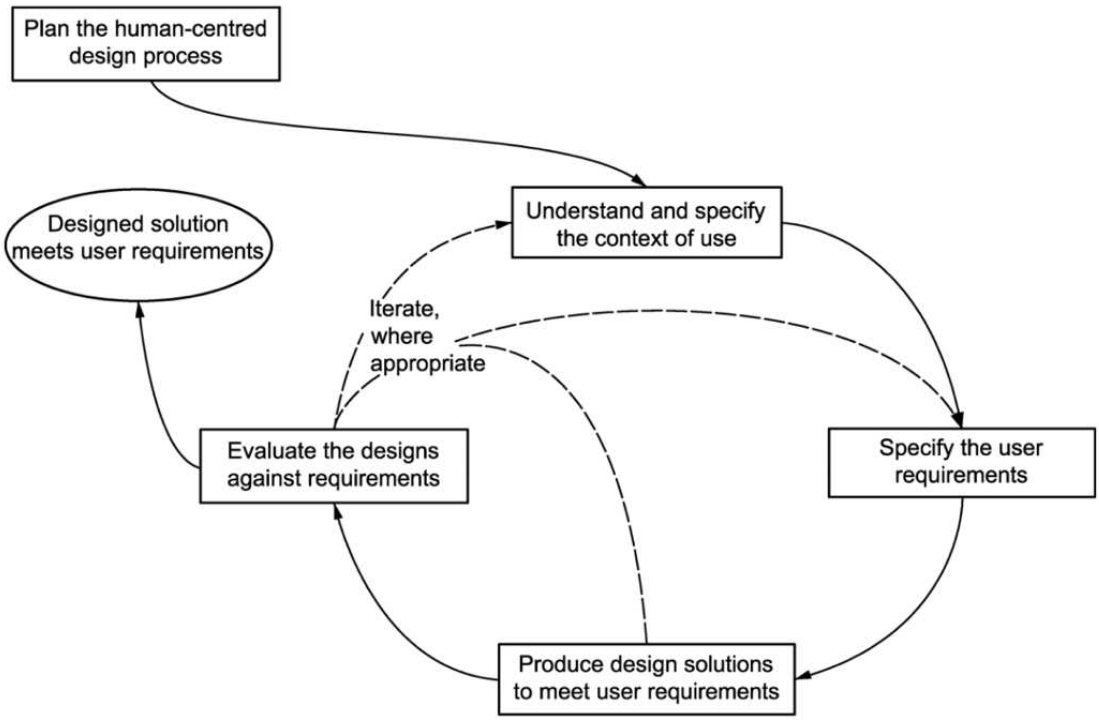

Figure 11. An illustration of the iterative human-centred design process (taken from ISO 9241 [13])

It is important to remark that ISO 9241 [13] provides a framework and design principles, but the concrete activities and methods applied in the process have to be selected from case to case. This is why, in this thesis, Coskun et al.'s [61] application of the human-centred design process on designing for sustainable behaviour change will be used (displayed in Figure 5). This model consists of three stages:

- "Exploration" which matches with the ISO phases of "Understand and specify the context of use" and "Specify the user requirements";
- "Generation" corresponding to the ISO stage of "produce design solutions to meet user requirements"; and
- "Evaluation" relating to the ISO stage of "evaluating the design against requirements".

Similar to the ISO process, the model focusing on design for sustainable behaviour change is also allowing for iterations in the process. In this thesis, the repeated iteration applies between the stages of "Generation" and "Evaluation".

3.1.2 Methodological overview

Figure 12 visualises the different stages of the research applied in this thesis.

In the *exploration stage*, the methods of user interviews, a quantitative survey, personas and a customer journey were conducted to understand the user's needs, motivations and pain points and identify design opportunities. Data were analysed in the team through affinity mapping. Affinity mapping is a process of synthesising qualitative data in the team with the aim to "share the [research] data, and develop interpretations on which the [whole] team agrees" [77, p. 94]. For this purpose, notes from multiple interviews are clustered on the wall into higher-level groupings which help give insight into the user research findings.

In the *generation stage*, design strategies were defined, a user journey and a visual design guide were created. Besides, the content was researched and written for the application. The first wireframes were designed and prototyped using InVision.

In the *evaluation stage*, a first functional prototype was tested with users, and a co-creation session was held to identify further feature demands. Based on the second wireframe iterations, a high-fidelity prototype was developed. This prototype was fully programmed and functional. However, it showcased some bugs and was not entirely based on the visuals of the wireframes due to the limited time available for the development phase. This high-fidelity prototype was tested in a two-weeks user study with participants who interacted with the app throughout the study period. Afterwards, a post-survey and five in-depth interviews were conducted with users and analysed through affinity mapping.

Lastly, the third and final wireframes were designed, and the fully functional high-fidelity prototype was updated based on these designs.

In Figure 12, there are red boxes displayed in the evaluation stage. They indicate iterations in the process. The development of wireframes and prototypes is a "generation" rather than "evaluation", but it is still part of the iterative development process of the mobile app.

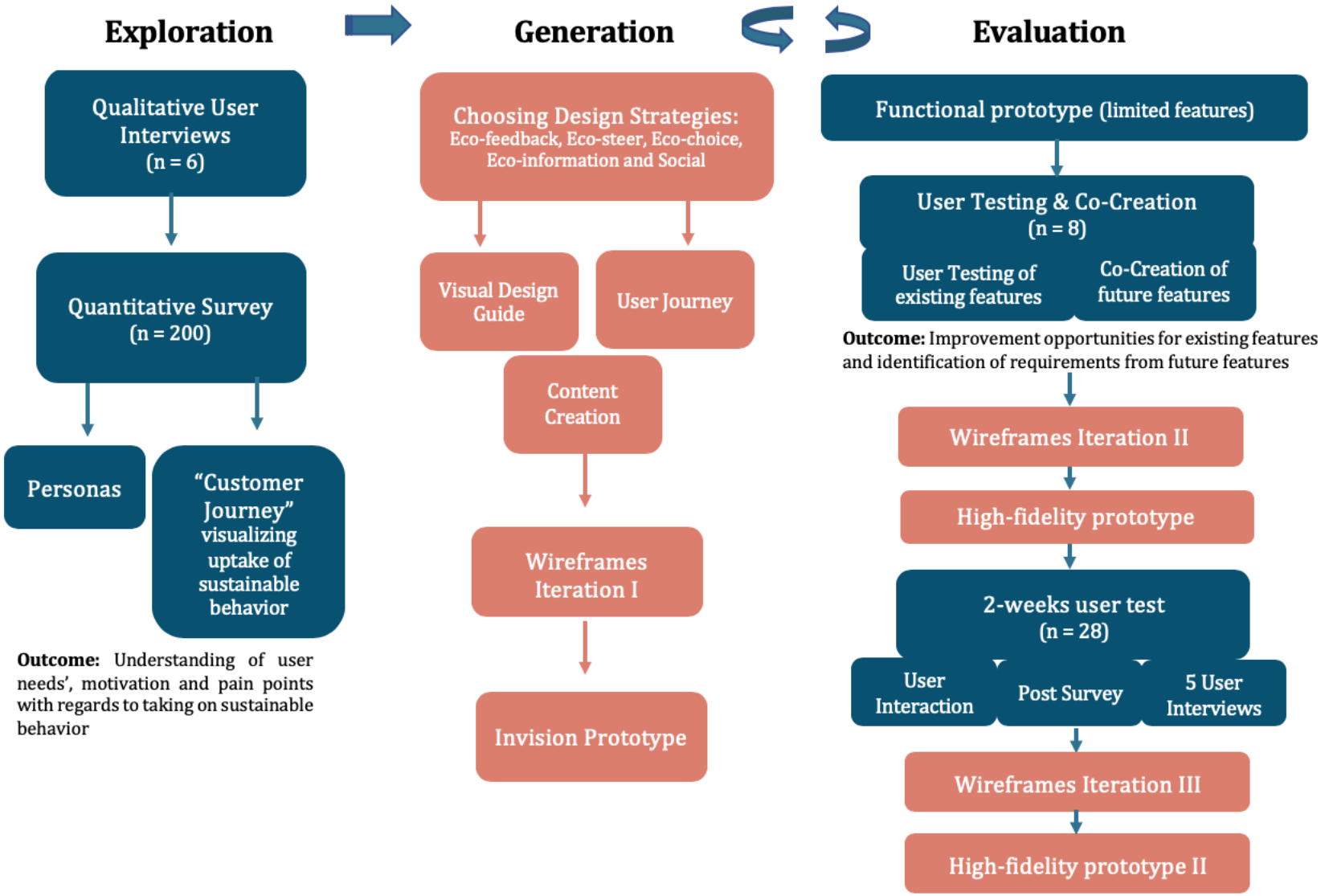

Figure 12. Methodological overview of the process and methods used in the design process of the sustainability app. Diverse methods were applied across the stages of exploration, generation and evaluation. In the evaluation part, the red colour indicates where new wireframes or prototypes were developed and thus an iteration of the "generation" stage took place.

3.2 Exploration

In the exploration stage, first target behaviours or products (section 3.2.1) and target users (section 3.3.2) were identified. Next, design opportunities for behaviour change (3.2.3) were investigated. Diverse qualitative and quantitative methodologies were applied and are described in detail. The intermediate results, such as insights from user interviews, are presented. Personas and their "journey to sustainable behaviour" are introduced and supported by visualisations.

3.2.1 Choosing a target behaviour or product

The target product chosen in this master's thesis is a mobile application. However, no focus is put on a particular behaviour in the context of sustainability. Instead, the focus lies on the currently unaddressed research gap of addressing *several different behaviours* with one single application. Here, according to the suggestion of Clear et al. [62] high impact opportunities were identified. These included: Nutrition (meat vs plant-based nutrition), mobility (car vs public transport vs car), waste (e.g. using reusable cups or bottles), consumption (recycling of clothes) and finance (being customer at sustainable banks).

One reason to choose these behaviours was the fact that users can theoretically control them. An average target user in Germany can choose what to eat, how to commute (unless living in a remote village), which clothes to buy and from which store, which bank to be customer offer and – to a limited extent – how much waste to generate.

Another reason to choose these behaviours is that they can be seen as "high impact". They can have a significant impact on the user's carbon or water footprint. CO2 can be saved, for instance, through changing from transportation via car to public transport or – ideally – to the bicycle (0g Co2 per km). The consumption of meat is, for instance, associated with a higher virtual water footprint. Virtual water is the "amount of water that is embedded in food or other products needed for its production" [78, p. 1]. One large steak of beef (300g) for instance carries a virtual water footprint of 4650 litres as compared to 650 litres for 500g of wheat [79]. Clothes also carry a high water footprint: one t-shirt requires up to 2700 litre of water in production [80]. It follows that users who change their target behaviour towards a more sustainable one can actively save CO2 emissions or "virtual" water.

3.2.2 Choosing a target user

In the process of choosing a target user, different parameters were considered and assessed qualitatively based on assumptions. Ultimately, the decision was made to address a younger target audience that is open towards exploring more sustainable behaviour opportunities. In the following paragraphs, key considerations leading to this decision are presented.

(Expected) sustainable mindedness of the users

According to the principle of Clear et al. [62], users should be addressed who are more likely to change their behaviour as this is where the app can have the largest impact. According to the Theory of Planned Behaviour [33], the action is predicted by intention. It follows that it should be easier to encourage people of sustainable activities if they already have a high intention for this behaviour. For this reason, the target users in this study should be open towards sustainable behaviour.

(Expected) openness to new technological solutions

A younger target audience tends to be more open towards using new technological solutions in general and smartphones and mobile apps in particular. The target users should thus also be interested in using new mobile applications.

The target group is easy to reach

Finally, given the time and financial constraints of the master thesis research process, an easy to reach target audience should be chosen.

In conclusion, the target users should be sustainability-minded, open towards new technologies and easy to reach during the research process. A reasonable target user group are thus *students or young professionals* because this group is likely to fulfil all the criteria above.

3.2.3 Identifying design opportunities for behaviour change

The identification of design opportunities for behaviour change is the first actual step of designing a new mobile application in a human-centred way. During this step, the current behaviour, needs, objectives and pain points of the target users are assessed. For this purpose, six qualitative in-depth interviews were conducted, and the findings were synthesised. For further validation, the identified parameters were then evaluated in a quantitative survey with 200 respondents. Lastly, two personas were created and the "journey to sustainable behaviour" was mapped out in the shape of a customer journey to inspire ideation and ultimately design.

Finally, a conclusion on the identification of design opportunities is drawn, and a first attempt to answer sub-question 1 of Research Question 1 can be provided. The final results will be summarised again in the results chapter of this thesis (Chapter 5).

Qualitative in-depth interviews

The first method applied was the semi-structured qualitative in-depth interview [81]. The six in-depth interviews (~1h) addressed consumer's awareness about sustainability topics as well as their current behaviour and mindset and their motivation, needs and pain points when it comes to sustainable behaviour and sustainable behaviour change.

The interviewees were 23-30 years old, three males and three females and originally from Germany (3), Russia, Belgium and the UK. Two participants were recruited based on the project team's knowledge about their sustainable behaviour (vegan consumption habits, climate activism) to understand how they started implementing this behaviour. The interest in sustainability topics of the four other interviewees was not known before the study. More details on the administration of the interviews as well as the interview guide can be found in Appendix A and the information sheet and consent forms distributed to users in Appendix B.

For the synthesis process of the interviews, the team first clustered the post-its onto the wall (Figure 13). Next, the interviewer talked about individual interviews and first insights. Based on the suggestions of analysing qualitative data by Taylor-Power and Renner [82], the team made topic groupings across interviews. The following topics were identified: Behaviour/Mindset, Customer Needs, Customer Pains, Customer Motivation, Challenges (for the App or Business), App Ideas/Features, Other Quotes.

In the next step, sub-categories were added to these groupings. The following paragraphs gives an overview of the sub-categories *of customer motivation, needs and pain points*.

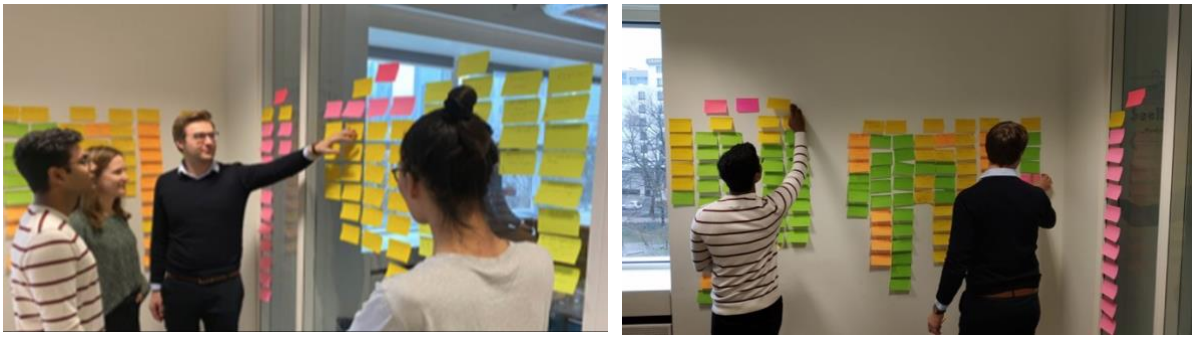

Figure 13. Affinity Mapping in the project team. The project team is clustering and discussing the insights from the qualitative user interview. Findings were then grouped into sub-categories and learnings drawn from the analysis for the design of the sustainability app.

Motivation

For users, motivation to act sustainable goes beyond "fighting climate change" and can be very personal. When asked why they performed a particular "sustainable behaviour" such as cycling, many interviewees described motivators such as "be healthy", "become more fit" or "save money". These motivators can have an impact on sustainability choices but are, however, not performed with the sole objective to act more sustainable. Across participants, the following motivating factors have been found: "climate crisis" as a motivator, gaining transparency, social pressure and

social support, pre-existing positive habits, lower cost, alignment with personal targets and eco-anxiety. In Appendix C, these motivators are further explained, and user quotes are attached.

Needs

The interviews also uncovered various needs that people have when it comes to "taking sustainable actions". Needs were a positive social environment, transparency and feedback of the individual's impact on the climate, information and education, aligning sustainable actions with (life)goals and a convenient and fun app. Particularly insightful was what supported the two interviewed "sustainable actors" in taking on such behaviour. For them, it was mostly social support, information and education through comprehensive educational and climate-activist sources that supported them in the process (see Appendix C for more details).

Pain Points

Pain Points address user's difficulties in implementing and keeping up with sustainable actions. These pain points are very diverse, and per interviewee, several of such factors have been found. Pain points were defined as obstacles, that keep people from taking sustainable actions or make their sustainable behaviour harder to maintain. Across interviewees, the following points were identified: lack of options, lack of transparency of products & services, lack of information and education, higher cost, negative habits and comfort zone, negative social environment or social isolation and limited capacities, time or infrastructure (see Appendix C for more details).

In the next analysis stage, patterns and connection in between the motivation, needs and pain points were identified. In the qualitative data analysis model by Taylor-Power and Renner [82], this aligns with stage four of the analysis process. It could be found that the factors of motivation, needs and pain points are strongly intertwined. This is logical as the overcoming of a pain point can often be similar to a fulfilled need and can then also serve as a motivator to take action.

Based on the identified patterns and connections, common themes were identified. Table 2 shows a summary of these identified topics with a description and exemplary quotes. Firstly, the critical factor of a supportive infrastructure is required to allow people to choose more sustainable actions. Further outstanding elements are the following factors: providing transparency into climate impact of own behaviour, products and services; tips and education around sustainable activities; a positive, supportive social environment; reduction of cost and the presence or the creation of habits to overcome existing comfort zones.

These factors can make it easier or harder for people to take on sustainable actions. In the next steps, the quantitative importance of these factors was evaluated through a survey.

Table 2. Overview of user motivations, needs and pain points.

Category	Description	Exemplary quotes
Infrastructure	Behaviour change is only possible if there are clear opportunities and choices to act - for instance when it comes to public transport options or sustainable clothing stores.	"I try to take the train whenever possible but sometimes it is just not realistic [from Sweden to Belgium.]" "Avoiding plastic is difficult, it is just everywhere."
Transparency	Transparency into climate impact of own behaviour, products and services. Interviewees reported that they are very interested in understanding how they personally impact the climate and that they wish for greater transparency in this context.	"[...] there is a very, very large lack of transparency, both regarding what is good and what an effect it has". "There is little information about what and how something is sustainable."
Tips & Education	Interviewees wished for information and education on topics such as "which actions to take" – e.g. which type of clothes to buy that are more sustainable - and "how to organize them" – e.g. what to cook and where to buy the ingredients needed for vegetarian meals.	"[I would like to know] whether it is more sustainable to get an eBook reader or to buy normal books". "when I first turned vegan […] I searched online for recipes and for where to buy stuff."
Supportive social environment	An important role plays the social environment which can be supportive of sustainable behaviour or, on the contrary, trigger less sustainable actions such as meat consumption. This is related to the "social norm" described by the Theory of Planned Behaviour which in this case can be more or less pro-environmental.	"When I am back home and my friends invite me to a BBQ with a lot of meat, it is difficult to keep up vegetarian eating habits." "yeah I feel more understood and supported from my friends and from meeting people I don't know because I think [being vegan] is getting more popular in the society"
Habits & Comfort Zone	Habits can either support the sustainable action (e.g. a positive habit of cycling) or they can mean being stuck in the comfort zone of a less sustainable behaviour (e.g. taking the car to work). As described in the theory section, breaking habits is difficult but once established, the positive habits have higher chanced to persist, too.	'Negative' habit: "I just like meat. I don't see myself giving up eating meat entirely." 'Positive' habit: "I like cycling and it is a good physical activity. It's nice that it's good for the climate at the same time."
Cost	Depending on the individual and their financial situation (e.g. employed vs. student) cost can play an important role in considering the uptake of sustainable behaviour. Sometimes, a lower price indicates choosing a more sustainable option (e.g. bicycle instead of car). In other cases, sustainable behaviour is more expensive. For instance, in the field of nutrition and consumption, eco-labels imply higher costs.	More costly: "From a student's point of view, sustainable things are often more expensive because, yes, it costs money if you either have smaller farms or if you do not keep animals in the cheapest way where they are full of antibiotics." Cheaper: "I do not have a car. But this is also because it is more expensive."

Quantitative survey

Quantitative surveys in user research are often applied in mixed methodology studies to "extend and quantify the findings of an initial exploratory phase" [83, p. 1313].

The survey was constructed using SurveyMonkey and was shared digitally to the research teams' and Futury's network. The questionnaire had 209 participants. Eighty-one participants (~39%) were male and 128 participants (~61%) female. The majority of participants was under 30 years old (~60%) and was thus part of the target user group. The survey respondents felt (rather) well educated about climate change (70%) and (rather) aware about which activities are more or less sustainable in daily life (79%) (see Figure 14). The complete survey results span 56 pages and can be provided upon request.

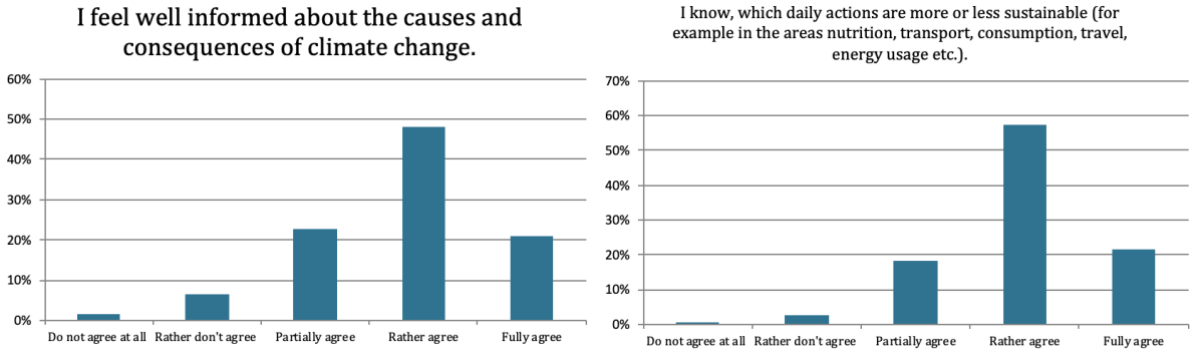

Figure 14. Overview of environmental concern and perceived knowledge about environmental impact of behaviour. Left: Participants self-report their level of information on the climate change's causes and consequences. They mostly (rather) agree to be well informed. Right: Participants indicate to what extent they know which actions in daily life might be more or less sustainable. The participants (rather) agree to know which actions are more or less sustainable.

The survey results were in so far relevant for this master's thesis, as they evaluated the most crucial pain points around sustainable behaviour change that concern a more significant segment of the target users. The pain points were measured on a scale from "1 - fully disagree" to "5 - fully agree" intending to derive a relative comparison between problem areas. Table 3 summarizes the corresponding statements and user ratings.

It was found that the most common pain points were lack of transparency (item 8), cost (item 4) and the opinion that others do not change either (social environment or social norms) (item 6). Common was also the perception that not many sustainable products or services are available which may indicate both the actual lack of such offers or the lack of awareness of sustainable alternatives (item 7). Less significant hurdles seemed to be the comfort zone (item 1), the lack of desire or time (item 2, item 3) and not knowing what to change (item 5). In an open question regarding the experience that users have made with sustainable behaviour change, further quotes related to varying pain points could be found. An excerpt of these quotes is listed in Appendix D.

Table 3. Pain points (quantitative). Respondents' rate the significance of hurdles involved in sustainable behaviour change

Item	Respondents "rather" or "fully" agreeing
1. It is difficult for me to change my everyday life to sustainability.	25.25%
2. I have no desire to change my everyday life to sustainability.	5.67%
3. I lack time to integrate sustainable behaviour into my everyday life.	11.86%
4. Living sustainably is more expensive than not doing so.	57.73%
5. It is unclear to me what I can change as an individual to live more sustainably.	11.86%
6. Most people in Germany do not change their everyday lives to sustainability.	50.00%
7. The selection of sustainable products and services is insufficient.	36.08%
8. There is a lack of transparency about the sustainability of products and services.	63.92%

The quantitative survey validated that, indeed, the topics identified in the qualitative interview hold true: transparency into climate impact of own behaviour, products and services; cost; and social environment are relevant pain points for many users.

Personas

Personas are a common interaction design technique, and they are "abstract representations of users" [84, p. 2] which are providing several benefits in the design process. For this thesis, personas were used to make the assumptions based on the qualitative and quantitative data collected in the research process more explicit. We focused on creating two personas representing our target audience: Anna Ambassador represents those users who are already "acting sustainable", for instance, through being vegan (see Figure 15). Ivan Impact represents users who started to take small pro-environmental actions such as reduce plastic usage but are unsure about what else to improve and where to begin (see Figure 16). These personas are essential for the on-going product design process as they help focus feature decisions on the motivators, needs, objectives and pain points that our different target users face – and as such help to prioritize what truly matters. Notably, personas are a tool to inspire the design, and they are iteratively adapted as more is learned about the target users.

Figure 15. Persona Anna Ambassador. This persona represents the target users who are already quite active when it comes to sustainable behaviour. They still face challenges in integrating sustainability across life areas, they lack support from like-minded people and want to be part of a bigger movement that can achieve more through a common effort.

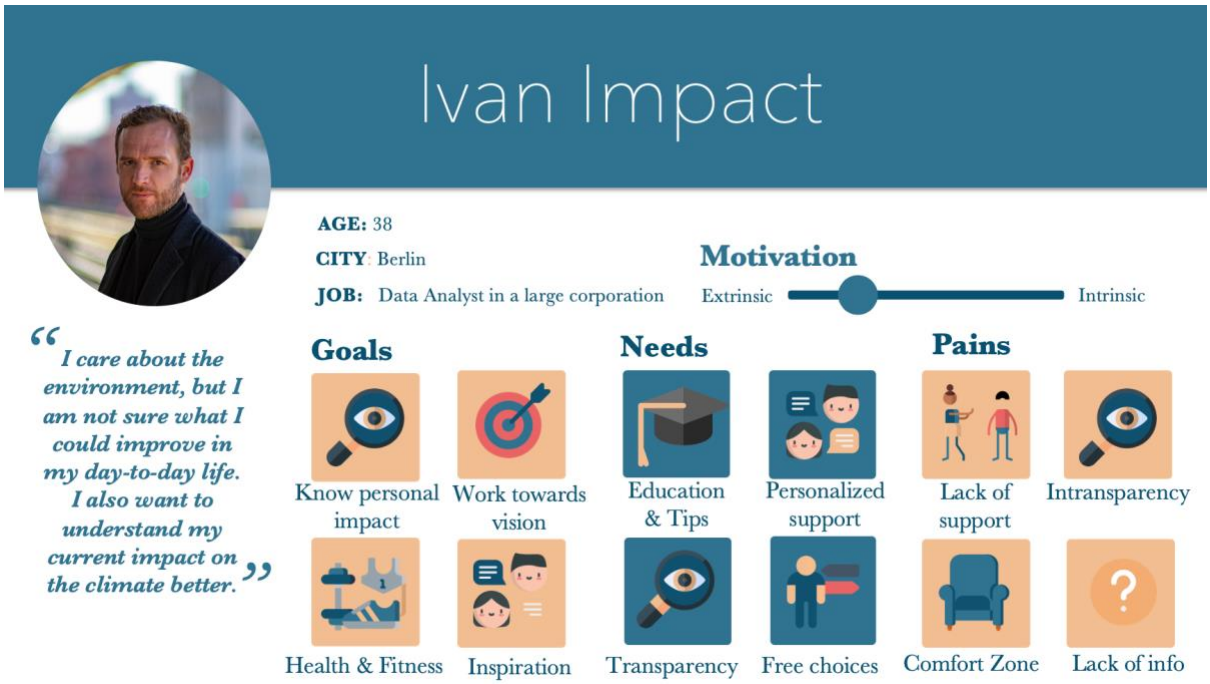

Figure 16. Persona Ivan Impact. This persona is representing those target users who "think sustainably" but do not "act sustainably" due to barriers such as lack of transparency and information, no social support or missing of clear opportunities to take action.

Map: Journey to sustainable behaviour

Based on the qualitative and quantitative findings and the identified personas, a process similar to Customer Journey Mapping [85] was conducted to understand the "journey to sustainable behaviour". This journey is relevant for the design of the sustainability app as the app has to encourage and support people along their journey to more sustainable actions. Figure 17 displays this journey. First, awareness for sustainability, for instance, environmental concern, and diverse motivational factors need to be given to encourage users like Ivan Impact to try out first sustainable actions. To move beyond this stage, it seems from our interviews that triggers like a new social environment or information and education can be highly beneficial for the individuals. Users like Anna Ambassador then need a different kind of support when they aim to establish their new behaviour, for example, detailed information on where to shop for vegan food, what to cook and how to ensure healthy nutrition. The journey map (Figure 17) should be seen as a useful visualisation to guide the on-going app development process and as a living document that can be adapted based on new learnings about the user and their behaviour.

Map: Process to sustainable behaviour

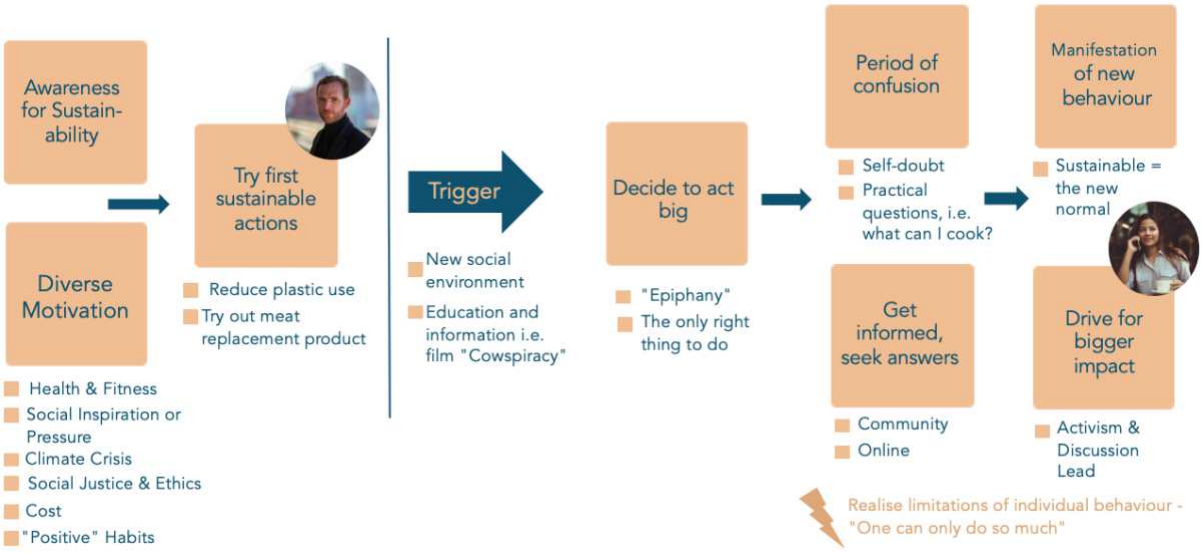

Figure 17. "The journey to sustainable behaviour" is a process based on findings from qualitative interviews and quantitative survey that visualises different stages of the uptake of sustainable actions. As such, it can inform the on-going design process of the sustainability app as the app should consider the various user tasks along the journey to sustainable behaviour.

