Master's thesis

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Smiling Earth - A Mobile Application to Promote Pro-Environmental Behavior

Master's thesis in Computer Science
Supervisor: Sobah Abbas Petersen
December 2021

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Abstract

This thesis presents the third iteration of Smiling Earth, a mobile application that aims to promote pro-environmental behavior, specifically reducing carbon emissions from transportation and energy. The design and creation research methodology was used to design and develop Smiling Earth.

The research goal was to develop and examine user perceptions of a theoretically-driven social, mobile application created to motivate, promote, and engage citizens to reduce their carbon footprint both on an individual level and in online communities. The theoretical framework used to describe behavior change was Social Cognitive Theory. The background study presents a literature review of Social Cognitive Theory, in addition to a review of Sustainable Human-Computer Interaction and Online Communities. The background study also includes a review of the previous iteration of Smiling Earth and a technology review of developing social mobile applications. The literature review is followed by how the application was designed, tested, and implemented. After the application was created, it was distributed to 18 users who used the application for one week. Quantitative and qualitative data were collected using questionnaires, observation, interviews, and user-generated data during the evaluation period

Analyzing the data revealed that social computing enhanced Smiling Earth and positively affected users' motivation to act more environmentally friendly. The thesis also examined how a persuasive mobile application can be implemented to support the key constructs of Social Cognitive Theory, including Self-efficacy, collective efficacy, observational learning, outcome expectations, and self-regulation. The results found different solutions to support the different aspects, including joining communities and making a climate action pledge. The evaluations also showed that communities based on locations (e.g., Oslo, Trondheim, Bergen), communities of interest, and communities of practice are suited to motivate users to act more sustainably. Due to privacy concerns, the participants used the application anonymously. Most of the participants expressed they would prefer the application not to be anonymous. Still, they also said they found it easier to interact with other users when not knowing their identity.

Samandrag

Denne masteroppgåva presentere den tredje iterasjonen av *Smiling Earth*, som er ein mobil applikasjon som forsøker å påverke brukarane til å bli meir miljøvenlege, hovudsakleg ved å redusere deira karbonutslepp frå transport og energi. Forskingsmetoden *Design and Creation* har vert nytta til å designe og utvikle denne iterasjonen av Smiling Earth.

Forskingsmålet var å utvikle ein mobil applikasjon basert på sosial kognitiv teori og som nyttar verkemidlar frå sosiale applikasjonar og nettverk, til å gjera brukaren meir motivert til å redusere deira klima fotavtrykk. Innleiinga byrjar med eit grunnleggande undersøking av litteraturen, teknologi og tidlegare iterasjonar av Smiling Earth, etterfylgt av korleis den nye applikasjonen vart utvikla. Når applikasjonen var klar til bruk, vart den testa av 18 deltakarar som brukte den i ei veke. Før, medan og etter deltakarene brukte applikasjon vart kvalitative og kvantitative data innhenta frå spørjeundersøkingar, intervju, og data som brukarane sjølv genererte.

Analysen av dataa viste at funksjonaliteten frå sosial applikasjonar forbetra Smiling Earth, og hadde ein positive innverknad på brukarane sin motivasjon til å handle miljøvenleg. Masteroppgåva undersøker også korleis ein mobil applikasjon kan implementerast for å støtte sosial kognitive teori. Resultata frå evalueringa av applikasjonen viser fleire deler av applikasjonen støtter dei ulike delar av teorien, der i blant det å vere med i nettsamfunn og gi klima-løfter visa gode resultat. Frå evalueringa viser det også at nettsamfunn basert på område (t.d. Oslo, Trondheim, Bergen) og nettsamfunn basert på erfaringsdeling og interessedeling er godt egna for å motivere brukarar til å ta meir miljøvennlege handlingar. Grunna personvern omsyn har deltakarane i applikasjonen vert anonyme. Sjølv om dei fleste deltakarane sa dei vill ha føretrekt å kunne bruke sitt eige namn, viser resultata at dei synast det var lettare å samhandle med dei andre brukarane når dei var anonyme.

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Chapter 1

Introduction

This chapter describes the motivations, contributions, and the definition of the research goal addressed in this thesis. Then, the goal is decomposed into seven research questions that will be answered throughout this thesis. The last section includes the overall structure of this report.

1.1 Motivations

The latest report from The Intergovernmental Panel on Climate Change(IPCC) is referred to as a code red for humanity[1]. Humans are "unequivocally" to blame, and rapid actions to cut greenhouse gas emissions could limit some of the impacts of global warming. In a UN statistic [2] from 2016, Norway ranked the 31st country with the most carbon emitted per capita globally, with an average of 7,84 tons of CO2 emitted every year. That is 67% more than the global average of 4.7 tons of CO2 per year. Our daily activities can impact one's carbon footprint, but it can be hard to know how much influence each choice has on the total emission. This application created in this thesis, called Smiling Earth, attempts to build awareness around transportation and energy usage emissions. It also highlights the positive aspects of acting environmentally friendly, like the increased calories burned when biking or the potential saving of driving a zero-emission vehicle.

Becoming more environmentally friendly helps the global environment, as well as it can benefit the local environment. Oslo City [3] produce a citizen survey where the results show that 77% of the citizens believe that accomplishing the environmental goals is essential, and 64% believe that the quality of life in the city will improve. There are many good reasons to make greener choices, but doing them is not always as simple. In a report by CICERO (Center for International Climate and Environmental Research - Oslo) [4], the Norwegian population's attitude towards climate change was mapped. A majority of Norwegians believe that climate change is happening because of human intervention and has negative consequences. Furthermore, the majority of the population agrees that they are themselves responsible for reducing their emissions. The report points out that while the belief in climate change is firm, concrete actions on the individual and political levels are lacking. People want to change, but they do not know how to or are reluctant to reduce their transportation footprint (car and flight) or reduce meat intake. The report concludes that social norms and tools to change behavior play a central role in the population's life. This master thesis aims to develop an ICT application based on ideas from social computing, which could support citizens to make a positive change and improve social norms.

Since the researcher has chosen a Computer Science specialization of software development, an additional motivating factor in this master thesis was to create an application that motivates users to make more sustainable habits, using the knowledge of software engineering obtained throughout the years at NTNU. Most of the courses the researcher has taken include software development and project work, but the time period for development has usually been short. This project, including the preliminary specialization project, was a unique opportunity to develop your own concept based on theories and background studies and then implement and test the product on real users, which has been a significant source of motivation throughout the research.

1.2 Project and Context

This master thesis was conducted within the field of Sustainable and Smart Cities and Human-Computer interaction. The research aims to achieve pro-environmental behavior change, specifically to reduce carbon footprint and create awareness around our impact, using a persuasive mobile application called Smiling Earth. The app was initially developed by Celine Mihn and improved by Ragnhild Larsen as a part of a larger European research project called DESENT. The Smiling Earth app is designed to increase users' awareness about their carbon footprints by providing feedback on how much CO2 they emit, based on their transportation habits, household energy consumption, and other lifestyle choices. In addition, the app supports environmentally-friendly goals and actions by providing estimates of money saved and kcal burned, based on the users' daily activities. Currently, the application only supports individual users. The main work done in this thesis was to enhance the application to support interaction between the users of the application and create online communities and then examine how this can influence the users and further promote sustainable behavior.

The research done in this report is a part of the course TDT4900 - Computer Science, Master Thesis at NTNU in Trondheim. The course is given in the fifth year and is the final course of the computer science master's degree. The purpose of this report is to show the student's ability to work independently on an advanced level and to acquire and create new knowledge within the student's field of specialization, in this case, software engineering. The thesis is a continuation of the work done in the specialization project and includes further research and continues to design, implement and evaluate the prototype developed in the previous project.

1.3 Contribution

The thesis contributes by producing an enhanced version of Smiling Earth as a new Proof-Of-Concept with social networking features to support communities and evaluate how the new features influence users to become more environmentally friendly. Tasks completed in the thesis include a literature review, iterative design, development and testing, and user evaluation of the new features. The new features are based on the principles of Social Cognitive Theory [5] and includes the ability for users to connect with each other, communicate, share content with each other, join online communities, and collaborate or compete with others as a group or individual, with the end goal of promoting a more sustainable lifestyle.

1.4 Research Goal and Research Questions

This chapter presents the research goals and research questions of the master thesis. The process of defining the goals and questions is based on the Goal/Question/Metric Paradigm (GQM) [6] commonly used in software engineering. The paradigm consists of three level. The first level referred to as the conceptual level, concerns defining a project goal for the report. The second level is the operational level, which contains the quantifiable research questions defined by the goal. The final level is the quantitative level. This level contains a set of metrics that will be used to answer each question. For this thesis, the metrics will be quantitative and qualitative data.

1.4.1 Research Goal

The research goal of this thesis is defined as:

Develop and examine user perceptions of a theoretically-driven social mobile application created to motivate, promote, and engage citizens to reduce their carbon footprint both on an individual level and in online communities.

In the project, a proof-of-concept mobile application was developed. The app was designed to use mechanics from gamified and social applications and based on the theoretical framework of Social Cognitive Theory and Online Communities. The end goal was to promote pro-environmental behavior, specifically reducing their carbon footprint and increasing the users' awareness of their environmental impact.

1.4.2 Research Questions

The research goal was decomposed into the following research questions:

RQ1: How can social computing enhance Smiling Earth?
As a future work from the previous version of Smiling Earth, it was requested to make the app more social. This question tries to answer how social computing could enhance the application.

RQ1.1: What social functions is most effective to motivate the users to act more sustainable?
A sub-question of RQ1 is to evaluate the different social features implemented to the application regarding their impact on users' motivation to make sustainable choices.

RQ2: How can social cognitive theory be used in Smiling Earth?
Social Cognitive theory is the chosen theoretical framework for promoting behavior change in this thesis. This question examines how the application can be designed to encourage behavior change by contributing to the key constructs Self-efficacy, Group-efficacy, Self-regulation, and Outcome expectation.

RQ2.1: Determine which intervention components support the key social cognitive theory constructs
This research question evaluates the different design components implemented in the system in regards to the constructs of Social Cognitive Theory.

RQ3: How do theories of online communities contribute to increasing user motivation and promoting pro-environmental behavior change?
There are many different kinds of online communities. This research question tries to answer how the users perceived being a member of one or more communities and what kind of community was most effective on users' motivation to reduce their CO2 emissions.

RQ4: How does anonymity affect the interaction between the users of Smiling Earth?
Due to privacy concerns, the identity of each user is hidden. Thus, the users will only see the other users generated usernames. This research question examines how anonymity affects users' interaction in a social application that encourages pro-environmental behavior change.

RQ5: How to implement a persuasive and social mobile application with support for both individuals and communities with existing technologies and methodology?

The research question will evaluate existing technologies, methods, and architectures used to develop mobile applications that track users' habits.

1.5 Thesis Outline

This section provides an overview of the different chapters of the thesis.

Chapter 1 - Introduction
The introduction chapter introduces the motivation and project, followed by a presentation of the research goal and research questions that the thesis tries to answer.

Chapter 2 - Research Process and Methods
The method chapter discusses the research methodology used and the process of answering the research questions.

Chapter 3 - Background
In the background chapter, Smiling Earth is described, the work done in the previous versions of Smiling Earth is summarized, and the results from the specialization project are presented. The future work suggested from the last thesis on Smiling Earth was used as a basis for this thesis.

Chapter 4 - Literature Review
In this chapter, the literature review is presented. The main topics are Social Cognitive Theory, Sustainable Human-Computer Interaction, and Online Communities. Additionally, a technological review of mobile applications is presented and a review of related applications.

Chapter 5 - Application Design
This chapter presents the prototype designed in the specialization project. It is based on the results of a co-design workshop conducted in the specialization project and on the results from the literature review.

Chapter 6 - Usability Evaluation of Design Prototype
After designing the prototype, the design concept was tested on users by conducting a usability evaluation. This chapter presents the findings and how a usability test was conducted to retrieve feedback and expose faults in the design.

Chapter 7 - Requirement Elicitation
This chapter presents the functional and non-functional requirements from usability tests, literature reviews, and technology reviews. Each requirement is described and prioritized according to how important the feature is for users' enjoyment of using the application.

Chapter 8 - Development
The development chapter presents the process of developing the new system. It includes how methodologies from Scrum and DevOps were applied when creating the application and an evaluation of the application according to the requirements.

Chapter 9 - Software Architecture
This chapter presents the software architecture of the system. The review includes an analysis of both the system's front-end and backend architecture.

Chapter 10 - User Evaluation of Application
This chapter explains how the user evaluation was conducted. It includes a description of the evaluation design and the data collected. The evaluation consisted of a pre-test questionnaire, then letting the participants install and use the application for one week, followed by a post-evaluation questionnaire. Additionally, some of the participants were invited to an interview to discuss their experiences further.

Chapter 11 - Results
This chapter presents the results from the user evaluation of the application.

Chapter 12 - Discussions
This chapter evaluates the results in regards to the research questions. Additionally, it described the limitations of the project and lessons learned by the researcher.

Chapter 13 - Conclusion
The conclusion chapter tries to answer the research questions based on the discussion and summarizes the work done in this thesis. Additionally, a description of further works is described. This includes elements that were not completed in the application and new directions to improve the application further.

Appendix A - Result from co-design workshop
This chapter shows the different scenarios created in the specialization project

Appendix B - Boards
This appendix presents the different boards created from the usability evaluation. Each board illustrated the participant's prioritization of the main features. The boards were used to assist in requirement prioritization.

Appendix C - Screenshots of Smiling Earth Client
Here the different screenshots of the final mobile application are shown.

Appendix D - Screenshots of Smiling Earth Server
Here the different screenshots of the Django backend application are presented.

Appendix E - Calculations
This section presents the calculations used in Smiling Earth. The calculations are the same as in the previous version and are used as a black box for this thesis.

Appendix F - NSD
This appendix presents the "Information about data collection and participants' rights" letter written using the template provided by Norsk senter for forskningsdata (NSD). The letter was distributed to all the evaluation participants before installing the application.

Appendix G - Pre Evaluation Questionnaire
Here a copy of the pre-evaluation questionnaire is presented.

Appendix H - Post Evaluation Questionnaire
Here a copy of the post-evaluation questionnaire is presented.

Chapter 2

Research Process and Methods

This chapter presents the research method and process used to answer the research questions. The research method is based on the book *Research Information Systems and Computing* [7] by B.J Oates. Additionally, a focus on ethical and legal privacy was included in the research method by applying for an NSD, following NTNU's storage guide, and applying privacy by design to comply with the General Data Protection Regulation (GDPR). The main research strategies used is *Design and Creation* and *Experimentation*.

2.1 Research Methods

The research method used is adopted from the book *Research Information Systems and Computing* [7]. The method begins with defining one's experience and motivations (Section 1.1) and carrying out a literature review (Chapter 4). From this, the research questions are created to be answered in the thesis and the conceptual framework. The framework describes how we can structure our thinking concerning the research topic and the process chosen. The following step is to select a strategy. Strategies comprise the overall approach to answering the research questions. The book defines six strategies: survey, design and creation, experiment, case study, action research, and ethnography. Next, data generation methods were chosen. Oates [7] defines four data generation methods, interviews, observation, questionnaires, and documents. The final phase in the research process model is data analysis. The data produced can either be quantitative or qualitative. Quantitative data analysis uses mathematical approaches to interpret and examine, while Qualitative data analysis looks for themes within the images created or the words people use.

The main components applied to the research process used in this thesis are identified in Figure 2.1. The model is inspired by Oates [7] but is adopted by adding User Generated Data as a data generation, and a co-design workshop was used to assist in creating the conceptual framework. These methods are shown as red boxes in addition to the blue boxes, which represent the methods used in the research process.

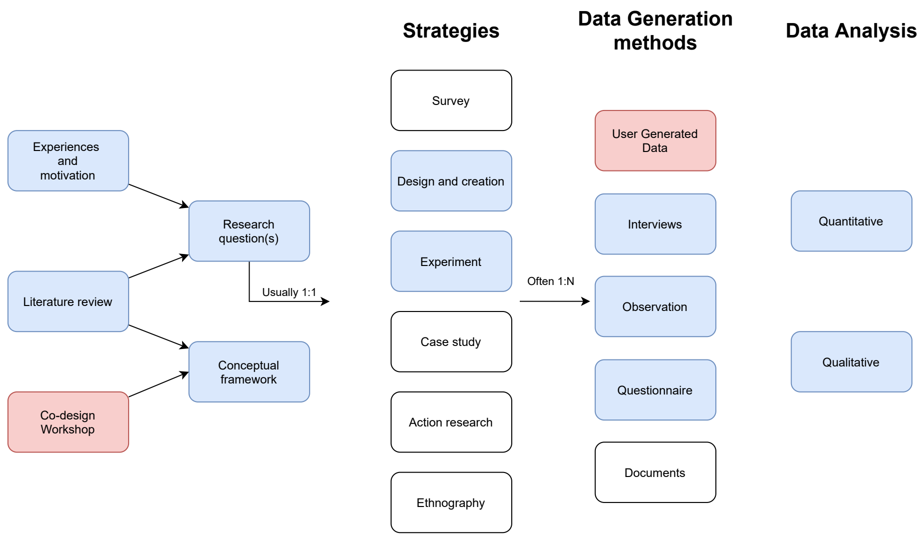


Figure 2.1: How the research process model used as shown by blue and red boxes. The model inspired from Oates [7], and has been altered by adding "User Generated Data" and "Co-design workshop" (red boxes)

2.1.1 Strategies

Oates presents different strategies that can be used to answer the research questions. The strategy used in this project is the *design and creation* and *experiment* strategy. The former focuses on developing new IT products, also known as artifacts. Oates describes different kinds of artifacts, but the expected outcome of this project is a set of *models* and an *instantiations* artifact. Oates [7] defines *models* as a "Combination of constructs that represent a situation and are used to aid problem understanding and solution development". The primary artifact produced in this master thesis is an *Instantiation artifact* which is defined as "A working system that demonstrates that constructs, models, methods, ideas, genres or theories can be implemented in a computer-based system" [7]. A Proof-of-Concept mobile application was created as the Instantiation artifact. The application incorporated communities of users and ideas from social computing. Additionally, the Experiment strategy was applied to evaluate the artifact produced by the Design and Creation strategy.

2.1.2 Data Generation

The three data generation methods used in this thesis, as described by Oates [7], were Interviews, questionnaires, and observations. They were used when conducting a usability test of an early prototype design, as described in Chapter 6.

In addition to the three data generation methods, user-generated data was used in final evaluation of the application together with interviews and questionnaires. As the users used the application during the evaluation period, they generated data that was stored on the backend server. The data generation is described in more detail in Section 2.2.7.