Conclusion and answering RQ 1, sub-question 1

In the initial explorative analysis, target users have been selected (young, sustainability-minded users) and target behaviours identified (nutrition, mobility, waste, consumption and finance).
Sub-question 1 of Research Question 1, which was formulated in Section 1.3, asked the following:

- *Sub question 1: Which user behaviour, needs, pain points and goals should be considered in the design process?*

In the process of identifying design opportunities for sustainable behaviour change diverse core needs of users have been identified which – once addressed – can also mitigate pain points and support users in achieving their goals. The following user needs were found: gaining transparency into the climate impact of own behaviour and products and service, reducing cost, providing a positive social environment, tips and educational insights.
Two personas and their representative journey to sustainable behaviour have been created to inspire the design process further.

3.3 Generation

In the generation stage, the stages of choosing suitable design techniques (Section 3.3.1) and generating ideas (Section 3.3.2) are described. Section 3.3.2 also provides a short conclusion. For choosing appropriate design techniques, Phase 2 and Phase 3 of the four stages model of Medeiros et al. [66] are followed. Phase 4 is not applied as the design process should remain user-centred. It is thus more beneficial to first test generic features with users and then re-assess the features based on the evaluation.

3.3.1 Choosing suitable design techniques

Phase 2: Control

For this master's thesis, based on Section 3.2, we can conclude that the app should assign more control to the user because of three main reasons.

Firstly, assigning high control to the product – in this case, the mobile app – is not feasible. It is not possible for an app on its own to make "real-life behaviour" such as vegetarian nutrition "impossible" to do. It follows that the mobile app *has to* assign high control to the user. Secondly, according to Zachrisson and Boks [69], power should be assigned to the user when the desired behaviour aligns with the user's beliefs, attitudes and intentions. For the design of the sustainability app, our target users are assumed to care about sustainability and thus, more control should be given to the user.
Thirdly, the app addresses a broad range of behaviour relevant for sustainability, such as nutrition, mobility and consumption. Users can have the choice which options to pick.

An additional advantage of assigning decision control to the user is that they can set their own goals. Lomas et al. [86] have shown that self-set goals are most motivating when they are moderately challenging, while externally defined goals should be more manageable. As a consequence, users might choose more difficult challenges when they can select them themselves.

Phase 3: Generic strategies

The generic strategies applied in this thesis should assign high control to the user. Relevant approaches are thus eco-information, eco-choice, eco-feedback and eco-spur. An additional strategy to consider is the integration of "social" elements around community building as these have been found to be important during the exploration stage (see Section 3.2 for details).

The interest in different features for a sustainability app was assessed in the quantitative survey and can be seen in Appendix E. The top 5 features evaluated by the users refer back to diverse design techniques: twice eco-feedback, eco-steer, eco-choice and eco-information. The first "social" feature follows on rank 6. Figure 18 visualises, which features concretely are desired by users and which generic design strategies those correspond to. The chosen generic strategies seem reasonable and social features can be a valuable add-on to the design. Interestingly, the eco-steer method ranking high suggests donations into sustainable projects as "rewards". At the same time, more "traditional" rewarding schemes like discounts on products or services rank relatively lower compared to the other design strategies.

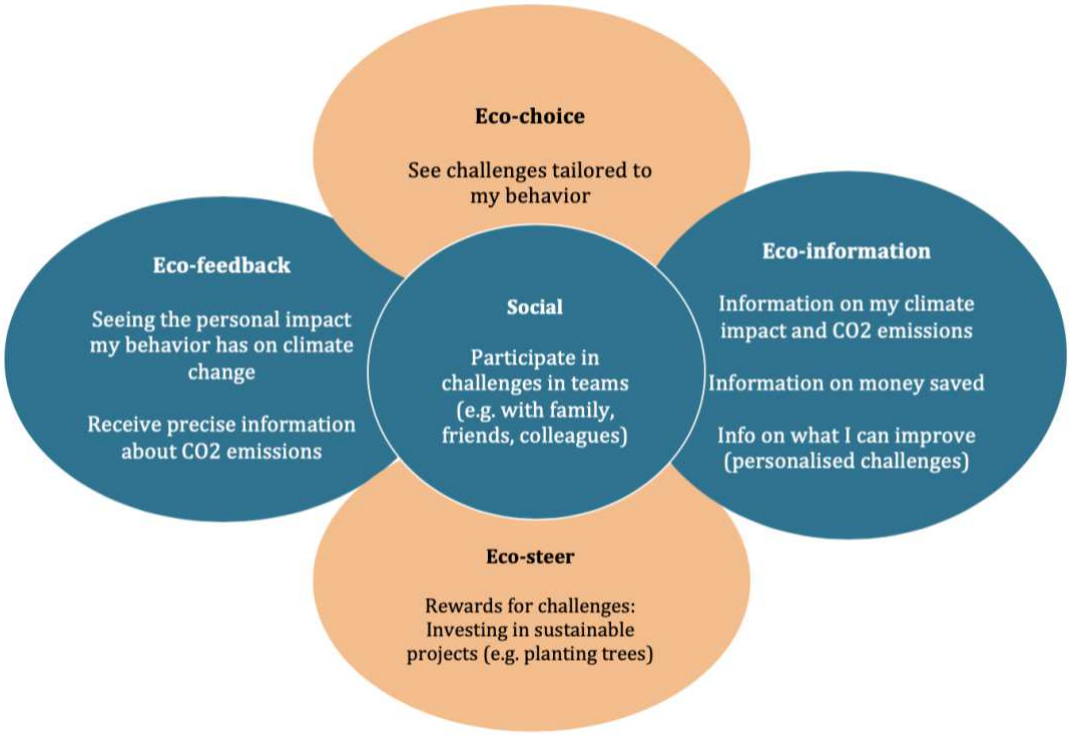

Figure 18. Features preferred by users for the sustainability app. Users show interest in features which can be grouped under the design strategies eco-feedback, eco-choice, eco-information, social and eco-steer.

3.3.2 Idea generation

In the idea generation process, content, features, a visual design strategy and first wireframes were ideated. Inspiration was drawn from similar applications that make users pay off their carbon-footprint (Section 2.3.1) or gamify and reward sustainable behaviour (Section 2.3.2). Also, the features desired by users were considered for the first iteration (see Figure 18 for details). In the following paragraphs, it is described how the content was chosen for the prototype iteration. Next, the user journey depicts the users' first interaction with the sustainability app. Finally, the first wireframe iteration is shown, which was turned into an Invision prototype. The overview of all methods displayed in Figure 12 can help understand the on-going design process.

Content Creation

In order to articulate the concept of an app to the user, the app needs to be filled with relevant content. For this reason, a simple behaviour was picked that was easy to design with the clear impact area around "emission" and "saving money": *bringing the coffee from home in a reusable cup, rather than purchasing a coffee-to-go in a disposable paper cup with a plastic lid*.

Besides, a name was given to the app: "Budge". Budge is an English verb meaning "to move slightly", and it was deemed a relevant term to describe the apps' objective of encouraging people to take the first steps towards more sustainability.

User Journey

The user journey of a user who uses the sustainability app was created to inform the wireframe design. The user journey of the prototype consisted of the user's tasks of setting up the app, picking a sustainable action, taking and reporting this sustainable activity and interacting socially, and enjoying rewards.

Figure 19. visualises the different stages of the user journey.

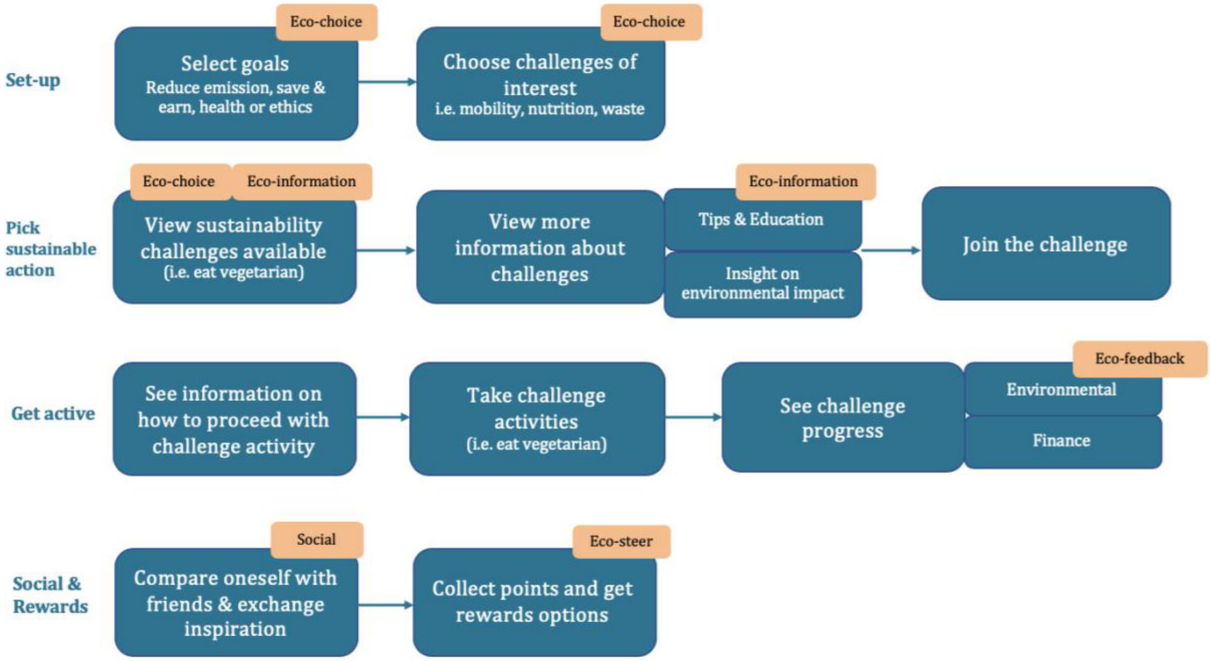

Figure 19. The User Journey for the first iteration of prototype. Users go through the stages of setting up the app, picking a sustainable action and getting active. Further features are teams or leader boards and reward options.

Visual Design

The role of visual design at this stage was to support communicating the concept. Besides, icons and colours were chosen that symbolise a "fun environment" to create a positive atmosphere rather than a "feeling of obligation". The leading colours chosen were blue and a light orange. Green was kept for visualising environment-related parameters like "Green Points" or icons such as trees or leaves. Figure 20 shows the colour scheme of the app.

Figure 20. Colour scheme with colour codes and colour names of the sustainability app. Chosen colours are Blue Sapphire, Teal Blue, Macaroni And Cheese, Illuminating Emerald, Light Grey.

Playful icons were chosen to support the light, gamified approach of the sustainability app. Figure 21 show six examples of icons related to sustainability challenges.

Figure 21. Excerpt of the icons in the first low-fidelity prototype. The icons were used to depict challenges around CO2 emission (car), animal rights (cow), financials & savings (coins with plant), mobility (bicycle) and health (heartbeat). The leaf is used to visualise the "Green points" that users can collect through taking challenges. These icons are from flaticon.com [87] and were accessed from the Premium version without the need to credit the creators.

Wireframes

For the first iteration of the low-fidelity prototype, wireframes were created in Sketch based on the user journey (Figure 19). The core wireframes depicting the app features are shown in Figures 22 to 24.

On Figure 22 (left screen) the app set-up is shown (eco-choice). Here, users can opt for goals and areas of interest for sustainability challenges. Making a choice allows users to personalise the app towards challenges that are feasible and appealing to them. On Figure 22, the centre screen enables users to view the sustainability challenges available (eco-choice). Users can see different action options available. They can pick and choose fitting opportunities. On the right screen (Figure 22), users can view more information about challenges (eco-information, eco-choice). They can read up details on the challenges such as challenge tasks and period and the expected impact of the challenge (e.g. CO2 or money expected to be saved). Besides, tips to pass a task are given.

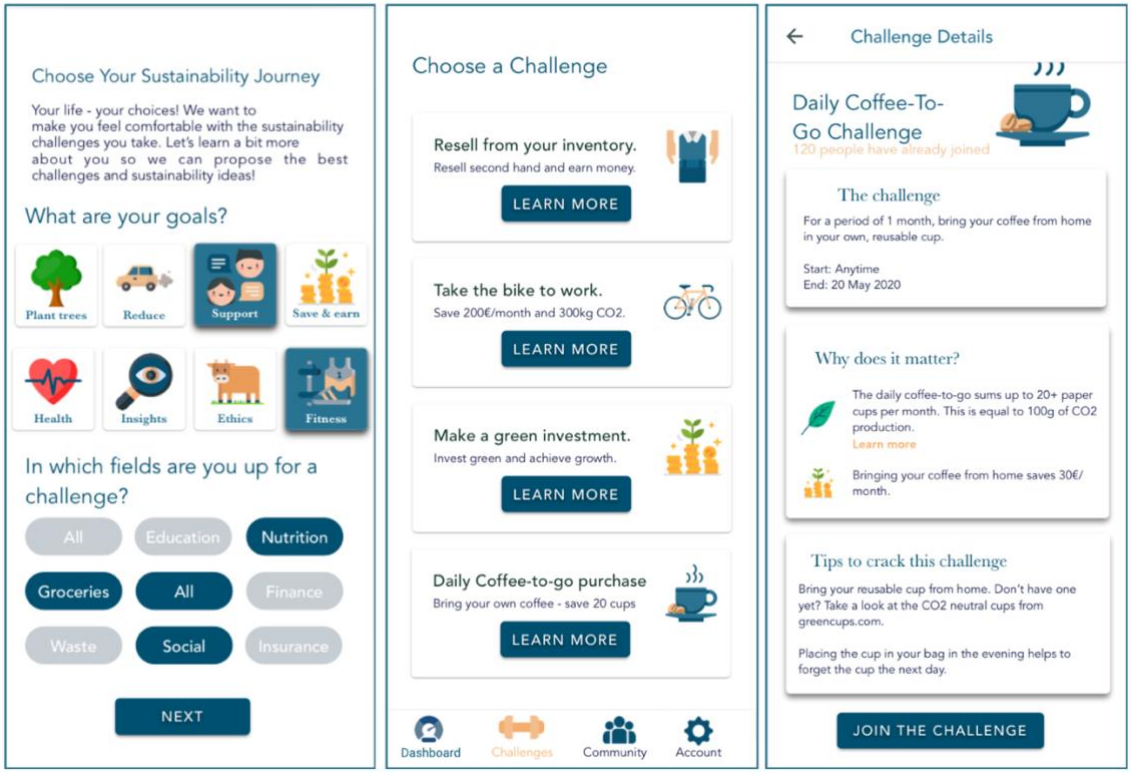

Figure 22. Wireframes of app set-up and challenge selection.

On the left screen of Figure 23, the challenge-specific progress is shown (eco-feedback). For a particular challenge, here the “coffee-to-go challenge”, financial servings per day are depicted, and CO2 emissions are mentioned compared to the kilometre a car could drive till the same amount of emissions would be produced. The centre screen gives a progress overview of challenges (eco-feedback). The visualisation of a “sustainability pulse” indicates how sustainable the behaviour currently is. The process in challenges is also shown through a progress bar. Additionally, financial savings, as well as CO2 emission savings, are depicted. On the right screen (Dashboard) tips and insights around sustainable behaviour are given (eco-information). In addition to providing insights into the transparency of one's actions, tips are added on the dashboard such as the tip: “Take a ‘Navy Shower’ – switch off the water while you put shampoo and soap”. These tips are intended to provide further action opportunities for the user.

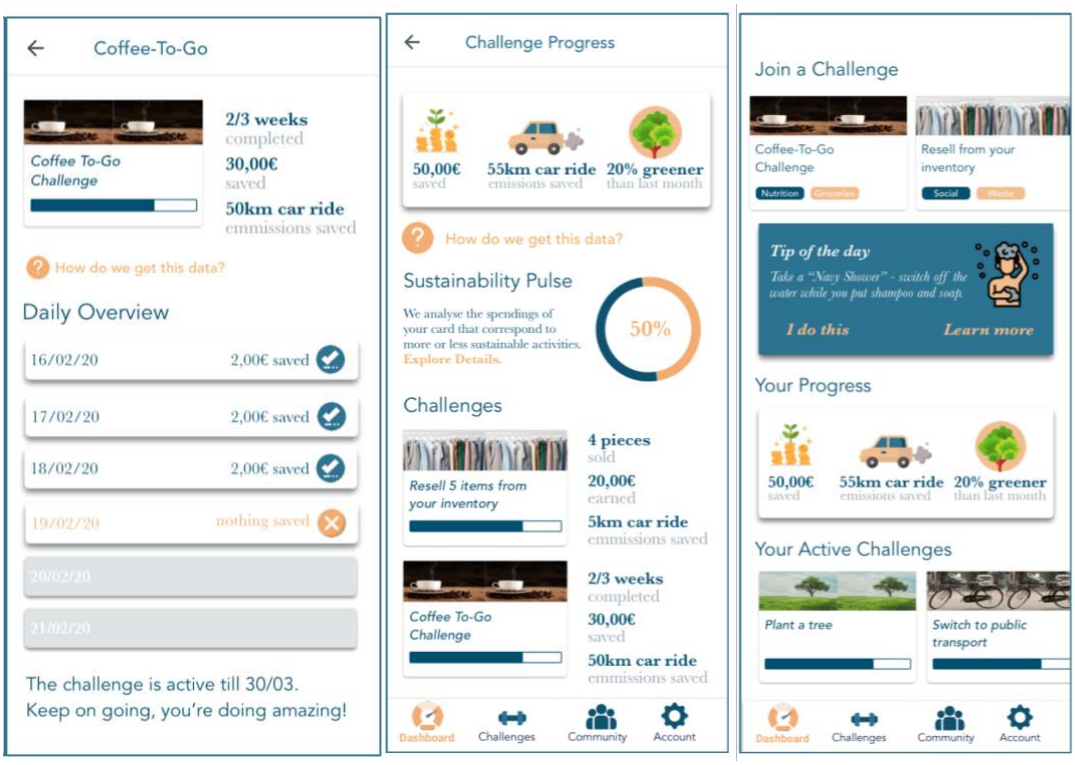

Figure 23. Wireframes of challenge progress and analytics.

Figure 24 (left screen) shows the social features overview. Users can open a leader board, access information about their team, chat inside the community or read up on someone else’s experience of the day. The right screen displays a leader board. Users can view a ranking of different teams towards each other. The best teams are visualised with a team picture and a position ranking.

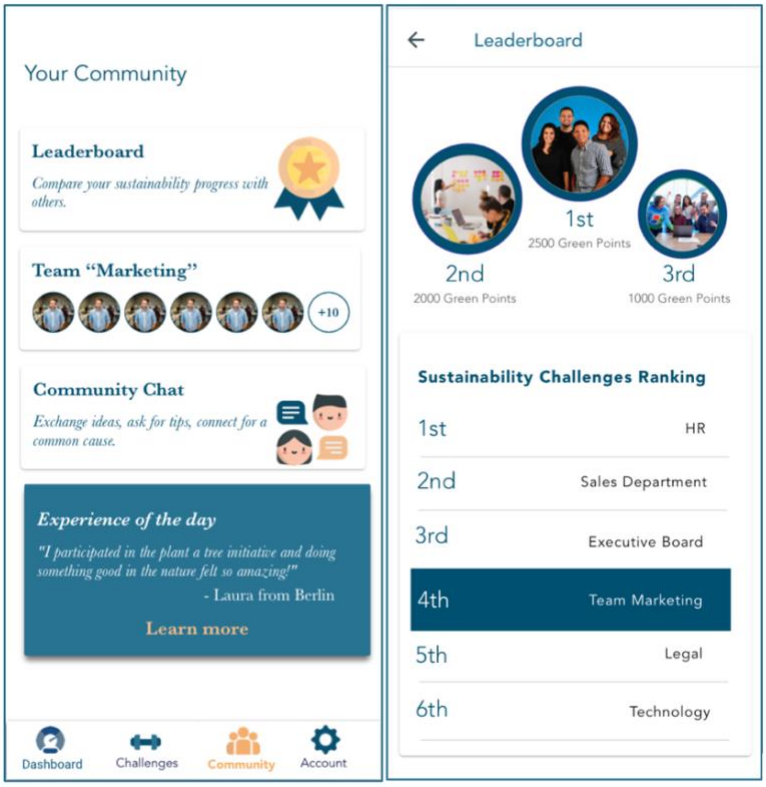

Figure 24. Wireframes of social features

Low-fidelity prototypes

The wireframes depicted above were turned into an Invision prototype to demo the product concept, design and features. Additionally, a functional prototype was developed by the developer on the project team. It was low-fidelity in the sense that it did not correspond to the visual design, and only a few features were functional. Users were able to pick a challenge of their liking, read challenge details about it and ultimately join the challenge (see Figure 23, centre and right screen). The functions of personalisation (see Figure 23, left screen) and challenge progress (see Figure 24) were implemented only as clickable wireframes. The wireframes displaying social features (Figure 25) were not included in the functional prototype at this early stage.

Conclusion

In the "Generation" section, a concept for the sustainability app has been created through content creation, a user journey and a visual design guide. The first iteration of the InVision prototype and a low-fidelity prototype with limited functionalities was created based on the wireframes. In the following evaluation stages, this prototype was tested with users and further iterated.

3.4 Evaluation: Low-fidelity prototype

This section describes the process of evaluating the first low-fidelity prototype to derive suggested iterations. In the following sections, the testing and evaluation procedure will be described (3.4.1). Then, the results will be presented (3.4.2), and a suggested iteration derived (3.4.3).

3.4.1 Procedure

The evaluation of the first prototype was done in a user-centred way with eight users in individual sessions. The users were briefed on the study and on the sustainability app's purpose and signed a form of consent before the start of the test.

The evaluation consisted of three parts:

- First, the **user interacted** with the low-fidelity prototype based on the use case of "choosing a challenge of their liking and joining the challenge."
- Secondly, the **interviewer guided the user through the prototype** again, discussing the different functional features and screens.
- Thirdly, a **short co-creation session** was held with the user to discuss future features and ideas.

The user testing took place via a Zoom call and was audio- and video recorded. The sessions lasted around one hour each. One team member interviewed the user while another team member took notes of the interaction in a structured manner. Detailed interview guides, the information sheet and consent form can be found in Appendix F and Appendix G.

Sampling

The eight participants were recruited based on convenience sampling due to limited time and budget. However, none of the interviewees was known personally to the interviewee, which ensured a higher degree of honest feedback during the interview process. Six participants were female, two males. The age ranged between 20-30 years with one exception: One of the participants was a 50+-year-old manager who represented a different generation and interacted with the app from the perspective of a team leader who might employ the sustainability app in his company. All young interviewees can be described with the persona of Ivan Impact: They are interested in sustainability topics which motivated them to participate in this research; however, they have not implemented changes towards more sustainable behaviour across life areas so far. The manager also expressed interest in sustainability and in sharing such an application with his employees, yet the manager would not be a target user of the application.

Prototype Interaction

The user was instructed to try out the prototype as if he or she would interact with it for the first time at home and was encouraged to *think aloud* during the whole interaction:

"Imagine that you just heard of this app Budge, which allows you to make more sustainable daily choices and integrate sustainable actions into your daily life. You heard that there are so-called sustainability challenges available on the app. These are challenges you can take on in your daily life to act more sustainable. They can, for example, be related to nutrition, transport or travel. Your task is now to log-in to the app and find a challenge that you actually would like to take on in real life. Please go through the app as if you would do it at home and think aloud what comes to your mind while using the app."

The user was observed while interacting with the app. Potential "errors" indicating a poor UX design were noted. Besides, comments of the user were registered. All users were able to complete the use case and join a challenge of their liking.

Prototype Walk-through

After the completion of the prototype interaction and use case, the user was asked to move back to the first screen where goals and challenge areas were chosen. Several questions were asked to understand the user's interaction choices and thought processes better. Topics of concern were: *Challenge areas available*, *reason for choosing the respective challenge areas*, *understanding of challenge-related task*, *choice process in picking a challenge*, *interest in challenge impact and background*, *feasibility of challenge in 'real life'*, *expectations from tracking of challenge progress*.

Co-Creation Session

The third part of the user testing included a co-creation session to understand the user's interest in various design features around the areas that had not been implemented yet. The relevant features were *tracking options (manual vs automatic), visualisation of challenge progress, reward options* and *social and community features.*

The interviewer briefly introduced different options available and then asked the user for their thoughts. After the user expressed their opinion, the interviewer asked for a ranking of top 3 feature choices for each area (e.g. tracking options). The objective of this rating was to gather information on the user's preferences. All visualisations used for the co-creation session can be seen in Appendix H.

Synthesis Process

The analysis of the user testing finding was done in various steps using Miro, the online whiteboard for digital collaboration (see Figure 26 for a screenshot).[5] First, the notes were clustered per interviewee and per screen (e.g. Challenge Overview screen). Next, the post-its were split into positive and negative observations, neutral comments and ideas. Then, for each screen, similar topics across interviewees were identified. The digital post-it notes were tagged. Names for the tags were assigned freely to ease the analysis and conclusions to be derived for the on-going interview process.

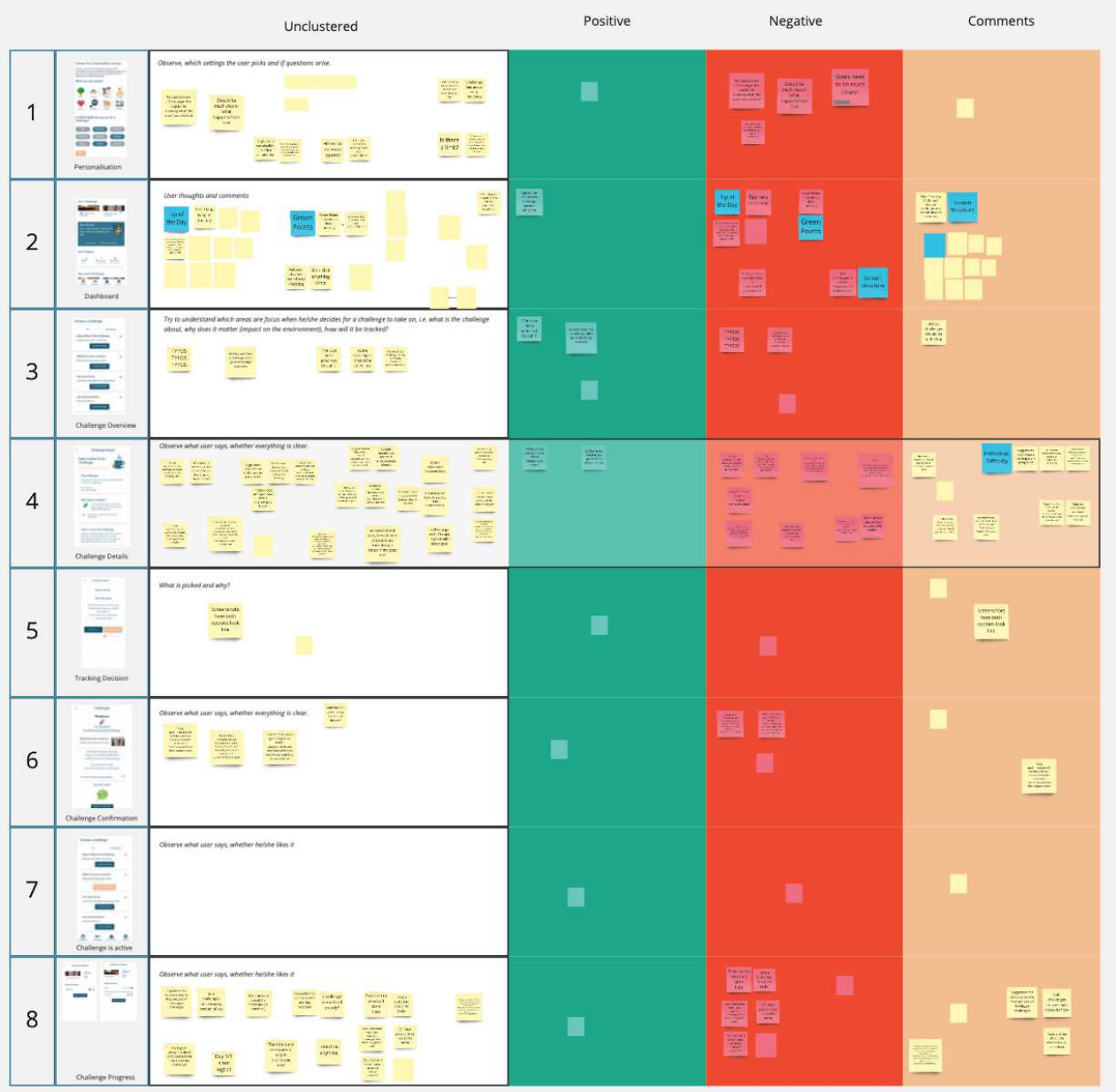

Figure 25. Affinity Map: notes from user test. An example for the notes taken for one of the eight users. First, the notes were not clustered and then sorted into positive (green), negative (red) and general remarks (orange).

[5] www.miro.com

After completing to tag all notes, the tagged categories were then expressed in concrete learnings for the improvement of the app and clustered into an affinity map visualising the improvement areas per feature (Figure 26).

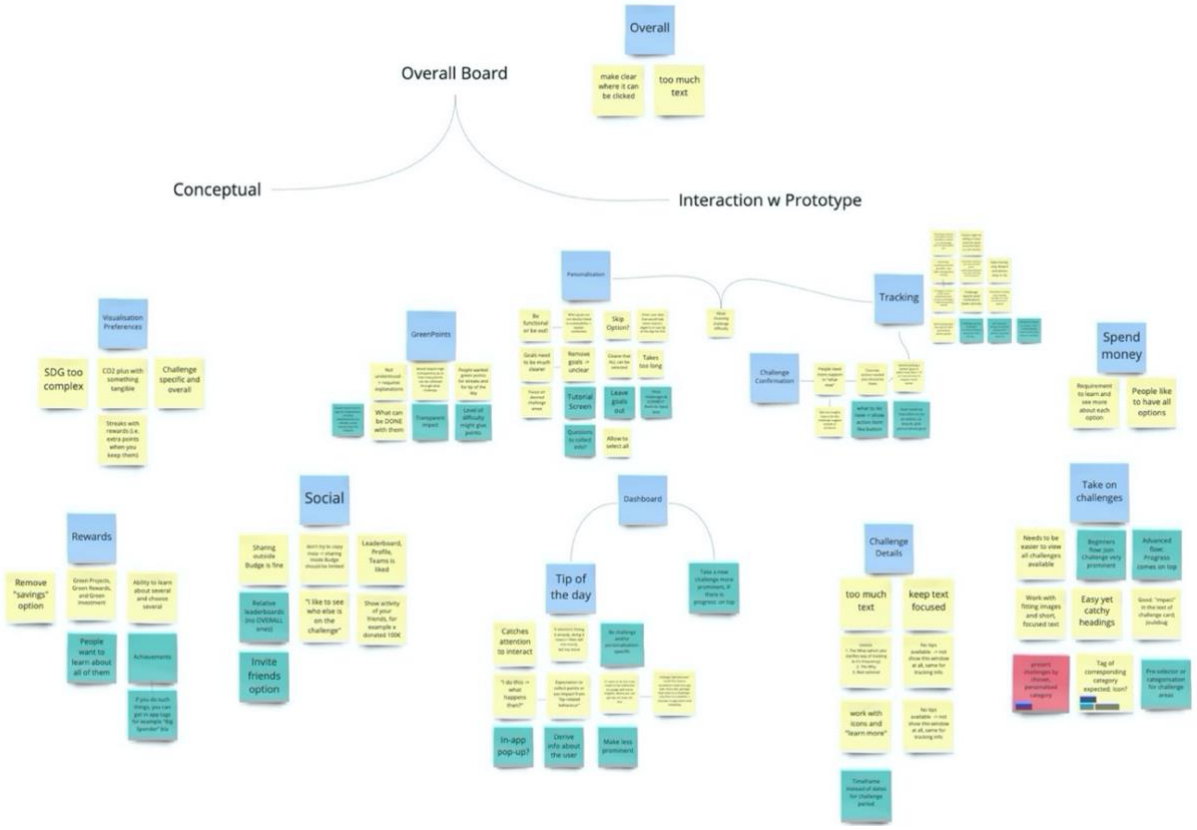

Figure 26. Affinity Map: synthesised findings from User Test. The affinity map of the core interview findings across the 8 user tests and co-creation sessions. All notes can be split into feedback on the interaction with the prototypes on the one hand, namely on Personalisation, Green Points (Rewards), Dashboard , Challenges and Challenge Details. On the other hand, conceptual feedback for future features is grouped around the progress visualisation, rewards and social categories.