2.1.3 Data Analysis

The data generation methods produced both qualitative and quantitative data. The qualitative data generated includes quotes by the participants from observations, open text questions in the questionnaires, and interviews. Steinar Kvale et al. [8] describe qualitative interviews as a key venue for exploring how subjects experience and understand their world by describing their opinions and experiences in their own words. Quantitative data, on the other hand, is numeric data. Data from the questionnaire and produced by the user of the application example of this. The Mann-Whitney test [9] were used to search for the relationship between people who owned a car or had easy access to one and the use of applications.

Triangulation
Triangulation was used to validate the data obtained from user testing. This is a common method where look for correlating results from two or more data generation methods [7]. Comparing and analyzing the qualitative and quantitative data was used to answer the research questions in this project.

2.1.4 Research Paradigm

Interpretivism was selected to be the philosophical paradigm considered in the master thesis. Oates [7] defines interpretivism as "*Interpretive research in IS and computing is concerned with understanding the social context of an information system: the social processes by which it is developed and construed by people and through which it influences, and is influenced by, its social setting*". The goal of interpretive research is to understand and interpret the meanings in human behavior. The researcher takes a more significant part in the study, and it is believed that it is impossible to remove all bias from the results and observations.

2.1.5 Ethical and legal consideration

Before starting with user feedback on the solution, the researcher filled out an application to the Norwegian Center for Research Data (NSD) for approval to process and store personal data collected during the user tests. The application contains information about the sample participants, the purpose of the research, and what data to be collected. Then, using the guidelines from NSD, a form of consent was created that each participant had to sign before their data could be collected. The consent form informed the participants about their rights, the data collected, and information about the experiment. The form can be read as a whole in Appendix F. The essential details concerning the processing of personal data in the form were:

- Each participant will receive a generated username with no connection to their real name.
- The participant's personal information (Name and e-mail) and the mapping to their username will be stored in an encrypted document according to NTNU's data storing guidelines. Only the researcher and supervisor can access them.
- All data will be anonymized, and it will not be possible to identify any of the participants in this master thesis.
- Participants can request insight into their collected data, and they can at any time choose to withdraw their consent and no longer be part of the experiment.

Privacy by design

Separating the participant's personal information from the collected user data is a proactive method of preventing potential personal data from being leaked. Furthermore, without having the mapping key to the collected data, it is impossible to figure out the identity of the data owner. By doing so, we were applying privacy by design to the solution. In addition, encrypting the database with the user-to-participant information further protects each participant's data.

2.2 Research Process

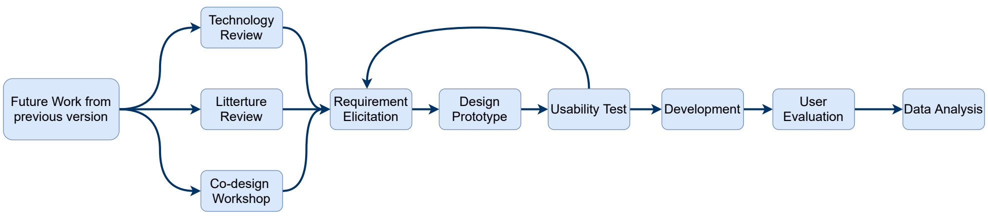


Figure 2.2: The overall research process

The research process was divided into four phases. First, a prestudy was conducted to understand the application's needs better. The prestudy continues the research done during the specialization project. The next phase improved the design concept created in the specialization project and evaluated the prototype with potential users regarding its usability. The design was created using Figma, a software for creating wireframed models of an application. The third phase consisted of implementing the Proof-of-Concept application and distributing it to the evaluation participants. When designing and developing the prototype, the primary development process used was User-Centered design, which in short focuses on involving the end-user as much as possible. The final phase consists of retrieving feedback about how they liked the application and their thought regarding social features, communities, and motivation to act environmentally friendly.

2.2.1 Literature review

The master thesis is a continuation of the prestudy done in the specialization project during the spring of 2021 [10]. The prestudy includes a literature search on existing literature and related applications. During the preliminary research, Google Scholar and Oria.ntnu.no were used on various relevant topics to understand the task and find a research gap during this phase. Some relevant keywords were used when searching for articles, such as sustainable human-computer interaction, pro-environmental behavior change, social, mobile applications, smart cities, online communities, and persuasive technology. In addition, papers recommended by my supervisor were used in prestudy. The literature review used the snowballing method and the Bidirectional citation searching to completion (BCSC) search method [11]. The latter refers to creating a pool of articles found through systematic and unsystematic search periods. Then iteratively filtering out the irrelevant articles and adding new ones by applying the snowball method. The snowball method refers to investigating the citation already cited in the article to identify additional documents [12].

Furthermore, the literature review uses the two previous master theses by Celine Mihn and Ragnhild Larsen[13] [14] as a foundation for further research and development, as they created the first version of the application. The Conceptual framework was formed based on the literature review, and together with experiences and motivations, the research questions were created.

2.2.2 User Centered Design

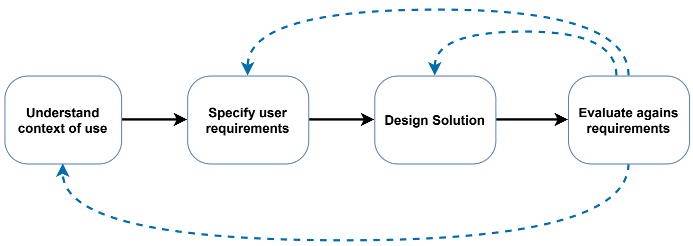


Figure 2.3: The different phases of User Centered Design [15]

User-Centered Design (UCD) was used during the design and creation phase in this thesis. The process is sometimes referred to as Human-Centered Design. It is an iterative development method in where designers concentrate on the users and their needs in each phase of the design process [15]. The term was popularized by Don Norman [16] in the book User-Centered System Design: New Perspectives on Human-Computer Interaction. The process consists of four phases (see Figure 2.3). Norman [16] describes the processes as so; first, we need to understand the context of use for the application. Next, we need to specify the user's requirements. Based on those requirements, we can go to the next phase, "design solution". The solution can be, e.g., a paper prototype, a wireframe model, or a functioning application. The following and final phase is to use the prototype to evaluate it against user requirements. Based on the evaluation, we make further iteration of the four phases.

2.2.3 Design Prototype

Rogers et al.[17] define a prototype as a "manifestation of a design that allows stakeholders to interact with it and explore its suitability". Regarding the User-Centered design process, creating a prototype is a part of the third phase. Prototypes enable the developer to visualize the concept, explore new designs, and be helpful when discussing ideas with stakeholders [17]. A high-fidelity prototype was created using Figma in the specialization project and was further improved in this thesis. A high-fidelity prototype lets you interact with the design solution without having any code or logic underneath. See chapter 5 for more information about the prototype.

Nielsen Usability Heuristic evaluation for User Interface Designs
Jakob Nielsen created in 1994 the ten general principles for interaction design [18]. The principles are called heuristics as they are rules of thumb and not specific guidelines. The ten heuristics for user interface design are listed in Table 2.1. The heuristics were applied when creating the new design concept proposed in Chapter 5.

Usability Heurstic		Description
1	Visibility of system status	The design should always keep users informed about what is going on through appropriate feedback within a reasonable amount of time.
2	Match between system and the real world	The design should speak the users' language. Use words, phrases, and concepts familiar to the user. Follow real-world conventions, making information appear in a natural and logical order.
3	User control and freedom	Users often perform actions by mistake. There needs to be a quick and easily accessible way to leave unwanted action.
4	Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform and industry conventions.
5	Error prevention	Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6	Recognition rather than recall	Minimize the user's memory load by making elements, actions, and options visible. The user should not have to remember information from one part of the interface to another.
7	Flexibility and efficiency of use	Shortcuts — hidden from novice users — may speed up the interaction for the expert user such that the design can cater to both inexperienced and experienced users.
8	Aesthetic and minimalist design	Interfaces should not contain information that is irrelevant or rarely needed. Every extra unit of information in an interface competes with the relevant units of information.
9	Help users recognize, diagnose, and recover from errors	Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.
10	Help and documentation	It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.

Table 2.1: Jakob Nielsen ten Usability heuristics for User Interface Design

2.2.4 Usability Testing

As the name suggests, interaction with potential users is critical in User-centered design. During the specialization project, a co-design workshop was hosted to generate ideas and designs for the application. The result was used to create a prototype of the application as described in Chapter 5. To further involve users, a usability test of the application was conducted to further improve the design solution before developing the application. Usability tests are a standard observational methodology in interface design to uncover problems and opportunities in the product [19]. The usability test includes five parts—first, an introduction about the test, followed by observing the participant using the prototype to solve tasks. Next, the participant was interviewed about how it was to use the application and given a 10-question questionnaire. Lastly, the participant was asked to prioritize the different features to be implemented according to importance.

Think-Aloud
Think-Aloud is a method where the participant is asked to use the system while thinking out loud, meaning expressing their thoughts as they navigate through the system [20]. Think-Aloud experiments are a cheap, robust, and flexible way of collecting the participant's first impression of using a system. According to Nielsen

that the process may be the single most valuable usability engineering method [21]. In this thesis, the method was applied during the observation phase of the usability testing to expose usability faults in the prototype.

System Usability Scale

System Usability Scale (SUS) was used to evaluate the overall usability of the design prototype. The method was created by John Brooke [22] is industry-standard for assessing the perceived usability of a system and is readily available. The SUS consists of a ten-question Likert scale that gives a general view of the user's impression of a system's usability. Sauro [23] has developed a set of metrics that can help in interpreting the SUS score. From his evaluation of over 10 000 responses of products, he states that a score below 68 % is below average. Therefore, before implementation of the new application could start, the goal was that the design prototype should achieve a SUS score over 68 %. This is described in more detail in Chapter 6.

2.2.5 Requirement elicitation

Requirement elicitation is the process of collecting user requirements. A requirement is defined by Rogers et al. [17] as a statement about the indented product that specifies what it should do or how it should perform. A requirement should be specific, unambiguous, and as clear as possible [24]. From the previous master thesis about Smiling Earth, some requirements were not implemented and new ones were requested during user evaluation. These requirements have been collected into a list called a backlog. The co-design workshop session conducted the specialization project aimed to brainstorm new ideas and requirements. These requirements are used as the basis for the new design shown in chapter 5. Requirement elicitation is an iterative process. During the thesis, the requirements were continuously changing before the implementation started. The complete list of requirements is listed in Chapter 7. Some requirements from the backlog and workshop were removed from the final list to fit this project's scope and time limitation.

2.2.6 Development

Chapter 8, describes the development process in more detail, but in short, it consists of dividing the semester into time periods called *Sprints*. Each sprint consists of different tasks to be completed by the end of the period. The first period consisted of a technological review of mobile applications development and planning what to develop throughout the sprints by distributing previously elicited requirements. Agile and iterative practices such as scrum and DevOps were applied during the development process. Instead of completing one part of the system, you make smaller iteration and continuously improve the element throughout the development period. DevOps methodology refers to constantly integrating and deploying your product to a real-world environment, which means deploying new functions and testing the latest version of the mobile application as often as possible.

2.2.7 User Evaluation

The user evaluation was planned to see how well the new application functions and collect data to answer the research questions. The evaluation process consisted of assembling participants to join, designing the evaluation, distributing the applications, and collecting data. Before the participants installed the application, they were asked to answer a questionnaire concerning demographic information. The evaluation period lasted for one week. Afterward, the participants were asked to answer another questionnaire about their experiences of using the applications —some participants were also asked to be interviewed in order to collect more data.

Technology Acceptance Model
The Technology Acceptance Model (TAM) is one of the most influential models of

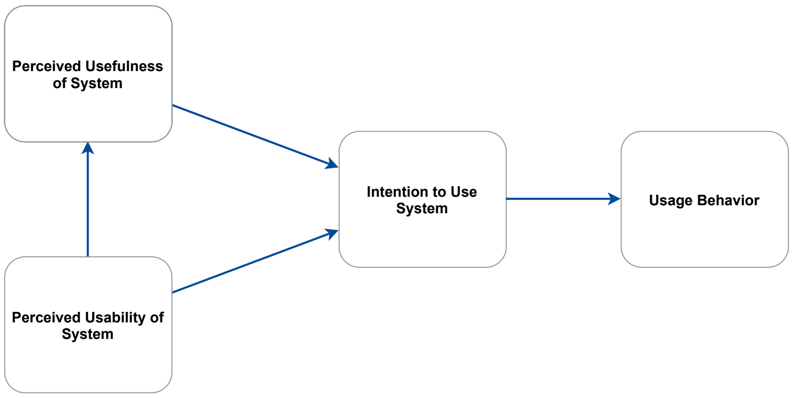


Figure 2.4: Technology Acceptance Model [25]

technology acceptance [26]. It was initially presented by Davis [27] in 1989. He stated that two primary factors influence individuals' intention to use new technology: perceived ease of use and perceived usefulness. Davis defines the perceived ease of use as "The degree to which a person believes that using a particular system would enhance his or her job performance" and perceived usefulness as "the degree to which a person believes that using a particular system would be free of effort" [27]. Figure 2.4 illustrates the relations of the components in TAM.
The model was used to evaluate the user's intention to use Smiling Earth. Both the perceived ease of use and usefulness were measured in the user evaluation of the application. The method was also used by Larsen [14] in the previous version of Smiling Earth. Since the last version was created without functioning social features, the Technology Acceptance Models were used to compare and determine

how adding social features affected the intention to use the application.

Chapter 3

Background

The background chapter presents the results from the prestudy. The background study of Smiling Earth was initially written during the spring of 2021 for the specialization project [10]. Some parts have been updated, and new sections have been added to this master thesis, but some sections remain unchanged. The chapter presents the previous versions of the application Smiling Earth and the work done in the specialization project.

3.1 Smiling Earth

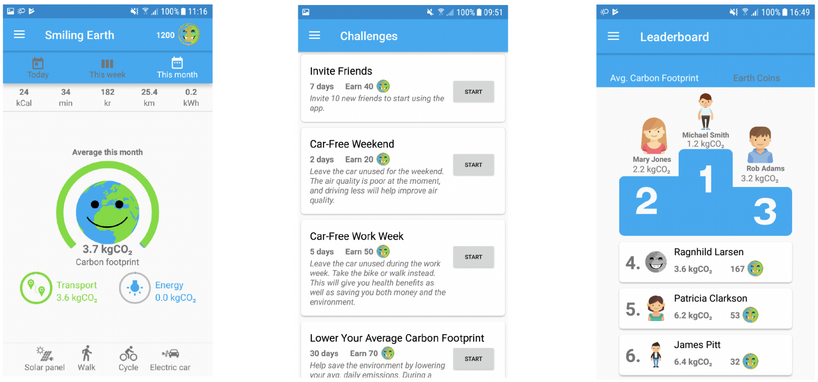
Smiling Earth is an Android application created in part with a project called Smart Decision Support System for urban energy and transportation, also known as DESENT [28]. The project is a collaborative research project between The Netherlands, Austria, and Norway and aims to provide an intelligent decision support tool to be used for smart grid and City planners and the goal is to develop an intelligent energy control concept of household/vehicle energy use through the implementation of advanced ICT technology [28]. One of the main goals is to motivate citizens to change their transportation and energy habits.

3.1.1 Earlier work on Smiling Earth

This master thesis is based on and is a continuation of the work done in the previous master thesis by Celine Minh [13] and Ragnhild Larsen [14]. The first iteration of the application implemented a way to track users' transport and energy

Figure 3.1: The different moods of Smiling Earth dependant on the users carbon emission

emissions. The goal was to see how a mobile application can help achieve positive lifestyle change in regards to energy and transportation usage and promote the installation of more sustainable equipment and means of transportation [13]. Figure C.4.a shows the Smiling Earth chart, which comprises of two parts. One is the circular chart showing how close the user is to reaching their daily limit of emitted CO2. The goal is to keep their daily emissions below 4.0 kg. The second component is Smiling Earth, whose mood changes from happy to sad (see Figure 3.1) as the users emit more. The app was created using the mindset of persuasive technologies [29], referring to technology designed to change users' mindsets or behavior through persuasion. The recorded emission was visualized to enlighten users about their emissions and how changing their habits, e.g., walking instead of driving or purchasing a solar panel, could affect their economy, emission, and health.



(a) The home screen **(b)** Challenge view **(c)** The leaderboard view

Figure 3.2: Screenshots from the previous version of Smiling Earth by Ragnhild Larsen [14]

In the second version by Ragnhild Larsen, the app was improved by adding gamification features. Her thesis looked at how users could become more motivated to act Eco-friendly by completing challenges (Figure C.4.b) and compete with other users (Figure C.4.c). When finishing a challenge, the users were rewarded with a digital currency called *earth coins*. The intention was that users could exchange earth coins for other digital items or even use them to get coupons that could be used in the real world. Earth coins were implemented, but there was not enough time to realize the market. The user evaluation of her application showed that a combination of behavior change and gamification positively affected the users to act more sustainably.

A limitation of the previous versions of the applications is that there is no support for users to connect with each other. Larsen started to add social features to the application, but this was not completed as the application did not have a backend server and thereby worked more like a high-fidelity prototype [14]. Both Larsen and Minh's versions of Smiling Earth based their work on the Transtheoretical Model (TTM) for behavior change. The model suggests that behavior change occurs in five consecutive steps, Precontemplation (not ready), Contemplation (getting ready), Preparation (ready), Action, and Maintenance. The TTM identifies different processes of change that lead to transitions between the stages [30]. A shortcoming of the model is that it focuses primarily on the individual and is not designed for communities and social applications [31] [32] thereby, a goal for further development is to find a new framework to describe behavior change in a social setting.

From a developer's perspective, Larsen suggested improving and changing the system's structure. The previous versions used a project structure called fragments, which is made to develop a system for tablets and mobile. The system is designed to be used mobile-only, so fragments are unnecessary and make the software architecture more complex. It was suggested to find a better method for structuring the software.

3.2 Feeback from the user evaluation of version 2

From the user evaluation and interviews in Larsen's thesis, the participants addressed several improvement points. One of them was the method of tracking activities. Several users said the tracking was faulty and often recorded the wrong duration or did not record anything at all. Additionally, it was suggested that the application should support more means of transportation, like bus, train, or even air travel, as this is a significant contributor to people's carbon emissions. Some participants also found some parts of the user interface a bit confusing.
Larsen suggests that the application should simplify the user interface for future work, make the tracking more accurate and editable, and add support for tracking more means of transportation (bus, train, air travel) [14]. Additional, since the social aspects of the application, was not completed, completing this should be a priority for further development

3.3 Backlog Creation

The remaining features that were not implemented in Larsen's work are collected in a backlog log. The backlog can be found in Table 3.1. The main feature that was not implemented is a backend server. A functioning backend enables the application to connect users and create a social network.
Additionally, the feedback from the user evaluation, as discussed in the previous section, is added to the backlog.

The backlog was used as a basis for further development of Smiling Earth.

ID	Requirement	Priority
B-FR4	The app shall provide personalized feedback on how the user is doing, and how that affects the environment	High
B-FR5	The app shall provide practical examples of related things that the carbon footprint represents	High
B-FR7	The app shall display information regarding the user's behavior on a daily basis	Medium
B-FR7-1	The app should explain the cause of the possible deviation from the user's habits	Medium
B-FR8	The app shall raise the user's awareness about the effect of gas emission	High
B-FR9	The app shall provide a comparison of the user's data with the community	Low
B-FR10	The user shall be able to compare his/her results with his/her friends	Low
B-FR11	The user shall be able to compete with other users	Low
B-FR12	The user should be able to join collaborative challenges	Low
B-FR13	The app should allow the user to share his/her results in external social media	Low
B-FR14	The user shall be able to correct the details of transportation used during a journey	Medium
B-FR15	The app shall distinguish different means of transportation used during a travel	Medium
B-FR16	The app should estimate the gas emission during travel based on the number of people in the car	Medium
B-FR19	The data generated by the app shall be stored anonymously	High

Table 3.1: The backlog from the previous version of Smiling Earth. The IDs refer to the Backlog-Functional Requirement number.

3.4 Specialization project

The specialization project consisted of three phases: a prestudy, requirement elicitation, and developing a new design concept. The prestudy focused on reviewing the earlier version of Smiling Earth as discussed in the previous section and finding a new model for behavior change that considers social interaction and communities. From reviewing the literature, it was found that Social Cognitive Theory seemed to be a fitting model. The model is described in detail in Section 4.1. To assist in the idea generation process, a Co-design workshop was conducted with the potential user. The workshop used the MyG methodology [33], which is a kind of gamification brainstorming session. The workshop generated many new ideas and use-cases for the application. The main ideas are summarized in this section. A new design was proposed based on the outcome of the workshop and background study. The design was created using Figma and worked as a wire-frame prototype. The design is discussed in more detail in chapter 5.

3.4.1 Workshop

User participation in creating a product is essential in the User-Centered Design process. Arranging co-design workshops with potential users were used to engage users in the developing process. The objective of the workshop was to generate new ideas and gather feedback on ways to improve Smiling Earth. The objective for the participants is to find solutions on how to engage users within a community and interact with each other to encourage a more environmentally friendly lifestyle. The expected outcome from the workshop is a set of new features and requirements.

Participants
The participants in the workshop were selected with help from my supervisor. The participants were other computer science or informatics students that had the same supervisor as the researcher. An advantage with participants is that they all had some understanding Human-Computer Interaction principles and understood the development process of creating an application. The participants also had some knowledge from other social applications to get inspiration from.

Method
The workshop used The MyG Methodology[33] which was developed as a means for idea generation. The workshop is called game storming, a play on gamification and brainstorming. The goal is to use gamified cards to help with the brainstorming process. The methodology consists of three parts, setting the context, conducting the workshop using the MyG process, and crowning the best idea.
In order to simplify the workshop process, some divergence of the MyG mythology was made. A template was created in order to streamline the workshop and can

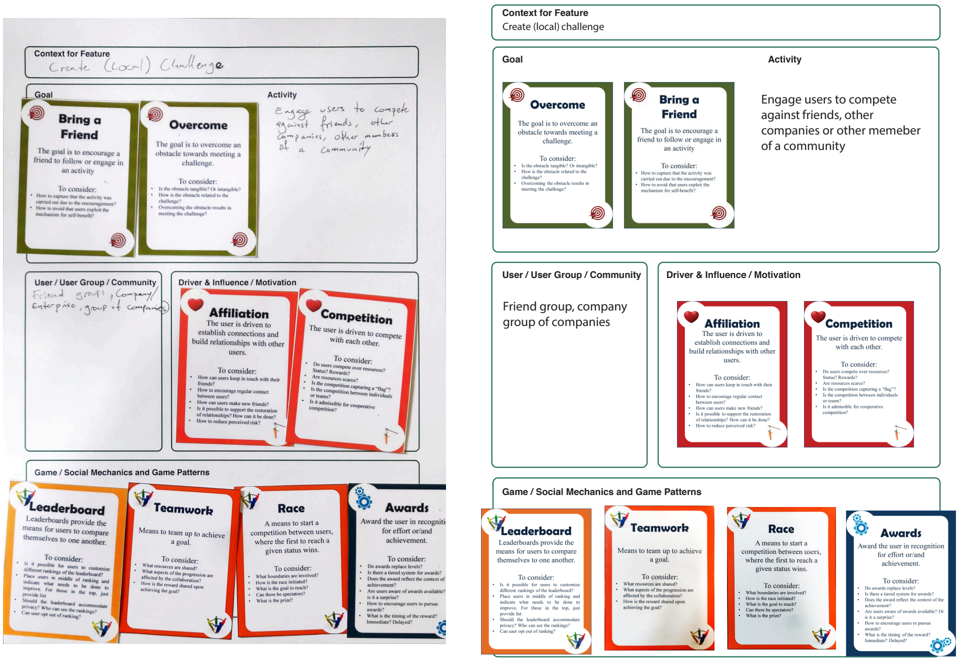


Figure 3.3: Boards created to represent creating challenges between users or communities

be viewed in Appendix A. Additionally, some of the cards were removed, and new ones were added.

Scenarios

During the workshop, the participants created five new ideas to be pursued in the application. The ideas were captured using a printed A3 paper version of the template. While the participants discussed ideas, the researcher noted the scenarios and discussions. Each template represents a different user scenario that could be applied in the application. A filled template will be referenced as a scenario or a board from now on. The participants got 45 minutes to create as many scenarios as they managed. When the group was finished with a scenario, it was documented by taking a picture of the board. Afterward, the group was handed another empty template. One scenario created during the workshop is illustrated in Figure 3.3. The other scenarios are shown in Appendix A, and their contents are summarized in the next section.

3.4.2 Requirements

This section describes the requirements that were collected from the workshop. Each requirement is listed in tables and prioritized from discussion with the participants. The requirements will be used when designing the new concept of Smiling Earth.

Avatar

The first scenario created as described by Figure A.5 and Figure A.6 was the ability to have an avatar that could represent the users. Based on the avatar, the user should be able to customize it. Additionally, it was suggested to add different items to the avatar that could be unlocked by completing challenges, attending events, or purchasing digital goods for the avatar. The functionality of the avatar is listed in Table 3.2.

ID	Description	Priority
W-FR1	The user shall be able to create an avatar	Medium
W-FR2	The user shall be able to customise the avatar	Medium

Table 3.2: Functional requirements from workshop concerning Avatar

Challenge

The next user scenario created was to enhance the challenges created in the previous versions. It was suggested that each challenge should have a leaderboard and that the users should be able to create their own challenges. Additionally, the participants suggested adding challenges between groups of users /communities. The communities could be called *teams*, and the competing teams could be called *rivals*. Completing a challenge could reward the user or unlock new challenges. The functional requirements for challenges as suggested by the participants are listed in Table 3.3.

ID	Description	Priority
W-FR3	The user shall be able to join a challenge	High
W-FR4	A team shall be able to join a challenge	High
W-FR5	A challenge shall have a leaderboard	Medium
W-FR6	The user shall be able to create a challenge	Low
W-FR7	The user shall receive an award when completing a challenge	Low
W-FR8	The user shall be able to unlock another challenge when completing a challenge	Low
W-FR9	The user shall be able to invite others to join a challenge	Low
W-FR10	The user shall be able to unlock resources containing information and ideas for becoming more environmentally friendly by completing a challenge	Low

W-FR11	The user shall be able to unlock items for the avatar by completing a challenge	Low

Table 3.3: Functional requirements from workshop concerning Challenges

Event
Like with challenges, it was suggested to add events that users could attend. The events could be physically meet ups or digital one. Events worked similarly to challenges, such as receiving an award for attending an event. The requirements for events are listed in Table 3.4.

ID	Description	Priority
W-FR12	The user shall be able to join an event	High
W-FR13	A team shall be able to join an event	High
W-FR14	The user shall be able to create an event	Low
W-FR15	The user shall receive an award when attending an event	Low
W-FR16	The user shall be able to unlock another event when attending an event	Low
W-FR17	The user shall be able to invite others to attend an event	Low
W-FR18	The user shall be able to unlock items for the avatar by attending an event	Low

Table 3.4: Functional requirements from workshop concerning Event

Market
The market was first introduced by Larsen in the previous version of Smiling Earth but not implemented. The participants of the workshop liked the ideas very much and wanted to create a board on the topic. The board can be view in Appendix A.4. The market could use earth coins to as payment to purchase digital good such as items for your avatar. The requirements suggested from the workshop is listed in Table 3.5

ID	Description	Priority
W-FR19	The user shall be able to buy items for the avatar using earth coins	Low
W-FR20	The user shall be able to buy resources like information and tips on becoming more environmentally friendly	Low

Table 3.5: Functional requirements from workshop concerning Digital Market

3.4.3 Summary

This chapter presented the previous work on Smiling Earth and during the specialization project. The backlog and ideas generated from this chapter will be used as a basis for further development and the outcome of the technology and literature review.

Chapter 4

Literature review

This section comprises the literature study done in this project. The review contains the behavior change model Social Cognitive Theory by Albert Bandura, a study of sustainable human-computer interaction, and a review of online communities.

4.1 Social Cognitive Theory

In 1988 Albert Bandura presented a theory called Social Cognitive Theory (SCT). Bandura proposes that a person's behavior is affected both by personal factors and the social environment. SCT provides a framework for studying and understanding human thought and behavior. The theory describes how the functioning of humans can be understood in terms of five capabilities; symbolizing capability, forethought capability, vicarious capability, self-regulatory capability, and self-reflective capability [34]. Additionally to examining a person's capacity to interact with their environment, SCT describes how people work together for collective actions. Like in an organization or community where people's actions can achieve environmental change that profits the entire group.

Social cognitive theory strives to develop and realize the best in people both at the individual and collective level [35] and has been used in many different tasks. SCT was used to reduce population growth in India and Mexico and promote gender equality [36]. The theory was adopted in creating a television series where the main character addressed these themes. The series was immensely popular, and a random sample of the viewers showed an increase in knowledge around the topic and a change of behavior. The theory has also been used to explain pro-environmental behavior change. In a paper from 2019, Bandura [37] describes how the Friday for Future and the environmental youth movement led by Greta Thunberg can be modeled after the Social Cognitive Theory and how the movement promotes large-scale environmental change supported by the use of social media
Social Cognitive Theory was chosen as the main theoretical framework since it

focuses more on the social and community aspects compared to Trans Theoretical Model, as was used by the previous versions of Smiling Earth (see Chapter 3). Additionally, SCT has been suggested to be a logical fit for new technologies such as Social Media Platforms [38] [34]. This section discusses the core concepts of Social Cognitive Theory and how the theory can be applied when designing the application.

4.1.1 Observational learning

The idea behind observational learning is to model your behavior based on others. Thereby the concept is often referred to as social modeling. While learning through action can occur, learning by imitation is more effective for enhancing the rate of learning [30]. Modeling enables people to shortcut the tedious and sometimes costly trial-and-error learning by profiting from others' success and mistakes [36]. Social cognitive theory illustrates the concept in terms of four sub-functions, attention, retention, production, and motivation [39]. Attentional processes suggest that the person must be able to observe and extract information from the modeled event. Retention is about remembering the event you witnessed. Production concerns the ability to reproduce what you saw, and the last sub-factor, motivation, is about your motivation to reproduce what you observed. An example of successfully applying observational learning is shown in the study by Sussman et al. [40]. Social modeling was used in the research to promote pro-environmental behavior change by increasing the number of people who would compost their waste after a meal in the cafeteria. The result from the study showed that people were 42% more likely to compost after observing two individuals who modeled the behavior. Additionally, they saw that the behavior change was sustained after the models were removed.

Smiling Earth tries to use observational learning by facilitating users to observe challenges, emissions, and posts that users in their network are sharing.

4.1.2 Self Efficacy

Perceived self-efficacy refers to beliefs in one's capabilities to organize and execute the courses of action required to produce given attainment [5]. Bandura [5] has demonstrated that individuals who initially doubt their capacity feel dissatisfied with themselves and their achievements, and they are likely to lose interest in the task.
Social Cognitive theory identifies four ways of developing self-efficacy. Firstly, one develops self-efficacy by building on prior experiences that one has mastered. Another way is to model your wanted behavior after someone who has already mastered it. Thirdly is to enhance one's physical and emotional state, and lastly is to persuade people verbally [5].

The research by Taberno et al.[41] shows a clear connection between having high self-efficacy and high intrinsic motivation regarding environmentally responsible behavior. Furthermore, the article explains the importance of combining intrinsic motivation and self-efficacy as generators of other self-regulatory mechanisms that motivate behavior. The researchers looked at people's incentives to recycle. The results illustrate that individuals with a high understanding of their recycling capacity engage more in recycling behavior, feel more satisfied with their behavior, set more ambitious goals, and have greater intrinsic motivation.

4.1.3 Collective efficacy

From self-efficacy, Bandura further extends the concept to communities of people. Similar to individuals, groups also have a set of capabilities. Collective efficacy refers to a group's beliefs in their capability to perform an action that brings the desired outcome. Bandura demonstrates its effect by how organizations work together in order to achieve their goals [5]. As a group's perceived collective efficacy increases, the stronger its members' motivational investment in their tasks, the more resilient to setbacks, and the greater their accomplishments [42]. The same principles for obtaining self-efficacy can similarly be applied to collective efficacy, like building on mastery, modeling behavior to other team members, e.g., team leader, and that the members of the team are in a physical and emotional state to improve the group's efficacy.

4.1.4 Self-regulation

Self-regulation is the method of controlling one's emotions, thoughts, and behavior in the face of temptations and impulses. Bandura [5] recognizes six steps in which self-regulation is achieved:
(1) self-monitoring is a person's systematic observation of her own behavior; (2) goal-setting is the identification of incremental and long-term changes that can be obtained; (3) feedback is information about the quality of performance and how it might be improved; (4) self-reward is a person's provision of tangible or intangible rewards for himself; (5) self-instruction occurs when people talk to themselves before and during the performance of complex behavior, and (6) enlistment of social support is achieved when a person finds people who encourage her efforts to exert self-control.

In a study by Look et al. [43] they used a web portal where the users of an energy company could review their consumption and set goals. The results showed that goal setting and feedback positively impact energy-efficient behavior in private households. Bandura [36] argues that long-term goals help people set the course for personal change but are too distant to overrule current influences on behavior. On the other hand, short-term goals motivate and provide direction for our current actions.

Glanz et al. [34] describe the importance of social support and refer to studies where people worked towards quitting smoking. The result showed that social support and positive feedback were essential drivers in achieving the goal.

Examining self-regulation in regards to Smiling earth, the first version added functionality for users to monitor their behavior and set a personal goal to reduce emissions. In addition, the Smiling Earth metaphor is a way for users to receive feedback on their performance. In the second iteration of Smiling Earth, gamification was added. By completing challenges, users obtain a self-reward. The concept of social support is missing from the previous versions of Smiling Earth (as discussed in Chapter 3) and is a central contribution to the application in this thesis.

4.1.5 Outcome Expectation

Outcome expectation is a central psychological determinant of behavior in social cognitive theory. Bandura defines outcomes as "not the characteristics of agentive acts; they are the consequences of them" [44]. Outcome expectations are the results or desired outcomes of intentional actions in which individuals choose to engage [45]. If a person has high outcome expectations, it could motivate the goal-striving process [46]

In terms of Smiling Earth, users may not know the expected outcomes of their actions regarding the carbon footprint. For example, most people know that driving a car is less climate-friendly than riding a bike, but how much? Therefore, an emission calculator was implemented in the first version of the application to enlighten users on how much more carbon is emitted, money spent, and calories burned to ride the bike than driving.

4.2 Sustainable Human-Computer Interaction

Human-computer Interaction (HCI) refers to the interplay between technology, humans, and society [47]. Sustainable Human-computer Interaction (SHCI) is a developing research field focusing on design systems to influence users to behave and live sustainably [48]. Makoff et al. [49] divides the field of SHCI into two. The first is Sustainability in Design, which refers to taking sustainability as part of the product's material design and the complete life-cycle. Sustainability is multifaceted and includes issues such as related to energy, recycling, and footprint. The other part concerns issues around how to support sustainable lifestyles and decision-making through the design of technology and is referred to as Sustainability through Design. The Smiling earth application is an example of sustainability through design.

In a 2010 review of the literature [50], persuasion was found to play a significant role in SHIC, covering around 45% of the articles reviewed. Of the articles comprising persuasion, about 45% based their theoretical rationale on BJ Fogg's theory of persuasive technology. He defines[51] persuasion as "an attempt to change attitudes or behaviors or both". Persuasive technology follows from the definition to be any technology that is designed to change attitudes or behaviors or both. Tscheligi, Reitberger, de Ruyter [52], and Markopoulos [53] argue that persuasive technology is a central element of SHCI. By giving the users information about their actions' environmental impact, increases the value of pro-environmental behavior.

Early work in SHCI has focused on shaping people's choices to reduce consumption based on negative motivations. When presenting the negative outcomes from users' actions, we are playing on their guilt to improve their lifestyle [48]. Gamification has been used to counter the negative motivational forces [48]. For example, letting users compete and reach goals can generate positive motivational forces. Looking at gamification was one of the central concepts added in the former version of Smiling Earth by Ragnhild Larsen (see Section 3.1.1).

In 2020 Hanson et al.[54] published a systematic literature review of papers from the last decade of SHCI. The paper's goal was to categorize produced papers based on the United Nations' Sustainable Development Goals (SDGs). A total of 71 articles were reviewed, and 51 of them (70%) could match with SDGs. The results showed that from the 51 papers, 26 were related to SDG No. 12 sub-target 2. Goal number 12.2 states: "By 2030, achieve the sustainable management and efficient use of natural resources"[55]. The majority of the papers described so-called eco-feedback systems. Another 16 articles were related to the other targets of SDG no. 12 "Sustainable consumption and production". The results from the review reveal that the research view of SHCI has been too narrow.