3.4.3 User Testing Results

In the next paragraph, a textual summary is given for the different categories identified and clustered in the affinity map (Figure 26).

Personalisation

Three main feedback points around the personalisation on-boarding screen were identified (Figure 22, left wireframe).

Firstly, users require more explicit goals. They want to understand what all of the goals stand for and did not have a clear understanding of “Insights” or “Emission”. Besides, users were wondering how their goal selection affects the app content that is shown to them.

Secondly, users mentioned that other personalisation features could be more beneficial, such as asking whether the user is already vegetarian to adjust displayed challenges accordingly.

Take on Challenges

Users repeatedly said that it should be made simpler for them to view all challenges available. The reason for this was that some users did not navigate to the challenge detail screen (see Figure 22, centre screen). Instead, they accessed specific challenges through the dashboard screen (Figure 23, right screen) where "Trending challenges" were displayed at the top. For the challenge overview (Figure 22, centre screen) users were irritated that all challenges were shown to them, rather than only those aligned with their goals selected before.

Challenge Details

For the challenge details screen (see Figure 22, right screen) most users were **not** reading the text and indicated that there was overall too much text on the screen for them to read.

After joining a challenge, users would have expected concrete action triggers towards "what" to do, such as a button to click when a challenge was completed. One user asked for insights on how to do the challenge and suggestions on brands or products to use to get started.

Feedback on the intersection of content and design was to offer timeframes for challenges rather than dates. This way, users would be able to join the challenge anytime they desire.

Dashboard

On the dashboard screen (Figure 23, right screen), all users interacted with the "Tips" spontaneously, and they all overall liked this feature. However, they expected the option to see more details on the tips or suggestions on how to turn the advice into action. For instance, if a tip was to wash the hair with hair soap rather than shampoo from the plastic bottle, which hair soap could be recommended? What had to be taken care of when using hair soap?

Users also asked for more personalised tips around their sustainability habits and on-going challenges.

Rewards: Green Points

Users were not understanding Green Points and through which activities how many points could be collected. Besides, they were wondering *what to do* with the Green Points. They also expressed the desire to receive Green Points not only for the challenges but also for streaks and tips.

Tracking

In the follow-up co-creation session, users were presented with three options for tracking depicted in Appendix H, Figure 42: Self-reporting, self-reporting with picture upload as proof of sustainable action and automated tracking. The users' preference for a tracking method was varying across the eight respondents. Two users each favoured automated and self-reported monitoring, while three users preferred self-reported tracking with picture upload. Notably, four

users rated automatic tracking as the least preferred option and three rated picture uploads as the least attractive. Nobody reported self-reporting as the most unattractive option. Users furthermore commented that for the automated tracking option, they require high transparency into how and which data is being collected. Several users suggested enabling various tracking options so that they can choose their preferred reporting style.

Challenge Progress Visualisation

In the co-creation session, alternatives to visualise the challenge progress were also discussed Appendix H, Figure 43). There was a clear preference for having **tangible visualisations** such as comparing the CO2 impact to car kilometres or trees. Besides, users would want to see their progress both specific for a challenge as well as overall. The users disliked the SDG evaluations as being "too complex".

Social

Users were presented with six different social elements (Appendix H, Figure 44). These were a Social Wall, sharing of challenges and progress on other platforms/social media, commenting and interacting, viewing the experiences of other users, joining and competing in teams, leader board and profiles. In an open discussion, users had to comment their thoughts on the different options and explain their preferences. Users mainly liked the features of *Leader board, Profil*e and *Teams*. Some users mentioned that sharing outside the sustainability app (e.g. Instagram) could be interesting while "having another Instagram" inside the app would not be required.

Rewards

For the Reward options, users were able to discuss whether they preferred the donation into Green Projects, receiving personalised Green Partner Rewards or investing their money "green". Users were interested in all options and asked for further explanations to make a decision (see Appendix H, Figure 45 for details).

3.4.4 Conclusions for Iteration

For the next iteration and development of a high-fidelity prototype, the research team structured required action items into area, conclusion and their priority in a team effort.

Table 4 shows the conclusions drawn for the different current and future features described under 3.4.3. The core features were prioritised.

Table 4. A summary of the conclusions drawn for iteration based on the user testing

Area/Screens	Conclusion	Priority
Overall	Less text, more visualisation	High
Personalisation	Highly desired; Only include the selectors once they are functional; provide tutorial screens	Medium
Take a challenge	Clearer access to ALL challenges; provide a categorisation to easier find fitting challenges; make it very obvious for first time users that they have to take a challenge first	High
Challenges	Focused text on *what* to do and *why*; more icons for visual representation and nested cards with optional additional content	High
Challenge confirmation	Give "clear next action" steps on how to start or what to do, e.g. opportunity to report challenge progress	High
Dashboard (Information)	Keep tips because they are highly desired by users; make the tips' challenge or personalisation specific	Medium
Rewards: Green Points	Used for internal objectives first; later transparent. We would have different reward options for green points (e.g. donate, partner companies). Level of challenge difficulty to define points	Medium
Visualisation	CO2 with tangible comparisons; challenge specific	High
Social	First step: leader board; secondly: forming and competing in teams; later: sharing a social feed	High

High priority items were to use less text and more visualisations, to make the entry into challenge selection and the identification of exciting challenges easier and to clarify to users, which concrete activities they have to take. Besides, users need to be able to report their progress easily. The interviewees furthermore preferred challenge-specific, visual representation of their progress. For the design strategy of "social", user desire leader boards and the forming of teams most.

3.5 High-fidelity prototype

The iteration described under Section 3.4.4 led to the final stage of the human-centred design process applied for this thesis: the creation and evaluation of a new, high-fidelity prototype.
The prototype was designed based on the findings of the evaluation (see Section 3.4). Figure 28 and 29 depict crucial screens that demonstrate the changes done based on the previous user testing round. The high-fidelity prototype – a web application – was fully programmed for the user testing by the developer on the team (see Section 1.1 for a description of team roles distribution). It showcased some technical drawbacks due to the limited timeframe available for programming. The web application was very slow as it was hosted on a free server. Besides, not all elements were functioning well in the prototype. For instance, a once ticked checkbox could not be unticked. This feature was not programmed. The functional prototype has meanwhile been updated, but the Invision version is still accessible **here**[6].

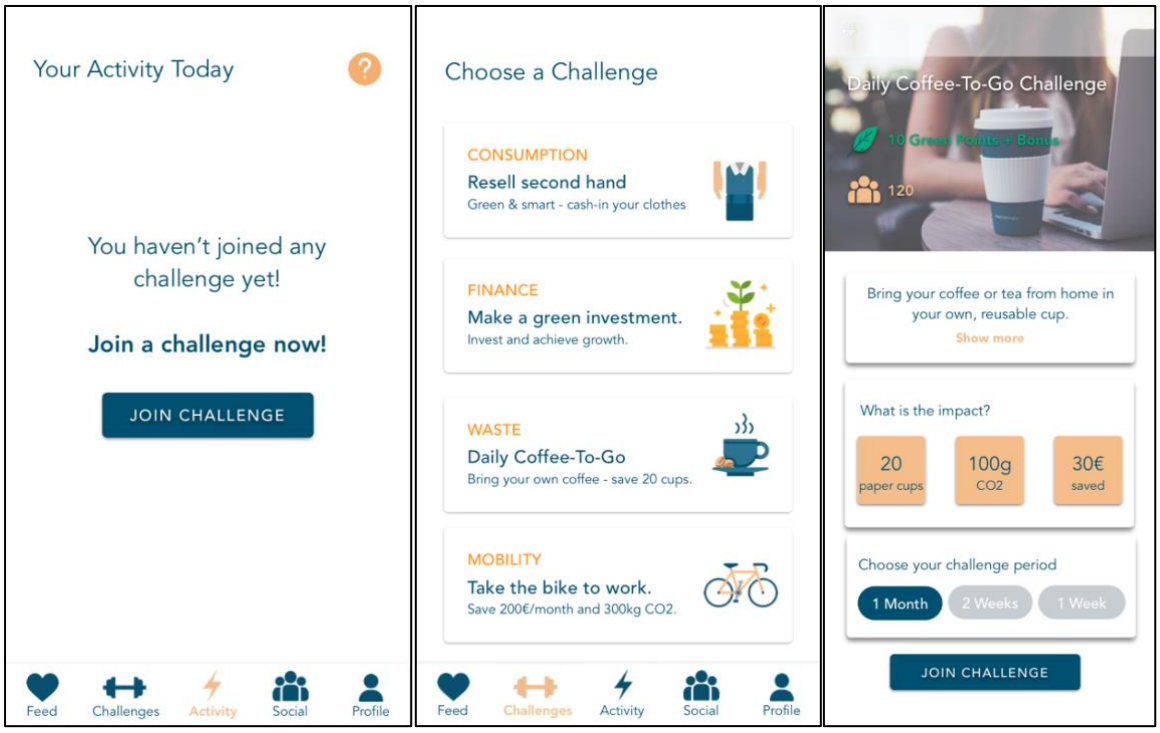

Figure 27. High-fidelity prototype part I. Left: Empty activity board before challenge were joined, Centre: Challenges Overview with categorisation of challenges, Right: Challenge details with less text and illustration of achievable impact

Figure 28 shows how the previous learnings were implemented. Appendix N allows for comparisons to the prior stage of the wireframes.
The navigation bar was changed to have the "Activity" Screen at the centre which would serve as the place to report challenge progress. An empty activity board (left) gives a clear pathway to the user to join a challenge. In the centre, the challenge overview screen is made cleaner by removing

6 Access to the Invision Prototype: https://invis.io/6CX81N6XKQR

the dominant “Learn more” button and focusing on the challenge content. A category was assigned to each card to support the user in finding challenges of their liking.

The right screen displays the challenge details screen. As requested by users, the most text has been removed. Instead, visualisations of the impact in orange boxes and an opportunity to “show more” allow the user to better extract the core information with the opportunity to learn more if desired. Additionally, real photographs were added on the challenge details screen to make the challenge task more tangible and relatable. The option to choose the challenge period allows for some difficulty selection by the user.

The new, simplified design shown in Figure 29 can be compared via Appendix N. Left, as requested by users, they get information on how Green Points work once they have joined a challenge.

In the centre is the Activity screen that is crucial for the adapted design. Users can report their progress on the challenge, get a transparent overview of the development in “days” and in “impact parameters”. On the right screen, the Leader board was adjusted, and the opportunity to add future “Team” features is represented by the “My Team” heading on the top right of the screen.

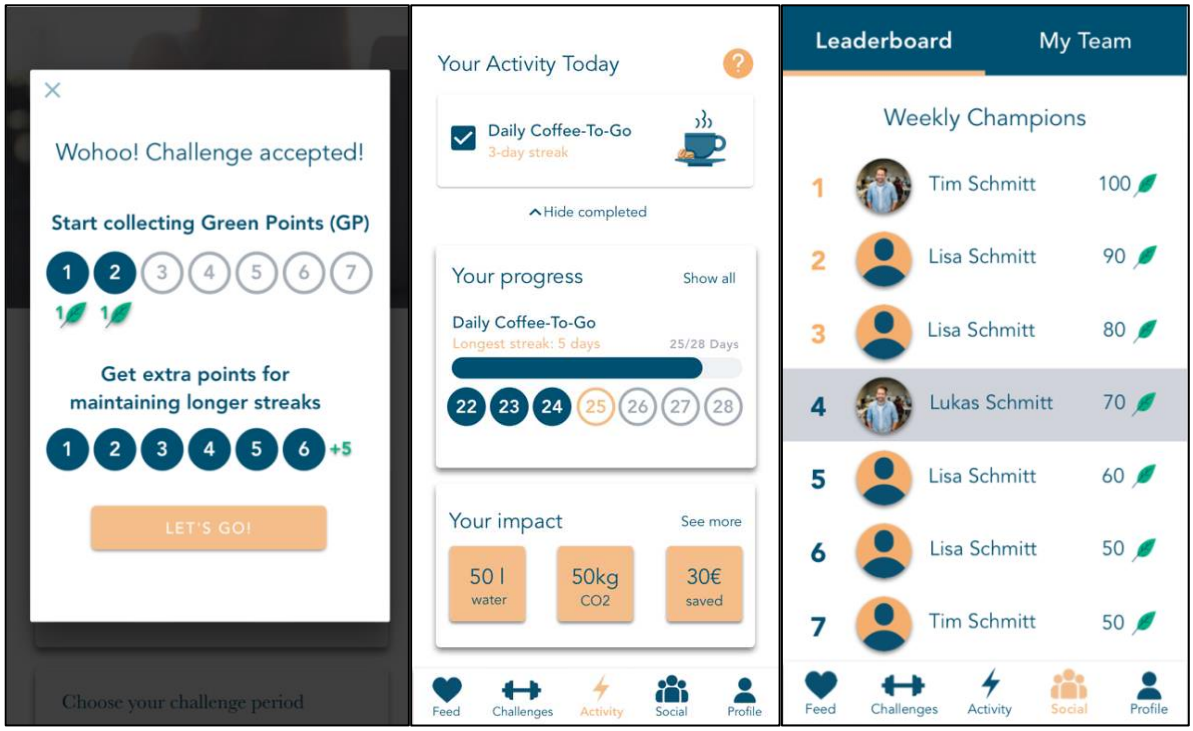

Figure 28. High-fidelity prototype part II. Left: challenge confirmation with guidance on green points system, Centre: activity screen to report progress and view impact. Right: Leader board iteration to view user ranking.

3.6 Conclusion

Chapter 3 has discussed the human-centred design process of the high-fidelity prototype presented in Section 3.5. The goal of the process was to design a mobile app that encourages people to take on sustainable actions across different areas of life. In order to create such an app, the phases of exploration, generation and evaluation proposed by Coskun et al. [61] have been followed [61] (see Figure 5).

The phase of *Exploration* (Section 3.2) focussed on understanding the users, their behaviour and opportunities for the design for sustainable behaviour change. In the *Generation* stage (Section 3.3), design strategies to achieve behaviour change were decided upon and implemented. Finally, the low-fidelity prototype was evaluated with users and conclusions for iteration were drawn (Section 3.4). The outcome of the iterative design process is a fully-functional high-fidelity prototype (Section 3.5).

However, this high-fidelity prototype is not the final outcome and far from perfection. The human-centred design process is iterative, which demands the adapted prototype to be re-tested with users. As the prototype is fully functional, the evaluation could take place in a real-life setting with users. In the next stage of the research process, a field study was set-up to test the prototype during a two weeks study with 30 users from the chosen target group. The set-up and methods of this study are presented in the next chapter (Chapter 4). The final results in terms of “Design” can be seen in Section 5.. There,the final prototype is presented, and the Research Question 1 is answered: *How might we design a mobile app that encourages people to take on sustainable actions across different areas of life?*

4 Field Study Setup

In this chapter, the field study setup, namely general procedure and methodologies are described. Section 4.1 introduces the overall study design and the distribution of participants. In Section 4.2, the methodologies which were applied to answer Research Question 1 are introduced. Section 4.3 describes the methods used to answer Research Question 2. The conclusion summarises the field study set-up and objectives (Section 4.4).

4.1 Study Design and Participants

In this section, the design of the field study is described in more detail addressing the general procedure, sampling method and participants.

The functional app was tested in a two-week field study. Figure 30 visualises the different research stages from a user's perspective. First, the users were briefed in an onboarding call. Next, a digital pre-survey was conducted via Google Forms to collect user data on demographics, attitudes around sustainability and current sustainability-relevant behaviour (see survey questions in Appendix I). Users then interacted with the app for two weeks. They were instructed to take on sustainability challenges and integrate the sustainable actions into their daily life. Users also had the opportunity to submit feedback via Google Forms or email during the study period.

After the interaction period, five users were interviewed in-depth on their experience with the app usage (see Appendix J for the interview guide). Additionally, all users filled a Google Forms survey that collected ratings about the user experience and future demands from the sustainability app (Section 4.2). The form also assessed constructs required to evaluate the potential impact on behaviour change (Section 4.3). The interview findings partially informed the survey content. The post-survey questions are attached in Appendix K. All detailed results from the survey can be provided upon request.

Figure 29. In-field user study process. The image shows how it was presented to the users. It consisted of a pre-survey, two weeks of app interaction, a post-survey and five in-depth user interviews.

The participants were recruited based on convenience sampling due to the limited time and budget. Initially, 35 respondents filled out the pre-survey, and 30 respondents filled out the final survey. 27 respondents could be matched correctly to an existing participant ID so that their answers between pre- and post-survey could be compared. Of the 27 participants in both surveys, 19 (70.4%) were female and eight male (29.6%). Four respondents were aged 18 to 21 (14.8%), nine respondents aged 22 to 25 (33.3%) and fourteen participants 26 to 29 years old (51.9%). The respondents were sustainability-minded and aware of the need to act sustainably. They strongly agree (81.5%) or agree (18.5%) that *"climate change has been established as a serious problem and immediate action is necessary"*.

4.2 Methods RQ1

In this section, methods to answer Research Question 1 and its sub-questions are introduced. As introduced in Section 1.3, the first Research Question (RQ1) asked:

> *RQ1: How might we design a mobile app that encourages people to take on sustainable actions across different areas of life?*

Sub question 1 was already addressed in the Exploration stage of the research (see Section 3.2.3). Relevant sub-questions to answer with the field study are:

- *Sub question 2: Which design strategies might be appropriate when designing a mobile app that targets sustainable behaviour change across life areas?*
  Design strategies have already been chosen for the design of the app. Now, it will be evaluated whether users appreciate the chosen design strategies.

- *Sub question 3: Which kind of user experience, and which features should an app have that encourages people to take on sustainable actions across life areas?*
  It has to be investigated whether the user experience is positive enough to encourage users to interact with the app. Besides, feedback on specific features will be collected.

Pre-Survey

The pre-survey collected data on demographics, on typical behaviour related to sustainability and constructs relevant for the Theory of Planned Behaviour. As these parameters are mainly of interest to answer RQ2, they will be explained in detail in Section 4.3.

Qualitative User Interviews

Five in-depth interviews of ~60min were conducted via video call. The goal was to understand the global user experience with the app and gather feature-specific feedback. The researcher led

the interviews while one assistant was taking notes. Besides, a few new features were shown to the interviewees. The full interview guide can be found in Appendix J.

Based on the notes, an affinity map was created using the software Miro to synthesise the qualitative findings and define opportunities to iterate and further improve the app. Also, the qualitative interviews further informed the quantitative survey set-up intending to incorporate and quantitatively validate aspects that repeatedly came up in the user interviews.

Post-Survey

Sub-question 2 of Research Question 1 is addressed by rating the user's experience with specific features that correspond to the design strategies. Users ranked their experience with the app on different scales, both globally and specific to the design strategies of eco-choice, eco-information, eco-feedback and social. The goal was to understand whether the design strategies were causing the desired effects. Examples of the questionnaire items can be found in Table 5. All items were assessed on a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

Table 5. Example items to assess different features

Design strategy/goal	Item Examples
Support the uptake of sustainable actions	The app makes it easier for me to integrate sustainable actions into my life. The app motivates me to follow a sustainable lifestyle.
Eco-choice and challenge fit	The challenges were relevant to me. The challenges were difficult.
Eco-information	The app gives me new ideas and tips on how to act more sustainable.
Eco-feedback	The app makes the impact of my personal behaviour on the environment more transparent. The app showed me that my decisions matter for the environment.
Social	While using the app, I felt part of a 'sustainability community.'

Sub-question 3 of Research Question 1 is addressed with identifying user experience ratings and collecting feedback on features. The user experience with the mobile app was measured with a digitized version of the validated User Experience Questionnaire (UEQ) [88], [89]. The UEQ measures the parameters attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. The parameter *attractiveness* stands for the user's overall impression of the product. *Perspicuity* describes how easy it is to get familiar with the product and learn how to use it. *Efficiency* asks whether the product is fast and if users can solve their tasks without unnecessary effort. *Dependability* assesses to what extent users feel in control of the interaction and whether it is secure and predictable. *Stimulation* asks how exciting, motivating and fun to use the product is. Lastly, *novelty* is the evaluation of the creativity of the product and whether it catches the user's

interest. The researchers provide an Excel Analysis sheet on the website [90] which was used for analysing the results of the UEQ and provides a tool to conduct a benchmark comparison with 452 studies across diverse product categories. See Appendix L for the UEQ questionnaire.
At the end of the post-survey, users were asked which future features they would like to see in the mobile application, and they had the chance to give open feedback about the app and its usage. The questionnaire is attached in Appendix K.

4.3 Methods RQ2

In this section, the methods to answer Research Question 2 are introduced. Research Question 2 asked:

> *RQ2: To what extent can a mobile app support people in taking on more sustainable actions across different areas of life?*

Four hypotheses were formulated which need to be validated or falsified in order to answer RQ2 (see Section 4.3.1). Methods to assess Hypotheses 1 to Hypotheses 4 are presented in Section 4.3.2 and 4.3.3. Finally, the data pre-processing and preparation steps are explained in Section 4.3.4.

4.3.1 Hypotheses

Research Question 2 needs to be broken down into more specific hypotheses that can be validated or falsified through statistical analysis. Four hypotheses have been created for this purpose.
It will be assessed whether users show more sustainable behaviour while using the app compared to their previous behaviour frequency (H1). Also, it will be evaluated whether parameters that have been proven to *predict* behaviour change have changed through the app interaction. For this analysis, the Theory of Planned Behaviour (2.1.1) serves as a baseline. According to the Theory of Planned Behaviour, sustainable behaviour change can be predicted by changes in *attitudes towards sustainable behaviour* (H2), *perceived behavioural control* (H3), and the *intention to act sustainably in the future* (H3) [33].

The following hypotheses were thus formulated:

- H1: The interaction with a sustainability app leads to an increase in sustainable behaviour during the interaction period.
- H2: The interaction with the sustainability app leads to an increase in positive attitudes towards sustainable behaviour.
- H3: The interaction with the sustainability app leads to an increase in perceived behavioural control with regards to sustainable behaviour.

- H4: The interaction with a sustainability app leads to an increase in the intention to act sustainably.

4.3.2 Measuring behaviour change during app-usage (H1)

Hypothesis 1 states that interaction with a sustainability app leads to an increase in sustainable behaviour during the interaction period. According to the research teams' best knowledge, there is no validated questionnaire assessing "sustainable behaviour" for the relevant parameters nutrition (meat vs plant-based diet), mobility (car vs public transport vs car), waste (e.g. using reusable cups or bottles), consumption (recycling of clothes) and finance (being customer at sustainable banks). Thus, an own questionnaire was created for this master's thesis. In Appendix K, the full post-survey questions are attached.

The items created for this purpose are displayed in Table 6. One statement assessed one particular behaviour (e.g. "cycling"). The behavioural scales as shown in the "Scale" column in Table 6 had to be transformed into a numeric scale to perform statistical analysis. Higher numbers represented a more positive, pro-environmental behaviour. For the frequency ratings, "never" was assigned a "1" and "always" a "7" with respective numeric equivalents along the scale. For nutrition, *omnivore* was assigned 1, *vegetarian* and vegan a 4. *Pescatarian and flexitarian* were both given a 2 as it is a form of consuming animals while being more mindful about it.

Notably, users self-report the behaviour and its frequency. Different users, of course, evaluate shower time length differently or define "sometimes" or "often" in different ways. The measurement thus refers to the *self-perceived* behavioural frequency and evaluates potential changes in this self-reported behaviour.

Table 6. Construct, items and scale to measure frequency of behaviour

Construct	Item Examples	Scale
Behaviour: Nutrition	Which category describes your nutrition best?	Omnivore (1), pescatarian (2), flexitarian (2), vegetarian (3), vegan (4)
Behaviour: All other areas	I keep my showers short. I used a refillable water bottle For distances < 5 km I take the bicycle.	never (1) – almost never (2) – rarely (3) – sometimes (4) – often (5) – almost always (6) – always (7)

For measurement of the mean difference between two sets of observations in a repeated-measure approach with the same participants, either the paired sample t-test (normally distributed data) or the Wilcoxon signed-rank test (non-normally distributed data) is applied [91]. Thus, the distribution of the data has to be checked before picking the indicated statistical method.

The t-test or Wilcoxon signed-rank test is first applied to all users that participated in the study. This includes users who, for instance, did not take the "Vegetarian week" challenge and are thus less likely to have changed their behaviour when it comes to nutrition. A second analysis is conducted with only those users who *participated in the corresponding challenge*.

In the analysis, only those behaviours are considered that at least 60% of users picked as a challenge. The reasons for this is that participation in challenges is regarded as a crucial factor in encouraging behaviour change.

In the evaluation of the t-test or Wilcoxon signed-rank test, the p-value of 0.05 will be used to identify the statistical significance of the results at a 95% confidence level. [91]

The previous methods measure statistical differences in self-reported behaviour. In addition to that, users answer one more relevant survey question. They are asked to estimate how frequently they have done their challenge behaviour as compared to before the field study.

4.3.3 Measuring the predictors of behaviour change (H2-H4)

For the evaluation of hypotheses 2-4, parameters of the Theory of Planned Behaviour [33], namely *attitudes towards sustainable behaviour*, *perceived behavioural control (PCB)* and the *intention to act sustainably* in the future were used. No validated questionnaires are assessing all parameters of the Theory of Planned Behaviour applied to the "sustainable behaviour" context. As a consequence, own items were created. Based on the initial Cronbach's Alpha analysis (see 4.3.4), a selection of items was chosen to measure the respective constructs (see Table 7). Higher numbers represent a more positive attitude, PCB or intention towards sustainable behaviour.

Table 7. Construct, items and applied scales for measurement of Hypothesis 2 to Hypothesis 4

Construct	Items	Scale
Attitudes	1: The way I personally behave makes a difference to the environment. 2: I am aware what I can do to act more sustainable (e.g. in the areas of nutrition, transport, consumption, travel etc.) 3: I believe that I know enough about the environmental impact of my daily behaviour. 4: Living sustainably is more expensive than not doing so. *(inverted)* 5: I can influence what the government does regarding sustainability. 6: I can influence what the companies do regarding sustainability.	1 – strongly disagree 5 – strongly agree

Perceived behavioural control	1: It is difficult for me to change my everyday life to more sustainable behaviour. *(inverted)* There is a lack of transparency about the sustainability of existing products and services. *(inverted)* There are enough sustainable products and services offered. *(inverted)*	1 – strongly disagree 5 – strongly agree
Intention	1: I am determined to establish more sustainable habits in my life. 2: It is important to me that I follow a sustainable lifestyle.	1 – strongly disagree 5 – strongly agree

The means of the respective constructs were compared before and after the two-weeks usage of the sustainability app through a paired t-test (for normally distributed data) or a Wilcoxon signed-rank test (for non-normally distributed data). For Hypothesis 3 (PCB), one additional item could be analysed: in the post-survey, users were asked whether the app makes it easier to integrate sustainable actions into their life. Hypothesis 4 (Intention) is supported by an item in the post survey that asks participants whether the app motivates them to follow a sustainable lifestyle.

4.3.4 Data Preparation

The statistical analysis was conducted using Excel and SPSS. In the first step, respondents were excluded who did not participate in both of the surveys. The remaining participant count was 27. The pre- and post-study survey results were merged by participant ID in SPSS. Next, non-numeric scales (e.g. frequency of behaviour) were brought onto numeric scales. Higher numbers meant a "more sustainable answer" thus more frequent sustainable action or attitudes. Inverted scales were inverted to fit this scheme.

A Cronbach's Alpha test was conducted to identify whether the items intended to measure the same construct yielded similar results. For instance, it was assessed whether the seven items measuring "attitudes" were internally consistent.

Next, a mean was drawn across the item responses to create the scales "Attitudes", "PCB" and "Intention".

The scales were tested for normal distribution using a Shapiro-Wilk test in order to support the decision of whether to use parametric or non-parametric statistical analysis tools [92].

5 Results

This chapter presents the results of the field study regarding Research Question 1 (Section 5.1) and Research Question 2 (Section 5.2).

5.1 Results Research Question 1

The results relevant to answer Research Question 1 asks for how a mobile app supporting sustainable behaviour change should be designed. In this section, the interview findings are summarised (see Section 5.1.1). Next, the survey results are described (see Section 5.1.2). In Section 5.1.3, the results of the User Experience Questionnaire (UEQ) are reported. Lastly, the final results for the app design in the timeline of this master's thesis based on the new findings are shown (Section 5.1.4).

5.1.1 Interview Findings

Interview results focus on improvement opportunities for design. The full affinity map based on the five semi-structured in-depth interviews is shown in Figure 31.

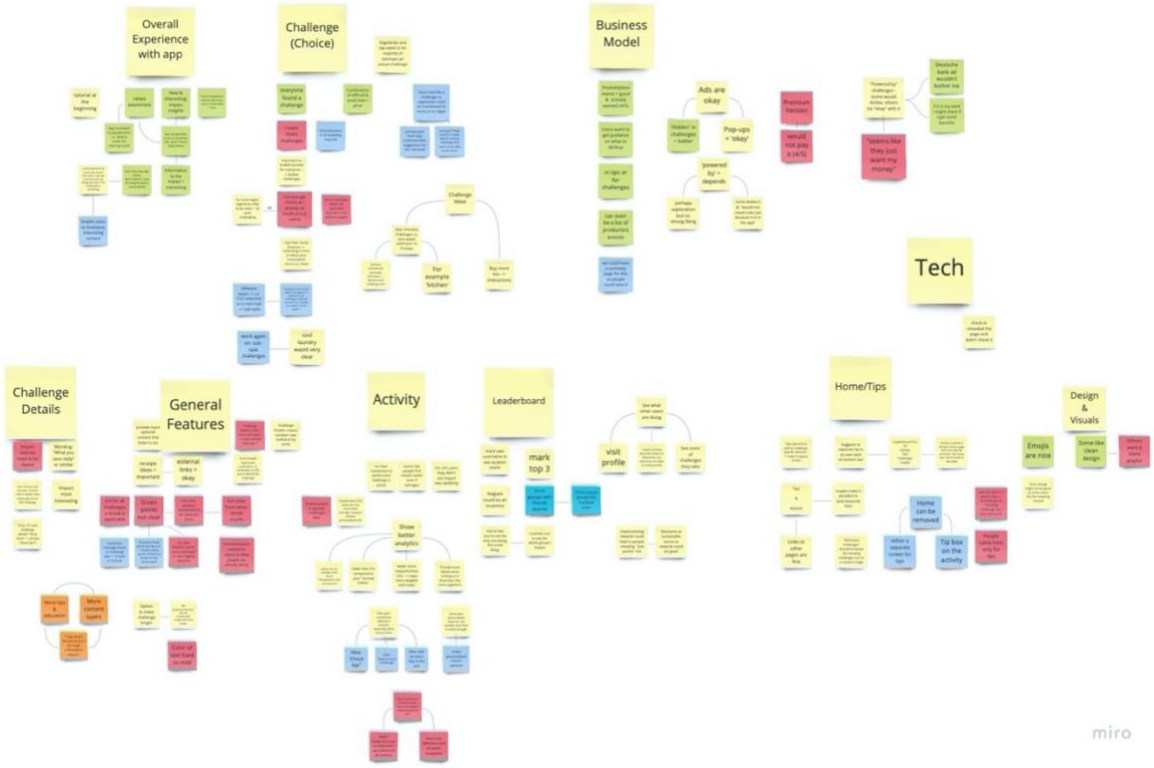

Figure 30. Affinity map: Qualitative post-study interviews. The affinity map of the qualitative interviews consists of feature-specific clusters, overall experience feedback, business model, tech, design and visual feedback

In the affinity map, findings were collected about the different features to understand opportunities for improvement. These were challenge (choice), challenge details, activity, leader

board, home and tips. Besides, feedback about the overall experience with the app was clustered, and business model feedback and design and visual feedback were assigned into one cluster.
In the following paragraphs, the main findings for the different clusters will be summarised. For screens related to the feedback summarised below, please refer back to Figure 28 and Figure 29.