This master thesis and development of the next version of smiling Earth, focuses more on SDG 11 and SDG 13 as they have received little attention in SHCI. SDG 13 (Climate action) tries to engage people to take urgent climate action to mitigate climate change.
Sub-target 13.3, "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning,"[56] will be the main focus regarding SDG 13 in the next version of Smiling Earth.
The goal of SDG 11 is to "Make cities and human settlements inclusive, safe, resilient and sustainable"[57]. By promoting pro-environmental behavior change among the citizens and enabling community features in the next version, we hope to increase communities' inclusiveness and sustainability in cities. Additionally to supporting SDG 11 and 13, the application shall continue to support SDG 12 (Ensure sustainable consumption and production patterns)[55].

4.3 Online Communities

Connecting to other users and joining online communities has become common in the past decades. With Web2.0 the rise in popularity came social network sites like Facebook and Twitter to chatrooms and forums. In addition, during the Covid-19 pandemic, virtual teams and communities reached an all-time high as people were forced to work from home.

In order to support collective efficacy, the app needs to create communities for the users. But how do we group people who do not know each other? One method is to place users together into groups randomly. Optionally the users can be arranged into groups based on their location or common relation to a site, known as Community of Place. Another way can be to create groups where the users have a common interest, so-called Communities of Interests. According to Henri and Pudelko [58], the community members often identify themself to the topic rather than with the other members. They found that participation, learning, and identifying constructions within communities of interest are complex and depend on the members' degree of involvement.

A fourth option is to organize users in Communities of Practice as suggested by Etienne Wenger [59]. He defines these the term as "Communities of Practice are groups of people who share a concern or passion for something they do and learn how to do it better as they interact". Communities of practice are everywhere, from school or work projects to our hobbies. The community members are bound by their activities and what they do through mutual engagement in the activities. [60]. Wenger et al. [61] define three crucial characteristics for communities of interest. Firstly, the members of the community have a shared domain of interest. Secondly, the members engage in collective discussions, activities, help each other and share information about the field of interest. Finally, the third characteristic is practice. The members of the community are not just interested in the subject, but they also practice it.

4.4 Summary

This section presents the review of the literature of related topics used in this thesis. The review of social cognitive theory shows potential to replace Trans Theoretical Modal as the model for behavior change since it focuses more on social interaction and supports community building. From the review of Sustainable Human-Computer Interaction, many persuasive applications have focused on Fogg's behavior model and UN Sustainability goal 12. Thus this thesis will primarily examine how Social Cognitive Theory can be applied to persuasive application and additionally focus on supporting SDG 12 and promoting SDG 11 and 13 by engaging the users to take concrete climate actions and build strong communities. SDG 11 is concerned with making cities and human settlements inclusive, safe, resilient, and sustainable). While number 13 focuses on improving education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning.

4.5 Related Works

This section describes different applications that have related functionality or focus on achieving the same goals as Smiling Earth.

4.5.1 Joulbug

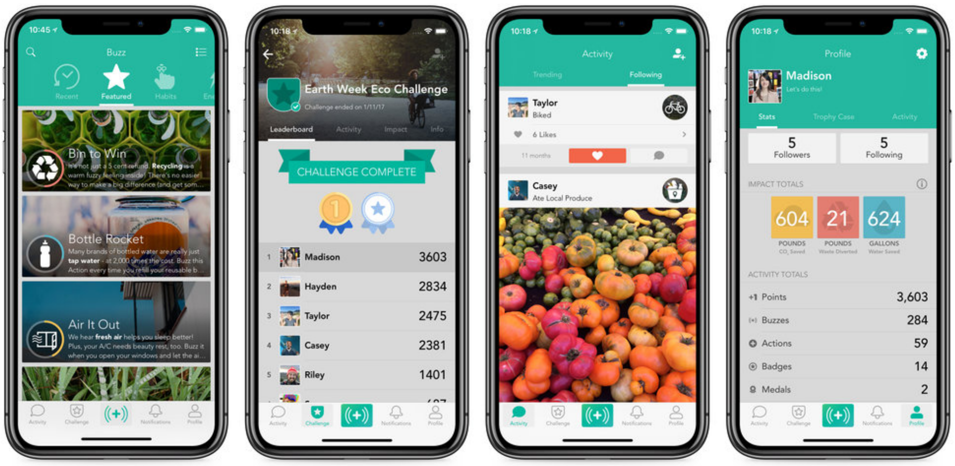


Figure 4.1: Screenshot from Joulebug

Joulebug is an Android and iOS application that tries to make your everyday habits more sustainable at home, work, and play [62]. In Joulebug, you can join challenges to become more sustainable and compete with others. In addition, users can connect with other users and share news with their network. Joulbug focuses on both individuals and businesses. In the enterprise version, companies can create teams for their employees and compete to become the most sustainable team in the business. The user tracks their habits buzzing each time they complete an action, like recycling a bottle, walking to work, etc. By completing challenges, users receive badges that are shown on their profile page. Screenshots from Joulbug are shown in Figure 4.1.

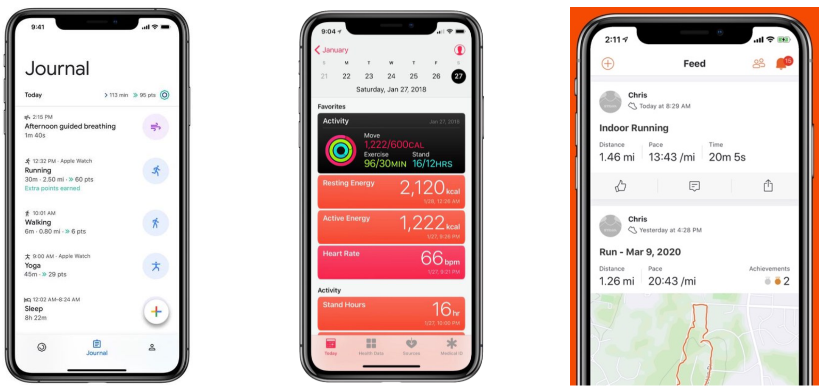
4.5.2 Ducky.eco

Ducky is a Norwegian company that has created various web solutions to promote environmentally friendly behavior. Their three main products targets enterprises, schools, and cities [63]. The product for enterprises and schools offers a web application that focuses on engaging the employees and schools to act more sustainably and compete to reduce their emissions. Additionally, the company hosts *Klimakonkurransen* (The Climate championship) for businesses and *NM i Klima* (The Norwegian championship for sustainability) for schools. The goal is to compete against other businesses or schools to become the most environmentally friendly institution. Finally, the solution for cities aims at increasing the visibility of the citizen's emissions and can be used as a tool to reduce the emissions from consumption. The application can calculate the citizens' estimated household emissions classified by: energy, consumption, food, transport, and public.

4.5.3 Capture - Carbon footprint and CO2 tracker

Capture [64] is the application that is the most similar to Smiling Earth. It is a mobile application that automatically tracks users' emissions based on their movement. For example, it can track if you are walking, bike, or in a vehicle and then calculate your emission. Additionally, the app considers the user's food habits and adds the CO2 emitted from eating meat. Capture offers a solution for users to reduce their emissions by purchasing carbon offsets within the application. For individual users, there are no social aspects to the application. Organizations, on the other hand, can create teams for their employees. The employee receives a code that can be used to join a team. Within a team, the members can compare results, and the organization can compare the difference between the teams.

4.5.4 Health and fitness applications



(a) Google Fit **(b)** Apple Health **(c)** Strava

Figure 4.2: Screenshot from popular health and fitness applications

Health applications have become increasingly popular for tracking activities and promoting a more healthy lifestyle. These applications are often referred to as mHelth, an abbreviation for mobile health. The term is used for the practice of medicine and public health supported by mobile devices [65]. Many health applications have implemented social technologies and gamification to encourage the user. Strava is the most popular application for logging and sharing running and cycling workouts with others. For daily activity tracking, applications like Google Fit and Apple Health are very popular as they come pre-installed on Android and iOS devices. These applications automatically track the user's movements and give them an overview of their activities and calories burned.

Social Cognitive Theory in mHealth
Social Cognitive Theory (SCT) has materialized as one of the most extensively used theoretical frameworks in health behavior study [66][67]. In an article by Farfaglia et al. [68], a structured literature review of mobile health applications was completed to find social cognitive theory-driven design evidence. The literature search retrieved 447 articles, and after filtering the articles based on their selection criteria, 152 articles were reviewed. The findings showed that SCT provides a framework for designing, implementing, and evaluating electronic health intervention applications. Furthermore, the reviews highlight several interventions where SCT has been successfully used, and creating online environments where the social presence and information richness are used as the overall strategy has several advantages. It was also concluded that electronic health applications have the potential to act as sticky media, meaning that they can help sustain the desired behavior over a longer time.

4.5.5 Summary

This section has reviewed some related works to Smiling Earth. Exciting applications like *Joulbug*, *Ducky*, and *Capture* have the same goal as Smiling Earth, which is to support a more sustainable and environmentally friendly lifestyle. Examining Ducky and Joulbug, these application focuses on the social aspects and gamification of behavior changes but is based on user input to calculate the carbon footprint. As with Capture, Smiling Earth is a persuasive application that automatically can track user emissions. In contrast to Ducky and Joulbug, Capture is mostly an eco-feedback application and not a social application. This thesis goal is to make the application more social and support concepts of Social Cognitive Theory to promote a more environmentally friendly lifestyle. From mobile health applications, many popular applications do similar work to promote a more healthy lifestyle, like *Apple Health*, *Google Fit*, and *Strava*. Additionally, Social Cognitive Theory has been used as the theoretical framework of choice for many electronic health applications. However, from the review of related works and the literature, it is not known to the researcher any persuasive applications like Smiling Earth that focus on promoting a more environmentally friendly lifestyle based on Social Cognitive Theory and adding functionality from social computing.

4.6 Technology Review

This section describes the technology review done in this thesis. The study begins by analyzing modern mobile development methods and how to track the user's activities. Then a review of how to develop the backend server is discussed. The goal of the backend application is to host the API and Database. The final subsection describes the different solutions for hosting the backend applications.

4.6.1 Mobile Application Development

Since the introduction to smartphones and application markets such as the Google Play Store and Apple App Store, mobile application development has been a hot topic in software development. There exist many different mobile application development frameworks and languages. They are often categorized into two groups, native frameworks, and cross-platform frameworks. Native frameworks include Swift for iOS and Java or Kotlin for Android devices. The previous versions of Smiling Earth were developed using conventional Android methodology with Java.

Figure 4.3: Flutter Logo

An advantage of this development method is that you have easy access to the different functionalities in phones using Android Native Development Kit (NDK). There is also an advantage of the performance using native languages.

A disadvantage is that you need to create two applications if the application is used on both iOS and Android. This is the main concept behind the cross-platform methodology, where you make one app that can work on both operating systems and in web browsers. Cross-platform frameworks have been around for a while, with Cordova and Xamarina, but they did not really take off before the introduction of React Native by Facebook and Flutter by Google. This is illustrated in Figure 4.4, showing how the different frameworks are trending on Stack Overflow (a forum for software developers) [69]. The trends are showing that native development has been declining since 2015, while cross-platform frameworks like Flutter and React native have increased their popularity.

Another advantage of Flutter and React from a developer's perspective is that they enable hot reloading of the application, making it easy to do rapid changes and test them quickly on the device. Additionally, both frameworks have a big community of developers creating plugins that can easily be added to the application. A disadvantage of cross-platform development is the performance of the application [70]. However, Flutter can perform almost as well as native applications in many cases, and if performance is the most important, then native applications will most likely perform better.

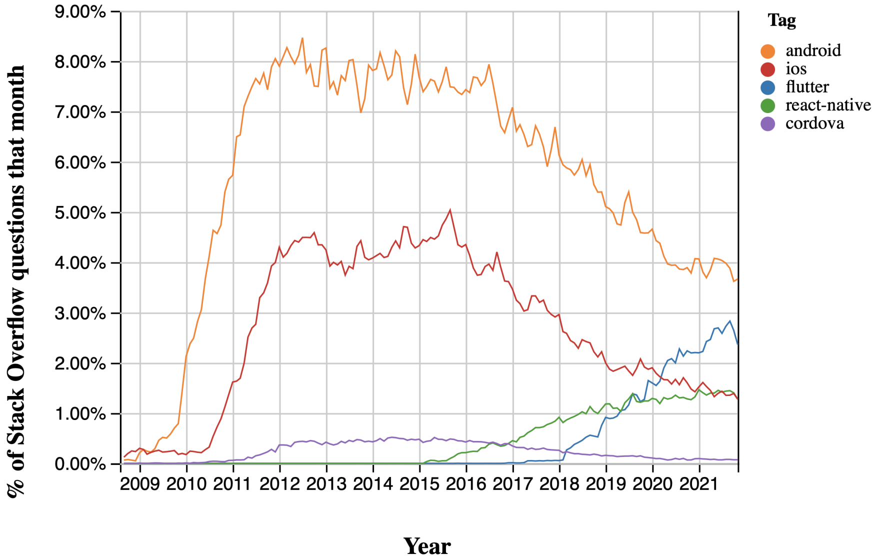


Figure 4.4: Trending frameworks on Stack Overflow [69]

As discussed in Section 3.1.1, the architecture of the previous version could have been designed better, and Larsen suggested redesigning the architecture to be mobile-first. Because of this and that the researcher had some prior experience developing Flutter applications, the new version of the Smiling Earth was developed using Flutter. By using Flutter, much of the Java code from the previous versions will have to be translated to Flutter.

4.6.2 Tracking user's activity

As mentioned in Section 3.1.1, many users complained that the activity tracking was faulty in the previous versions of Smiling Earth. Therefore, this version tries to improve the tracking solution. The app uses Google Activity Recognition API. The API is built on top of sensors available in the device [71]. The API automatically detects activities by periodically reading the data from the sensors.

The application calls the API using a plugin[72] to flutter developed by Copenhagen Center for Health Technology (CACHET) [73]. The plugin work as a middleware between the application and the API and provides event-based information about the detected activities. The plugin can detect if the users are in a vehicle, on a bicycle, on foot, running, or still. When the plugin detects the activity has changed, the application starts recording the duration. When the activity changes again, the recorded duration and activity type gets stored in the local database on the device.

4.6.3 Backend

The goal of the backend is to store data and handle requests from the users. There are many different solutions to solve this. The overall structure of the backend consists of an application running as an access point for the users to connect to and process requests to the database. This means we first need to create an access point, also known as an Application Programming Interface (API). The last 20 years have introduced different APIs, such as SOAP API, GraphQL, GRPC, and RESTful API, the latter being the most common. With REST (Representational state transfer), API data is sent over HTTP or HTTPS through a GET, PUT, POST, or DELETE request. Many frameworks exist for creating REST APIs, such as Spring Boot, .NET, Express, Flask, and Django Rest Framework (Django DRF). All frameworks offer much of the same functionality, but as the researcher had prior experiences with Django DRF, it was chosen to build the backend services.

Figure 4.5: Django Rest Framework Logo

Django Rest Framework is described as a powerful and flexible toolkit for building Web APIs[74]. The framework is based on Python. Djangos design philosophy focuses on loose coupling and tight cohesion, which enhances the modifiability of the system. It also focuses on writing less code and quick development. As quoted from their website, "Django should allow for incredibly quick Web development" [75]. The framework also comes with a helpful admin site for managing the data in the system, as shown in Appendix D

Database

As with REST frameworks, there exist many different database solutions. The solutions can be mainly divided into two categories, Relational Database Management Systems (RDBMS) and NoSQL. RDBMS is the traditional method of storing data in tables and centers on relations between the tables and entities. While NoSQL is better for storing unstructured data and for applications experiencing rapid growth [76]. As this version of smiling earth creates a social network, relations are essential. Therefore, using RDBMS is preferred.

Figure 4.6: PostgreSQL Logo

Additionally, Django is created around using RDBMS. Django supports different databases, but it uses SQLite, a simple RDBMS by default. This database works well for local development and prototyping but is not recommended to use in production. For productions, it is advised to use PostgreSQL[77]. Therefore, the system was set up to use SQLite for local development and PostgresSQL for production.

4.6.4 Hosting Solutions

The backend services have to be hosted on a server. Today there exist many cloud services offering Platform-as-a-Service(PaaS) solutions. This means that as a developer, you can focus on creating the applications and managing the data while the platform manages networking, middleware, Runtime, O/S, and other server-related concerns [78]. Examples of PaaS are Amazon AWS, Google Cloud, Microsoft Azure, and Heroku. The latter was chosen to host the development version of the backend application because of the researcher's prior experiences using Heroku and since it is free to set up. This meant that the backend application could be set up immediately at the beginning of the development process, enabling rapid testing of the system. Heroku was not used in production since it does not comply with NTNU data storing requirements. In dialogue with Norsk Senter for forskningsdata (NSD), the data stored in the evaluation of the application was classified as internal [79]. In order to follow NTNU's data policies [80], the data would have to be stored with one of NTNU's collaboration partners, such as Microsoft. Thereby, when testing the application with real users, the backend solution was hosted using Microsoft Azure, running on servers located in Norway.

4.6.5 Continuous Integration/Continuous Deployment

Continuous integration and continuous development (CI/CD) is a method for frequently publishing new updates to a system by adding automation into the stage of app development. To do so, we can use automation servers to reliably build, test and deploy the new versions of the system[81]. An example of this is *GitHub Actions* [82], a CI/CD platform that automates our workflow directly inside GitHub. In this project, GitHub was used to store the repositories and used for version control, thereby the natural choice was to use GitHub Actions for CI/CD.

GitHub Actions

Figure 4.7: Github Actions Logo

4.6.6 Summary

This concludes the technology review done in this thesis. As it was suggested to update the structure of the previous applications, and as cross-platform are increasingly in popularity, Flutter was chosen as the framework of choice to create the new Smiling Earth. This enables the application to use pre-build packages to track users' movement, hopefully improving accuracy. For the backend solution, Django was selected to be used in a combination of SQLite as the development database and PostgreSQL as the production database. By using CI/CD in Github, the project can be set up to use different environments when new developing. This makes it possible to create a developing environment hosted on Heroku and a release environment hosted on

Microsoft Azure. Two environments were created to enable rapid prototyping as Heroku is free to use for smaller applications, while Azure uses a pay-as-you-go policy. Finally, Azure was chosen as the production environment as it complies with NTNU's data storage policies.

Chapter 5

Application Design

This chapter describes the overall design concept and design choices taken when developing the design prototype. The prototype is a high-fidelity wireframe prototype created using Figma during the specialization project[10]. The decisions made when creating the prototype are based on the literature review, the backlog from the previous version of Smiling Earth (see Section 3.1), and requirements and use-cases elicited from the co-design workshop conducted in the specialization project. Additionally, some ideas were taken inspiration from health and fitness applications, such as Apple Health, Google Fit, and Strava, as described in Section 4.5.4. The prototype can be previewed in Figma [1]

5.1 Design

As described in Section 3.1.1, the previous versions of Smiling Earth aimed to create awareness around one's emissions and to promote a more sustainable lifestyle by adding gamification. The new feature proposed in this design prototype is to challenge the users further to close the science-action gap and create inclusive communities, thus supporting UN's SDG no. 11 and no. 13. In addition, we will look at how to use principles from Social Cognitive Theory, and adding social interfaces to the application can promote environmentally friendly habits.

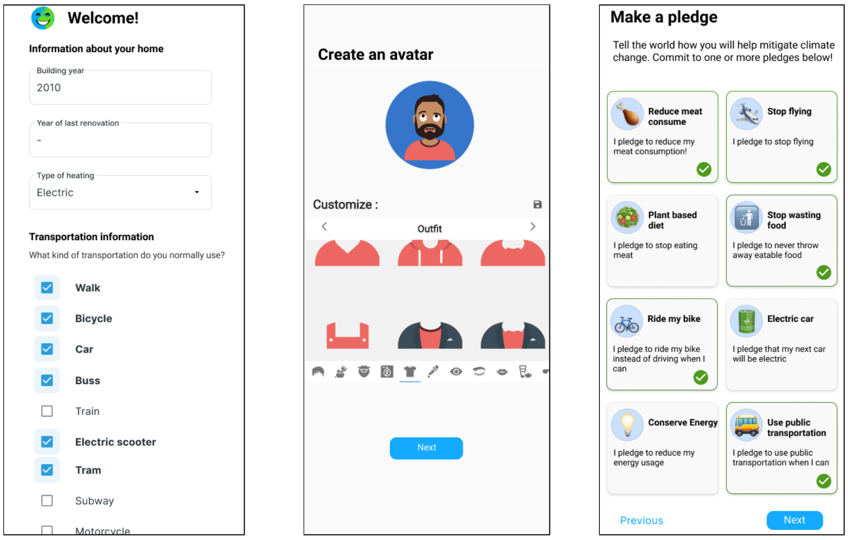
The prototype builds upon the design made by Celine Mihn and further developed by Ragnhild Larsen of smiling earth, as described in Section 3.1. From their further works and prestudy, it was evident that socializing the application and adding communities could enhance the application. Therefore, a co-design workshop was conducted in order to brainstorm ideas and new features to be implemented (see Section 3.4.1). Furthermore, Nielsen's ten usability heuristics on User Interface Design was applied as a guideline for designing the new prototype. Additionally, the design patterns and best practices described in *Designing Social Interfaces*[52] were reviewed. The book has greatly assisted in designing an application to en-

[1] `https://www.figma.com/file/y1ij0MrbOQGdXqPnUIDhdT/Smiling-Earth?node-id=0%3A1`

courage user interaction and community building. Also, the book "100 Every Designer should know about people" [83] has been helpful to understand better why people act as they do.

The following sections give a detailed description of the different concepts created during the design period. A selection of the concepts is described and illustrated with Figures. Other concepts are only defined and can be viewed in Figma [2].

5.2 Registration



(a) Personal habits **(b)** Avatar creation **(c)** Select pledges

Figure 5.1: The registration process

A new registration process has been designed with two main elements. Figure 5.1.a is the same concept already exists in Smiling Earth. The screen contains information about the user's transportation habits. Additionally, there will be a screen with detailed information about the user's car if they own one and a screen for basic information about the user.

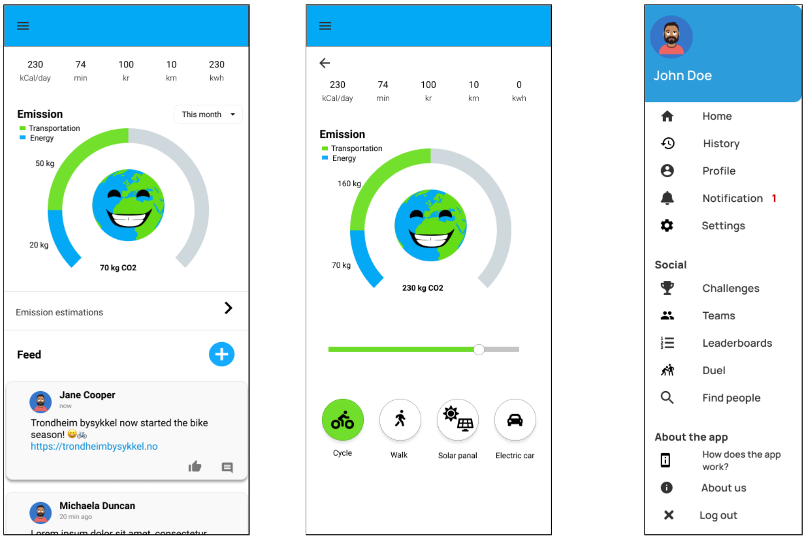
A new concept added to the system is adding an avatar to represent the users. This was suggested in the co-design workshop (see Section 3.4.1). The design is shown in Figure 5.1.b, and is based on an open-source Flutter plugin called Fluttermoji. This plugin includes a simple way of creating and storing personal and will be used in the final Proof-Of-Concept application.

The second element added to the registration process is making a climate action pledge. The idea behind the concept was to support SDG No. 13 Climate action now by making one or more pledges to mitigate climate change. The pledge

[2] https://www.figma.com/file/y1ij0MrbOQGdXqPnUIDhdT/Smiling-Earth?node-id=0%3A1

will be public to other users, and the user shall be able to update their pledges later. The different pledges were created from several brainstorming sessions. For example, a pledge could be to stop flying, use the bike more or eat less meat. Figure 5.1.c shows the suggested design of the pledge screen. The mentioned pledges in the figure are examples of pledges and not a complete list to be implemented.

5.3 Home screen



(a) Home Screen **(b)** Emission Estimation **(c)** Navigation Drawer

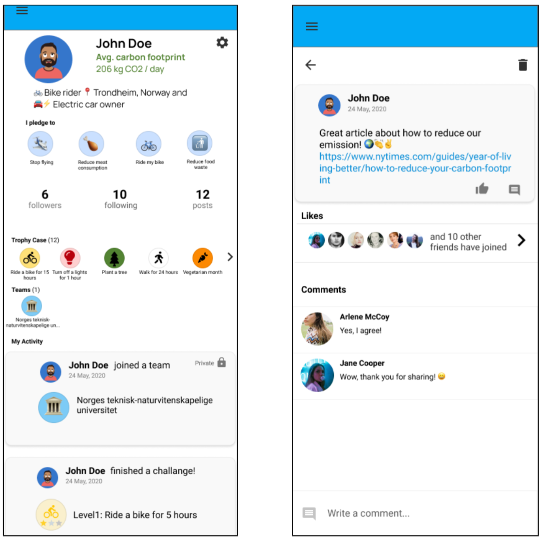
Figure 5.2: The updated home screen

The home screen has been updated as shown in Figure 5.2. From the feedback described in Section 3.1, it was suggested to simplify the home screen and the estimation. The new home screen is shown in Figure 5.2.a and consists of three components. The first and second part concerns the user's emissions and includes the top header and the Smiling Earth emissions charts. The header previews how many calories burned, money saved, and time spent on walking or driving and how much energy was used in the past period (one day or one week). The Smiling Earth charts presents how much CO2 the user has emitted during the same period and compare it to the daily limit of 4kg CO2. The earth is smiling as long as you can keep the emission below 4kg and change the mood as you increase the carbon emitted. The third part includes a new scrollable *feed* with the latest actions from the other users in the user's network. This includes posts, joined challenges, pledges made, joined teams, and shared activities. The goal of the feed is to facilitate observational learning and social modeling and support social encouragement. In the *feed*, the user can see, comment, and like content created by other users or teams the user is a member of.

Figure 5.2.b displays the new emission estimation view. Previously the view was on the home screen together with the daily recorded activities. From Section 3.1, it was suggested to simplify the home screen, and thus has this view been moved into a separate page, accessible from the home screen.

The navigation side menu, often referred to as a *navigation drawer*, is updated in this version of Smiling Earth, as shown in 5.2.c. The user will navigate between the different pages using the navigation drawer. The new design of the drawer has been updated, accompanying the new features and grouping the related feature to keep it structured. Grouping associated items enhance the readability and usability of the application [17].

5.4 Profile



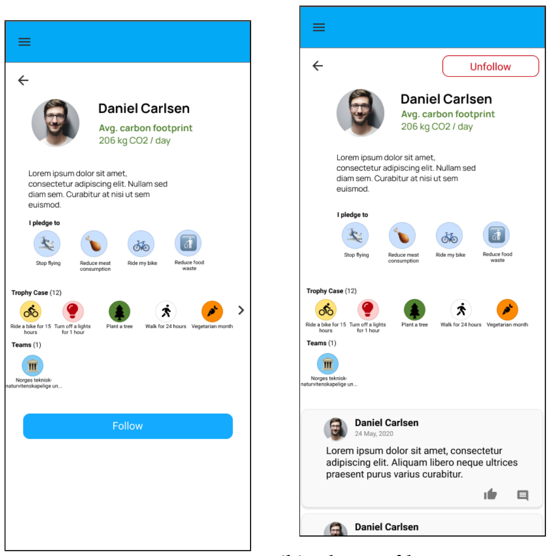
(a) Profile page **(b)** Detailed Post View

Figure 5.3: Showing the view of *my profile*

A profile is the face of the user in the system and is a core piece in a social offering. According to [52], profile pages should be used in an application that encourages user-generated content and promotes relationship building. The profile should display to others the central information about the user (name, profile picture, a short biography) and relevant content concerning smiling earth. The concept is shown in Figure 5.3. On the profile pages, emission goals and pledges will be displayed to motivate others further to take climate action (SDG 13). Previously completed challenges are presented to show the users' concrete actions to mitigate climate change. Additionally, the teams the user is a member of are revealed on their profile.

Like the one on the home screen, a feed shows the users' activities, referred to as a *Post*. The Post may be private and thus only available to the present user. It is possible to go to a detailed view of a post by tapping on it. The detailed view is illustrated in Figure 5.3, and includes a list of comments and the users who have liked the post.

A profile is the face of the user in the system and is a core piece in a social offering. According to [52], profile pages should be used in an application that encourages user-generated content and promotes relationship building. The profile should display to others the central information about the user (name, profile picture, a short biography) and relevant content concerning smiling earth. The concept of *My profile* is shown in Figure 5.3. On the profile pages, emission goals and pledges will be displayed to motivate others further to take climate action (SDG 13). Previously completed challenges are presented to show the users' concrete actions to mitigate climate change. Additionally, the teams the user is a member of are revealed on their profile.



(a) Preview of a user profile **(b)** The profile page a user in your network

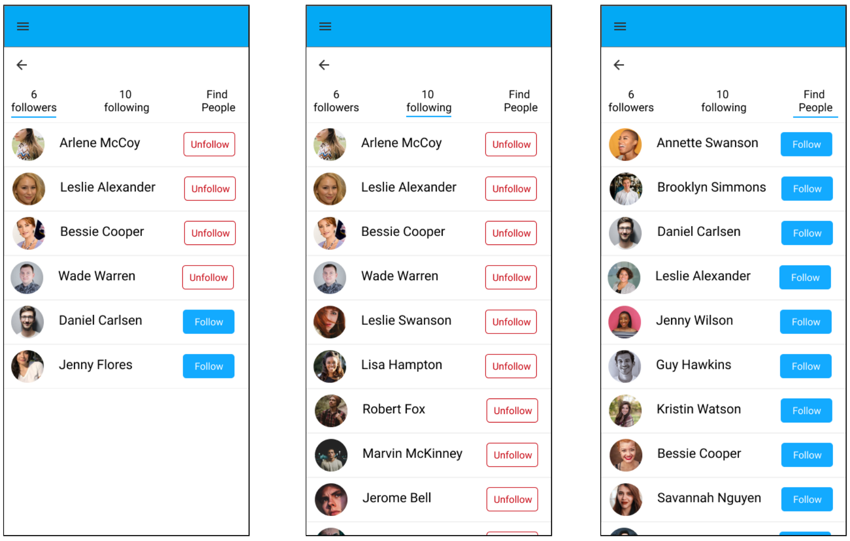
Figure 5.4: Showing the view of other users profile

Like the one on the home screen, a feed shows the users' activities, referred to as a *Post*. The Post may be private and thus only available to the present user. It is possible to go to a detailed view of a post by tapping on it. The detailed view is illustrated in Figure 5.3, and includes a list of comments and the users who have liked the post.

Similar to My Profile, it is possible to view other users' profile pages. This is shown in Figure 5.4. There are two kinds of profile pages, the one for users you follow and those you don't follow. The latter is a preview of their profile, containing limited information. The view is illustrated in Figure 5.4.a. When you follow a user, you get access to their profile containing all their public information, as shown in Figure 5.4.b.

5.5 Following and followers

In the prior version of Smiling Earth, a "friends" screen was added. The idea was that users could send friend requests to other users to connect. In this Smiling Earth version, friendships have been swapped out for one-way-following, also known as asynchronous following. According to [52], one-way-following should be used in situations where the content is more important than the relationship. The "following" screen is shown in Figure 5.5. It is divided into three columns, the first for users who follow you. The second is for the users you follow, and the third is for finding new users to follow.



(a) List of *followers* **(b)** List of *following* **(c)** List of other users

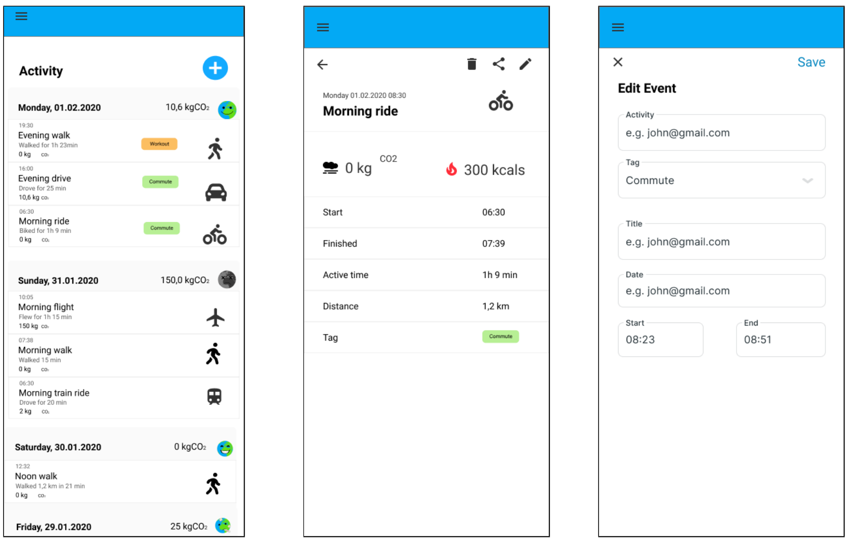
Figure 5.5: How the follower concept was designed

5.6 History

The history screen is inspired by the journal screen found in Google Fit (see Section 4.5.4). The idea behind that the users can get a list view of their previous recorded activities. Each list item contains information about the duration and the amount of carbon emitted from the activity. The list items are grouped by date, and the total CO2 emission of that day is shown. As this number may be hard to interpret, the smiling earth figure is used to understand the consequence. The earth is happy as long as the daily emitted carbon is less than 4 kg. The list view is shown in Figure 5.6.a. The user can tap on one of the elements from the list view and go to a detailed view. This view is shown in Figure 5.6.b. Here the user is presented with more information about the activity and the ability to edit, delete or publish the activity to their network.

From the feedback discussed in Section 3.1, it was stated the activity tracker was faulty or wrong. A limitation with the Google Activity Recognition API used by smiling earth is that it can only track walking, running, biking, and traveling in a vehicle. It cannot determine what kind of vehicle you are in. This version adds the option of editing recorded activities if they are wrong, as shown in see Figure 5.6.c. The user may also add an activity that was not recorded or if they did not have their phone during the activity. This also makes it possible to add new transportation methods like flying, a feature requested from the evaluation discussed in Section 3.1.

Another feature added is the ability to add tags to activities. We can group events and calculate the total amount of carbon emitted or time spent on the tag by adding a tag. E.g., users could tag their commute activities, and at the end of the month, they can tell how much carbon was emitted in their commute, or challenges can be created that check all the tagged activities. The system encourages users to share activities with their network to promote climate action. For example, say a user took a 5-hour train ride instead of flying, then the user could share the action and compare the emission with flying to tell how much carbon was saved.

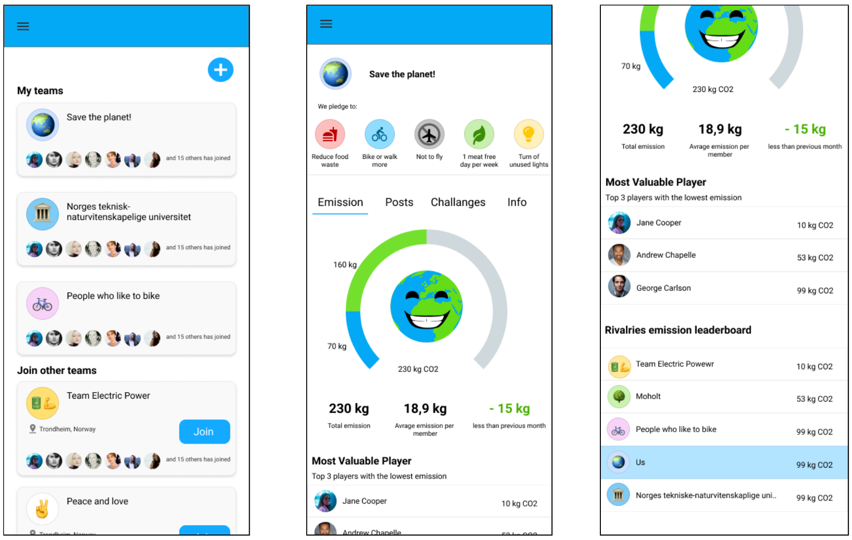


(a) List of recorded activities **(b)** Detailed view **(c)** Edit view of an activity

Figure 5.6: The history view containing the recorded activities

5.7 Teams

Online communities were added to the system in this thesis. During the co-design workshop, it was suggested to call the groups for Teams, as the different communities could compete and compare their results. The design for teams is shown in Figure 5.7 and Figure 5.8. A user shall be able to join or create a team from a list of teams, as shown in Figure 5.7.a. Each team has a scrollable dashboard similar to the home screen. It also includes leaderboards of the most valuable players in terms of emitted carbon and comparing their emissions to other teams, called rivals. This feature is shown in Figure 5.7.b and Figure 5.7.c.
The team's pages are divided into four parts. The first is the "Team Home" screen as described above. The rest is the feed(posts) screen, challenges screen, and information screen.