Overall Experience

Users overall stated that the app increases their awareness and gives them new and exciting insights into their impact; and tips and inspiration about what to do to act more sustainable.
One user, for instance, said: "*The app motivates to pay attention to things, for example to what is actually inside the cleaning liquid".* Another user stated: *"The app helped me a lot to understand why leaving away the 'good meat' is important, too".* Beyond this, two users found it interesting to access the sustainability content in one place: *"On the internet, there is so much [too much] information but here I can have an overview and can go back if I am interested in something."*

Challenge Choice

Users all found a challenge to take and valued having a choice, yet they still wish for more challenges. While for three users, several challenges seemed difficult (e.g. vegetarian or tap water), two users found they did not have enough choice as they already do most of the listed activities. Users also had ideas for future challenges such as "The Bathroom" challenge: *"There could be high-level challenges with smaller sub-tasks. For example, a bathroom challenge and then it tells you to buy a bamboo toothbrush or a sustainable shampoo."*

Challenge Details

On this page, users found the "Impact" most interesting. They would like to understand the sources of the impact in even more depth. Only one in five users read the challenge details under "show more". Small suggestions included to make the icons for "participants on this challenge" clearer and reword the impact title into "What you save daily".

Activity

Users missed a clear connection to the Green points and the origin of their "impact" (e.g. CO2 savings) once the challenge was active. It was not transparent to them how the Green Point system worked. Two out of five users did not see that their impact data changed when they logged an activity. Users mentioned that they sometimes forgot to update the progress and then did not collect the points. For some users, it was not possible to stick to the challenge at all times. For instance, eating vegetarian was difficult when eating with the family.
Some users expressed that they would like to have personalised input (e.g. kilometres cycled), while others find it useful enough with averages.

Leader board

On the leader board people like to see that *"you're not the only one doing this small thing"*. They expressed that it could be useful to form groups with friends and see the whole groups' impact. Besides, people would like to see what other people are doing, for example, through visiting their profile: *"I want to know what the others do differently and why they have so many points".*
People have mixed feelings regarding rewards. Some want them; others do not.

Home and Tips

The home screen was visited by users only to view the tips. They liked the advice. For two users, the tips somehow seemed to belong to the "Trending challenges" mentioned on top. Users would prefer if there were tips specific for their on-going challenge available.

Design and visuals

While some users liked the clean design, others wished for a more playful design. Users liked the icons.

Business Model

Business model findings refer to learnings that investigate potential options to monetize the app. All users said product placements such as of sustainable shampoo on the app would be good to receive guidance on what to buy. Users expressed that they would also be fine with ads and prefer that these are "hidden" in challenges rather than appear as a pop-up. All five users said that they would not pay for a premium version of this app.

5.1.2 Post-survey results

The survey results indicate to what extent the users were supported in taking up sustainable actions by the current app. The effects of the chosen design strategies *eco-choice, eco-information, social* and *eco-feedback* are evaluated. The users' overall user experience is assessed. Additionally, feedback is collected for the last iteration in the design process for this master's thesis. In the analysis, the answers of all 30 users that filled out the post-survey were considered.

Eco-choice and challenge fit

The choice offered to users through different challenges available was considered (very) relevant by ~59% of the users. The following insights from the open comment section indicate why the challenges might not have been relevant to some of the users:

"[Because of Corona] I stay at home, so transport-related questions are not really applicable. Most of the activities I did just as frequently as usual; however eating vegetarian was one activity which I did more frequently than I would otherwise have."

"Some of the challenges already represent my normal behaviour so I couldn't take them."

"*The challenge 'take the bike to work' is very specific. Currently, I don't go to work or university, and if I do, I rather walk. If the challenge was more general (take the bike/walk, also to the shop, to meet a friend, etc.), then more people could join the challenge."*

Eco-information

86.7% (strongly) agreed that the app gives them new ideas and tips on how to act more sustainable (see Figure 32). In total 4 out of 30 users are neutral or disagree that the app provides useful or new information to them.

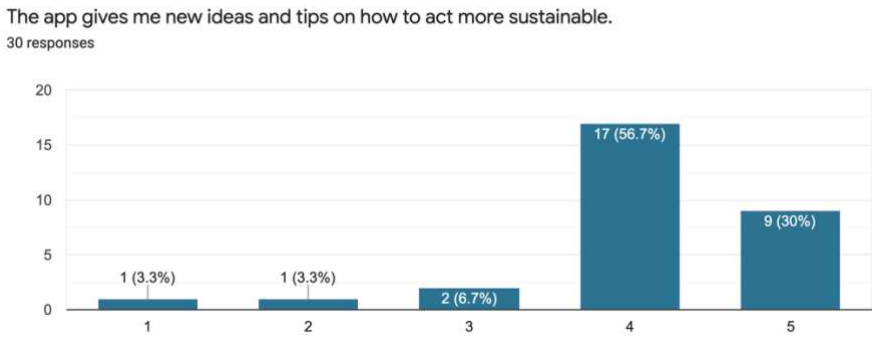

Figure 31. Eco-information user rating. Users largely agree that the app gives then new ideas and insights on how to act sustainably.

The following open comments give more indications on the user's answer choices:

"It could be nice if the tips you get, depend on the challenges you took and help you complete them (could also be generated by the users)."

"Those challenges do not bring any new value; I can put in any other platform. The challenges have to bring some value from this app that I can't get from other solutions."

"The information is the same I find in the internet or searching, give something new."

Eco-feedback

Users mostly agree with the statement that the app makes the impact of their behaviour more transparent (66.7% or two-third of the users), 10% strongly agree. 23.3% are neutral or disagree with this statement (see Figure 33). 70% of users (strongly) agree that the app showed them that their decisions matter for the environment. In total, 7 out of 30 users are neutral or disagree that the app made the impact of their personal behaviour on the environment more transparent.

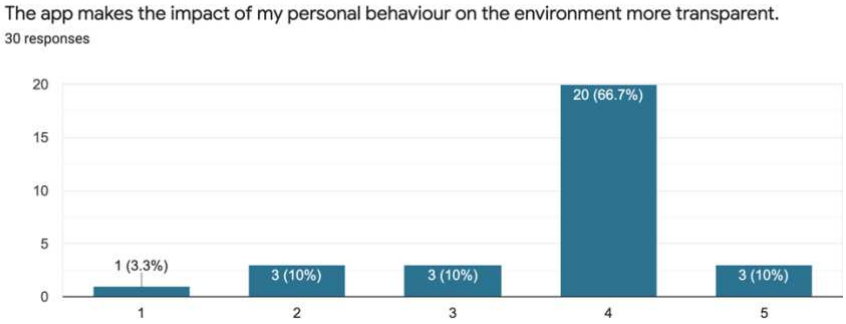

Figure 32. Eco-feedback user rating. Users largely agree that the app makes their impact on the environment more transparent.

Following open comments were received:

> *"All the time it was a number that went up, I did not have feedback or visualization that explain my actions."*
>
> *"The visibility of my impact was minimal in the app"*

Social

Users (strongly) disagree with the statement that they felt they were the only ones taking sustainable actions (80%). Part of a 'sustainability community' felt 56.7%, while 40% disagree with feeling part of such a community (Figure 34).

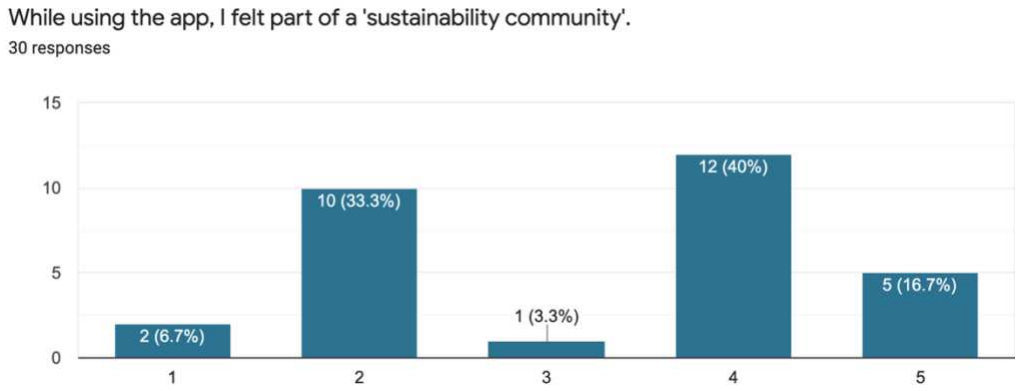

Figure 33. Social features user rating: Users felt part of a sustainability community

Several interesting comments were received regarding the ambiguous results for "sustainability community". An excerpt is presented below:

> *"I didn't know the people of the ranking or contact them often. Also, I didn't know their progress, just a few numbers that didn't represent that much for me."*
>
> *"It is easier for me to feel a sense of belonging to a community when I can physically meet people of that community."*

"It would be better if you could have a group of friends or colleagues in the app, instead of strangers. That would highly improve the thought of belonging to a community. Or maybe matching it to the "Facebook friends."

"I find the app as a reminder good, but I do not feel motivated by the other participants because I do it for myself."

"Overall, the app is a great initiative for sustainable development. The main feature I liked was the leader board. While it was just a bunch of meaningless online points, but it was those points that motivated me and kept me going. […]"

Future Feature Ratings

The survey asked how important specific features were for the users that had not been implemented yet. These featured had been ideated based on findings from the qualitative interviews. The objective was to understand which elements should be improved first. The ratings were collected on the scale from 1 (not important at all) to 7 (very important). Below, the most relevant findings are summarised.

Looking at the challenges choice and challenge type offered, 90% of users agree on needing more challenge options. 56% of users also find it (very) important to customize challenges. Users do not need the app in their native language, which might be related to their high education level.

For challenge details, 63.3% of users find it (very) important to see tips for a challenge (e.g. recipes). 50% finds it (very) important to track their impact, e.g. the kilometres they cycled rather than using averages. 53.3% of users want to choose the exact challenge period by themselves.

On the activity screen and the "reporting of challenge progress", 20% of users strongly dislike the introduction of push notifications. At the same time, 63% find push notifications (very) important. 56.7% of users want to see clearer the Green Points they collect for a challenge activity. Users mainly do not find it relevant at all (56.7%) to share their progress to social media.

When looking at the Home Screen features, a highly desired feature by users is to receive customised tips based on the challenge they take. 90% tend towards (very) important with regards to this feature. 80% of users additionally wish for more background information about the tips. Besides, more than half of the users (56.7%) find it (very) important to receive product and service recommendations, such as 'sustainable shampoo' in the future.

With regards to Leader board and Rewards features, the most preferred feature is the ability to turn Green Points into donations for "green projects". This feature is rated as (very) important by 73.3% of participants. Still popular is the function of exchanging Green Points into rewards for "sustainable stores" (63.3%). Lastly, many users would like to create private leader boards with friends, rating this feature as (very) significant (60%). Users have mixed opinions on the features to access other people's profiles to see their challenges and progress, interacting with other users and chatting with others.

Open feedback

Additional open feedback was collected through the post-survey, which is introduced in Table 8.

Table 8. Additional open feedback collected from the post-survey

Topic	Comment
Push Notifications	*"A notification once a day would be nice, I forgot to check the challenges a lot, maybe one where you can set the time yourself"* *"I find push notifications very gut through which you get reminded daily to enter the information into the app."* *"In my opinion, push notifications [...] would be annoying for the user."*
Enter challenge progress later	*"It would be great if you could enter challenge progress afterwards if it is being forgotten"* *"The option to enter one day later would be great. Sometimes you forget to enter and are then demotivated when you could not collect points for a few days."*

5.1.3 User Experience Questionnaire (UEQ)

The full results of the UEQ can be seen in Appendix M. Table 9 shows the mean and variance of the UEQ per scale. Figure 35 shows the same content graphically. According to the researchers, values between -0.8 and 0.8 represent a more or less neutral evaluation of the corresponding scale, values >0,8 represent a positive evaluation and values < -0,8 represent a negative evaluation.

Table 9. UEQ Scales mean and variance. The arrows indicate the positive, neutral or negative evaluation of the scale

UEQ SCALES (MEAN AND VARIANCE)		
ATTRACTIVENESS	↑ 1.211	0.85
PERSPICUITY	↑ 1.500	1.38
EFFICIENCY	→ 0.717	0.84
DEPENDABILITY	↑ 1.050	0.70
STIMULATION	↑ 1.200	0.96
NOVELTY	↑ 0.883	0.82

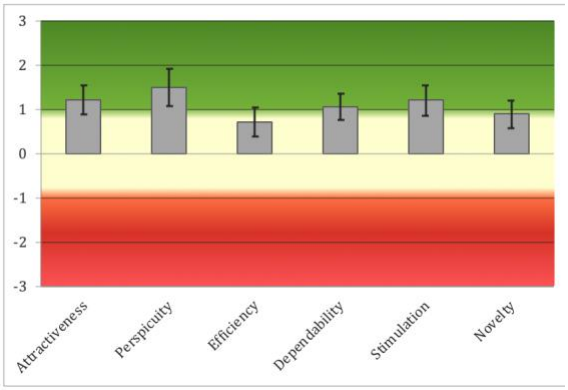

Figure 34. Visualisation of the mean and variance of the UEQ Scales

For the individual items (see Appendix M), twenty-five of thirty are positive, four are neutral, and one is negative. Neutral ratings were achieved on the scale *creative vs dull* (Novelty), *boring vs exciting* (Stimulation), *usual vs leading edge* (Novelty) and *attractive vs unattractive* (Attractiveness). The only negative rating was recorded for the item *fast vs slow* (Efficiency).

The benchmarking evaluation of the User Experience Questionnaire (UEQ) compares this app's user experience with the data of 451 studies by more than 20,000 users (see Figure 36). The

designed sustainability app ranks above average on the scales *attractiveness, perspicuity, stimulation* and *novelty.* It scores below average on the scales *efficiency* and *dependability.*

The underlying items reveal the causes of the poor results for efficiency and dependability. While all items for efficiency achieved positive results, the item "fast vs. slow" achieved negative results of -1 and as such is the only negatively performing parameter. The classification of the app as very slow is not surprising as the app hosted on a free sever showcased loading times of several seconds. The negative rating of "fast vs. slow" thus may have influenced the overall outcomes for "efficiency". In an improved, faster version of the app, this shortcoming may be improved.

For dependability, the items standing out with comparatively fewer positive ratings are "unpredictable vs predictable" (0.8), "secure vs not secure" (0.9) and "meets expectations vs does not meet expectations" (1.1). These results might stem from the slow speed of the app and, partially, technical immaturity of the prototype. For instance, a once ticked checkbox could not be unticked. Passwords could not be changed.

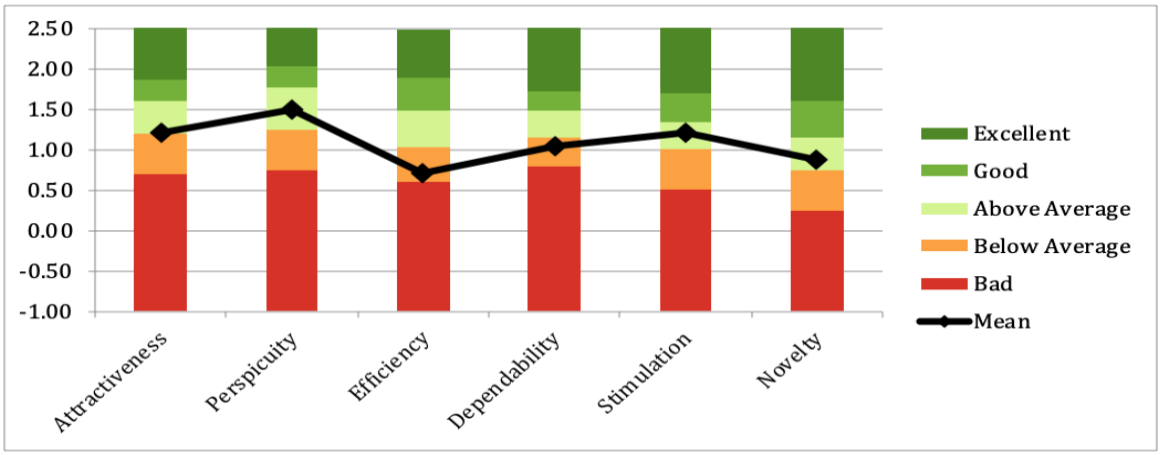

Figure 35. Benchmarking graph of the designed sustainability app on the UEQ. The app ranks above average on 4 out of 6 parameters and below average on 2 out of 6 parameters.

5.1.4 Final Iteration: Functional, re-designed app

The results of the two weeks in-field user testing study show that the design strategies implemented in the app were mostly effective and received well by the users. Nevertheless, the app can be further improved. Based on the learnings from the field study, a final iteration was built that incorporates some of the improvement areas that were identified during the user study. The final wireframes are shown in Figure 37 to Figure 39. The transformation of the initial wireframes to the final ones in three iteration steps can be reviewed in Appendix N.

The final results of the last iteration are a minimum viable product which was programmed by the developer on the team based on the final wireframes (Figures 37 to Figure 39). The functional app can be accessed via smartphone at **m.budge-app.com**. Registration is possible via e-mail.

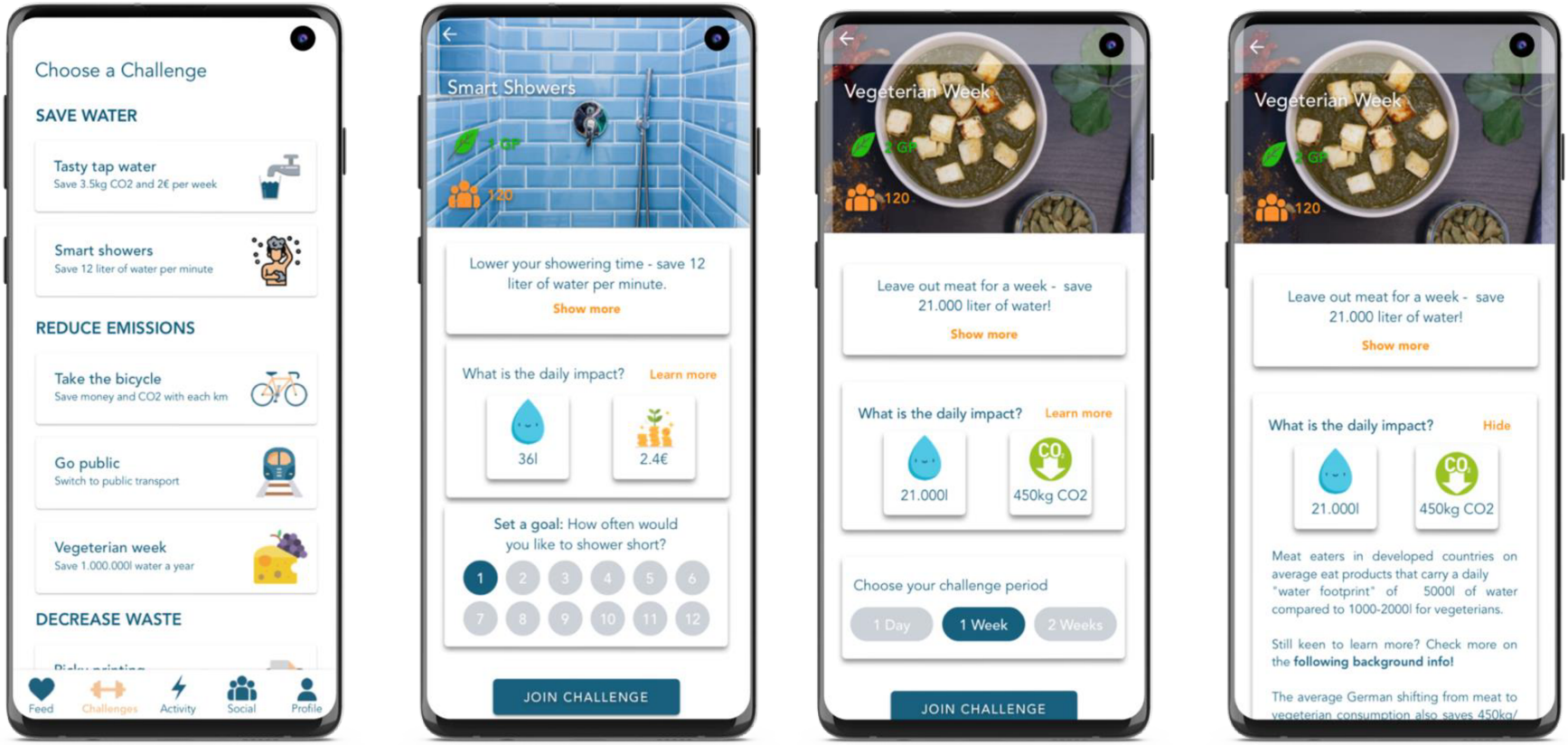

Figure 36. Final Wireframes: Challenge Screens.

The images in Figure 37 show the challenge overview screen (left) and challenge details screens (3 right screens). On the left challenge screen, the challenges were categorised into the impact areas “save water”, “reduce emissions” and “decrease waste”. The second left screen shows a “Milestone” challenge. As users might now shower every day or others might shower twice a day, users have to choose how often they would like to do the activity and then aim to achieve the self-set goal. The second screen to the right shows the “normal” challenge details screen. Users can learn more by selecting the drop-down and then find further links in the text to gain additional background information.

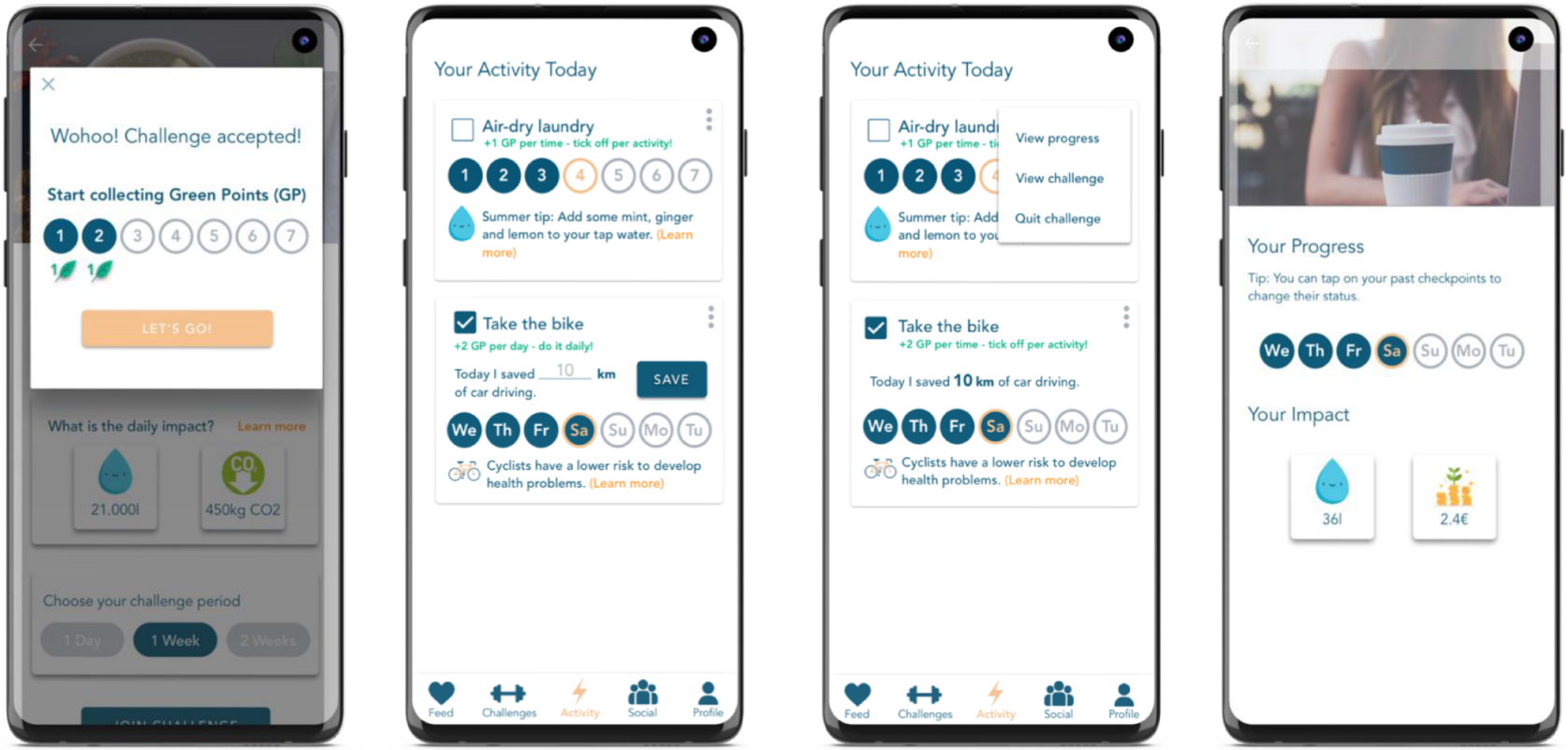

Figure 37. Final Wireframes: Progress Screens.

The images in Figure 38 show the challenge confirmation screen (left), the activity screens in different states (centre screens) and the challenge-specific progress screen. The challenge confirmation message was shortened, and streak systems were excluded. On the activity screen, users have the option to input the individual data such as cycled kilometres for personalised impact calculations. The second screen from the right, shows how the screen looks like after a user confirms the kilometre count. Besides, as displayed in the drop-down, users can enter a detailed challenge progress, view the initial challenge description and quit the challenge. The right screen shows the challenge specific progress page. Here, users can see again how their activity has been for this particular challenge and how much impact they have achieved based on it.

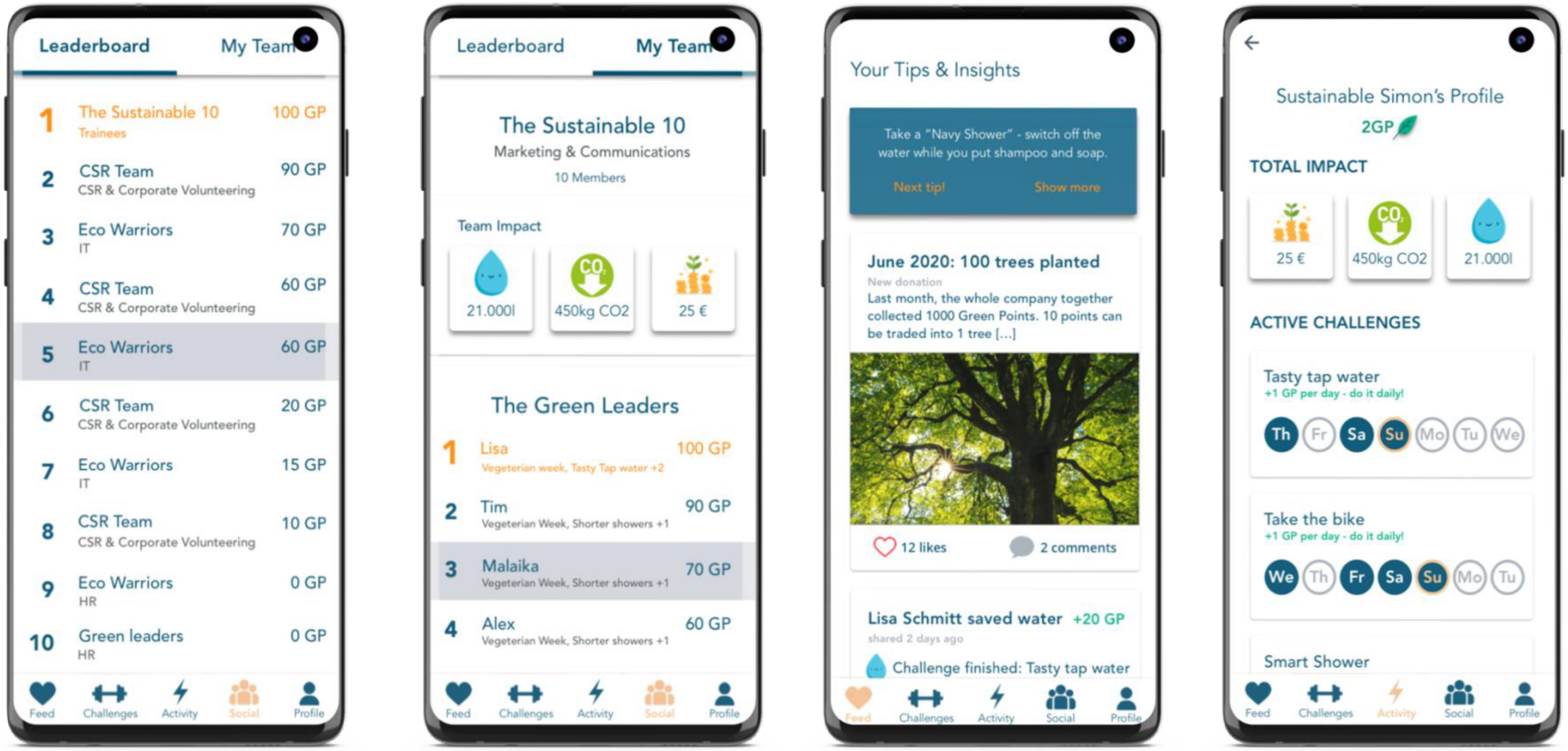

Figure 38.Final Wireframes: Social and Profile.

In Figure 39, on the left screen, the global team leader board is depicted in which teams compete against each other. Teams can be viewed by clicking on the names. The user's own group can also be accessed by clicking on "My Team" at the top. Here, the overall team impact is shown alongside the team leader board. On the second screen to the right, the "Social Feed" is displayed. The feed enables to view and potentially post progress, tips, ideas and articles. The right screen is the profile screen. It shows the users progress on different challenges and the total impact and Green Points.

5.2 Results Research Question 2

In this section, results regarding Research Question 2 are presented. First, findings regarding the descriptive analysis and data pre-processing are presented (5.2.1) which are relevant for all hypotheses. In 5.2.2 results specific for Hypothesis 1 are reported. Section 5.2.3 presents the results for Hypotheses 2-4.

5.2.1 Descriptive Analysis & Data Pre-processing

In this section, first, the frequencies of challenges and thus, behaviour change attempts are shown through a frequency table to identify which behaviours should be looked at for the t-test or Wilcoxon signed-rank test. Next, the results of Cronbach's alpha test and the Shapiro-Wilk test for normality will be presented. Additionally, an overview of the descriptive data analysis is given.

Challenge Frequencies

The challenges taken by most users are the Vegetarian Challenge (81.5%), Tap water challenge (77.8%) and Smart Shower Challenge (59.3%). For the nutrition analysis, participants taking the Vegan Challenge can also be included as they also set themselves an, even more challenging, nutrition target. Vegan and Vegetarian will thus be combined. Table 10 shows all frequencies of challenges taken while marking the behaviours chosen for further analysis green.