(a) Team List View **(b)** Team dashboard 1 **(c)** Team dashboard 2

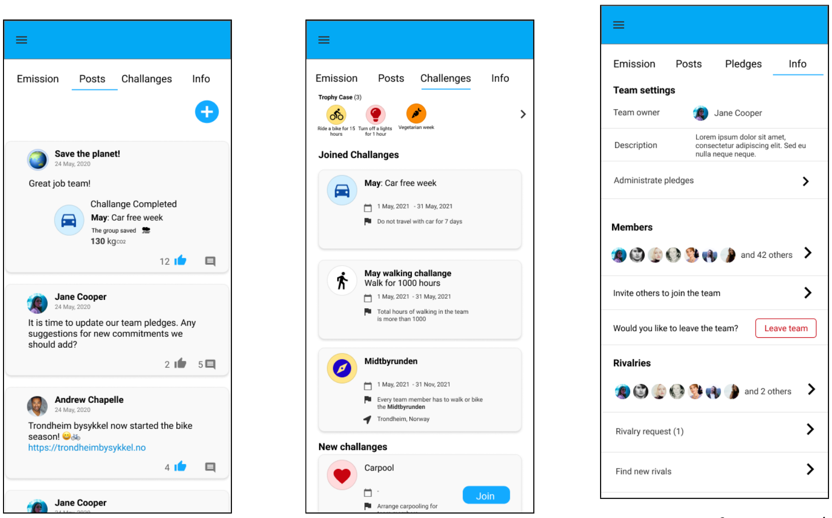
Figure 5.7: The Team View. The team dashboard is a scrollable view

The feed is a forum is presented in 5.8.a. This view aims to facilitate communication, discussion within the teams. The team members can comment and like posts published on the team feed. In addition, auto-generated posts such as joined or completed challenges will be posted here to motivate the team further.

In order to facilitate action within a team, group challenges and rivalries were created. Challenges function in the same way as for individual users (see section 5.8), only that the whole group's effort is calculated. The list view of teams' challenges is shown in Figure 5.8.b. The members can tap on one of the challenges to get a detailed view of the team challenge.

Rivalries are relationships between groups. One-way-following was chosen as the relationship between users as the content was more important than the relationship. The relationship is more meaningful for rivalries than the content; thereby, a two-way-following is more fitting.

The information screen displays information about the team and is shown in Figure 5.8.c. This includes name, icon, description, and members. It also shows who is the administrator for the group, which is the founder of the team. The administrator has special privileges like editing the group information from this page.



(a) Teams post

(b) Teams challenges

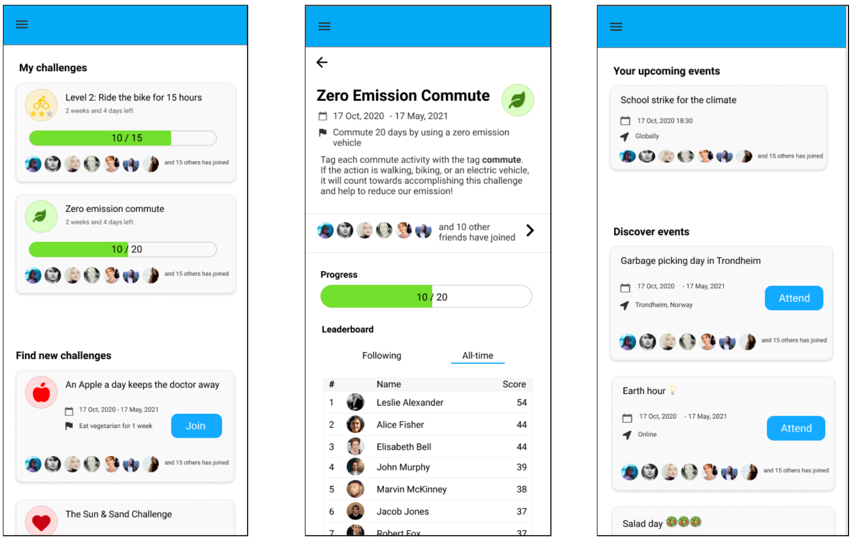
(c) Teams information/settings

Figure 5.8: The different team views

5.8 Challenges and Events

Challenges were added to Smiling Earth in the second version (see Section 3.1). However, due to time limitations, the feature was not completed. In this version, the challenges have been further developed to include social interfaces. When users go to the challenges page, a list view is shown of all joined and available challenges as shown in Figure 5.9.a. Each list item shows the challenge name and how many have joined. In addition, some challenges may be location restricted, meaning they are only available for users within a region. For challenges that the user has joined, the progression is shown. According to [83], users are motivated by seeing their progress, especially the closer they get to reaching the goal. To further support this, some challenges may be progressive. As you complete a challenge, you may unlock the next level.

By clicking on one of the challenges, users are presented with a detailed view



(a) Challenge List View **(b)** Challenge Detailed View **(c)** Event List View

Figure 5.9: Challenge and Event views

of the challenge (see Figure 5.9.b). The view includes a description of the challenge and a list of all the users that you follow who have joined the challenge. It also contains a leaderboard. In the leaderboard, the user can see how he/she scores compared to others who have joined, or they can filter on only people they follow.

From the workshop conducted in the specialization project, the participants requested to join and create events. Events are designed similarly to challenges (as shown in Figure 5.9.c) but differ as events occur within a short time window and do not contain a set of tasks to be completed. An event could be a physical meetup or something every participant is doing at the same time. For example, Earth hour could be an event where all users turn off all of their lights simultaneously for one hour.

5.9 Notification

As mentioned in the background study (see Section 3.1), it was suggested to add notifications when a user is close to completing a challenge. This could be a method of verbally persuading the users to complete a challenge, which is described as one of the steps to support users self-efficacy as described in Section 4.1.2. Notification could be expanded to include all types of feedback in the application. This helps the user get an overview of recent events and brings users back

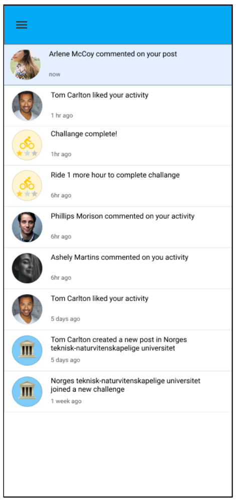
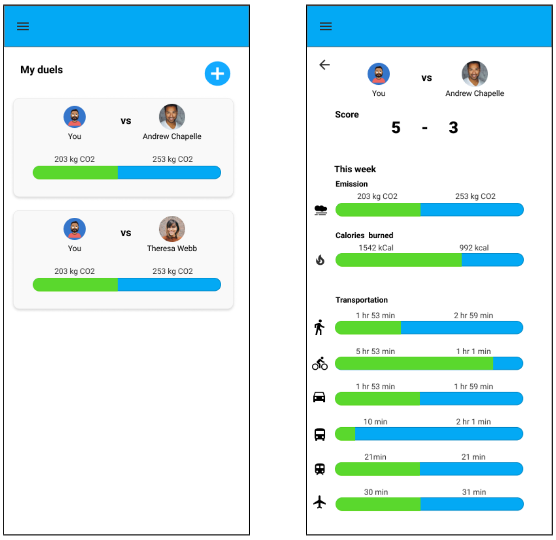


Figure 5.10: A list of the past notifications the user has received

into the application[52]. New notifications are highlighted with a different color. Though notification could be helpful, it must not be overused as this could annoy the user. The notification stream is shown in Figure 5.10.

5.10 Duel

A duel is a mode where the participants can directly compare different attributes like how much CO2 is released, how much time they have spent walking or riding a bike. The concept is inspired by a similar feature in Apple health (see Section 4.5.4) to promote user engagement and competition. The duels are weekly, meaning that the user with the lowest released carbon by the end of the week wins and gets the point. The following week it starts all over again. The application will keep the score between competing duels. The idea behind duels is to keep users returning to the app weekly or daily to get an update on their duels. The concept design is shown in Figure 5.11



(a) List of duels **(b)** Detailed duel view

Figure 5.11: The duel view

5.11 Summary

This chapter presented the new design prototype created in Figma. It included an introduction and description of the new features added to Smiling Earth and how to navigate between the different pages. The main features to be added are a profile, follow/following relations between users, the feed on the home screen, and communities (teams). These are essential building blocks in a social application like the new version of Smiling Earth. Additionally, challenges, a feature that was not completed in the previous version (see Section 3.1), has been updated.

Chapter 6

User evaluation of Prototype

As part of the user-centered design process, the user should be included as much as possible [15]. Conducting a usability test of an early prototype is a method of involving the user in the process. The purpose of this usability test is to evaluate whether the design works as intended and to iron out faults in the prototype. Additionally, the participants will help to prioritize which features to be implemented first in the development process. This chapter will discuss how the usability test for the design concept described in Chapter 5 was conducted. The usability test includes four parts, first an observation, followed by an interview with the user. Next, the participant was asked to fill out a questionnaire about the usability of the app. Finally, they were invited to sort cards with the different features according to what is most important to them.

6.1 Planning Usability Test

In order to receive feedback on the design concept described in Chapter 5, an in-lab usability test was conducted. The usability test followed the principles and advice from the book "Usability testing essentials" [84]. Participants were recruited from the researchers' network. All participants were in the age group 20-30, and all had prior knowledge of social media applications. According to Jakob Nielsen [18], the number of participants needed to find most usability faults in an application is five. More than five participants will return mostly overlapping results. Thereby five usability tests were conducted. The lab test followed the bare essentials for testing in a lab [84] which includes a dedicated room, a desk, and a computer. The participants were asked to execute six tasks and complete them using the wireframe prototype in Figma (see Chapter 5). Each participant was asked to think out loud while completing the tasks. When they encountered a problem, or something was unclear, the researcher noted it. To protect the rights of the participants, the evaluation applied for approval from *Norsk senter for forskningsdata* (NSD) before starting the test. From dialog with the NSD, the experiment was classified as anonymous since the evaluation did not store any participants' personal information. This meant there where no need to create a form of consent.

Nevertheless, the participants were all informed about their rights and what data would be collected before starting the evaluation.

Length of Test Sessions
Each test session will be last about one hour.

- Introduction 5 min
- Observation: 25 min
- Interview: 10 min
- Questionnaire: 10 min
- Card sorting: 10 min

6.1.1 Introduction

Every test session starts with a quick introduction to the project and assignment. Firstly, the participant is thanked for being interested in joining the usability test. Then the application was introduced, the purpose of the study and the testing process. Each participant was informed about their rights and that all notes and information gathered from the session would be anonymous. The participants were asked to think out loud and ask any questions concerning the task or application. Finally, they were given an introduction to how the Figma prototype worked.

6.1.2 Observation

The first assignment for the usability test was to complete seven tasks using the Figma prototype. The tasks were designed to evaluate the new features of the application. However, not all of the features designed in the prototype would be evaluated, as the usability test should not last too long, and it is recommended that a usability test should not contain more than eight tasks [85]. Each task consisted of a user goal and a user task. The user goal is what we want the participant to achieve, while the user task is the actual task the participant was given.

6.1.3 Post-test questionnaire - System Usability Scale

The System Usability Scale (SUS) by John Brooke[22] was chosen to assess the usability of the application as it is industry-standard and readily available. The SUS is a ten-question Likert scale that gives a general view of the user's impression of a system's usability. Each question has a five-option response from *Strongly agree* to *Strongly disagree*. After every participant had completed the evaluation, the average response of each question was calculated, and then the total SUS score. First, the SUS score is determined by adding all odd-numbered questions (1, 3, 5, etc.) and subtracting them by 5. Then all even-numbered questions are added and subtracted total from 25. Finally, by summing the two numbers and then multiplying them by 2.5, we receive a total score as a number out of 100.

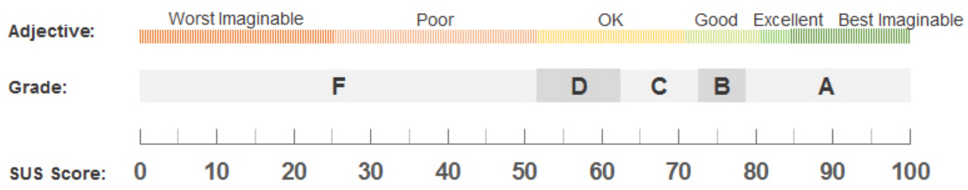


Figure 6.1: Grading and adjective for evaluating the System Usability Score [86]

Jeff Sauro [23] recommends comparing the result to a benchmark, such as an industry standard, to understand the SUS score better. He has created a grading system by reviewing over 500 products [86]. The results show that the average score of all products evaluated was 68. Furthermore, he argues that anything over 80 is graded as an A. The grading scale is shown in Figure 6.1.

6.1.4 Interview

Including an interview in the usability test provided an additional method for the participants to share their experiences in their own words [84] and to collect further feedback that was not discovered in the observation and questionnaire. The questions are listed below and include remarks about the application's design and features and the process of using the Figma prototype.

- What is your overall impression of Smiling Earth?
- What concepts of the application did you enjoy the most?
- What is your overall impression of Smiling Earth?
- What did you like the least?
- How was the experience of using the prototype to complete this task?
- What are your thoughts on the design and layout?
- Was there something you would like to change or add?

6.1.5 Card Sorting

Card sorting is a tool used early in the development process to better understand the users' preferences [84] and prioritize tasks for requirement elicitation. The task was performed by sorting post-it notes containing a feature in the application, according to what is most significant for the participants in an application like Smiling Earth. Additionally, a post-it note was added where the participant could suggest other features they would like to have in the application.

The board and post-its notes was created in a digital workshop application called *FigJam* [1], an online whiteboard created by Figma. The participants performed the

[1] `https://www.figma.com/file/hcTu6rHwORe9ABz25Gelvp/Usability-Test`

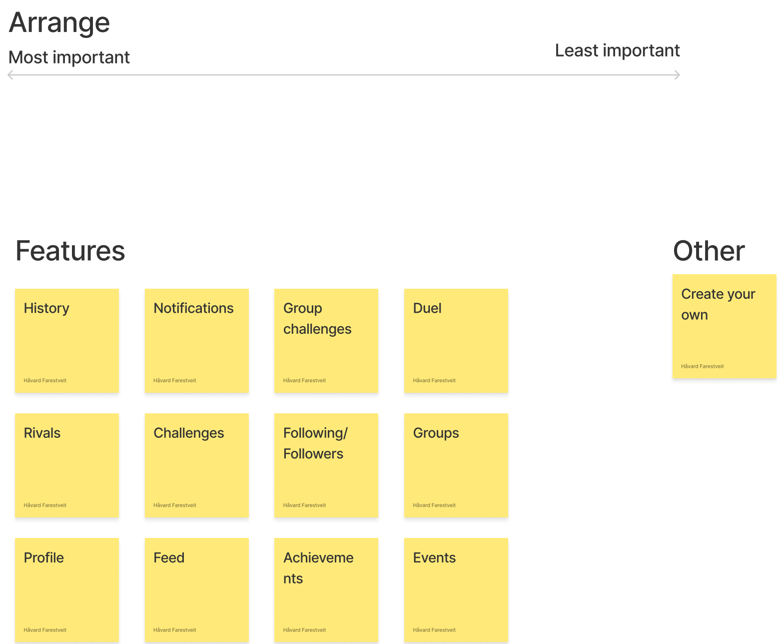


Figure 6.2: The board each participant was given and asked to prioritize from left to right according to the feature they found most important.

tasks digitally. The starting point each participant was given is shown in Figure 6.2.

6.2 Results

This section presents the results from the usability evaluation. First, the observation is presented, followed by the results from the questionnaire. Then the comments from the interview are summarized, and finally, the results from the feature prioritization are shown.

6.2.1 Observations

This section presents the results from the observation phase of the usability test.

Create a new user
Creating a new user went well for all users, with no or little problem in completing the task. One participant wanted the font size to be larger, and another participant pointed out the lack of help text or guidance on some of the input fields. Adding this could let the user better understand what and why this information is needed.

Additionally, the user missed an option for electric bikes in the vehicle list. Another user would have liked to have an option to fill some of the fields later, like how many kilometers they drive per year. Selecting climate action pledges went fine, but many participants would like more alternatives. Two users stated they would like to create a custom pledge.

How much carbon have you been emitting the past month?
This task was also completed with only minor issues. All users found the number quickly, but many mentioned that the text could be even more precise and maybe in another color. Two users would like to change the title from "emissions" to "your emissions". It was also mentioned that the graph on the home page was missing labels.

Find out what day you emitted the most during the past week.
Almost all users were a bit confused by this task. After registration, they landed on the home screen. The participants looked at the graph on the home screen to figure out this. After a while, when they could not answer the questions from the home page, they started to navigate to other pages and quickly found the "History page" and solved the task. Many of the participants stated that it was obvious where they should have looked when they saw the history page. Two of the participants said they liked the smiling earth icons on the table header that responded to the emitted carbon that day.

Find out if you are following "Lisa Hampton".
In this task, there were two possible methods of navigating to the user. All participants clicked on the "find people" tab in the navigation menu. After completing the task, they were shown the other option to go into your profile and click following. All participants said this was also a logical way of solving the task. Furthermore, while being on the profile page, three participants mentioned they liked the page's layout as the layout was familiar with other social applications.

How are you progressing in the challenge "Zero-emission Commute" compared to other users that you are following.
This task was completed without any problem. A user commented that navigating to the page was intuitive. The only problem that occurred was that one user pointed out that there was a miss-match between the score and the progress bar. This issue was fixed before the following participants started the evaluation.

You are a member of the team "save the planet". Find out how the team is doing in the challenge May: walking challenge compared to any rivaling teams?

This task also went smoothly without any issues. One participant said that they liked the standard navigation layout between the different pages in the application, referring to that the different features in the application are presented the same way. First, a list view of all the different pages to choose and then by clicking on them, you navigate to a detailed view. All the participants understood the concept of rivaling teams/groups.

You've got a new notification. What is it about?
Everyone completed this task without any problems. Three participants mentioned that it was like any other social app, which is easy to understand.

6.2.2 Questionnaire

From the post-test questionnaire, the sustain usability score is calculated with the formula described in section 6.1.3. The final score of the prototype was 85,5. The results from the questionnaire are shown in Table 6.1.