Table 10. Frequency of challenges taken in field study

Challenge	Absolute Participants	Percentage
Vegetarian	22	81.5%
Vegan	5	18.5%
Vegetarian or Vegan	25	92.6%
Tap water	21	77.8%
Smart Showers	16	59.3%
Take the bike	12	44.4%
Air-dry laundry	14	51.9%
Cold laundry	7	25.9%
Natural cleaning	4	14.8%
Re-cycle, re-use, re-sell	2	7.4%

Cronbach's Alpha α

The Cronbach's Alpha α was calculated for those constructs that were measured through various items (see Table 11). While for *attitudes* and *intention,* α is at least acceptable, it is unacceptable for PCB [93]. As a result, for attitudes, all 6 items were combined to measure the overall sustainability-relevant attitudes. For intention, the two relevant items were combined. PCB is

measured with only one item that is presumed to cover the construct best: *"It is difficult for me to change my everyday life to more sustainable behaviour."*

Table 11. Cronbach's Alpha for the constructs "Attitudes", "Intention", "Perceived behavioural control (PCB)"

Construct	Items	Cronbach's Alpha	Interpretation
Attitudes	6	0.70	acceptable
Intention	2	0.60	questionable
PCB	3	0.41	inacceptable

Test of Normality

The Shapiro Wilk Test (see Appendix O, Table 13) shows that only *attitudes before* and *attitudes after* the intervention are normally distributed. Thus, for *attitudes*, the t-test can be applied. The means of all other variables have to be compared using the non-parametric Wilcoxon signed-rank test.

Descriptive Analysis

In Table 12, the descriptive statistics of all relevant scales can be seen. *PCB, attitudes* and *intention* are measured on a scale from 1 to 5. The behaviour frequency is measured on a scale from 1 to 7. The higher the respective rating, the more sustainable is the parameter.

An interesting parameter to look at is the skewness of the data. Skewness is considered significant from a value of +/- 1 [94]. According to the descriptive statistics shown in Table 12, the data is profoundly right-skewed for nutrition values *before* the study and heavily left-skewed for tap water during the study.

Table 12. Descriptive Statistics of all relevant scales

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
attitudes_before	27	2.67	2.00	4.67	3.1049	.61870	.599	.448	.199	.872
attitudes_after	27	1.33	2.83	4.17	3.4259	.41172	.292	.448	-1.013	.872
PBC_before	27	4.00	1.00	5.00	2.8519	1.02671	.087	.448	-.688	.872
PBC_after	27	3.00	2.00	5.00	3.2593	.98421	-.046	.448	-1.220	.872
intention_before	27	2.50	2.50	5.00	4.0556	.66986	-.528	.448	-.174	.872
intention_after	27	2.00	3.00	5.00	4.2222	.65535	-.257	.448	-1.069	.872
nut_before	27	3.00	1.00	4.00	1.3704	.74152	2.317	.448	5.601	.872
nut_after	27	3.00	1.00	4.00	2.0741	.95780	.694	.448	-.221	.872
tap_before	27	5.00	2.00	7.00	5.4444	1.60128	-.923	.448	-.298	.872
tap_after	27	6.00	1.00	7.00	5.9630	1.76464	-1.799	.448	2.303	.872
shower_before	27	4.00	3.00	7.00	5.1852	1.17791	-.082	.448	-.764	.872
shower_after	27	3.00	4.00	7.00	5.6296	1.00568	-.139	.448	-.973	.872

A further investigation into the histogram of these two parameters indicates that before the survey, most people are omnivores (Figure 40, left column in the left picture). After the study, most people drink tap water (Figure 40, right column in the right image). The data is severely skewed. The existence of this skewed data is another indicator to opt for non-parametric tests.

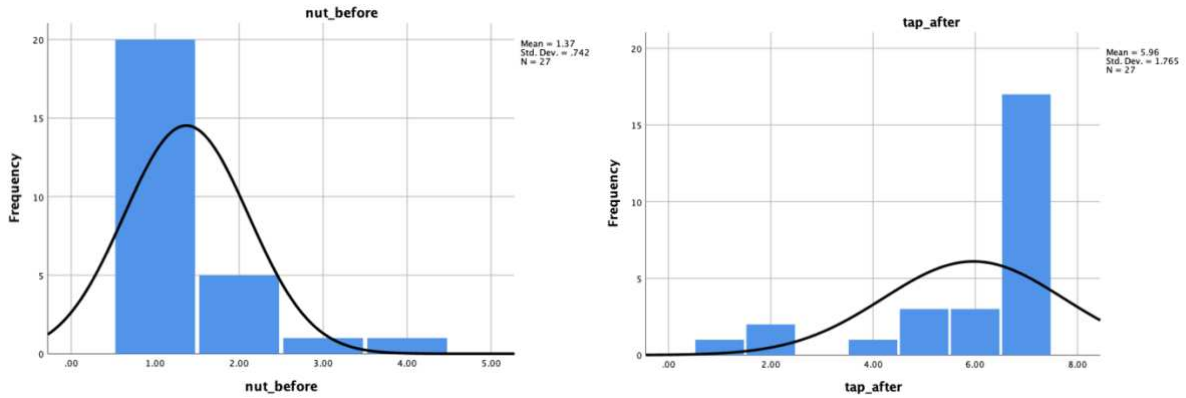

Figure 39. Histograms of nutrition (before study) and tap water consumption (after study) are heavily skewed.

5.2.2 Hypothesis 1 (Behaviour change during app-usage)

As described in section 4.3.2 in a first step, the Wilcoxon signed-rank test was applied to the whole sample of test users, including those that did not take on corresponding challenges encouraging a particular behaviour change. Next, the test was repeated per behaviour (nutrition, tap water, shower) only for those users, that took on the corresponding challenge.

Wilcoxon signed-rank test: All participants

The results for the Wilcoxon signed-rank test (see Appendix O, Table 14) indicate that the self-reported consumption of tap water has significantly increased during the study period as compared to before the study period with $p = 0.37 < p\ 0.05$. The self-reported nutrition has significantly increased towards more sustainable nutrition with $p = 0.000 < p = 0.05$. For showering, there is no significant increase in more sustainable showering behaviour with $p = 0.86 > p = 0.05$.

Wilcoxon signed-rank test: Participants in relevant Challenges

The Wilcoxon signed-rank test was repeated for those participants active in the relevant challenges. These were 25 in vegetarian/vegan week, 21 in tasty tap water and 16 in smart showers.

The analysis showed that the scores of all three behaviours (nutrition, tap water drinking, showering time) were statistically significantly higher than the pre-study ratings ($p < 0.05$). This

may indicate that sustainable behaviour was self-reported as significantly more frequently done during the usage of the sustainability app as compared to before. Appendix O, Table 15 shows these results in detail.

Self-evaluation by users

In addition to the statistical analysis, users were asked to estimate how frequently they have done their challenge behaviour as compared to before (see Figure 40). In the self-report, 25.9% indicated that they did the activities of their challenges (e.g. eating vegetarian, drinking tap water) much more frequently than usual and 40.7% reported doing the action more frequent than usual. 29.6% of participants reported doing the activity just as regular as usual. 3.3% (1 person) said having done the activity much less frequent than usual.

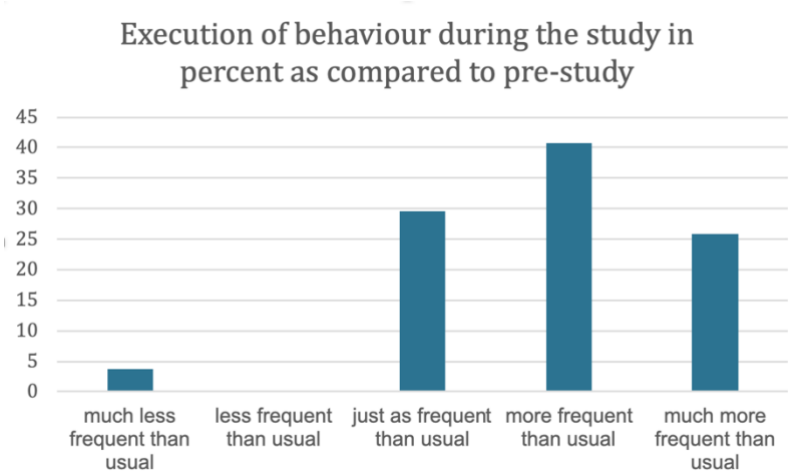

Figure 40. Overview of the self-reported frequency of performed activities

5.2.3 Hypothesis 2-4

This section describes the results for Hypotheses 2 to Hypotheses 4, which all address the different parameters of the Theory of Planned Behaviour.

Hypothesis 2

A paired-samples t-test was conducted to compare attitudes towards sustainable behaviour pre- and post-study. There was a significant difference of $p = 0.002 < p = 0.05$ in the scores for pre-study (mean = 3.10, SD = 0.62) and post-study (mean = 3.43, SD = 0.41) (see Appendix O, Table 16). The difference indicates an increase in positive attitudes towards sustainable behaviour during the study period.

Hypothesis 3

A Wilcoxon signed-rank test was performed to compare perceived behavioural control and the intention to act sustainably in the future pre- and post-study, respectively. For perceived behavioural control, a significant difference was found with $p = 0.037 < p = 0.05$ (see Appendix O, Table 17). The finding indicates that participants agree significantly more frequently that the change towards more sustainable behaviour is easy as compared to before the study.

In the self-evaluation by users, this finding is reflected, too. ~48% of users (rather) agree that the app makes it easier for them to integrate sustainable actions into their life.

Hypothesis 4

The results for the *intention to act sustainable* are not significant with $p = 0.137 > p = 0.05$. It follows that there is no statistically significant difference between people's intention to act sustainably in the future before and after the sustainability app usage (see Appendix O, Table 18).

In the self-evaluation by users, ~67% (rather) agree with the statement that the app motivates them to follow a sustainable lifestyle.

6 Discussion

The discussion chapter is structured into a discussion of Research Question 1 (Section 6.1), Research Question 2 (Section 6.2) and a general discussion of the whole master's thesis (Section 6.3). Each section consists of further sections that address answering the research question(s), limitations and future work.

6.1 Discussion of Research Question 1

In this chapter, Research Question 1 is answered (Section 6.1.1), the limitations of the findings are discussed (6.1.2), and suggestions for future work are given (Section 6.1.3).

6.1.1 Answering Research Question

The answering of Research Question 1 will be approached by answering the sub-questions first and then concluding an answer for Research Question 1 as a whole.

As introduced in Section 1.3, Research Question 1 asked the following:

> *RQ1: How might we design a mobile app that encourages people to take on sustainable actions across different areas of life?*

Sub questions that should be answered to address Research Question 1 were the following ones:

- *Sub question 1: Which user behaviour, needs, pain points and goals should be considered in the design process?*
- *Sub question 2: Which design strategies might be appropriate when designing a mobile app that targets sustainable behaviour change across life areas?*
- *Sub question 3: Which kind of user experience, and which features should an app have that encourages people to take on sustainable actions across life areas?*

Answering sub-question 1

Diverse core needs of users have been identified which need to be met to support them in taking on sustainable behaviours and achieving sustainability goals mitigating existing pain points. The following needs were identified: gaining transparency into the climate impact of own behaviour and of products and services, reducing cost, providing a positive social environment, tips and educational insights about sustainable behaviour.

Answering sub-question 2

The design strategies eco-choice, eco-information and eco-feedback explained by Bhamra and Tang [59] have proven to be of particular relevance when designing a mobile app encouraging behaviour change across life areas. Users need to *choose* which activities to take on (*eco-choice*) as there are plenty of diverse life situations imaginable that can be addressed more sustainably. Users demand *eco-information* through tips on which actions to take and insights into their behavioural impact. They also liked the *eco-feedback* design strategy, which aimed to help them understand their impact on the climate better. Nevertheless, there was some lack of clarity on what specific feedback mechanisms (e.g. Green Points) meant. The added design strategy of *social* has proven useful for most users, but not everyone feels already but of a sustainability community by using the app. The lack of a "community-feeling" might be explained in two ways. On the one hand, there are users that *"do not feel motivated by the other participants because [they] do [the activities] for themselves."* Such users might not feel part of a sustainability community, but they also do not need to feel part of it for changing their behaviour. On the other hand, some users did not feel connected enough to the other users, stating that *"it would be better if you could have a group of friends or colleagues in the app [...]."* Social elements can thus motivate some users, but others not - although no one disliked the social features, they were just not used by some users.
Eco-steer might be an efficient, additional design strategy that was implemented through leader boards and in-app Green Points in the current prototype. This strategy of *eco-steer* might be of even more relevance when introducing the exchange of Green Points into donations to sustainable projects or discounts to sustainable businesses.

Answering sub-question 3

The research has shown that the following detailed features are of particular importance for users: Community through collaborating and competing in teams, gamified challenges to have actionable behavioural options supported by tips and insights, transparency into the activities and their impact on the environment and a large amount of information, tips and education around the sustainability topic.
The user experience was assessed through the User Experience Questionnaire (UEQ). Here, a more detailed analysis is required as the validated results lead to interesting conclusions. The UEQ achieved positive results for the second iteration of the prototype (Figure 28, 29). The user experience rating for the scales *attractiveness, perspicuity*, *dependability*, *stimulation* and *novelty* was positive. For *efficiency,* the user experience rating was neutral. In the benchmarking, however, the app performed worse than average on *efficiency* and *dependability*. As described in the Results section (Section 5.1.3) this may be attributed to the item "fast vs slow" which achieved negative results of -1 and as such is the only negatively performing parameter.

Further technical immaturities such as the lack of changing the password do not align with the user's expectation and may lead to disappointment.
For answering the sub-question 3, it can thus be concluded that the User Experience needs to be excellent and as expected as it might, therefore, overshadow the user's goal to act more sustainably and be even demotivating or distracting for the user.

Answering Research Question 1

The research has shown that the human-centred design approach with a focus on De Medeiros et al.'s [66] strategy of designing for sustainable behaviour change, can be well applied when designing a mobile app encouraging people to take on sustainable actions across life areas. The *exploration* phase was required to understand current user behaviour, needs and pain points. The *generation* phase was essential to pick general design strategies that later were effective in the field user tests. The *repeated evaluation* of the mobile app allowed for continuous improvement of the app in a user-centred way. At the core of the designed application are "sustainability challenges" which are activities that users can take on for a given time. They can track these activities and receive further information about them. Users want to have free choice in picking those activities while being supported through suggestions and advice on the impact of different behaviours. They also require support in the process of "acting sustainable" through information and tips, transparency and insights into their actions. The app should provide this information in a personalised manner. Additionally, gamified elements such as leader boards and the formation of teams help users to remain engaged and work towards a goal. The exemplary design of such an app can be reviewed in Section 5.1.4.

6.1.2 Limitations

The applicability of the findings and the developed final app presented in Section 5.1.4 has several limitations which can be grouped into participant demographical limitations and the non-final state of the mobile app.

Participant Demographics

The first limitations concern the user group of the in-field user study and thus the generalisability of the results. The user group mainly consisted of young employees or students below 30 years. They do not represent the general public. A bias might exist as young people are more tech-savvy, more educated and more used to apps with gamification elements and community features than the average population. Secondly, younger people tend to be more interested in sustainability topics and also take more action in this field.

A different limitation derives from the app usage frequency and from the user motivation to participate in the study. 38% of participants who filled out the final survey to evaluate the app did not use the app frequently (3 times per week or less). It is questionable whether these users were able to judge the app in detail. In the pre-survey of the app, it showed that 49% of participants had a motive for using the app that was not related to the wish to act more sustainable. Instead, users participated out of curiosity (40%) or because they wanted to help the student conducting the research (8.7%). With such an objective, the participants might not represent perfectly well the target customer group of individuals that want to change their behaviour towards more sustainable actions.

State of the mobile app

The second area of limitations relates to the mobile app.

There is currently a limited amount of content in the app available. Therefore, not everyone was able to find an appropriate challenge or useful tips and insights in this prototype.

Technical limitations of the prototype might have impacted the user experience during user testing and the UEQ ratings. Users had to deal with long loading times and the non-functioning of basic elements (e.g. the tick box on the activity screen could be ticked, but not ticked off). Not surprisingly, 60% of users said that technical issues affected their user experience.

Finally, the app was tested for only two weeks - a short period when targeting behaviour change. It may be questioned whether the app keeps the user engaged in the long-term.

6.1.3 Future Work

The app should be tested again once technological problems have been solved, and the usability has been improved. The user tests should be conducted over a more extended period of time to understand what kind of features are desired for long-term usage. The research should also be expanded to different age groups and education levels to ensure generalisability. More content is required, such as challenge options, background information on sustainability and tips on sustainable behaviour. The content should be dynamic to allow the adjustment to individual goals. The app should also be interactive to encourage people further to participate, for instance, through editing goals or inputting their own challenges. Push notifications and similar techniques should be explored to remind users of the challenges and sustainability task.

6.2 Discussion of RQ2

In this section, the findings reported under Section 4.3 are discussed to answer Research Question 2 (see Section 6.2.1), the limitations are described (see Section 6.2.2) and future work opportunities are presented (see Section 6.2.3).

6.2.1 Answering Research Question 2

Research Question 2 asked:

> *RQ2: To what extent can a mobile app support people in taking on more sustainable actions across different areas of life?*

The research question was devided into four hypotheses. The answers will first be provided per hypothesis and then for the overall Research Question 2.

Hypothesis 1

Hypothesis 1 stated:

- H1: The interaction with a sustainability app leads to an increase in sustainable behaviour during the interaction period.

The research findings (see Section 5.2.2) indicate that the hypothesis has been validated. The self-reported frequency of sustainable behaviour was significantly higher across participants during the app usage as compared to before the app usage for the area of nutrition and the consumption of tap water. There was no statistically significant increase measured for showering time. When the analysis was, however, conducted only on those participants that joined the "shower" challenge, the results were statistically significant for all behaviours.
Remarkably, the significant increase in behaviour frequency for "short showers" applied only to those users that participated in the "shower" challenge. This finding might indicate that *taking a challenge,* committing towards an activity may be one crucial motivator for people to stick to the new behaviour.

Hypotheses 2-4

Hypotheses 2-4 included the different parameters in predicting behaviour based on the Theory of Planned Behaviour:

- H2: The interaction with the sustainability app leads to an increase in positive attitudes towards sustainable behaviour.
- H3: The interaction with the sustainability app leads to an increase in perceived behavioural control with regards to sustainable behaviour.

- H4: The interaction with a sustainability app leads to an increase in the intention to act sustainably.

The findings described in 5.2.3 indicate that the interaction with a sustainability app leads to a significant increase in positive attitudes towards sustainable behaviour and in perceived behavioural control.
The *attitudes* scale consisted of six items. The in-depth analysis into the changes on item level reveals that while there are positive changes on all item scales, only two items increase statistically significantly. The **awareness measure** *("I am aware of what I can do to act more sustainable, e.g. in the areas of nutrition, transport, consumption, travel etc.") increases significantly.* The **knowledge measure** *("I believe that I know enough about the environmental impact of my daily behaviour."*) also shows a significant increase.
It can thus be said that the usage of the sustainability app makes participants significantly more aware of what they can to do act sustainable and be substantially more knowledgeable on the environmental impact of their daily behaviour.

For *perceived behavioural control*, the finding implies that participants perceive sustainable behaviour as easier to get done as compared to their pre-study opinion.
The interpretation of this result might be that acting sustainably and being presented with opportunities and tips for the sustainable action, made clearer to the user that these actions are not necessarily difficult or painful.

The *intention to act sustainably* increased slightly from 4.06 to 4.22. However, this increase was not significant. An explanation for the lack of significant improvement may be found in the pre-study data for the parameter *intention*. Users already scored very high on the intention parameter before the study. The data on this parameter had a mean of 4.06 on a scale from 1 to 5. There was thus not much opportunity for improvement throughout the study. Four participants, for instance, already scored the highest possible mean value of 5 and could not increase this value further.

Conclusion

Hypothesis 1 was validated: the interaction with a sustainability app leads to a statistically significant increase in sustainable behaviour during the challenge period. However, it has to be considered that this significant behaviour change depends on the sustainability challenges that users take on. It is likely to take place not across all areas of life but only in those areas in which users have selected a challenge to take on.

Hypothesis 2 was validated: the interaction with a sustainability app led to a statistically significant increase in positive attitudes towards sustainable behaviour. It has to be considered that not all attitudes increased significantly, but that the main focus was on a rise in awareness and knowledge.
Hypothesis 3 was validated: the interaction with a sustainability app leads to a statistically significant increase in perceived behavioural control in this study.
Hypothesis 4 was **not** validated: the interaction with a sustainability app does not lead to a statistically significant increase in the intention to act sustainably.

For Research Question 2, it can be concluded that a mobile app can support people in taking on more sustainable actions across different areas of life in two ways.
Firstly, sustainable behaviour during the challenge period can be increased through targeted sustainability challenges that support users in performing the action more frequently.
Secondly, constructs that have been proven to encourage behaviour change as parameters in the Theory of Planned Behaviour [33] can also be targeted by the sustainability app. The usage of the sustainability app leads to an increment of positive attitudes towards sustainable behaviour (mainly knowledge and awareness) and an increased PCB towards sustainable actions.
The findings need to be put into context by several limitations (6.2.2). At the same time, the results are promising. They have been achieved with a non-final prototype and a small sample size of participants.

6.2.2 Limitations

For the interpretation of the results of Research Question 2, several limitations need to be considered. These revolve around the topics internal consistency and validity, self-reported measures, choice of study participants, generalisability and further criteria impacting sustainable behaviour which were not considered in the study.

Internal Consistency and Validity

The post-study questionnaire that measured relevant constructs in this master's thesis was created by the research team and was not a previously validated questionnaire. From this circumstance, several shortcomings arise.
The validity of the questions might be impacted. It was not tested whether attitudes, PCB and intention are covering the concepts defined in the Theory of Planned Behaviour (see Section 2.1.1 for definitions). Also, the parameters for behaviour (nutrition, tap water, shower time) as well as PCB were only covered by one single item. Risks are that users misinterpreted these items, which might impact the interpretability of the research findings.

In this context, it may also be criticised how the nutrition scale was created (Section 4.3.2): Numbers were assigned to "omnivore (1)", "flexitarian (2)", "pescatarian (2)", "vegetarian (3)" and "vegan (4)", assigning the same distance between omnivore (1) and flexitarian (2) as between vegetarian (3) and vegan (4). There is no scientific basis stating that the relationship between nutrition and sustainability can be categorised accordingly, e.g. that flexitarian is "omnivore +1" and vegan is "pescatarian +2".

Other factors, such as regionality and the eco-friendliness of produce, were not considered in assessing the sustainability level of a particular food consumption type. The way nutrition is clustered and rated, may thus be an oversimplification of the complex topic of nutrition and sustainability.

A further drawback regarding validity is that the significant increase of sustainable behaviour, sustainable attitudes and PCB might not only derive from the usage of the app. As the study consisted additionally of a kick-off call, a pre- and a post-study, there might be some effect just from participating in an investigation around this topic.

The internal consistency (reliability) may also be affected. Internal consistency is a measure based on the correlations of individual items indenting to measure the same construct [95]. In this study, it was measured with Cronbach's Alpha. Cronbach's Alpha was found to be unacceptable, questionable or, at its best, acceptable for the rating scales attitudes, intention and PCB (see 5.2.1). From this fact follows that it is not guaranteed that the items measured the same construct and that acceptable reliability may not be given in case of repeated measures. At the same time, Cronbach's Alpha is partially criticised, and it may anyways be argued against using it as the only objective cut-off value for internal consistency measures [96].

Self-reported measure

All measures were collected through questionnaires and as such derive from subjective estimates of the study participants.

As participants had to report their behavioural frequency, we have to assume that they are able to estimate well how frequently they have done a particular behaviour. The interpretation of the scale such as "often" vs. "almost always" might differ among respondents. The self-report is not as convincing as the objective measure as we do not *know* how frequently the behaviour was actually done and to what extent it increased.

Another typical drawback of self-reported measures is that these measures are prone to the social-desirability bias, especially when dealing with sensitive issues such as sustainable behaviour that is more socially "desirable". [97]

As described in Section 3.5, the sustainability app showcased technological shortcomings during the field study that may have impacted the user's judgement of the app.

Study Participants

The participant population consisted of 27 participants. This is a relatively small number for statistical calculations and may come ahead with an increased risk of finding false-positive reports. [98]

The fact that the average results were already very high on some constructs before the start of the study (e.g. intention = 4.06/5) might have led to finding no significance on this construct.

Generalisability

As explained under 4.1, the pre-survey showed that 49% of participants had a motive for using the app that was not related to the wish to act more sustainable. This might have impacted the generalisability of the findings regarding the target group "young and sustainably-minded".

The generalisability might also be impacted when looking at the type of sustainable behaviour that was investigated. While the most prevalent challenges of "vegetarian consumption", "tap water consumption" and "smart showers" yielded significant results, this was not the case for those behaviours for which users did not take on challenges (e.g. clothes/finance). Based on the current findings, it thus cannot be said that users will also change their behaviour across other relevant areas of life apart from their challenge-relevant behaviour.

Finally, the generalisability cannot be assumed for long-time behaviour change. Participants used the app for a period of two weeks. For more extended periods, it was found by previous research that engagement can decrease over time with the novelty effect reducing [22]. It can thus not be argued that the usage of the sustainability app will lead to behavioural change the long-term.

6.2.3 Future Work

Future work should resolve the limitations presented in this study. In general, repetition of the research study with larger sample sizes and longer duration is required while improving the currently existing study drawbacks.

State of the App

As described in Section 3.5, the sustainability app was not final during the in-field user tests. The app should thus be further improved based on the findings of the user study (see Figures 37 to 39 for the final wireframes). Better results may be expected when technical drawbacks and shortcomings in terms of the user experience are resolved.

Measurement

Validated questionnaires should be used to measure both "sustainable behaviour" and the constructs relevant for the Theory of Planned Behaviour. For the measurement scales, several items per construct should be used to lower the risk of misunderstandings through the respondents. Where possible, objective measures can be taken to mediate the social desirability bias. For instance, kilometres cycled could be automatically tracked. From the app, it could also be derived if someone states to have eaten entirely vegetarian for a week if the activities were ticked off accordingly every day.

Sustainability-relevant activities

While the app already investigated broad different activities and users were able to choose which behaviour they wanted to change, some areas of life such as finances or consumer goods were not addressed. In the future, it should be investigated whether the findings hold true for these areas of life as well.

Long-term behaviour change

Long-term behaviour change has rarely been researched in the field of sustainable behaviour, even though it is crucial for the design of efficient interventions [61]. The focus on long-term sustainable behaviour change across different areas of life is thus a vital topic for future research.

6.3 General Discussion

In the general discussion, a reflection on the overall results will be conducted (Section 6.3.1), which includes a comparison with literature and a critical assessment. In Section 6.3.2, overall limitations will be discussed, and in 6.3.3 suggestions for future work will be presented.

6.3.1 Reflection on the Results

This section discusses the combined results of Research Question 1 and Research Question 2 (5.1.1) and compares them to the existing literature (5.1.2).

General Findings

This thesis aimed to investigate how to design an app that encourages people to take on sustainable actions across life areas. As one of the first research papers addressing behaviour change in different fields with one mobile application[7], the statistically significant results with regards to sustainable behaviour change can be seen as promising. It was found that an application designed in a human-centred way based on the needs and pain points of the users and which is iteratively improved based on user feedback, can indeed support people in taking more sustainable actions.

Running like a common thread through this thesis are the user needs and pain points which were identified early in the process informed the design strategy decisions and were clearly addressed by the designed mobile application. The in-depth findings on typical user needs and pain points showed that the target users have the intention to act sustainable (4.05/5 average rating on intention pre-study). However, they frequently lack the knowledge about which actions to take.

They also miss the insight into the impact that their choices have on the environment. Those pain points were addressed through employing design strategies of eco-choice, eco-feedback, eco-information, eco-steer and social elements. The app features include challenges that provide action alternatives, tips and education around the topic and insights into the environmental and financial impact of decisions. And those features were effective: While answering RQ2, it was found that users felt statistically more knowledgeable and aware of their environmental impact and on which action alternatives to take. The final iteration of the app (Figures 37 to 39) included even further improvements which were demanded by users and which first seemed unexpected. In their strive of getting more information on which actions to take and which impact these

[7] To the best knowledge of the research team, no previous work investigated the process of designing a mobile application tackling broad sustainable behaviour change and evaluated the effectiveness of this application in a real-life setting.

actions may have, users even demand push-notifications reminding them of their daily tasks and advertisements displaying sustainable products and services.

Despite the promising results from the master's thesis study, it also has to be said that there are limitations (Section 6.3.2) to consider and future work (Section 6.3.3) that has to be conducted.

Comparison with literature

Several parallels to existing literature were found. User pain points in the uptake of sustainable behaviour were confirmed, namely the invisibility of energy or water as a resource, the difficulty to change habits and the lack of awareness into the climate-impact of own actions (e.g. [65]). In user research (interviews and surveys), similar results were found in this thesis research. Users have similar needs and pain points when it comes to changing behaviour across *different* areas of life, such as nutrition and mobility. Users require insight into complex parameters such as the water footprint of nutrition and need support in their habit change through tips, insights, push notifications and even sustainable product advertisements.

The main new contribution of this master's thesis is the insight that *one single mobile application* has the potential to achieve statistically significant behaviour change across *different* areas of life. The thesis focused on elements beyond the most commonly researched ones (electricity and water consumption [61]) through, for instance, targeting nutrition and mobility behaviours.

The design strategies employed have been used in the past when designing for sustainable behaviour change. Among the most common procedures reported by Coskun [61], the following ones have also been included in the mobile app design in this master's thesis: *offering advice on environmental problems, providing a choice to action these problems, providing feedback on behavioural impact, setting goals for being more sustainable, ensuring commitment to be sustainable, rewarding sustainable behaviours, comparing one's performance with others, making sustainable behaviours easier to do*.

A newly applied design strategy was to enable users to not only compare their performance with others on a leader board but to collaborate in teams actively. The social feed additionally allows users to share progress and gain insights specific to one's community (see Figure 39 third screen from left). Users liked these social elements and community features and thus, the design strategy of "social features" should be considered when designing for sustainable behaviour change.

Critical Reflection

This paragraph expresses critical reflections on the implications of this master's thesis and its results. It can be critically reflected which suggestions these findings have for the initial research objective: supporting people in acting more sustainable to achieve overall higher sustainability.

The master's thesis research attempted to address "different areas of life" to understand how to have a more significant impact through design. The findings gave reasonable indications on which approaches work well (Section 5.2.3). However, while the research questions aimed to address "different areas of life", the main impacted areas were "nutrition", "tap water consumption" and "shower". Not all areas of life were investigated which is why the findings cannot be generalised for "all" areas of life.

Another drawback might lie in the user's eco-choice to pick their behaviours themselves. This freedom to choose might hinder the focus on certain high-impact opportunities. It is relatively easy to shower shorter, but harder and more impactful to eat vegan. Most users opted for the shower option only. This means that although the app achieved significant results, these might not be the most impactful ones. Along these lines, there is another challenge: the mere process of creating and suggesting the best sustainable activities to take is difficult. Is it better to eat a chicken egg from a regional farmer or a piece of tofu imported from Brazil? Is it better to purchase 50 paper books or one digital eBook reader? It is not always clear which activities are more sustainable. The research of appropriate content for the sustainability app is thus far from trivial to give actionable advice.

Another unaddressed topic is that the uptake of sustainable behaviour is much more complicated than it might appear in this master's thesis. The parameters in the Theory of Planned Behaviour are not the only ones predicting whether behaviour change will take place. There are, for instance, very practical infrastructural or life situations that do not allow people to change their behaviour towards more sustainability. In simple terms: while the app can inform about how much better it is to take the bike instead of the car – this is not feasible for all distances and for all commute journeys. The social reality of people also plays a role. A lack of social support was a pain point identified in the early in-depth interviews of this study. These pain points led to including community-features like leader boards and a social feed in the app. However, an individual's offline social reality is arguably more crucial. One of the users, for instance, stated in the questionnaire: *"It is difficult to keep up with the goals when you live with several people in one household, who do not have the same goals, especially for food."*

Finally, it should be critically reflected on what extent individuals can make "sacrifices" for a more sustainable lifestyle. It is impossible to ask individuals to prioritise sustainability above all else. What is meant by that is shown by this quote of an interviewee in an impressive manner: *"Do you know which is the single most impactful positive decision for your environmental footprint? […] The decision not to have children."* The ability to change for individuals is limited, and so is the impact that they can have with their behaviour change. Industries, economies, countries must change their behaviour, too, to achieve a large-scale effect.

6.3.2 Limitations

This section discusses the limitations of this master's thesis for both Research Question 1 and Research Question 2. For specific limitations on the research questions, please refer to the respective sections (Sections 6.1.2, 6.2.2).

A primary limitation in the interpretability of the potential impact that the application could have is that the app was not tested in its "final version". Of course, the iterative nature of the human-centred design process suggests a continuous improvement of a product, so it is difficult to agree on when a product is finalised. Nevertheless, in this case, the app was technically immature, which was shown by 60% of users agreeing that the technical problems with the app impacted their user experience.

The in-field user testing also brought more results as to how to design the app for fulfilling the user needs even better. The results might have been more promising if the final version of the app had been tested, such as displayed in Figure 37 to Figure 39. The fact that this non-finalised app already achieved a statistically significant behaviour change in users and changes in attitudes and PCB may indicate that an improved app could have even a more significant impact.

Another main limitation is the short period of two weeks for which the app was used in real life by the participants. The usage of the mobile app helped to change behaviour, attitudes and PCB in the short-term. Just like in most performed research on the topic, the long-term change of behaviour was not investigated and cannot be predicted based on a two-week in-field study. However, as most relevant behaviours are habitual [50], long-term behaviour change should, in the end, be targeted and measured. The statistically significant findings might not translate to the long term as research has shown that the user engagement with a sustainability app might decrease over time with a decreasing novelty effect of the new product [22].

Finally, the measurement of behaviour change based on the Theory of Planned Behaviour using the parameters attitudes, PCB, and intention may be criticised. As outlined under 2.1.2, behaviour change can have different influential factors than those considered by this theory. Also, the measurement of the constructs may be further improved by using validated questionnaires.

6.3.3 Future Work

In the future, the app should be iteratively improved based on user feedback. It should be filled with more relevant, personalised content. Highly desired features such as push notifications and more products and service recommendations should be implemented. The highest value of the application seems to be around education, tips, creating awareness and increasing impact. This opportunity should be further explored through high-quality, scientifically-backed content.

An improved version of the app can then be tested again with a more extensive and more diverse test user group. The tests should ideally be performed over a more extended period, e.g. half a year or longer, to identify long-term behaviour change opportunities. Validated questionnaires should be implemented to measure the relevant parameters for predicting behaviour change.

Further ahead in the future, an exciting opportunity to explore is to connect the sustainability app to more objective data tracking tools and smart applications. Many users are interested in their impact and might thus be willing to, for instance, share movement data that could be used to identify the mode of travel and hence the CO2 impact of mobility. The connection to smart applications such as bulbs and fridges could help to track the environmental impact of behaviour, and beyond that support in more sustainable actions through eco-technology features (e.g. bulb switches of when nobody is in the room).

As mentioned in the Critical Reflection (6.3.1), it cannot be individuals alone who change their behaviour. The business operations of companies need to change, and the laws of regulators need to adapt to criteria of sustainable development as soon as possible. Only if all players are acting, starting on a personal level, through a business level, to a state and global level, climate change and social inequalities may be tackled. And the sustainability app designed in this thesis can play a small part in that big, global challenge.

7 Conclusion

The master's thesis on design for sustainable behaviour change has investigated how to design a mobile app that encourages people to take on sustainable actions across different areas of life (e.g. nutrition, mobility, waste). Furthermore, it was researched, to what extent such an app can support people in taking on more sustainable actions.

The Theory of Planned Behaviour provided the theoretical basis for designing for behaviour change. The focus was on the parameters (environmental) attitudes, perceived behavioural control and intention [33]. The framework for design which was applied consisted of an exploration, generation and evaluation stage [66].

Research Question 1 asked how a mobile app encouraging sustainable behaviour change across different areas of life should be designed. It was shown that for the target group of young, sustainability-minded people the elements of transparency, tips and education, a supportive social environment, overcoming negative habits and ensuring low costs were found to be crucial in the uptake of more sustainable behaviours. The designed mobile app assigns high control to the user and supports through design strategies of eco-information, eco-choice, eco-feedback and eco-spur. At the core of the app are sustainability challenges in which users participate, collaborate and compete in a community environment and receive targeted, personalised feedback and tips. The app was tested in a two weeks field study with 27 target users. The analysis showed that users are particularity interested in receiving eco-information and tips on which action to take and wish for guidance to overcome habits, such as push notifications to remind them of their actions. The app showcased technological immaturity that might have impacted the overall experience with the app. At the same time, the User Experience Questionnaire (UEQ) found that the app already ranks above average on the scales *attractiveness*, *perspicuity, stimulation* and *novelty.* The below-average results on efficiency and dependability need to be improved.

Research Question 2 asked to what extent the designed mobile app can support people in taking on more sustainable actions across different areas of life. The analysis of field user study showed that participants acted statistically significantly more sustainable with regards to the self-reported behaviours "nutrition", "tap water consumption" and "shower time" during the interaction period as compared to before. The role of the self-chosen challenges seemed to play a crucial role. For instance, in the field of "showering", those users that committed to change their behaviour by taking on the challenge on the app, changed their behaviour statistically significantly. At the same time, this was not the case for those users that did not commit to the challenge.

Users' positive attitudes towards acting sustainable and their perceived behavioural control also statistically significantly increased. In particular, their awareness of potential sustainable activities to take and their knowledge about their impact on the environment increased.

Several limitations exist that should be overcome in the future. Non-validated questionnaires were used to measure behavioural frequency and the parameters of the Theory of Planned Behaviour. The test group was small and highly homogenous, the potential social-desirability bias that is prominent in sustainability-related areas might have impacted the answers, and technological immaturities of the app could have influenced the overall user experience.

In the future, in-field studies should be expanded to more areas of life (e.g. travel, finances) and should be applied to a larger user group and over a more extended period of time to investigate long-term effects of the usage of a sustainability app on behaviour change.

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Appendix

Appendix A - Exploration: Interview Guide

Hi _____, my name is.....

Thanks for taking the time to speak with us about the topic sustainability. To the background of the interview: we are working on an innovation project to develop new products that raise people's awareness of sustainability and support them to act more sustainable in their daily life. To develop something useful we would like to find out what sustainability means to our potential customers. Parallelly, I am writing my master thesis about this topic and would like to use the knowledge and learnings from here for my research.
So, we would like to find out what sustainability means to you, how you integrate it in your daily life and where you find difficulties and hurdles in integrating it.

There are no right or wrong answers it's all about your personal experience and your opinion. The interview will last around 60 minutes.

We would like to record the interview. The recording would be used only internally in the team to gain knowledge that is relevant for our project or for my master thesis. Every information would be anonymized and treated confidential. Are you okay with that?

Have you received and read the interview brief? Please take your time to read and sign the consent form, if you agree with all the points.

Do you have any questions before we start? Then I start the audio recording now.

Start of the interview:

I. Warm-Up: Sustainability – Opinion on the topic [5 min]

1. Introduce yourself briefly – who are you and what are you doing? How old are you?

2. How would you define the word 'Sustainability'?

3. Would you describe yourself as environment conscious/sustainable?

4. Do you believe that your personal behaviour and choices can make a difference with regards to climate change/sustainability? Why?

II. Daily behaviour *[show Design Probe – ,Lifestyle Areas'; attached below]* [15 min - flexible focus]

5. Here are a few photos that show different areas of life. Could you describe, how sustainability is relevant in your life in those areas? Are you doing anything to be more sustainable there?

6. Did you make any changes in your daily life to act more sustainably? Which?

A. Daily behaviour & (changing) needs – Groceries

7. Where are you buying your groceries (like food, hygene products)? Are you also considering bio/sustainable products there?

8. Have you always shopped this way? Why?What made you change your habits? Have you always made your groceries like that or did you use to visit other stores? Or: what keeps you from doing it, which challenges do you face?

9. How was it for you to shift towards more sustainable stores? Was it easy or where there difficulties, too?

10. Some people say it is difficult to integrate purchasing from sustainable stores in their daily life. Do you stay motivated to engage in it? How?

B. Daily behaviour & (changing) needs - Clothes

11. Where are you buying your clothes? Are you also considering eco/sustainable products there? Why (not)? What keeps you from trying it (which difficulties)?

12. Have you always made your groceries like that or did you use to visit other stores?

13. How was making the change? Was it easy or where there difficulties, too?

C. Daily behaviour & (changing) needs - Transport

14. In your daily life, how to you get around? Do you care about sustainability?
15. Have you always done that or did you use other transportation methods?
16. How was making the change? Was it easy or where there difficulties, too?

D. Daily Behavior & (changing) needs - Banking

17. Have you ever heard of sustainable/green banking? How would you describe it? Do you know any sustainable bank?
18. Have you ever heard of sustainable/green investments? How would youd describe it?
19. Do you have the impression that banks play an important role when it comes to make economy greener? Which role?
20. Would you consider a green bank account or investments? Why not?

OPTIONAL: E. Daily Behavior & (changing) needs - Others

21. Are there other areas in your daily life in which you try to act more sustainable? IF yes: Which are those? What made you act more sustainable there? IF now: What keeps you from acting more sustainable there? Do you face any barriers?
22. Did you face any challenges when shifting towards more sustainable transport/fashion stores/…

III. Motivation/Support/Community [10 min]

23. (We spoke about many topics around sustainable behaviour now. What motivates you to act more eco-friendly?)

24. What consequences does it have for the environment if you change your personal lifestyle? How big is your influence? (If mentioned: What do you think about that it is difficult to know your own impact? Would you like to know more in detail the consequences of your behaviour?

25. Are your family and friends environment-conscious? How do you find that? Why do you think they are not acting sustainably?
26. What do your friends/family say about your sustainable choices? What does their (lack of) support mean to you? Why?

IV. Sustainability App **[use the App screens to support]** [20 min]

27. Let's imagine you would be responsible to develop an app that helps you to act more sustainable. What should this app do?

28. Finally, I would like to show you the idea that we currently develop to make more people act sustainably and integrate sustainable behaviour into their daily life. Please, be very honest with us and do not hesitate to criticise our application, because this is how we can learn and improve the idea.

V. Budge Discussion

Explain Budge while showing the challenges screen.

- What are your thoughts on that? Can you see yourself using the application?
- What would you think how these challenges are suggested? Would it be general challenges or specific to your behaviour (example car/bicycle to work)? Customised e.g.: concrete kilometres, CO2 and money saved
- What could be challenges you would like to see here? -> mention Inventory
- Have you ever used other apps with challenges such as Fitbit or Duolingo?
- What would you expect to get out of it when accomplishing a challenge? (introduce options)
- Introduce the savings part. What do you think about it?
- We also thought about creating competitions and participate in teams in the challenges. Would you like to participate in such team challenges? With what kind of people (Friends, Family, Work).
- (How would you find it if such an app was offered by a bank?)

Appendix B - Exploration: Information Sheet and Consent Form

Information Sheet: Interview on 'Integrating sustainability into daily life'

02 March 2020

Dear Interviewee,

Thank you for participating in this interview around 'integrating sustainability into the daily life'.

The interview is conducted as part of the innovation project "The Mission II: Banking Be Green" which is organised by the innovation platform Futury. In this project, student teams of four aim to develop a mobile application around 'Sustainability'.
In addition to that, the team member Naima Volz will use the anonymised interview findings for her Master Thesis at the University of Twente, Netherlands which has the related topic 'User-centred design for sustainable behaviour change'.
The research goal is to investigate how to support people in integrating sustainable actions into their daily life and overall explore ways to engage people in more sustainable behaviour. A further goal is to understand how a digital application could be developed that would support people in this sustainable behaviour.

The interview will last around 60 minutes. The interview will be audio-recorded. The recording will only be used internally for the innovation project "The Mission II: Banking Be Green" and for the Master Thesis of Naima Volz. The interview will be transcribed.

All the information provided for this study will be treated confidentially. The results of this interview may be reported during the project "The Mission II: Banking Be Green" and in the Master Thesis of the researcher Naima Volz. In any report on the results of this research, the interview participant's identity will remain anonymous. This will be done by changing the name and disguising any details of the interview which may reveal the identity, or the identity of people spoken about.
The data such as audio recordings and written notes will be stored in a Cloud Environment to which only project members have access. The research data will be deleted after the end of the project "The Mission II: Banking Be Green" or the Master Thesis evaluation, whatever is the latest.

The participant in this research will not directly benefit from the participation in the interview.
If a participant wishes to withdraw from the ongoing interview, he or she can do so at any time without any negative consequences.

Researcher contact details for further information:

Naima Volz: n.volz@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl.

Consent Form for Interview on Sustainability in Daily Life

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the boxes next to the statement to confirm your agreement.

Taking part in the study

I have read and understood the study information dated [02/03/2020], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

I understand that taking part in the study involves audio-recorded interview. I understand that the information will be recorded via written notes and audio recording. I understand that the audio recording will be transcribed as a text.

Use of the information in the study

I understand that information I provide will be used in an anonymised form for the project work in the project "The Mission: Banking Be Green II" by Futury and for academic reports and publications.

I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.

I agree that my anonymised information can be quoted in research outputs.

Future use and reuse of the information by others

I give permission for the audio-records that I provide to be archived in Microsoft Teams by the researcher for the purpose and duration of the research.

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name [printed]	Signature	Date

Study contact details for further information:

Naima Volz: n.volz@student.utwente.nl / naima.talent@futury.eu

Appendix C - Exploration: Synthesis of User Motivation, Needs and Pain Points

User Motivation

Sub-category	Description	Exemplary quotes
"Climate crisis" as a motivator	For **interviewees that are already pursuing more sustainable behaviour** such as vegan consumption habits and long-distance travel via train, the motivators are closely tied to environmental topics. These interviewees reported getting motivated through the awareness about climate change and the need for climate action and ethical topics such as animal welfare. Two vegan interviewees independently mentioned the film "Cowspiracy" as the trigger that finally engaged them to fully turn vegan. "Cowspiracy" is a 2014 documentary film which explores the impact of animal agriculture on the environment[8].An interviewee used the term "climate crisis", coined by environmental activist Greta Thunberg, and went as far as to state: *"All I want in life is being a climate activist"*. For highly sustainable-conscious interviewees, awareness about the relation of climate change and social justice was a further motivator. For instance, one interviewee explained that "our" consumption habits and production processes in the "Western World" causes global warming which however more heavily impacts developing countries through natural disasters. This was described as a major social injustice by the interviewee: *"Climate justice is also a really important aspect that people need to understand. You know it's an issue of justice in some countries. People have been living particular lifestyles and this causes other people in other places who are not rich and white to die".*	"All I want in life is being a climate activist". "Climate justice is also a really important aspect that people need to understand. You know it's an issue of justice in some countries. People have been living particular lifestyles and this causes other people in other places who are not rich and white to die".
Transparency	Learn about their own CO2 footprint and gain knowledge about their personal impact on the environment. Interviewees reported that they are very interested in understanding how they personally impact the climate and that they wish for great transparency in this context: *"[...] there is a very, very large lack of transparency, both regarding what is good and what an effect it has".* Knowing the personal impact could then motivate them to change their behaviour or identify which behaviour to change.	"[...] there is a very, very large lack of transparency, both regarding what is good and what an effect it has".

[8] Wikipedia, "Cowspiracy" [100]

Social pressure	Social pressure can motivate people to act more environmentally conscious and more sustainable. One interviewee for example said that climate change was all over the media which pressured her to take action as well.	"Sustainability is everywhere now. So I feel bad when I'm not doing anything about it."
Social support	One of our interviewees that meanwhile is a climate activist, only became aware about sustainability and sustainable behaviour once she joined university and got in touch with students that were highly environment-conscious and active. The interviewee now experiences support from her new peer group of climate activists and a very positive environment to connect with like-minded people.	"It's just really nice people […] we plan activities together like a sewing workshop to fix our own clothes […]"
Pre-existing positive habits	Pre-existing positive habits could for instance be the habit of cycling to school and later university throughout the lifetime. Cycling then has become a fully normal activity which has been performed independently from its meaning for the climate. The fact that cycling is also better for the climate than using a car is just a side effect.	"I like cycling and it is a good physical activity. It's nice that it's good for the climate at the same time. [...] you would need to make a real real sacrifice not doing things you want to do."
Lower cost	A further motivator can be cost. In some lifestyle areas such as mobility, the unsustainable decision may be more costly than the more sustainable one. As an example, the ownership of a car is relatively costly which is why many students cannot afford owning a car. Nevertheless, our interviewees cited the fact that they did not own a car as a sustainable action and behaviour, although it was "only" caused by the parameter of "cost". The cost parameter however does not apply to all daily activities as it has for instance been reported as a hurdle in turning towards more sustainable actions in the context of food and nutrition.	"I do not have a car […] but this is also because it is too expensive."
Alignment with personal targets	Overall, we found that what motivates people to act sustainable goes beyond just fighting climate change and can be very personal. For a solution designed to support people in taking sustainable actions that shall be used across different lifestyle areas, it can be derived that the sustainable action has to align with the personal targets of the individual users. This could for instance be to pursue health and fitness activities such as cycling which at the same time are good for the environment.	"I do sustainable things but I also enjoy these things. I think that's key."
Eco-anxiety	Lastly, a feeling of discomfort with inaction can e people to act. Both interviewees that already act quite sustainable explained feelings known as "eco-anxiety" [9].	*"I think with the eco anxiety, this complete feeling of despair, being able to do something really useful and feeling you're actually doing things, does help."*

[9] Eco-anxiety is the non-clinical "chronic fear of environmental doom" combined with feelings of helplessness and fear about the future [99]

User Needs

Sub-category	Description	Exemplary quotes
Social Environment	An important role plays the social environment in which people are, which can be supportive of sustainable behaviour or, on the contrary, trigger less sustainable actions such as meat consumption. One interviewee explained that after moving to a new city and starting to study, her new social circle was of great support when taking on more "sustainable" behaviour while being understood and appreciated. Another interviewee recently starts to experience more support from family and friends which she enjoys: *"yeah I feel more understanding and support from my friends and from meeting people I don't know because I think it's getting more popular in societies."*	*"yeah I feel more understanding and support from my friends and from meeting people I don't know because I think it's getting more popular in societies."*
Transparency and feedback of climate impact	Many participants would like to gain transparency, know the impact that they have on the environment and would like to reduce it. Similarly, they are interested in constant feedback into their activities and their impact. This is underlined by the following statement of an interviewee: *"I would like to know what my behaviour means for the environment."* Interviewees also need transparency to be able to make more informed choices - for example, when it comes to choosing sustainable stores or products. At the moment, there often seems a lack of options available.	"[...] there is a very, very large lack of transparency, both regarding what is good and what an effect it has". *"I mean now I have to research every time I buy shoes or something to check that they're vegan - a bit annoying but you know. [...] Or when I was trying to buy a new coat and then on this one website they had a sustainable filter and so I was like, oh great - clicked on a sustainable one - and then thousands of coats disappeared and there were only three coats left."*
Information and Education	In the process of starting to take sustainable actions and maintaining them, they wished for information and education on topics such as "which actions to take" - i.e. to eat vegetarian - and "how to organise them" - i.e. what to cook and where to buy the ingredients needed for vegetarian meals. A simple example came from an interviewee that would like to know *"whether it is more sustainable to get an eBook reader or to buy normal books.*	The sustainable-minded interviewee who is also a climate activist said the following with regards to shifting behaviour: *"I think the key with that is that you need to be really motivated and educated. Like when I first [started eating vegan] I was watching most documentaries and everything. [...] There's a lot of things that you must learn when you're going vegan or trying to reduce. Because yeah if you just have eaten meat all your life it's like really hard to even know like ... this sort of period of confusion like what do I eat. But you just can find Youtubers or like Veganuary is a really good resource for people going vegan it gives you sort of some meal plans I think. [...] the most important thing is you need to really have a strong motivation and educate yourself and be clear on why you are doing it.*

Aligning sustainable actions with (life)goals	On a more personal level, several interviewees mentioned their need of setting realistic goals which could keep them motivated and engaged. This means that the sustainability goals should be aligned with other targets related for example to health or fitness goals. In contrast, there are also thresholds to sustainable actions that do not align with lifegoals. One interviewee for instance pointed out provocatively that *"the most impactful thing for the climate you can do is having one less child"*. Such a decision however could clearly lead to an unhappy life for individuals that wish to have children. This drastic example underlines that sustainable activities should not contradict, but rather support life goals.	*"the most impactful thing for the climate you can do is having one less child*
Convenient and fun app	Lastly, any app which supports users in sustainable behaviour should be convenient, easy and fun to use.	*"in any case, it should be user-friendly and easy to use."*

User Pain Points

Sub-category	Description	Exemplary quotes
Lack of options, Intransparency of products and services	*Lack of options, Intransparency of products & services* One pain point described was the intransparency of the climate impact of own actions and of products and services. In more detail, people found it hard to understand what their own current impact on the environment is, what and how they could change it and what impact that would have (compensation behaviour) as well as which products or services they could use to act more sustainable. As an example, one interviewee said: *"there is a very, very large intransparency, both regarding what is good and what an effect it has".* However, even if a certain transparency is provided, for instance by an e-commerce store, problems of limited product availability may emerge.	*"there is a very, very large intransparency, both regarding what is good and what an effect it has".* *"[...] or when I was trying to buy a new coat and on this one website, they had a sustainable filter. And so I was like, oh great - clicked on a sustainable one - and then thousands of coats disappeared and there were only three coats left."*
Lack of information and education	Related to this point, lack of information and education emerged as a hurdle to act sustainably. For instance, when asked, in which field they already took sustainable actions, few people mentioned their shopping behaviour for clothes or electronic products although these actions can have a significant impact on the total environmental footprint and sustainable brands already exist as alternatives. A conclusion is, that there might be a lack of awareness for such brands and sustainable alternatives.	

Cost	Some interviewees perceived cost as an obstacle to sustainable action. Thus, perceived cost can be seen as another pain point where for example the purchase of sustainable food items is perceived as more costly than the purchase of "normal" products. Students frequently mentioned the cost factor.	*"From a student's point of view, sustainable things are often more expensive because, yes, it costs money if you either have smaller farms or if you do not produce them in the cheapest way where the animals are not full of antibiotics. I understand that everyone who doesn't have so much first swallows when he sometimes pays 30-40% more for it. On the other hand, I just noticed that I have been consuming much more consciously since then so it might in the end be the same amount."*
Negative Habits and Comfort Zone	Some interviewees simply do not want to leave their comfort zone and make the (perceived) effort required to achieve a more sustainable lifestyle. The attitude might however be different across life areas such as mobility or nutrition. For instance, one interviewee explained: *"I just like meat. I don't see myself giving up eating meat entirely."* The comfort zone on the other hand, keeps people stuck in their old behaviour schemes: *"[Car vs. bicycle] ... I think there is a big difference, so this is the convenience factor that you somehow want to indulge in or don't really think about."*	*"[Car vs. bicycle] ... I think there is a big difference, so this is the convenience factor that you somehow want to indulge in or don't really think about."* *"[Car vs. bicycle] ... I think there is a big difference, so this is the convenience factor that you somehow want to indulge in or don't really think about."*
Negative Social Environment or Social Isolation	he social environment can trigger people into acting less sustainable. One interviewee for instance said: *"When I am back home and my friends invite me to a BBQ with a lot of meat, it is difficult to keep up vegetarian eating habits."* Related to that, the lack of a supportive peer group that also is sustainably minded can pose a hurdle in taking on such behaviour and habits. Similarly, the hurdle that others do not act so why should I, is also quite common.	*So people, I hear it a lot, that people think it doesn't make a difference if I just do it myself. But you know that's the same logic for voting or you know… it does make a difference and it's about, you know, sort of societal change."* *"I mean my family or my friends they asked me 'Do you really think it makes a difference if you recycle what you consume?' [...] people in Russia don't believe that if they will use water more or if they will try to save water, it will make any difference."*

Limited capacities, time or infrastructure	Many interviewees mentioned that the sustainable alternative is sometimes not feasible. For instance, one interviewee explained that the train was *"not reliable"* and *"taking longer than the car"* which is why he opted for commuting by car. Even the two dedicated interviewees that already changed their travel and nutrition habits, stated that they *"cannot do everything at once"*. For instance, one of the interviewees said that her target for this summer is to *"start working on that plastic thing. Avoiding plastic is really hard - it is everywhere [...]. When I have passed my exams and have more time, I want to look into it. [..,] It could be my 'summer 2020 thing.'"* As a consequence, it becomes clear that one person can only do so much, and it is extremely challenging even for very dedicated persons to implement changes across all living areas in parallel.	*"start working on that plastic thing. Avoiding plastic is really hard - it is everywhere [...]. When I have passed my exams and have more time, I want to look into it. [..,] It could be my 'summer 2020 thing.'*
Eco-anxiety	Lastly, pain points related to sustainable actions can also be motivators. Both interviewees that already act quite sustainable explained feelings known as "eco-anxiety". Eco-anxiety is a non-clinical "chronic fear of environmental doom" combined with feelings of helplessness and fear about the future, often expressed by the younger generation (Wikipedia, "Eco-Anxiety", 2020). One interview explicitly mentioned the term "eco-anxiety" and that dealing with it can be difficult and it becomes easier to handle with a peer-group that experiences the same feelings: *"I think with with the eco anxiety, or just this complete feeling of despair, being able to do something really useful and feeling you're actually doing things, does help."* As such, eco-anxiety could also be seen as a (painful) motivator to take sustainable actions.	*"I think with with the eco anxiety, or just this complete feeling of despair, being able to do something really useful and feeling you're actually doing things, does help."*

Appendix D - Exploration: Quantitative Survey Quotes

Cost
"As a student, I find it difficult to make a change (higher prices for sustainable food)"
However, there were also respondents stating the opposite:
"Many things are cheaper (second hand, less consumption, reusable products, homemade)"

Lack of information/education and transparency
"Evaluating situations, whether in the supermarket or mobility, takes some time. It takes time till you find out what you can buy and no longer need to read the label and before you know from which routes you should / can rather go by car than by train."
"Too few restaurants and canteens that offer organic meat products."
"There is little information about what and how something is sustainable."

Not comfortable / Laziness or negative habits
"It is not easy to change oneself."
"Of course it is sometimes more difficult and you think it would be easier otherwise but you just have to overcome your laziness."

Negative Social Environment or Standing alone; Lack of support when starting sustainable behaviour
"Family discussions/lack of understanding from the husband"
"Also at family reunions or gifts from parents, grandparents want the same topic if you do not eat something or if you do not want to be bought new, the others think you are ungrateful, or they project the rejection onto you and think you reject what is offered to offend them"

However, there were also respondents having a positive social environment:
"Discussion in the partnership - changes fixed and implemented. Works "

Limited capacities, time or infrastructure
"Domestic travel only by train is easy to do, but travel abroad is not always. The alternatives are often missing here"
"Because of my low income, it is sometimes difficult to buy unwrapped food. I am now growing more of my own vegetables in the garden so that I have to shop less and know exactly where my food comes from! "
"Plastic reduction is particularly difficult because almost everything is packed"

Appendix E - Generation: Feature Ranking

Features	Category	very unimportant	unimportant	rather unimportant	rather important	important	very important	Weighted Average
I want to see what impact I personally have on the climate through my behaviour.	Eco-feedback	2.21%	0.55%	5.52%	23.76%	30.94%	37.02%	3.92
I want the reward for my challenges to be investing in sustainable projects (e.g. planting trees).	Eco-steer	3.31%	3.31%	6.08%	27.07%	30.94%	29.28%	3.67
I would like to receive precise information about my CO2 emissions.	Eco-feedback	3.31%	6.63%	9.39%	23.76%	35.36%	21.55%	3.46
I would like to see challenges tailored to my behaviour.	Eco-choice	4.97%	3.31%	10.50%	28.18%	39.78%	13.26%	3.34
I want to see the money I save through sustainable challenges in the app.	Eco-information	3.87%	6.63%	11.60%	27.07%	30.94%	19.89%	3.34
I would like to participate in challenges in teams (e.g. with family, friends, colleagues).	Social	6.08%	8.84%	19.89%	22.65%	29.28%	13.26%	3
I want my financial expenses to be recorded by the app (e.g. supermarket, petrol station, restaurant) in order to receive information about my influence on the climate.	Eco-information	8.29%	8.84%	15.47%	29.83%	28.73%	8.84%	2.88
I would like to receive discounts from sustainable providers (e.g. clothing, food) if I pass challenges.	Eco-steer	6.08%	8.84%	21.55%	33.15%	19.89%	10.50%	2.83
I want to collect points in the app for completed challenges.	Eco-steer	6.63%	9.39%	24.86%	25.97%	24.31%	8.84%	2.78
I want to be able to create and run my own challenges that others can do.	Eco-choice	8.84%	11.05%	19.34%	28.73%	23.76%	8.29%	2.72
I want to receive rewards for sustainable behaviour.	Eco-steer	6.63%	15.47%	23.20%	22.10%	24.31%	8.29%	2.67
I want my financial expenses to be recorded by the app (e.g. supermarket, petrol station, restaurant) in order to receive rewards in the app.	Eco-steer	12.15%	14.36%	20.99%	27.07%	18.23%	7.18%	2.46
I would like to compare myself with others who also do challenges.	Social	13.26%	17.13%	31.49%	18.23%	14.36%	5.52%	2.2

Appendix F - Evaluation Low-Fidelity Prototype: Interview Guide

A. Users are able to find, understand and take on challenges according to their preferences.
B. Users appreciate that their progress is being tracked and prefer less manual work in the tracking progress.
C. Users, as a preferred reward, want to donate saved money and approve that a commission is given to Budge.
D. Users are engaged and motivated by community challenges and leaderboards.
E. Users prefer a light, fun design.

Welcome to our research study! Thank you for taking the time.
Together as a team, we are currently developing a sustainability app. The goal of the app is to support people in taking sustainable actions during the daily life. There are two goals of this study. One goal is, that I will ask questions to understand better what you would need from an app like ours. These will mostly be open questions and there are no right or wrong answers – instead it is about understanding what YOU think.
The second goal of this study is to evaluate and test our prototype. It is not about testing you, instead it is about understanding what you like about the app, what you do not like and what we should improve. So please also feel free to criticize.
There it is important to know that the app is not final yet, this means that some things will not work as expected because they are not yet developed. You can still comment on everything, I will let you know if we come to a situation where something is not developed yet.
Niklas shared with you the information sheet, did you receive and read it? Perfect, so as mentioned, we would like to record the call as we want to review your interaction with the prototype and your feedback, is this okay? Then I am switching it on now.

I. WARM UP
Introduction
Introduce yourself, say a few words about yourself, for example your profession and where you're from.
Sustainability Definition
To start with, I would like to know what you understand as sustainability, how would you define it?
Sustainable Actions
Secondly, I would like to know which role sustainability and sustainable choices play in your daily life. Do you already take any actions in daily life that you consider to be sustainable?
Taking challenges

> I would like to know now, if you have ever used any app which made you learn something or change your behaviors such as Duolingo to study a language or a gym app or for healthy food. How was your experience with it? Did you stay motivated and if so – why? What perhaps did not work well about it?