Question	Average score
1. I think that I would like to use this system frequently	4.2
2. I found the system unnecessarily complex	1.4
3. I thought the system was easy to use	4.2
4. I think that I would need the support of a technical person to be able to use this system	1
5. I found the various functions in this system were well integrated.	4.2
6. I thought there was too much inconsistency in this system.	1.6
7. I would imagine that most people would learn to use this system very quickly.	4.6
8. I found the system very cumbersome to use.	1.6
9. I felt very confident using the system	4
10. I needed to learn a lot of things before I could get going with this system	1.4

Table 6.1: Average score from the post-test questionnaire.

6.2.3 Interview

This section highlight summarizes the feedback received from the interview sessions.

1. What is the overall impression of smiling earth?
All users were positive towards Smiling Earth and the design. Some of the participants said they liked that the app used similar layouts to other social applications. This made it easy to understand the app. On the other hand, one user said they liked the user interface but were not fond of all the social aspects. The participant said that she used other social applications, mainly as a reader and not as an active participant. In addition, multiple participants expressed that the top bar on the home screen was confusing. They did not understand the connection between the numbers and suggested a more text-oriented solution or adding symbols to help understand the concept. One user said they would have liked a welcome message or something to make the layout more friendly. This was something the

participant was fond of from other applications that they used. Finally, some participants asked questions about how the emission calculations were calculated and proposed adding more fields like buying clothes or eating meat.

2. What concepts of the application did you enjoy the most?
One participant said that visiting others' profiles and looking at what pledges and actions they had done were a motivating feature. This spoke to the participant's curiosity. The same person also liked the challenges and the ability to compare their results to others. Another participant was very fond of collecting achievements and showcasing them on their profile. Finally, two users said that their favorite part was joining teams and collaborating to reduce their emissions or complete challenges.

3. What concepts of the application did you enjoy the least?
One of the participants emphasized the importance that not all of the activities should be public. Instead, it should be an option to publish an activity. Another user missed a better way of communicating with other users, like a chat or something similar. A third participant would like to have better rewards than digital trophies. The participant suggested rewards such as coupons, customizable in-app objects, or other digital content.

4. How was the experience of using the prototype to complete the task
All participants agreed that it took a minute or two to know what and where to press, but it generally was intuitive to use the Figma prototype. The first two users found a couple of bugs and spelling errors that were removed after the sessions.

5. What are your thoughts on the design and layout?
Most users liked the design and said the color choices were fine. Two users said they liked the layout and colors but suggested that the top application bar was too dominated and could be simplified. One participant also suggested adding a dark theme since they were used to having this in other apps. Another user suggested changing the menu on the team's page from a top navigation bar to a bottom bar, which the users were more familiar with from other applications.

6. Was there something you would like to change or add?
A participant suggested adding a bit more personal touches to the app. This could be changing the application's appearance or receiving a personal message instead of only showing numbers. The participant also suggested that the app could send a message to motivate the user to complete a challenge. The same participant missed something to keep them inside the app. Examples of this would be other content like videos or articles that make people use the app in longer sessions.

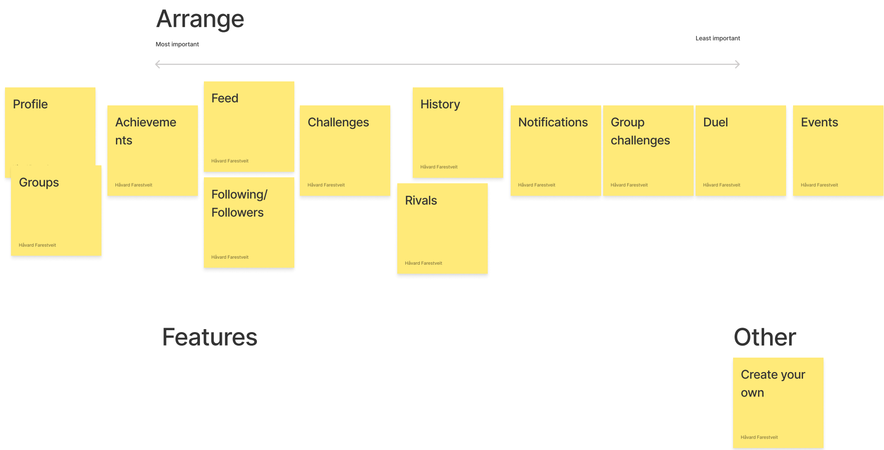


Figure 6.3: The average position of each feature

6.2.4 Board

All participant boards from the card sorting can be viewed in Appendix B. The average result is shown in Figure 6.3, and reveals that the most popular features to be implemented are Profile, Groups, and Achievements. Before implementing the application, the boards will be used to prioritize requirements.

6.3 Findings

The results from the usability test showed that potential users liked the app and found the user interface intuitive. Moreover, from the observation, all users completed the task with no or minor difficulties. Thus, no major usability faults were exposed, but some ideas for improvements were suggested. Such as to make the front page more personal and the top bar more intuitive.

From the post-test questionnaire, the prototype averaged a score of 85,5. According to Sauro[23], the average score for systems tested with the System usability scale is 67. Evaluating the score with the grading system shown in Figure 6.1, the design was graded A. Sauro denotes that receiving a score above 80.3 is the point where users are more likely to recommend the product to a friend or relative [23]

Chapter 7

Requirement Elicitation

This chapter describes the requirement elicited from the usability evaluation, interviews with users, and the technology and literature review. First, the functional requirements are presented, followed by a presentation of the quality attributes, which includes the non-functional requirements. Some of are the same as the once described in Chapter 3, others has been updated and new ones has be added. Some of the requirements descibred in Chapter 3 has been removed in order to reduce the scope for whats possible to complete in the this project, but is added in Future works in Chapter 13.

7.1 Functional Requirements

This section describes the main functionality of the application. Each requirement is listed in the different tables and includes an ID, a short description, and a priority. High priority means that the requirement is essential for running the application. Requirements with Medium priority are requirements that can improve the participant's enjoyment of using the application but are not essential to use the application. Low priorities are features that are nice to have further increase the user experience but not essential for the research. The list will be used to prioritize the different tasks to be done in the development process.

A common method for writing requirements is to use boilerplates. This is a grammatical structure with placeholders. The benefit of using boilerplate is that it allows requirements to be captured more consistently. Additionally, it is helpful when articulating the requirements, as it creates uniformity of the grammar and vocabulary used and assists in making the requirements atomic and verifiable [87].
The requirements were written using these boilerplate:

The <system/view/user/administrator> shall be able to <function><entity>
The <system/view/user/administrator> shall be able to <function><entity> when <statement>

A <feature of the system> shall be able to <function><entity>
A <feature of the system> can have <function>
The <system/view/user/administrator> shall be able to <function><entity> in <part of system>

7.1.1 User

ID	Description	Priority
FR1	The administrator shall be able to create new users	High
FR2	The user shall be able to sign into the system with provided username and password	High
FR3	The user shall be able to sign out	High
FR4	The user shall be able to see other users in a list	High
FR5	The user shall be able to follow other users	High
FR6	The administrator shall be able to delete users	High
FR7	The user shall be able to search for a user	Low
FR8	The user shall be able to view their own profile	High
FR8.1	The profile shall display a short biography (less than 200 characters)	High
FR8.2	The profile shall display the user's pledges	High
FR8.3	The profile shall display the user's activity posts	High
FR8.4	The profile shall display the user's achievements	High
FR8.5	The profile shall display the average daily emitted carbon from the past month	High
FR8.6	The profile shall display the teams that the user is a member of	High
FR8.7	The profile shall display the user's profile picture	Low
FR9	The user shall be able to view other users profile	Medium

Table 7.1: Functional requirement about user

7.1.2 Activity Tracking

ID	Description	Priority
FR10	The app shall automatically track the users movement	High
FR11	The app shall store recorded activities	High
FR12	The user shall be able to view the last recorded activities	High
FR13	The activity will show duration of activity	Medium
FR14	The activity will show start time	Medium
FR15	The activity will show how much carbon was emitted	Medium
FR16	The activities will be grouped by date	High
FR17	The grouped activities will show total emitted CO2 from that day	High

FR18	The user shall be able edit recorded activities	High
FR19	The user shall be able delete a recorded activity	High
FR20	The user shall be able to get a detailed view of an activity	Low
FR21	The detailed view will show calories burned	Low
FR22	The detailed view will show how much money was saved	Low
FR23	The activity can contain an optional tag	Low
FR24	The user shall be able to create an activity	High
FR25	The user shall be able share a recorded activity with their network	High

Table 7.2: Functional requirement about activity tracking

7.1.3 Post

ID	Description	Priority
FR26	The user shall be able to create a post	High
FR27	The user shall be able to like a post	High
FR28	The user shall be able to comment on a post	High
FR29	The user shall be able to view the latest posts from the users they follow in a feed	High
FR30	The user shall be able to delete a posts	Medium
FR31	The user shall be able to view the comments on a post	Medium
FR32	The user shall be able to view who have liked a post	Medium

Table 7.3: Functional requirement about posts

7.1.4 Teams

ID	Description	Priority
FR33	The administrator shall be able to create teams	High
FR34	The user shall be able to join a team	High
FR35	The user shall be able to view the teams total emission	Medium
FR36	The user shall be able to leave a team	Medium
FR37	The user shall be able to view a team leaderboard based on who has the lowest emission	Medium
FR38	The team view shall show a forum page where members can post comments	High
FR38.1	The user shall be able to create posts within a the team	Medium
FR39	The user shall be able to request other teams to become a rival	Low
FR40	The user shall be able to accept or decline rivalry request other teams	Low

FR41	The user shall be able to accept or decline rivalry request other teams	Low
FR42	The user shall be able to view a compare the teams emissions to their rivaling teams	Low
FR43	The team shall be able to join challenges	High
FR43	The user shall be able to create a team	Low
FR44	The user shall be able to invite other users to a team	Low
FR45	The user shall be able to search for new team by name	Low

Table 7.4: Functional requirement about teams

7.1.5 Notification

ID	Description	Priority
FR47	The user shall be able to receive notifications	High
FR48	The user shall be notified when new notifications are created	High
FR49	The user shall be able to view their notification	High
FR50	The notification view shall show the last 15 notification in chronological order	Medium
FR51	The notification view shall show new notifications in a different color	Medium
FR52	The system shall send a daily push notification to the user	Medium
FR53	The user shall go to the updated item when clicking on a notification	Low
FR54	The system shall send a push notification when new notifications are created	Low

Table 7.5: Functional requirement about notifications

7.1.6 Challenges

ID	Description	Priority
FR55	The system shall be able to create challenges	High
FR555.1	A challenge shall have a leaderboard of all participants	Medium
FR55.2	A challenge can have different levels	Medium
FR55.3	A challenge can be restricted to last a certain time period (A start and a finished date)	Medium
FR55.4	A challenge can be geographically restricted	Low
FR56	The user shall be able to view all joined, completed and not joined challenges	High

FR57	The user shall be able to view all challenges he/she has not joined	High
FR58	The user shall be able to join challenges	High
FR59	The user shall be able to view their progress in a challenge	High
FR60	The user shall be able to view all completed challenges	Medium
FR61	The system shall update the user's progress automatically	Medium
FR62	The user shall be notified when they are 50% completed with a challenge	Medium
FR63	The system shall create a post when a user has completed a challenge	Low
FR64	The system shall create a post when a user has joins a challenge	Low
FR65	The user shall be able to compare their results in challenge to other users in the challenge	Low
FR66	The user shall be able to compare their results in challenge to other users in the challenge	Low
FR67	The user shall be able to create a challenge	Low

Table 7.6: Functional requirement about notifications

7.1.7 Duel

ID	Description	Priority
FR68	The user shall to view all duels they have accepted	Medium
FR69	The duel view will compare the time traveled with different activities and emitted CO2	Low
FR70	The winner of the duel is the one with the lowest emitted CO2	Low
FR71	The winner of a duel will score a point	Low
FR72	The user shall be able to challenge another user to a duel	Low
FR73	The duel shall present the users emissions per kind of activity	Low
FR74	The user shall be able to accept or decline a duel request	Low
FR75	The system keep the score	

Table 7.7: Functional requirement about duel

7.1.8 Event

ID	Description	Priority
FR75	The administrator shall be able to create an event	Low
FR75.1	An event can be geographically restricted	Medium

FR75.2	An event shall have a start date and duration	High
FR76	The user shall be able to join an event	Low
FR77	By attending an event the user shall receive an achievement	Medium
FR78	The user shall view other users that have joined the event	Low
FR79	The user shall be able to create an event	Low
FR80	The user shall be able to invite other users to attend an event	Medium
FR81	The user shall be able to create an event	Low

Table 7.8: Functional requirement about events

7.2 Quality Attributes

This section describes the quality attribute requirements or non-functional requirements for Smiling Earth. A quality attribute requirement is defined by Bass et al. [88] as qualifications of the functional requirements or of the overall product. A qualification of a functional requirement is a non-functional property, such as how fast the function must be performed or how resilient it must be to erroneous input. The requirement is a measurable or testable property of the system used to indicate how well the system satisfies the needs of its stakeholders [88]. The main quality attribute for this system is *Modifiability*, *Usability*, *Security*, *Availability*, and *Privacy*. Different scenarios are described for each attribute and presented in this section.
The different scenarios are described using the template from the book *Software Architecture in Practice* [88]

7.2.1 Usability

Usability is concerned with how easy it is for the user to complete the desired task or to use the system efficiently. High usability is done by following established tactics such as Nielsen's 10 heuristics and receiving user feedback by conducting usability tests. The usability scenario is described in Table 7.9.

ID	UR1
Source	User
Stimulus	The participant should find the application easy to use
Artifact	Mobile Application
Environment	Run time
Response	90% percent of the participant shall find the application easy to use
Response Measure	Results from post user evaluation questionnaire
Priority	High

Table 7.9: 90% of the participant shall find the application easy to use

7.2.2 Modifiability

Modifiability is concerned with how easily changes to the system can be made. The change could come from different sources like the developer team, the system administrator, or users. The modifiability scenarios are described in Table 7.10, and Table 7.11, and includes that the system administrator shall be able to add new users, challenges. High modifiability is achieved by having a loose coupling between the components of the system and high cohesion. This could be supported by choosing technologies that focus on modifiability like Django and software architecture patterns like the Model View Controller.

ID	MR1
Source	Administrator
Stimulus	Want to add a new user
Artifact	Django admin page
Environment	Run time
Response	New users registered
Response Measure	10 minutes
Priority	High

Table 7.10: Add new user to Smiling Earth

ID	MR2
Source	Administrator
Stimulus	Want to add a new challenge
Artifact	Django admin page
Environment	Run time
Response	New users registered
Response Measure	10 minutes
Priority	High

Table 7.11: Add new challenge to Smiling Earth

7.2.3 Security

Security is a measure of the system's ability to protect data and information from unauthorized access while still providing access to users that are authorized [88]. Two scenarios are created to describe in Table 7.12 and Table 7.13. The first states that the client and server communication shall use secure protocols, and the second, that only authenticated users shall be able to access the server.

ID	SR1
Source	Developer
Stimulus	Reading and writing to the database should be done using secure protocols
Artifact	Server
Environment	Run time
Response	Shall return access denied when tring to connect to the database
Response Measure	less than 2 minutes
Priority	High

Table 7.12: Should not be able to read or write to the database outside of the Django Rest API

ID	SR2
Source	Client
Stimulus	Only authenticated users shall be able to send requests to the Rest API
Artifact	Server
Environment	Run time
Response	Shall return a "401 - Unauthorized" response from the server
Response Measure	less than 1 minutes
Priority	High

Table 7.13: Should not be able to read or write to the database outside of the Django Rest API

7.2.4 Availability

Availability is the property that the users shall be able to access the system when they want to. This system consists of two parts, a client and a server, and availability refers to the ability of the client to connect to the server. This quality attribute is described in scenario AR1, found in Table 7.14.

ID	AR1
Source	Client
Stimulus	The server shall be available 95% of the time
Artifact	Azure web application
Environment	Run time
Response	The Azure portal shall show that the backend server had less than 5% downtime
Response Measure	Less than 5% downtime in the Azure web app portal
Priority	Medium

Table 7.14: Should not be able to read or write to the database outside of the Django Rest API

7.2.5 Privacy

Privacy is closely related to security as both tries to prevent users data from being misused. Privacy focuses even more on this from normal usage of the application. The scenario PR1 described in Table 7.15 states that a user's identity shall be hidden from the other users.

ID	PR1
Source	Client
Stimulus	The users shall not be able to identify the other participants
Artifact	Mobile application
Environment	Run time
Response	
Response Measure	Shall not be able to identify the users when viewing their profile
Priority	High

Table 7.15: Should not be able to identify other users of the platform from their profile

Chapter 8

Development

This chapter describes the development process used when creating the new version of smiling earth. The overall process is illustrated in Figure 8.1 and includes a requirement elicitation phase (as described in Chapter 7), design phase (as described in Chapter 5), Technology review (as described in Section 4.6), Sprint planning, implementation and release phase. The implementation phase includes an iterative process of developing new features, building them locally, testing them, and deploying the changes. Elements from agile methodologies like Scrum and DevOps were used when developing the new system.