Thanks.

II. APP WALKTHROUGH
I would now like to show you our app. I will introduce you a short task and then I would like to ask you to complete the task. Remember it is not about how you solve it but seeing how you use it and learning what still does not work in our app. And lastly, I would like to encourage you to **think aloud** and tell us what you are currently doing, what you are looking for, as if you are describing your thoughts to ask.
Cool, I am now sending you **the link to the prototype** here in the chat, you should be able to open it.
Login Details
Website: prototype.budge-app.com

Email: user_8@budge.app
Password: b4u

Besides the Mute Button, there is the share button, can you share please
Does it work? Any more questions?

Users are able to find, understand and take on challenges according to their preferences.
Imagine that you heard of this app Budge, which allows you to take on sustainability challenges. These can be about taking on challenges in daily life related to nutrition, transport, travel and so on which are sustainable at the same time. You would now like to set-up this app and find a challenge that you actually would like to take on.
Your task now is to go through the app as if you would do it at home. **Your goal is to join a challenge that you would feel comfortable with taking on in real life.** We will later also discuss, why you chose to take this challenge. Any questions? Let's go.
Screen 1: User reads and chooses preferred settings.
a) Observe, which settings the user picks and if questions arise.
Screen 2: Empty Dashboard
a) Observe whether user manages to find all challenges available.
If not: You now clicked through x challenges. Do you think those are all challenges available at the moment?
Screen 3: All Challenges
a) Observe whether user makes use of the available filters.
Screen 4: Challenge Filters
a) Ask user to think aloud. Try to understand which areas are focus when he/she decides for a challenge to take on, i.e. what is the challenge about, why does it matter (impact on the environment), how will it be tracked? [questions for that below]
Screen 5: Challenge Details
a) Observe what user says, whether everything is clear.
Screen 6: Tracking choice – write down, which one the user picks.
Thank you.

Follow Up Interview on challenges
Great, you have chosen a challenge to take! I know have a few follow-up questions on that.
a) Are there any other options that you are missing here, like areas in which you would like to take on challenges?
b) Why did you choose this challenge? What do you think is now your task to pass this challenge?
c) How did you choose which challenge to take on?
d) There was the opportunity to learn more about the impact on the environment, did you see it? Are you interested in such information?
e) Do you feel you will be able to solve this challenge in real life? What did you think about the "How to tackle this challenge" section?
f) How do you expect the app to know now whether you solved your challenge task? How would you like this information to be recorded (automatically by the phone or manually by yourself)?
g) At the very first screen, you were able to set preferences for your challenges. What did you think about that? How did you decide which to pick?

Thank you so much!

Open Feedback: Challenge Ideas
Next, I would like to do a small brainstorming session with you, to gather some of your ideas on the topic of sustainability challenges.

- You've now seen a few challenge ideas. Are there others that come to your mind? Which challenge(s) would you like to take on? (Reminder through putting the personalization elements).
- Here are a few categories that we have thought of. Do you have any preference for an area? What kind of challenges would you like to take there?

Waste, Mobility, Food & Nutrition, Water, Energy, Lifestyle, Consumption, Banking & Finance, Travel, Donate, Household, Green Projects, Shopping, Social

III. Discussion: Preferred challenge tracking

Users appreciate that their progress is being tracked and prefer less manual work in the tracking progress.

Preferred collection type

Let's take another challenge example. For instance, you take on the challenge to travel via public transport for a week, instead of via car. For the app to know whether you actually used the public transport or your car to understand whether you completed the challenge, we need some information from you. How would you expect this information to be collected by the app?

- A: Reporting the action myself: Taking a photo/selfie/proof of the action
- B: Reporting the action myself simpler: just pressing a button when the action has been done
- C: Let the tracking be done automatically by the app i.e. through analyzing payment data and seeing, that a daily public transport ticket was used (this does not work always, but sometimes.

Reasoning for preferred collection

a) Why did you choose this option?
b) [if not the automated tracking] Why did you choose not to log it automatically?

Challenge Progress Tracking and Visualization

Imagine the outcome of the challenges you take would be shown to you, what. This can be related to the climate or also to your personal progress. What would you like to see there?
Here, several visualization options could be shown to the user. Then, we let the user rate how much he/she likes the options.

OPTION A: "Green Points" in the game
OPTION B: Estimated CO2 extraction
OPTION C: Estimated CO2 extraction compared to a car
OPTION D: Relative improvement to your previous behavior
OPTION E: Visualize goal they contribute to (i.e. SDG)
OPTION F: Objective -> See e.g. receipt on what money was spent

IV. Discussion: Rewards and Donations

Users, as a preferred reward, want to donate saved money and approve that a commission is given to Budge.

So, let's imagine you have participated in several challenges and you were able to save some money and of course also to improve your sustainable actions. We would now like to find out, what you would like to do next with the points you collected and the money you saved.
I would like to discuss several options with you and collect some of your ideas and feedback [show options via *Screensharing*]

A: Just save the money
B: Exchange green points for rewards like discounts in stores

C: Donate the "virtually saved" money into a green project. (Perhaps companies would join here and double the project?)

V. Design Choices and Discussion

Users are engaged and motivated by community challenges, social sharing and leaderboards.

As the last aspect, we would like to discuss about the community elements of our app. We want to make the app engaging to interact with other users and have a few ideas already how to do so.

But first we would like to hear from you: In an app like Budge that has sustainability challenges, how do you expect you would you like to interact with other users of the app and maybe even people outside the app?

- Social Wall
- Sharing
- Commenting and interacting (i.e. below a challenge, for now?)
- Chat
- Leaderboard

Users prefer a light, fun design.

[Here we can show different design options of the same screen and gather feedback. Perhaps 2 same scenes and then 5 design variations each and we evaluate them. Need to find design research methods how to evaluate design concepts against each other/]

Here, I will always show you two design options and ask you to pick the one of the two, which you prefer for our app. Sometimes, the text is not accurate, but it is about understanding roughly, which types of designs are preferred. So, you can always say "left" or "right". Ready?

VI. App Exploration & Satisfaction

Lastly, I would ask you to take 2 minutes and tap through the app, explore it functions and speaking aloud what you notice while trying out the functionalities.

- Overall ease / Satisfaction / Likelihood to use/recommend

Appendix G - Evaluation Low-Fidelity Prototype: Consent Form, Information Sheet

06 April 2020

Interview and App Evaluation: Integrating sustainability into daily life

Dear Interviewee,

Thank you for your interest in participating in the video-interview and app evaluation around the topic "Integrating sustainability into daily life".

This study is conducted as part of the innovation project "The Mission II: Banking Be Green" which is organised by the innovation platform Futury. In this project, student teams of four aim to develop a mobile application around "Sustainability". Our team is cooperating with Deutsche Bank, Bain & Company and Kaufland during this process. In addition to that, our team member Naima Volz will use the anonymised findings of this study for her Master Thesis which has a related topic: 'User-centred design for sustainable behaviour change'.

In this project, we are currently developing an application that helps people to integrate sustainable actions into their daily life. This could mean to bring re-usable bags for shopping, eat less meat or to use the bicycle instead of the car.

We know however, that taking such sustainable actions is not always easy. The goal of the interview is thus to understand how to make it easier with our app. What would you need from such an app? How would you like to use it?

We will also show you an interactive prototype of the app. You will be able to interact with it and give feedback on the interaction. This will help us to understand what already works well and how we can improve. Your honest feedback and critique are hereby highly appreciated!

The video interview will be conducted via Microsoft Teams. We will provide you with the calendar invite and access link beforehand. During the session, we will share a link with you to access our prototype. The study session will then last around 60 minutes. Two of our team members will be present: One interviewer and one notetaker. We would like to audio-record the interview and video-record your interaction with the app. The (anonymized!) recording will then be used for analysis internally for the project and for the Master Thesis of Naima Volz.

All information will be anonymized and treated confidential.

In case of questions, do not hesitate to contact us at naima.talent@futury.eu.

Best Regards,

N. Volz

Naima Volz & Project Team

Consent Form for Interview and App Evaluation on Sustainability in Daily Life

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the boxes next to the statement to confirm your agreement.

Taking part in the study

I have read and understood the study information dated [06.04.2020], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction. ☐

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason. ☐

I understand that taking part in the study involves audio-recorded interview and screen-recording of the interaction with the app prototype. I understand that the information will be recorded via written notes, audio recording and screen-recording. I understand that the audio recording will be transcribed as a text. ☐

Use of the information in the study

I understand that information I provide will be used in an anonymised form for the project work in the project "The Mission: Banking Be Green II" by Futury and for academic reports and publications. ☐

I understand that personal information collected about me that can identify me, such as my name or where I live, will not be shared beyond the study team. ☐

I agree that my anonymised information can be quoted in research outputs. ☐

Future use and reuse of the information by others

I give permission for the audio- and screen-records that I provide to be archived in Microsoft Teams by the researcher for the purpose and duration of the research. ☐

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name [printed]	Signature	Date

Study contact details for further information:

Naima Volz: n.volz@student.utwente.nl / naima.talent@futury.eu

Appendix H: Evaluation Low Fidelity Prototype: Visualisation of feature ideas

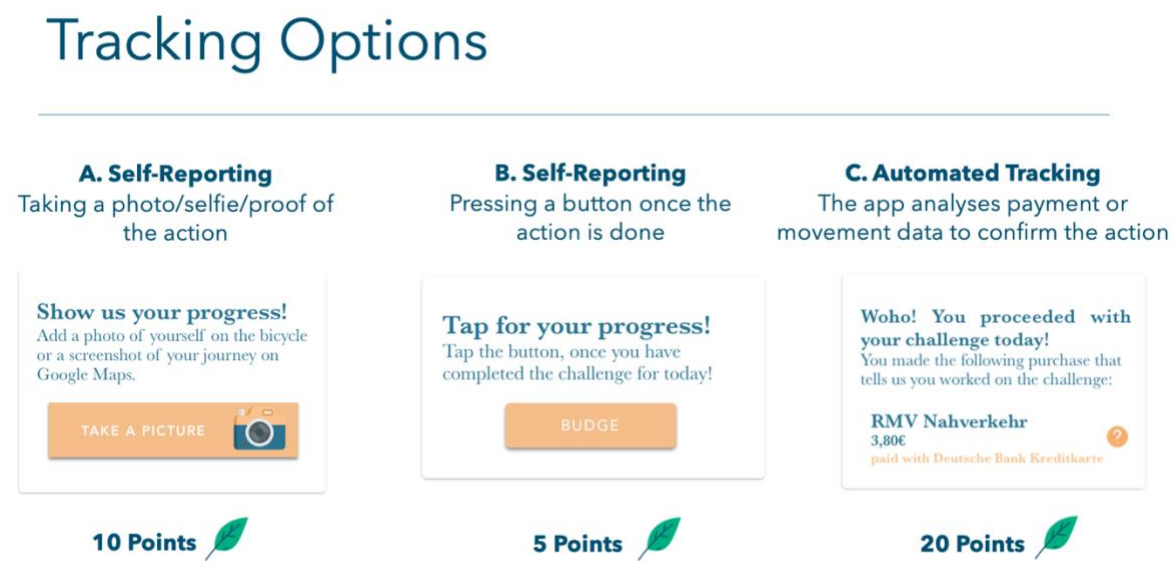


Figure 41. Different tracking options of challenge progress. The user was briefly introduced to these options and then asked, which reporting choice was preferred.

Figure 42. Design iterations and excerpts around the visualisation of challenge progress. Users prefer comparable measures like trees or kilometres driven in a car and are less interested in viewing progress towards SDGs.

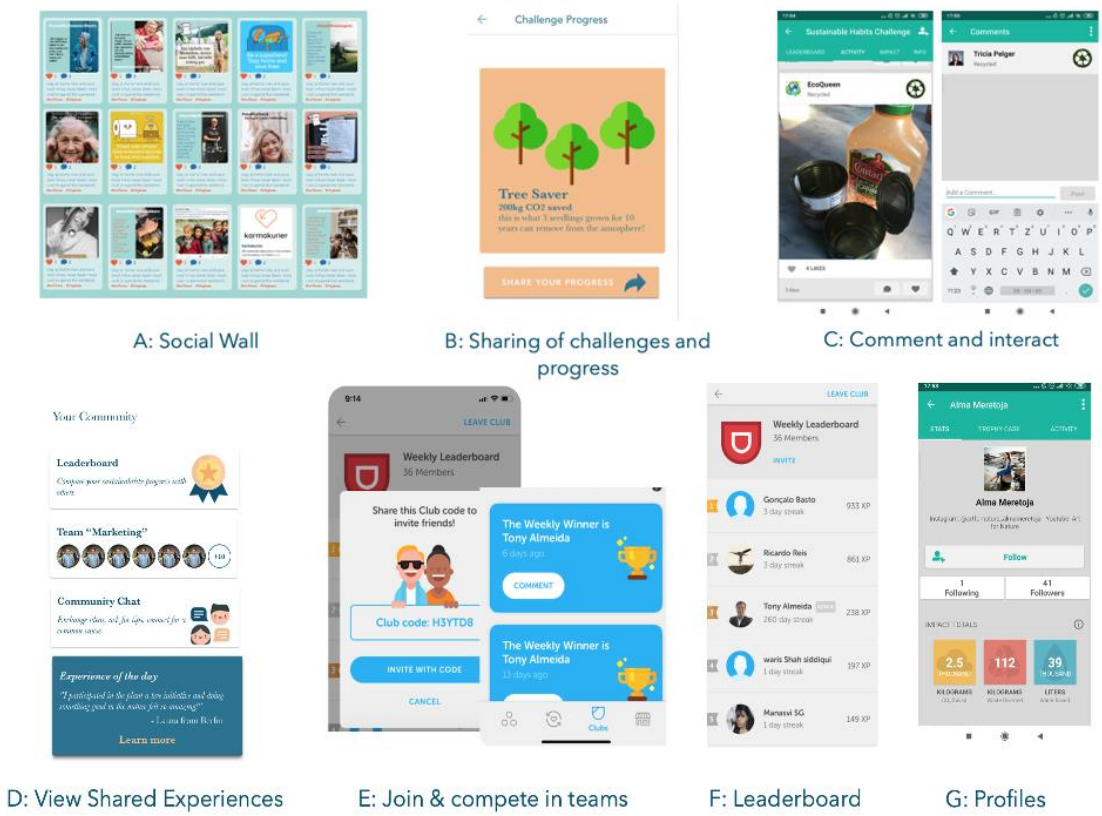


Figure 43. Design iterations on social and community elements. They were introduced to the user for a co-creation session around desirable features.

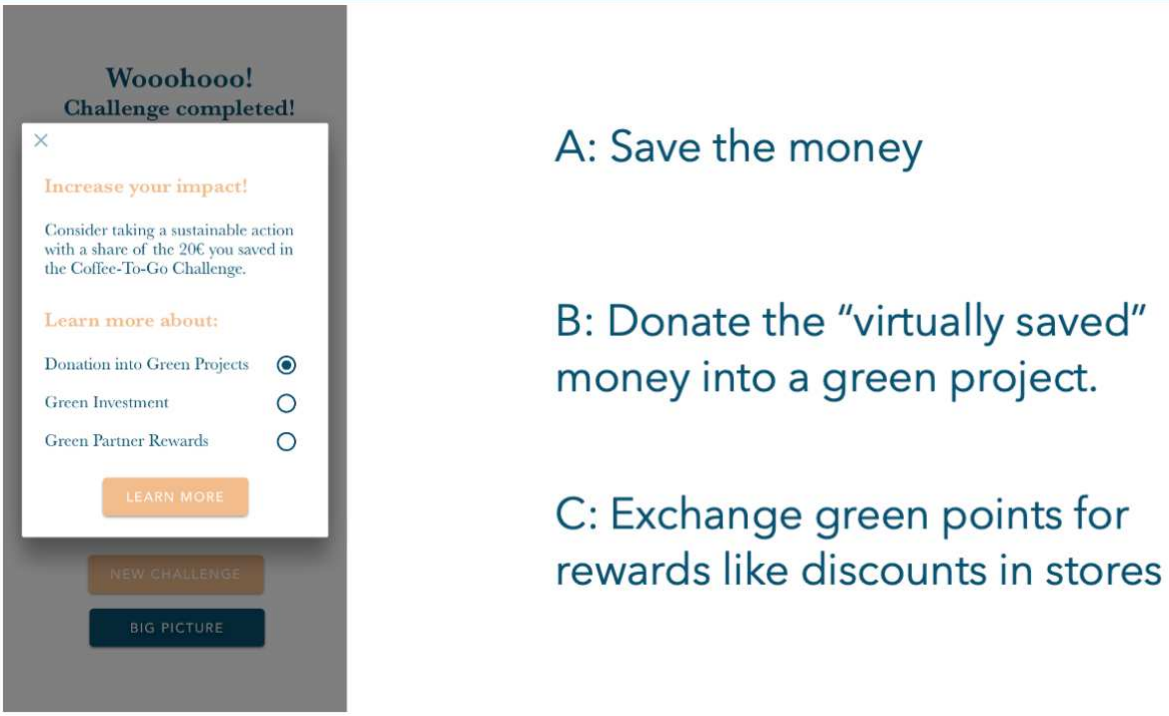
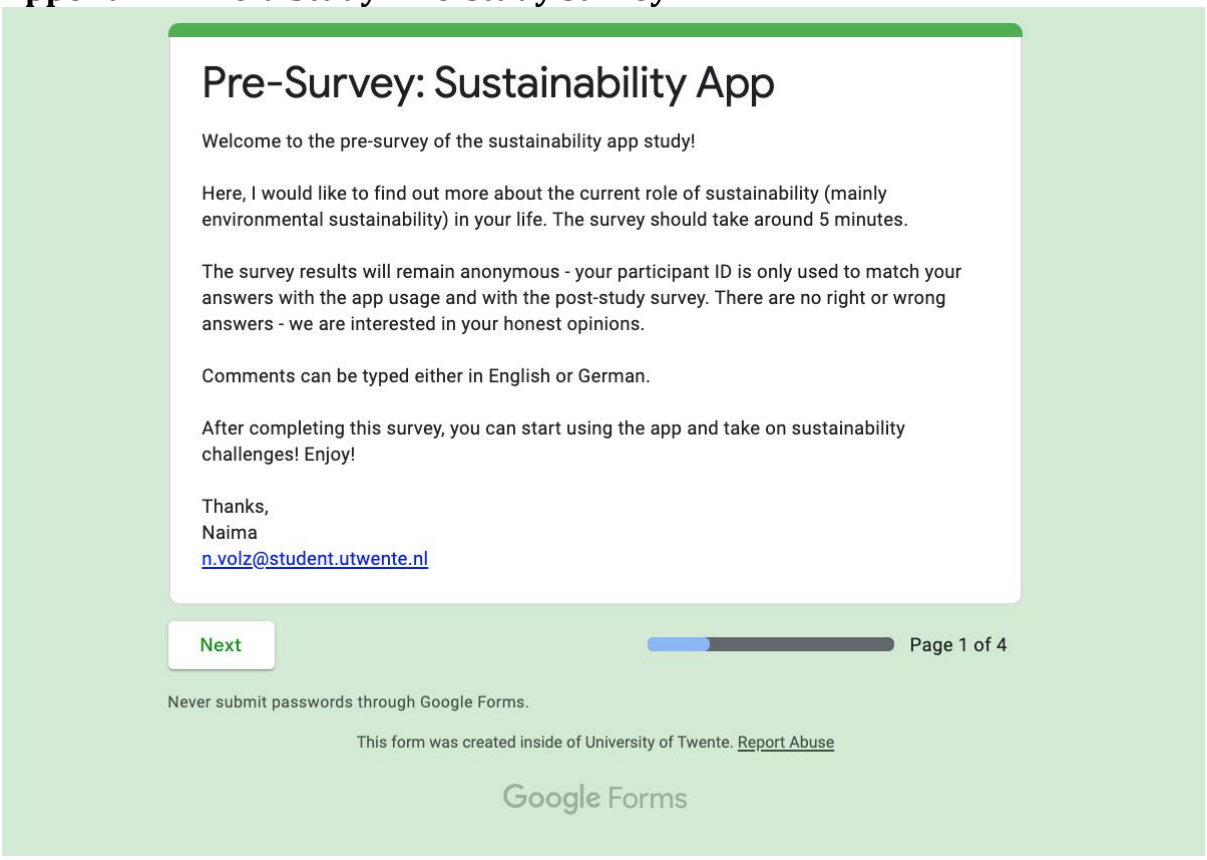


Figure 44. Options for rewards presented to users in the co-creation session.

Appendix I - Field Study: Pre-study survey



Pre-Survey: Sustainability App

Welcome to the pre-survey of the sustainability app study!

Here, I would like to find out more about the current role of sustainability (mainly environmental sustainability) in your life. The survey should take around 5 minutes.

The survey results will remain anonymous - your participant ID is only used to match your answers with the app usage and with the post-study survey. There are no right or wrong answers - we are interested in your honest opinions.

Comments can be typed either in English or German.

After completing this survey, you can start using the app and take on sustainability challenges! Enjoy!

Thanks,
Naima
n.volz@student.utwente.nl

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Google Forms

Pre-Survey: Sustainability App

* Required

Please enter your participant ID (you find it in the app under Profile -> Participant ID) *

Your answer

I self-identify as... *

- ◯ male
- ◯ female
- ◯ diverse
- ◯ I'd rather not say

What is your age? *

- ◯ 18-21
- ◯ 22-25
- ◯ 26-29
- ◯ 30-33
- ◯ 34-37
- ◯ 38-41
- ◯ 41+
- ◯ I'd rather not say.

Are you currently based in Germany? *

- ◯ Yes
- ◯ No

I am currently... [multiple selections possible] *

- ☐ a student
- ☐ employed
- ☐ self-employed
- ☐ out of work
- ☐ I'd rather not say

What is your MAIN motivation to participate in the sustainability app study? *

- ◯ Get active: Integrate sustainable actions into my life
- ◯ Learning: Learn more about sustainability and sustainable actions
- ◯ Curiosity: Try out a new sustainability app in an early stage
- ◯ Competition: Compete with others on the 'sustainability leaderboard'
- ◯ Other: _____

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Please rate in how far you agree with the following sentences on a scale from 1 = strongly disagree to 5 = strongly agree.

Human activities are the leading cause of the earth's rapidly changing climate. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Climate change has been established as a serious problem and immediate action is necessary. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

The way I personally behave makes a difference to the environment. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

It is important to me that I follow a sustainable lifestyle. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I am aware what I can do to act more sustainable (e.g. in the areas of nutrition, transport, consumption, travel etc.) *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Living sustainably is more expensive than not doing so. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I believe that I know enough about the environmental impact of my daily behaviour. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It is difficult for me to change my everyday life to more sustainable behaviour. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

There is a lack of transparency about the sustainability of existing products and services. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

There are enough sustainable products and services offered. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I am determined to establish more sustainable habits in my life. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I can influence what the government does regarding sustainability. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I can influence what the companies do regarding sustainability. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

In recent years, I have actively made changes in my life to live more sustainably. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Daily routines

Here, we would like to learn more about your habits and daily routines. If your current behaviour differs a lot from the pre-Corona times, please think of your "normal" habits and routines.

Which category describes your nutrition best? *

- ◯ Omnivore (includes meat, dairy, plant-based products etc.)
- ◯ Pescetarian (no meat, but fish)
- ◯ Flexitarian (predominantly vegetarian diet, but also occasionally high-quality, organically produced meat)
- ◯ Vegetarian (no meat or fish; however dairy and/or egg)
- ◯ Vegan (no meat and fish; no dairy and egg)

Please indicate how frequently you do the following activities. *

	Never	Almost never	Rarely	Sometimes	Often	Almost always	Always
I keep my showers short.	◯	◯	◯	◯	◯	◯	◯
For distances <5km, I am taking the bicycle or I walk.	◯	◯	◯	◯	◯	◯	◯
I consume bottled water from the store.	◯	◯	◯	◯	◯	◯	◯
I am washing my laundry cold (< 30 degrees)	◯	◯	◯	◯	◯	◯	◯
I am reselling or donating items that I don't use anymore.	◯	◯	◯	◯	◯	◯	◯

Please indicate how frequently you do the following activities. *

	Never	Almost never	Rarely	Sometimes	Often	Almost always	Always
I am willing to pay more for an environmentally friendly product.	○	○	○	○	○	○	○
(Even before Corona), I avoided the plane for holiday travel.	○	○	○	○	○	○	○
I am using a refillable water bottle.	○	○	○	○	○	○	○
I buy things that are likely to involve less energy or resource use.	○	○	○	○	○	○	○
I consider sustainability in my banking and/or investment decisions.	○	○	○	○	○	○	○

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Appendix J - Field Study: Post-study interview guide

On-boarding [5 min]

Thank you for participating in this interview.

- Short introduction and background, also about state of the app

- Interview topic: your interaction with the app, understanding what can be improved
- More detailed information than just via survey or in written form
- Please be honest, you can criticise the application and give negative feedback because we still are in the development process and want to improve the app
- Will be audio-recorded if this is okay for you

Great. Thank you.

1. Warm-up & Role of sustainability [7 min]

1. In this study, you had sustainability challenges to do which you integrated in your typical daily life. That's why, to start with, I would like to ask you to briefly tell us a bit about your current lifestyle during Corona, how did a typical weekday look like for you in the past two weeks?

2. When you think about sustainability, which role does it play in your daily life? [8], [27]
    - Have you ever gathered information around the topic of sustainability before? [9]
    - Have you ever tried to change a habit towards more sustainability? How did that go?

2. Challenge choice & experience [10 min]

Now, I would like to learn more about your experiences with the app.

3. During this study period, which challenges did you take part in? Why did you pick these? [22], [23]
4. What did you think about the choice of challenges offered? [22], [23]
5. How was your experience so far with using the app and participating in these sustainability challenges?
    - Did you actually do the tasks in real life? How was that? *(Probe: easy or difficult?)* [8]
6. In your perspective, how frequently did you do the activity [eating vegan/bicycle/tap water etc.] compared to your normal habits? What do you think about that *(probe: proud)?*
7. What do you think about the outcome of your challenge progress so far? *(Note: understand, whether users are positive about process)*

3. Future Use [5 min]

8. If you think ahead, do you think anything will change in your behaviour also after the study? [8], [27]
9. Will you continue using the app? [8] What would be your goal with using this app? What would you like to achieve? [8] [27]
10. Now that you tried out the app: What do you think generally about this concept of an app with sustainability challenges to reach more sustainability? [8]
11. Did you feel represented by the app? Do you feel the app is made for 'someone like you'? [6]

4. Walkthrough Screens & Detailed Feedback [28 min]

[Screen: Challenge Overview] [3 min]

12. Here are all the challenges listed. You already mentioned […]. Are there any other challenges that you wish were on the app?
13. At this screen, was it clear to you what to do?
14. Would you like to change anything about this screen? [20] Do you need any different/more information at this stage? [8]

[Screen: Challenge Details of a challenge that the user (mainly) took] [7 min]

15. When you reached this screen, what were your thoughts? Was it clear to you what you had to do?

16. What did you do? (i.e. where did you click – if not told, ask for 'learn more' and 'show more')
17. **Impact:** What were your thoughts on the impact displayed? (i.e. trust in it or doubt?) Do you think this impact corresponds to your own impact? [5] [6]
18. **Shore more:** what did you think about this information? Was it what you expected? Was it useful? Would you want any other information?
19. **Impact & Learn more:** what did you think about this information? Was it what you expected? Would you want any other information? [5] [6]
    Imagine you could customise this to your personal information, for example the kilometres you cycle or the time you shower. On a scale from 1 – 10, how important would that be for you?
20. Would you like to change anything about this screen? [20]
    Do you need any different/more information at this stage? [6]

[Screen: Challenge Confirmation] [1 min]

21. Did you read this screen? Was the information clear to you?

[Screen: Activity] [5 min]

22. This screen was about seeing your current activity and active challenges. When you had joined the challenge and saw this screen, what did you do? Was it clear to you what you had to do?
23. How frequently did you go to the app to report your progress? What do you think about doing this? [8] [16]
24. Did you usually remember to input the challenge process? What helped you to remember? [8] [16]

[Screen: Leaderboard] [16], [26] [5 min]

25. Have you come to this page? How often? Why? What did you do here?
26. When comparing yourself to the others, what were your thoughts (i.e. rather positive vs. negative, motivating vs. demotivating) [16], [26]
27. The leaderboard consists of Green Points. What do you think about these points?
28. So far, you were only able to compare yourself to all the app users on a leaderboard. Is there anything else you would like to do in this app together with other users? [16], [26]

[Screen: Home] [7 min]

29. Have you come to this page? How often? Why? What did you do here?
30. Did you read the tips?
31. What are your thoughts on the tips presented? (boring/interesting) [5] [6] [9]
32. Did you read the 'learn more' content? What did you think about it? Was it what you expected? Was it useful? [9]
33. We had the idea to generate tips that are directly related to the challenge you are on. What do you think about that? How important is this for you on a scale from 1-10?

5. General Feedback [5 min] & Ratings

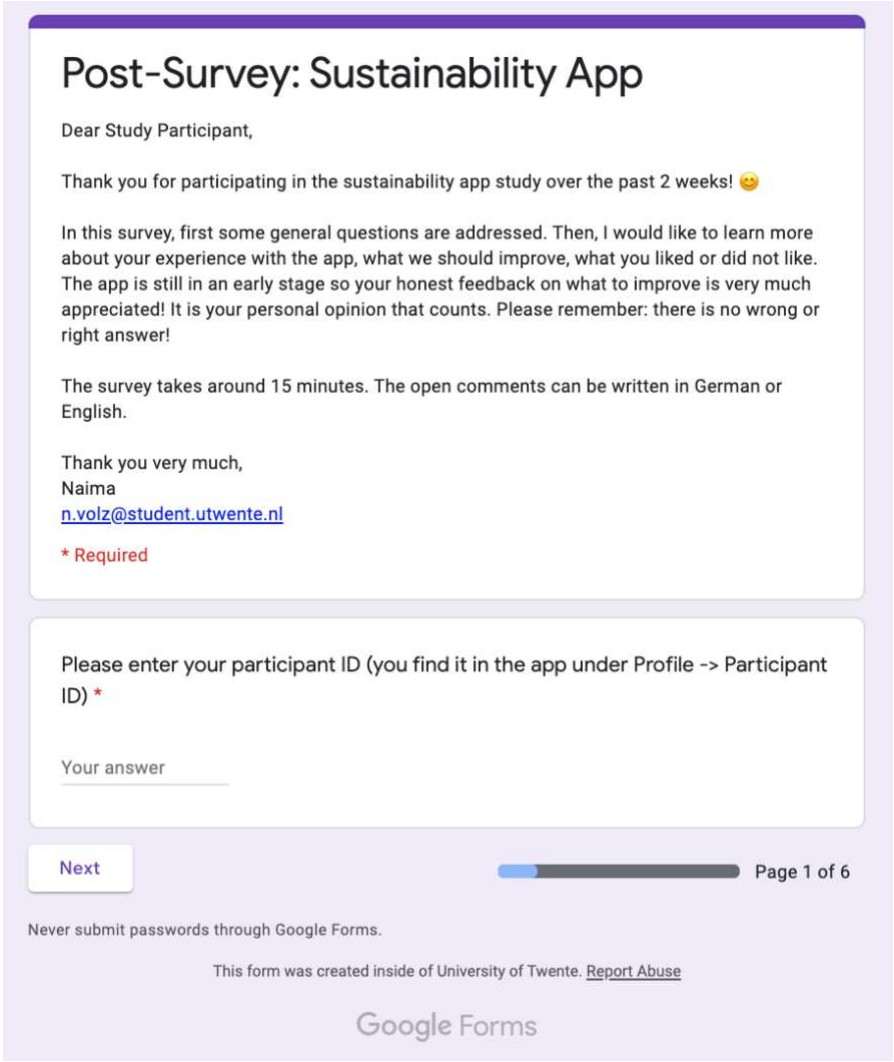
34. In which language did you use the app? *If English:* How was that for you? [7]
35. What were your thoughts on the design of the app?

Ratings to agree/disagree with (strongly disagree 1 – strongly agree 5)

The app is easy to use.
I learned how to use this app quickly.
The app is useful.
This app makes the things I want to accomplish related to sustainability easier to get done.
I like the overall design of the app.
I would recommend this app to a friend/ family member

Appendix K - Field Study: Post-study survey

This section introduces the post-study survey conducted through Google Forms. Screenshots were pasted in the thesis for this purpose.



Post-Survey: Sustainability App

* Required

Please rate in how far you agree with the following sentences on a scale from 1 = strongly disagree to 5 = strongly agree.

The way I personally behave makes a difference to the environment. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It is important to me that I follow a sustainable lifestyle. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I am aware what I can do to act more sustainable (e.g. in the areas of nutrition, transport, consumption, travel etc.) *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Living sustainably is more expensive than not doing so. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I believe that I know enough about the environmental impact of my daily behaviour. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

It is difficult for me to change my everyday life to more sustainable behaviour. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

There is a lack of transparency about the sustainability of existing products and services. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I am determined to establish more sustainable habits in my life. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I can influence what the government does regarding sustainability. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I can influence what the companies do regarding sustainability. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

There are enough sustainable products and services offered. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

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Post-Survey: Sustainability App

* Required

Daily routines

Here, we would like to learn more about your habits and daily routines over the challenge period (the past two weeks).

Which challenge(s) did you participate in? *

- [ ] Vegeterian week
- [ ] Vegan week
- [ ] Tasty tap water
- [ ] Take the bike
- [ ] Smart Showers
- [ ] Air dry your laundry
- [ ] Cool laundry
- [ ] Recycle, re-use, resell
- [ ] Natural cleaning

How frequently did you use the app over the past two weeks?

- ◯ Less than once a week
- ◯ 1x/week
- ◯ 2-3x/week
- ◯ Every second day
- ◯ Almost every day
- ◯ Every day
- ◯ Several times a day

Which category describes your nutrition best OVER THE CHALLENGE PERIOD? *

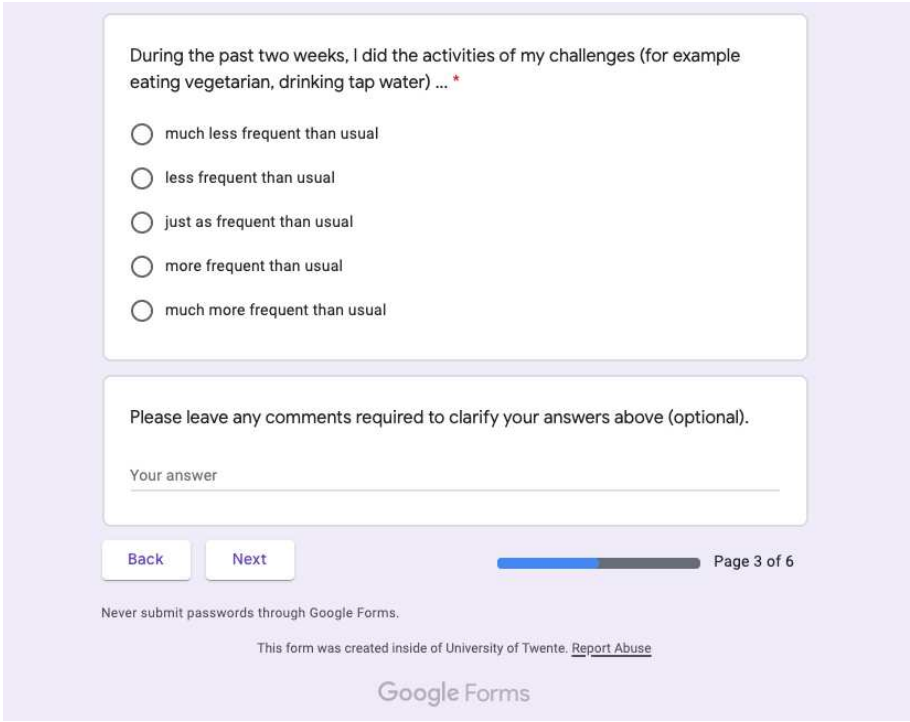
- ◯ Omnivore (includes meat, dairy, plant-based products etc.)
- ◯ Pescetarian (no meat, but fish)
- ◯ Flexitarian (predominantly vegetarian diet, but also occasionally high-quality, organically produced meat)
- ◯ Vegetarian (no meat or fish; however dairy and/or egg)
- ◯ Vegan (no meat and fish; no dairy and egg)

Please indicate how frequently you did the following activities over the CHALLENGE PERIOD? *

	Never	Almost never	Rarely	Sometimes	Often	Almost always	Always
For distances <5km, I took the bicycle or I walked.	○	○	○	○	○	○	○
I washed my laundry cold (< 30 degrees)	○	○	○	○	○	○	○
I resold or donated items that I don't use anymore.	○	○	○	○	○	○	○
I kept my showers short.	○	○	○	○	○	○	○
I consumed bottled water from the store.	○	○	○	○	○	○	○

Please indicate how frequently you did the following activities over the CHALLENGE PERIOD? *

	Never	Almost never	Rarely	Sometimes	Often	Almost always	Always
I considered sustainability in my banking and/or investment decisions.	○	○	○	○	○	○	○
I bought things that are likely to involve less energy or resource use.	○	○	○	○	○	○	○
I paid more for an environmentally friendly product.	○	○	○	○	○	○	○
I used a refillable water bottle.	○	○	○	○	○	○	○



During the past two weeks, I did the activities of my challenges (for example eating vegetarian, drinking tap water) ... *

- much less frequent than usual
- less frequent than usual
- just as frequent than usual
- more frequent than usual
- much more frequent than usual

Please leave any comments required to clarify your answers above (optional).

Your answer

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Google Forms

Your experience with the app

In the following, please let us know, how your experience with the app and with the sustainability challenges was. You will also have the chance to give open feedback at the end.
It is your personal opinion that counts. Please remember: There is no wrong or right answer!

The challenge(s) were difficult. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The app makes it easier for me to integrate sustainable actions into my life. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The challenges were relevant for me. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

While using the app, I felt I was the only one taking sustainable actions. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The app motivates me to follow a sustainable lifestyle. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The app gives me new ideas and tips on how to act more sustainable. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

While using the app, I felt part of a 'sustainability community'. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The app makes the impact of my personal behaviour on the environment more transparent. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I enjoyed participating in the sustainability challenges.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The app showed me that my decisions matter for the environment.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Please let us know any comments you may have to the ratings above (optional):

Your answer

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Rating the app

In how far did technical issues affect your experience using the app (for example error messages, slow speed, log-in failures)? *

	1	2	3	4	5	6	7	
Did not affect my experience at all	○	○	○	○	○	○	○	Affected my experience a lot

In-app experience ratings

Please rate your experience with using the app. The app is still in early stage, so you can ignore technical issues like long loading times and log-in failures.

Choose your responses spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression. Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the app. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember: there is no wrong or right answer!

Please check the following scales well as bad/good is varying per question. The app is...

*

	1	2	3	4	5	6	7	
annoying / unerfreulich	○	○	○	○	○	○	○	enjoyable / erfreulich

*

	1	2	3	4	5	6	7	
not understandable	○	○	○	○	○	○	○	understandable

*

	1	2	3	4	5	6	7	
creative / kreativ	○	○	○	○	○	○	○	dull / phantasielos

*

	1	2	3	4	5	6	7	
easy to learn	○	○	○	○	○	○	○	difficult to learn

*

	1	2	3	4	5	6	7	
valuable / wertvoll	○	○	○	○	○	○	○	inferior / minderwertig

*

	1	2	3	4	5	6	7	
boring / langweilig	○	○	○	○	○	○	○	exciting / spannend

*

	1	2	3	4	5	6	7	
not interesting / uninteressant	○	○	○	○	○	○	○	interesting / interessant

*

	1	2	3	4	5	6	7	
unpredictable / unberechenbar	○	○	○	○	○	○	○	predictable / voraussagbar

*

	1	2	3	4	5	6	7	
fast	○	○	○	○	○	○	○	slow

*

	1	2	3	4	5	6	7	
inventive / originell	○	○	○	○	○	○	○	conventional / konventionell

*

	1	2	3	4	5	6	7	
obstructive / behindernd	○	○	○	○	○	○	○	supportive / unterstützend

*

	1	2	3	4	5	6	7	
good	○	○	○	○	○	○	○	bad

*

	1	2	3	4	5	6	7	
complicated	○	○	○	○	○	○	○	easy

*

	1	2	3	4	5	6	7	
unlikeable / abstoßend	○	○	○	○	○	○	○	pleasing / anziehend

*

	1	2	3	4	5	6	7	
usual / herkömmlich	○	○	○	○	○	○	○	leading edge / neuartig

*

	1	2	3	4	5	6	7	
unpleasant / unangenehm	○	○	○	○	○	○	○	pleasant / angenehm

*

	1	2	3	4	5	6	7	
secure	○	○	○	○	○	○	○	not secure

*

	1	2	3	4	5	6	7	
motivating	○	○	○	○	○	○	○	demotivating

*

	1	2	3	4	5	6	7	
meets expectations	○	○	○	○	○	○	○	does not meet expectations

*

	1	2	3	4	5	6	7	
inefficient	○	○	○	○	○	○	○	efficient

*

	1	2	3	4	5	6	7	
clear / übersichtlich	○	○	○	○	○	○	○	confusing / verwirrend

*

	1	2	3	4	5	6	7	
impractical	○	○	○	○	○	○	○	practical

*

	1	2	3	4	5	6	7	
organized / aufgeräumt	○	○	○	○	○	○	○	cluttered / überladen

*

	1	2	3	4	5	6	7	
attractive	○	○	○	○	○	○	○	unattractive

*

	1	2	3	4	5	6	7	
friendly / sympathisch	○	○	○	○	○	○	○	unfriendly / unsympathisch

*

	1	2	3	4	5	6	7	
conservative	○	○	○	○	○	○	○	innovative

How likely are you to recommend the app to a friend? *

	0	1	2	3	4	5	6	7	8	9	10	
Not likely	○	○	○	○	○	○	○	○	○	○	○	Very likely

How likely are you to use this app yourself in the future? *

	0	1	2	3	4	5	6	7	8	9	10	
Not likely	○	○	○	○	○	○	○	○	○	○	○	Very likely

Imagine your employer offered you to use this app in your current company together with other employees to achieve more sustainability. (Note: if you are not working currently, please think of a previous employer). How likely are you to use the app in that setting? *

- ○ very unlikely
- ○ rather unlikely
- ○ neutral
- ○ rather likely
- ○ very likely
- ○ I haven't worked before.

Please briefly explain your choice regarding using the app in your company:

Your answer

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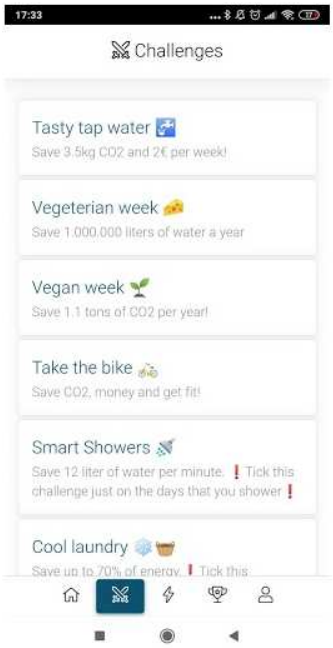
Future Features

Lastly, we would like to collect some feedback on new ideas that we have to improve the app.
Please let us know, how important such new features would be for you.

In the open comments sections, you can share your own suggestions and ideas with us!

Here you can see the screen that shows all challenges. Please indicate how important the following new features would be for you. *



	1 - not important	2	3	4	5	6	7 - very important
Have the whole app available in my native language.	○	○	○	○	○	○	○
Have more challenges to choose from.	○	○	○	○	○	○	○
Customise which challenges are shown to me based on my current lifestyle (for example 'I am vegetarian' or 'I am cycling daily').	○	○	○	○	○	○	○

Customise which challenges are shown to me based on goals (for example 'health' or 'fitness' or 'saving money').	○	○	○	○	○	○	○
Create my own challenges.	○	○	○	○	○	○	○
Have challenges with checklist tasks, for example 'steps to make your bathroom sustainable' and tasks like 'buy a bamboo brush', 'buy re-usable makeup remover pads' , etc.)	○	○	○	○	○	○	○

Please fill any other comments, feedback or ideas for this screen (optional):

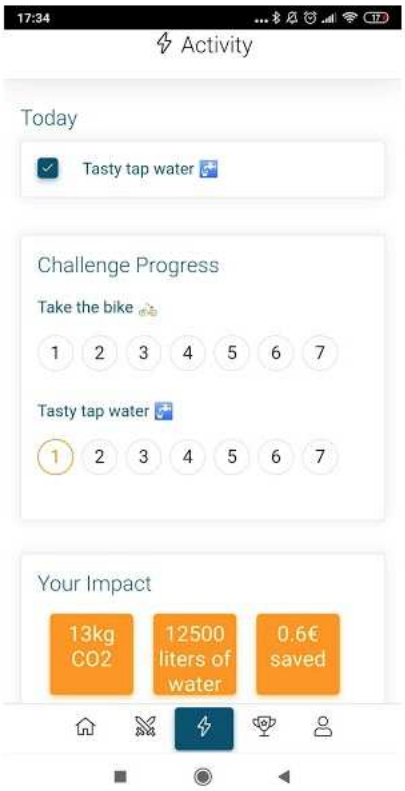
Your answer

Here you can see the screen with details on the 'vegetarian week' challenge. Please indicate how important the following new features would be for you on this 'challenge details' page. *

	1 - not important at all	2	3	4	5	6	7 - very important
Receive more background information on the 'sustainability impact'.	○	○	○	○	○	○	○
Track my PERSONAL impact (for example through providing the kilometres I cycle)	○	○	○	○	○	○	○
See more tips for a challenge (for example recipes).	○	○	○	○	○	○	○
Choose the exact challenge period myself (i.e. 1-2 weeks, 1 month, ...).	○	○	○	○	○	○	○

Please fill any other comments, feedback or ideas for this screen (optional):

Here you can see the Activity Screen. Please indicate how important the following new features would be for you. *



	1 - not important at all	2	3	4	5	6	7 - very important
See how many points I get for the activity.	○	○	○	○	○	○	○
See which other users are taking the challenges.	○	○	○	○	○	○	○
Share my challenge progress via Social Media.	○	○	○	○	○	○	○
Get more background information on where my sustainability impact comes from.	○	○	○	○	○	○	○
Get push notifications to remind me to input my challenge progress.	○	○	○	○	○	○	○

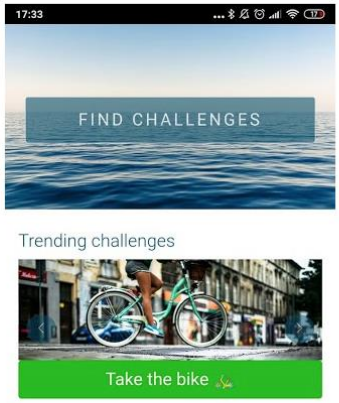
progress.

Implement a photo upload for all users to prove that the challenge was done.	○	○	○	○	○	○	○

Please fill any other comments, feedback or ideas for this screen (optional):

Your answer

Here you can see the Home Screen. Please indicate how important the following new features would be for you. *



	1 - not important at all	2	3	4	5	6	7 - very important
Have more tips available.	○	○	○	○	○	○	○
Be able to save my favourite tips.	○	○	○	○	○	○	○

tips.

Get products and services recommended, for example sustainable shampoo or clothes stores.	○	○	○	○	○	○	○
More background information about the tip (for example about the water consumption of different washing machines).	○	○	○	○	○	○	○
Receive customised tips for the challenges I am currently taking (for example around vegetarian nutrition).	○	○	○	○	○	○	○

Please fill any other comments, feedback or ideas for this screen (optional):

Your answer

Here you can see the Leaderboard. Please indicate how important the following new features would be for you. *

	1 - not important at all	2	3	4	5	6	7 - very importar
Create private leaderboards with friends.	O	O	O	O	O	O	O
Access the profile of others to see their challenges and progress.	O	O	O	O	O	O	O
Interact with other users (sharing, liking, commenting).	O	O	O	O	O	O	O
Chat with other users.	O	O	O	O	O	O	O
Exchange my Green Points into discounts from sustainable stores.	O	O	O	O	O	O	O
Exchange my Green Points into donations for sustainable projects.	O	O	O	O	O	O	O

In the future, there might be advertisements for sustainable products and services placed on the app (see below). How would you find that? *

	1	2	3	4	5	6	7	
bad	O	O	O	O	O	O	O	good

In the future, there might be sustainable product suggestions given in the tips or challenges (see below). How would you find that? *

	1	2	3	4	5	6	7	
bad	O	O	O	O	O	O	O	good

In the future, there might be challenges offered that are 'powered by' certain companies (see below). This could for example be banks, e-scooter rentals, sustainable travel companies etc. How would you find that? *

	1	2	3	4	5	6	7	
bad	○	○	○	○	○	○	○	good

Lastly, please fill any other comments, feedback or ideas regarding the app:

Your answer

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Google Forms

Appendix L - Field Study: User Experience Questionnaire (UEQ)

The validated questionnaire was downloaded from the official researcher's website where the researchers provide open access to it. The following text and items were adapted and integrated into the overall post-survey conducted via Google Forms (see appendix K).

Please make your evaluation now.

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	○	⊗	○	○	○	○	○	unattractive

This response would mean that you rate the application as more attractive than unattractive.

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember: there is no wrong or right answer!

Please assess the product now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26

Appendix M – UEQ Results

Item	Mean	Variance	Std. Dev.	Left	Right	Scale
1	1.0	1.5	1.2	annoying	enjoyable	Attractiveness
2	1.5	2.5	1.6	not understandable	understandable	Perspicuity
3	0.7	1.9	1.4	creative	dull	Novelty
4	1.7	1.7	1.3	easy to learn	difficult to learn	Perspicuity
5	1.2	1.3	1.1	valuable	inferior	Stimulation
6	0.5	1.5	1.2	boring	exciting	Stimulation
7	1.3	1.4	1.2	not interesting	interesting	Stimulation
8	0.8	1.4	1.2	unpredictable	predictable	Dependability
9	-1.0	2.2	1.5	fast	slow	Efficiency
10	1.0	1.6	1.3	inventive	conventional	Novelty
11	1.4	0.9	1.0	obstructive	supportive	Dependability
12	1.5	0.9	1.0	good	bad	Attractiveness
13	1.5	1.7	1.3	complicated	easy	Perspicuity
14	1.1	1.1	1.0	unlikable	pleasing	Attractiveness
15	0.8	1.0	1.0	usual	leading edge	Novelty
16	1.3	1.4	1.2	unpleasant	pleasant	Attractiveness
17	0.9	1.8	1.3	secure	not secure	Dependability
18	1.8	0.9	1.0	motivating	demotivating	Stimulation
19	1.1	2.1	1.4	meets expectations	does not meet expectations	Dependability
20	1.1	2.3	1.5	inefficient	efficient	Efficiency
21	1.3	2.6	1.6	clear	confusing	Perspicuity
22	1.1	1.6	1.3	impractical	practical	Efficiency
23	1.7	1.5	1.2	organized	cluttered	Efficiency
24	0.7	1.8	1.3	attractive	unattractive	Attractiveness
25	1.6	1.0	1.0	friendly	unfriendly	Attractiveness
26	1.1	1.7	1.3	conservative	innovative	Novelty

Appendix N – Visualisation of Wireframes Development through three stages

The wireframes evolved through three iterations. Features remained similar and a few new features were added. The transformation can be seen below and is commented with the major achievement in transformation throughout the design process.

Iteration 1 | Iteration 2 | Iteration 3

Figure 45. Challenge Overview Wireframe Development (left to right)

Iteration 1

Iteration 2

Iteration 3

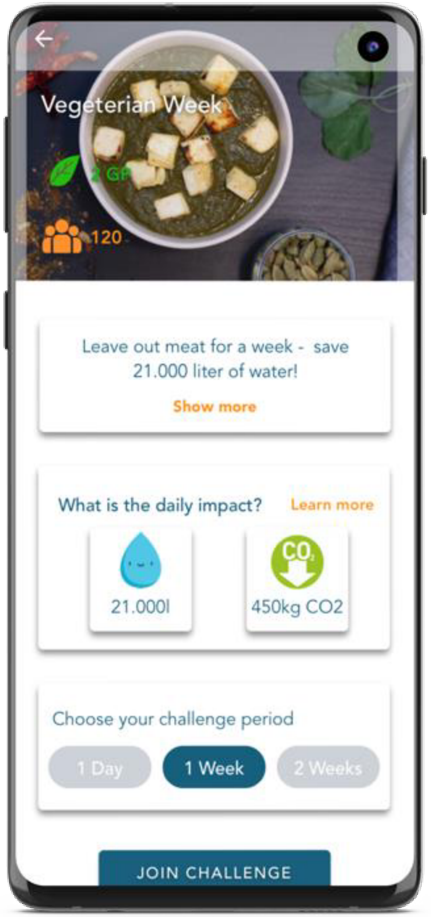


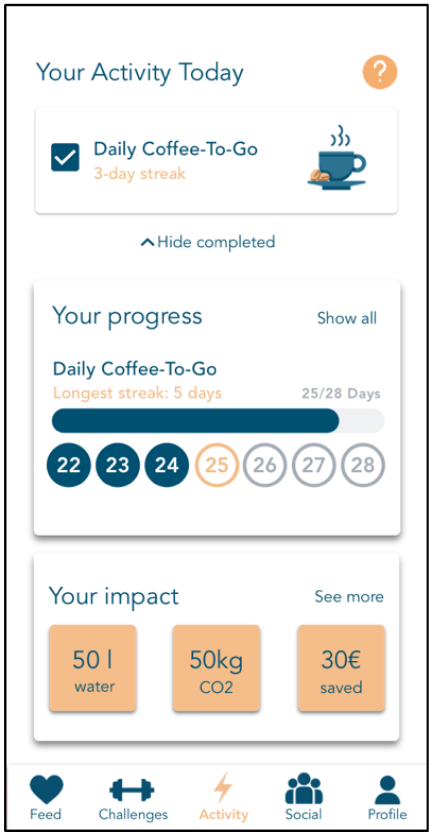
Figure 46. Challenge Details Wireframe Development (left to right)

Iteration 1

NONE

(no design for Activity Screen)

Iteration 2



Iteration 3

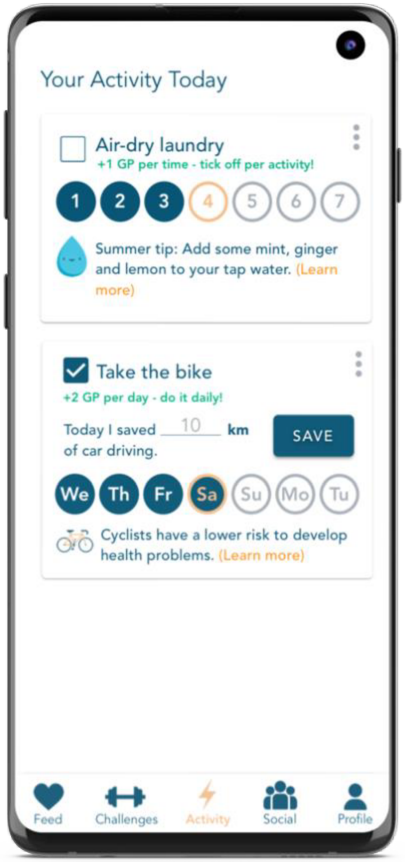


Figure 47. Activity Screen Wireframe Development (left to right)

Iteration 1 Iteration 2 Iteration 3

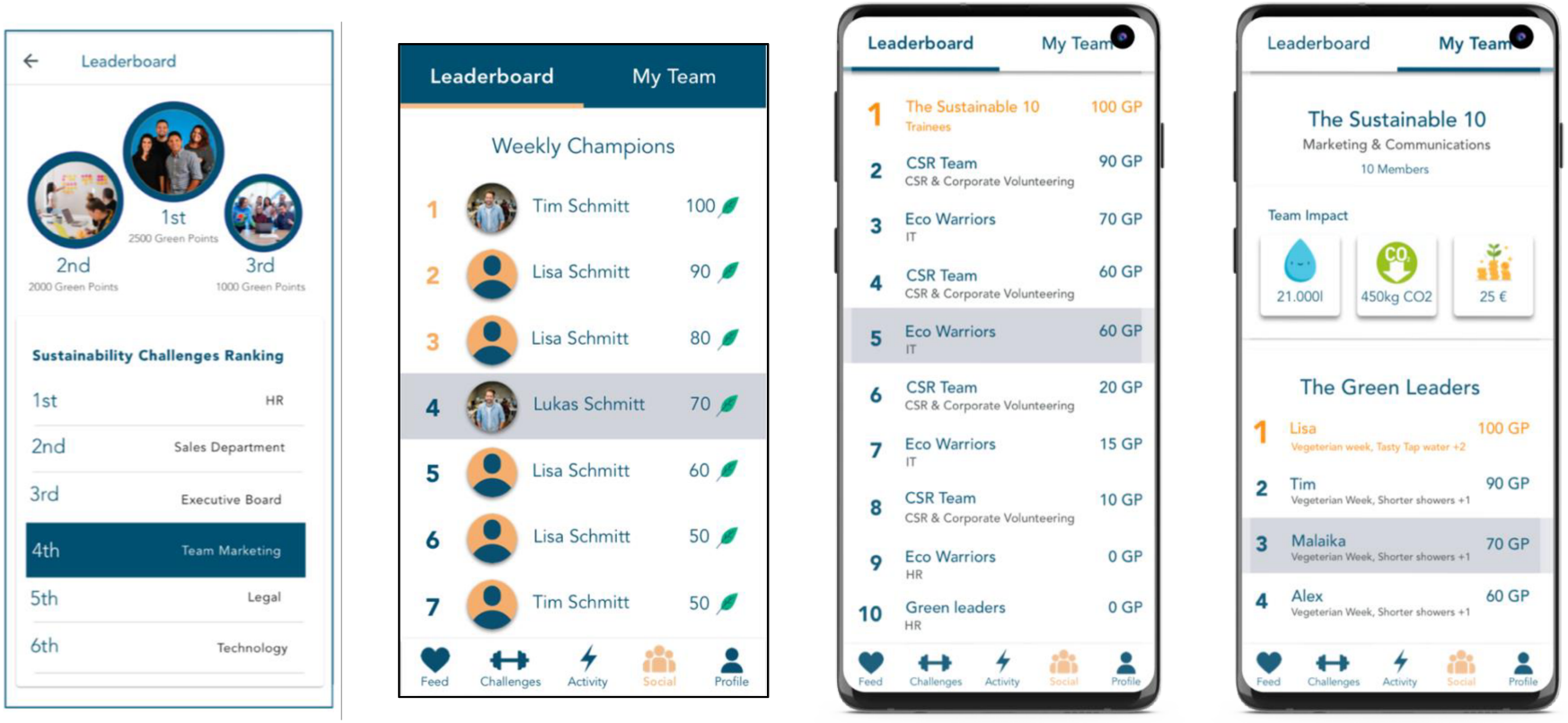


Figure 48. Leader board Wireframe Development (Left to Right)

Appendix O - Statistical Results

Table 13. Results of Shapiro Wilk Test for normality

	Shapiro-Wilk		
	Statistic	df	Sig.
intention_before	.920	27	.039
intention_after	.888	27	.007
attitudes_before	.966	27	.489
attitudes_after	.941	27	.126
PBC_before	.908	27	.021
PBC_after	.845	27	.001
tap_pre	.830	27	.000
tap_post	.653	27	.000
shower_pre	.921	27	.042
shower_post	.882	27	.005
nut_pre	.570	27	.000
nut_post	.841	27	.001

Table 14. Wilcoxon signed-rank test results for all participants and indications of significance.

Ranks

		N	Mean Rank	Sum of Ranks
tap_post – tap_pre	Negative Ranks	2[a]	12.50	25.00
	Positive Ranks	13[b]	7.31	95.00
	Ties	12[c]		
	Total	27		
shower_post – shower_pre	Negative Ranks	6[d]	7.83	47.00
	Positive Ranks	12[e]	10.33	124.00
	Ties	9[f]		
	Total	27		
nut_post – nut_pre	Negative Ranks	0[g]	.00	.00
	Positive Ranks	15[h]	8.00	120.00
	Ties	12[i]		
	Total	27		

Test Statistics[a]

	tap_post – tap_pre	shower_post – shower_pre	nut_post – nut_pre
Z	-2.083[b]	-1.719[b]	-3.578[b]
Asymp. Sig. (2-tailed)	.037	.086	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Table 15. Wilcoxon signed-rank test – challenge-specific results

		N	Mean Rank	Sum of Ranks
nut_post – nut_pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	15[b]	8.00	120.00
	Ties	10[c]		
	Total	25		

a. nut_post < nut_pre
b. nut_post > nut_pre
c. nut_post = nut_pre

	nut_post – nut_pre
Z	-3.578[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

		N	Mean Rank	Sum of Ranks
tap_post – tap_pre	Negative Ranks	1[a]	12.00	12.00
	Positive Ranks	13[b]	7.15	93.00
	Ties	7[c]		
	Total	21		

a. tap_post < tap_pre
b. tap_post > tap_pre
c. tap_post = tap_pre

	tap_post – tap_pre
Z	-2.693[b]
Asymp. Sig. (2-tailed)	.007

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

		N	Mean Rank	Sum of Ranks
shower_post – shower_pre	Negative Ranks	1[a]	3.00	3.00
	Positive Ranks	11[b]	6.82	75.00
	Ties	4[c]		
	Total	16		

a. shower_post < shower_pre
b. shower_post > shower_pre
c. shower_post = shower_pre

	shower_post – shower_pre
Z	-2.886[b]
Asymp. Sig. (2-tailed)	.004

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Table 16. Results of the paired sample t-tests for attitudes

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	attitudes_before – attitudes_after	-.32099	.48244	.09285	-.51183	-.13014	-3.457	26	.002

Table 17. Wilcoxon signed-rank analysis for perceived-behavioural control including test statistics

Ranks

		N	Mean Rank	Sum of Ranks
PBC_after – PBC_before	Negative Ranks	4[a]	10.25	41.00
	Positive Ranks	14[b]	9.29	130.00
	Ties	9[c]		
	Total	27		

a. PBC_after < PBC_before
b. PBC_after > PBC_before
c. PBC_after = PBC_before

Test Statistics[a]

	PBC_after – PBC_before
Z	-2.082[b]
Asymp. Sig. (2-tailed)	.037

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Table 18. Wilcoxon signed-rank analysis for the intention to act sustainable including test statistics

Ranks

		N	Mean Rank	Sum of Ranks
intention_after – intention_before	Negative Ranks	8[a]	9.50	76.00
	Positive Ranks	13[b]	11.92	155.00
	Ties	6[c]		
	Total	27		

a. intention_after < intention_before

b. intention_after > intention_before

c. intention_after = intention_before

Test Statistics[a]

	intention_after – intention_before
Z	-1.486[b]
Asymp. Sig. (2-tailed)	.137

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.