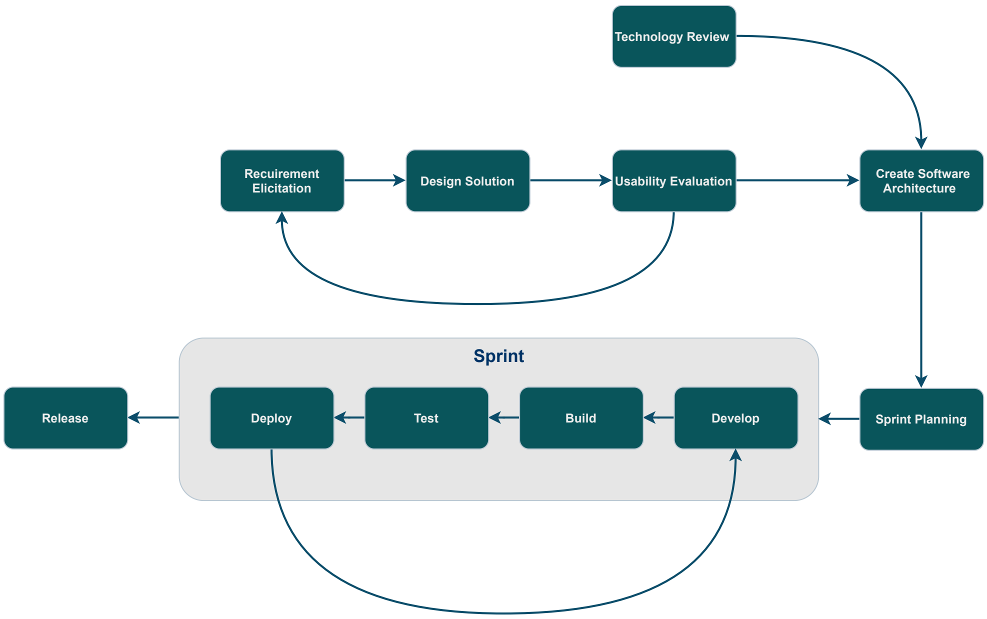


Figure 8.1: Development Process

8.1 Methodology

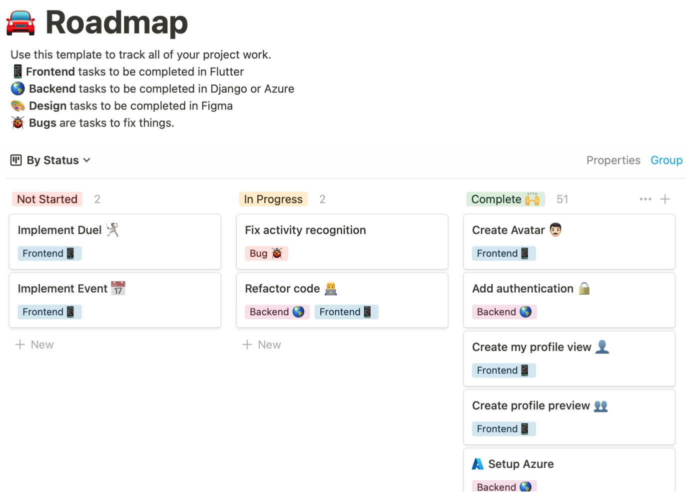


Figure 8.2: Notion kanban board

The development process used when creating the system was inspired by agile development methodologies like Scrum and DevOps. For example, the requirements were divided into groups called sprints. Each sprint had a time limit for when to be completed. The development timeline was divided into four sprints. The sprint plan is shown in Figure 8.3. A kanban board was created using Notion to keep track of the development progress and new issues. The board is shown in Figure 8.2 Additionally, bi-weekly stand-up meetings were held with my supervisor. We discussed the progress and areas to focus on until the next meeting during the sessions. Version control was used by hosting the project on GitHub. The project was divided into two repositories: a backend project (server) [1] and a frontend project (client) [2].

As described in Section 4.6.5, Continuous Integration and Continuous deployment were used when developing the system via GitHub Actions. This practice is a method commonly used in DevOps, which works complementary to the agile process described in the previous section. This is done by using branches in the Github repository. The repository uses three branches, main, develop and release. Each time a new commit is pushed to the developing branch, an action is run to build the project in GitHub Actions. If the build fails, there is an error in the code, and the developer is notified at once. When merging the developing branch into the main branch, an action is run to deploy the latest version to the Heroku Development Server. Finally, when merging the main branch into the release branch, the application is deployed to the release server running on Microsoft Azure. By

[1] `https://github.com/Havfar/Smiling-Earth-Backend`
[2] `https://github.com/Havfar/Smiling-Earth`

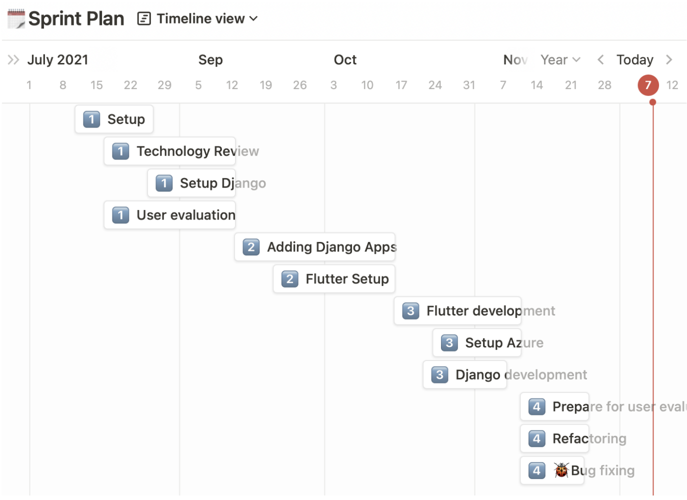
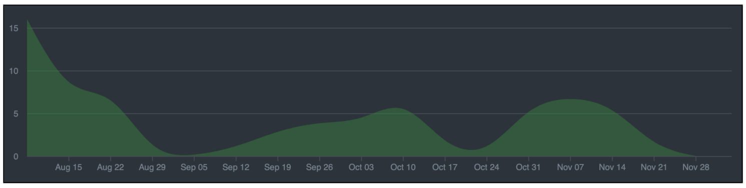


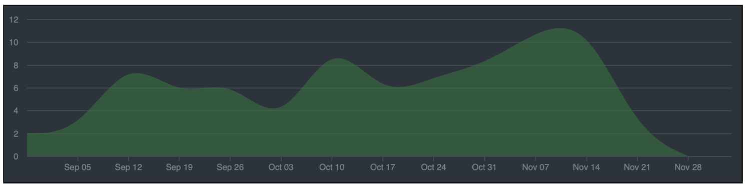
Figure 8.3: Sprint plan for developing the new application

CI/CD, we can get notified when there is an error before deploying it to the server, and it enables us to release often and thereby test the application rapidly.

Figure 8.4 shows the development progress of the system. During the process,



(a) Backend repository



(b) Frontend repository

Figure 8.4: The number of commits per day during the development of Smiling Earth

over 160 commits were pushed in total to the two repositories, where each commit contained new features or bug fixes. Figure 8.4.a illustrates daily commits to the backend application, and Figure 8.4.b shows commits to the frontend application. In the beginning, a lot of time was spent setting up the basic backend. This was needed in order to start developing the frontend application as a lot of data would be stored on the backend server. After the basic setup was completed, the main focus was on creating the client, with some backend updates when needed.

8.2 Evaluation of Requirements

This section evaluates how the application fulfilled the functional and non-functional requirements set before implementing the system. It is divided into two sections first, a review of the functional requirements, and then the quality attributes are reviewed.

8.2.1 Functional Requirements

Functional requirements define the central functionality that should be in place in the applications. The requirements were derived from the literature and technology review, a background study, and feedback from the usability evaluation of the prototype. Then the requirements were prioritized based on talking with the users and what made sense from a developer perspective. All functionality prioritized as High was added to the system. Most requirements prioritized as Medium or Low were implemented. However, some part was not implemented due to the time limitation of this project. The duel was not added with functionality, but a preview of how it could look like was implemented. Also, the event features were not added. From the usability evaluation events were the features that the least amount of participants wanted. It still would have been an addition to the system, but it was not prioritized to implement.
The tables in this section list each requirement and if it has been implemented. ✓indicates that it has been implemented, (✓) indicates that it has been implemented, but some users said they experienced problems with the features and - means not implemented.

User

ID	Description	Priority	Status
FR1	The administrator shall be able to create new users	High	✓
FR2	The user shall be able to sign into the system with provided username and password	High	✓
FR3	The user shall be able to sign out	High	✓
FR4	The user shall be able to see other users in a list	High	✓
FR5	The user shall be able to follow other users	High	✓
FR6	The administrator shall be able to delete users	High	✓
FR7	The user shall be able to search for a user	Low	-
FR8	The user shall be able to view their own profile	High	✓
FR8.1	The profile shall display a short biography (less than 200 characters)	Medium	✓
FR8.2	The profile shall display the user's pledges	Medium	✓
FR8.3	The profile shall display the user's activity posts	Medium	✓
FR8.4	The profile shall display the user's achievements	Medium	✓
FR8.5	The profile shall display the average daily emitted carbon from the past month	Medium	✓
FR8.6	The profile shall display the teams that the user is a member of	Medium	✓
FR8.7	The profile shall display the user's profile picture	Low	✓
FR9	The user shall be able to view other users profiles	Medium	✓

Table 8.1: Functional requirement about user

Activity Tracking

ID	Description	Priority	Status
FR10	The app shall automatically track the user's movement	High	✓
FR11	The app shall store recorded activities	High	✓
FR12	The user shall be able to view the last recorded activities	High	✓
FR13	The activity will show the duration of activity	Medium	✓
FR14	The activity will show start time	Medium	✓
FR15	The activity will show how much carbon was emitted	Medium	✓
FR16	The activities will be grouped by date	High	✓
FR17	The grouped activities will show total emitted CO2 from that day	High	✓
FR18	The user shall be able to edit recorded activities	High	✓
FR19	The user shall be able to delete a recorded activity	High	✓
FR20	The user shall be able to get a detailed view of an activity	Low	✓
FR21	The detailed view will show calories burned	Low	✓
FR22	The detailed view will show how much money was saved	Low	✓
FR23	The activity can contain an optional tag	Low	✓
FR24	The user shall be able to create an activity	High	✓
FR25	The user shall be able to share a recorded activity with their network	High	✓

Table 8.2: Functional requirement about activity tracking

Post

ID	Description	Priority	Status
FR26	The user shall be able to create a post	High	✓
FR27	The user shall be able to like a post	High	✓
FR28	The user shall be able to comment on a post	High	✓
FR29	The user shall be able to view the latest posts from the users they follow in a feed	Medium	✓
FR30	The user shall be able to delete a posts	Medium	-
FR31	The user shall be able to view the comments on a post	Medium	✓
FR32	The user shall be able to view who have liked a post	Medium	✓

Table 8.3: Functional requirement about posts

Teams

ID	Description	Priority	Status
FR33	The administrator shall be able to create teams	High	✓
FR34	The user shall be able to join a team	High	✓
FR35	The user shall be able to view the team total emission	Medium	✓
FR36	The user shall be able to leave a team	Medium	✓
FR37	The user shall be able to view a team leaderboard based on who has the lowest emission	Low	✓
FR38	The team view shall show a forum page where members can post comments	Medium	✓

FR38.1	A member of the team shall be able to create posts within a team	Medium	✓
FR39	A member of the team shall be able to request other teams to become a rival	Low	✓
FR40	A member of the team shall be able to accept or decline rivalry request other teams	Low	✓
FR41	A member of the team shall be able to accept or decline rivalry request other teams	Low	✓
FR42	A member of the team shall be able to view a compare the teams emissions to their rivaling teams	Low	✓
FR43	The team shall be able to join challenges	Medium	✓
FR43	The user shall be able to create a team	Low	-
FR44	The user shall be able to invite other users to a team	Low	-
FR45	The user shall be able to search for a new team by name	Low	-

Table 8.4: Functional requirement about teams

Notification

ID	Description	Priority	Status
FR47	The user shall be able to receive notifications	High	✓
FR48	The user shall be notified when new notifications are created	High	✓
FR49	The user shall be able to view their notification	High	✓
FR50	The notification view shall show the last 15 notification in chronological order	Medium	✓
FR51	The notification view shall show new notifications in a different color	Medium	✓
FR52	The system shall send a daily push notification to the user	Medium	✓
FR53	The user shall go to the updated item when clicking on a notification	Low	✓
FR54	The system shall send a push notification when new notifications are created	Low	-

Table 8.5: Functional requirement about notifications

Challenges

ID	Description	Priority	Status
FR55	The system shall be able to create challenges	High	✓
FR555.1	A challenge shall have a leaderboard of all participants	Medium	✓
FR55.2	A challenge can have different levels	Medium	✓
FR55.3	A challenge can be restricted to last a certain time period (A start and a finished date)	Medium	-
FR55.4	A challenge can be geographically restricted	Low	-
FR56	The user shall be able to view all joined challenges	High	✓
FR57	The user shall be able to view all challenges he/she has not joined	High	✓

FR58	The user shall be able to join challenges	High	✓
FR59	The user shall be able to view their progress in a challenge	High	✓
FR60	The user shall be able to view all completed challenges	Medium	✓
FR61	The system shall update the user's progress automatically	Medium	(✓)
FR62	The user shall be notified when they are 50% completed with a challenge	Low	✓
FR63	The system shall create a post when a user has completed a challenge	Low	✓
FR64	The system shall create a post when a user joins a challenge	Low	✓
FR65	The user shall be able to compare their results in a challenge to other users in the challenge	Low	✓
FR66	The user shall be able to compare their results in a challenge to other users in the challenge	Low	✓
FR67	The user shall be able to create a challenge	Low	-

Table 8.6: Functional requirement about challenges

Duel

ID	Description	Priority	Status
FR68	The user shall to view all duels they have accepted	Medium	-
FR69	The duel view will compare the time traveled with different activities and emitted CO2	Low	-
FR70	The winner of the duel is the one with the lowest emitted CO2	Low	-
FR71	The winner of a duel will score a point	Low	-
FR72	The user shall be able to challenge another user to a duel	Low	-
FR73	The duel shall present the users emissions per kind of activity	Low	-
FR74	The user shall be able to accept or decline a duel request	Low	-

Table 8.7: Functional requirement about duel

Event

ID	Description	Priority	Status
FR75	The administrator shall be able to create an event	Low	-
FR75.1	An event can be geographically restricted	Medium	-
FR75.2	An event shall have a start date and duration	High	-
FR76	The user shall be able to join an event	Low	-
FR77	By attending an event the user shall receive an achievement	Medium	-
FR78	The user shall view other users that have joined the event	Low	-
FR79	The user shall be able to create an event	Low	-
FR80	The user shall be able to invite other users to attend an event	Medium	-
FR81	The user shall be able to create an event	Low	-

Table 8.8: Functional requirement about events

8.2.2 Quality Attributes

This section presents the results from evaluating the quality attributes of the prototype application. The quality attributes are described in Section 7.2

Usability

Table 8.9 shows the results from testing the usability quality attribute UR1. The non-functional requirement was evaluated against the post-test evaluation described in Section 11.3.1. The results showed that 93% of the participants found the application easy to use, thereby surpassing the target for the requirement of 90%.

UR1: Usability of the application	
Environment	Run time
Stimuli	Response from post-test evaluation (see Chapter 11)
Expected Response Measure	90 % of the participants found the application easy to use
Observed Response Measure	93% of the participant found the application easy to use.
Evaluation	Success

Table 8.9: Evaluation of Usability Requirement 1

Modifiability

Table 8.10 and Table 8.11 illustrates the results from testing the modifiability quality attribute MR1 and MR2. The requirements were tested during run time. The goal was to add a challenge and create a new user within 10 minutes. By using the Django admin panel, the process of creating new entities is quick and easy. The process took around 1 minute for each requirement.

MR1: Add new user	
Environment	Run time
Stimuli	The administrator creates a new user from the Django admin panel
Expected Response Measure	Should take less than 10 minutes
Observed Response Measure	1 minute
Evaluation	Success

Table 8.10: Evaluation of Modifiability Requirement 1

MR2: Add a new challenge	
Environment	Run time
Stimuli	The administrator creates a new challenge from the Django admin panel
Expected Response Measure	Should take less than 10 minutes
Observed Response Measure	1 minute
Evaluation	Success

Table 8.11: Evaluation of Modifiability Requirement 2

Security

Table 8.12 and Table 8.13 presents the results from testing the security quality attribute SR1 and SR2. The requirements were tested during run time. The goal of SR1 was to prevent unwanted access to the database. This was solved by setting up Azure so that only the web service running the Django application could access the database. Any attempts of accessing the database from any other IP address than the one hosting the backend server fail.

The goal of SR2 is that only users with a valid token can access the Django application. When sending a request without a token or using an invalid token returns a 401 response, as shown in Figure 8.5.

SR1: Shall not be able to directly access the database	
Environment	Run time
Stimuli	Try to connect to the databse from a SQL management system (SQL workbench, Datagrip, Microsoft's DBMS)
Expected Response Measure	Not able to connect
Observed Response Measure	Not able to connect
Evaluation	Success

Table 8.12: Evaluation of Security Requirement 1

SR2: Shall not be able to access the API without providing auth token	
Environment	Run time
Stimuli	Sending a request to the different API access points
Expected Response Measure	Returns 401 Unauthorized
Observed Response Measure	Returns 401 Unauthorized
Evaluation	Success

Table 8.13: Evaluation of Security Requirement 2

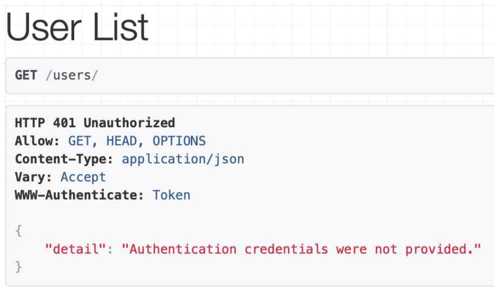


Figure 8.5: Response message when sending a request without a token or using an invalid token

Availability

Table 8.14 shows the results from testing the availability quality attribute AR1. The requirement was that less than 5 % of the responses from the server should be server errors (starting with 5xx). Figure 8.6 is a screenshot from Azure's response monitor and illustrates the reported 5xx responses from the backend during the test period. From the figure, only 11 responses were server errors. As presented in Section 11.2, during the test period, the server returned 11 000 responses. Therefore, this quality attribute requirement is approved.

AR1: The number of server error responses should be less than 5%	
Environment	Run time
Stimuli	Report on response starting with status code 5XX from the azure web portal
Expected Response Measure	Less than 5% of responses from the server shall be server error
Observed Response Measure	11 out 11 000 responses where 5xx server errors or 0.1%.
Evaluation	Success

Table 8.14: Evaluation of Availability Requirement 1

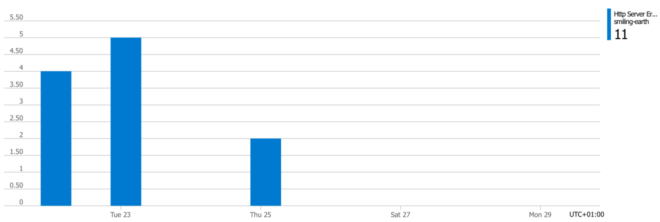


Figure 8.6: Number of server error responses from the backend server during the user test period

Privacy
Table 8.15 shows the results from testing the privacy quality attribute PR1. The requirement was that less than none of the participants should be able to identify the other participants from using the application. The requirements were tested by asking participants during the post-test interview sessions. The result was that none of the participants could identify the other participants.

PR1: The users shall not be able to identify the other participant	
Environment	Run time
Stimuli	From interviewing the users, they where asked if they could identify any other users
Expected Response Measure	No one knew the other user's real identity
Observed Response Measure	None of the participants interviewed knew the identity of the other participants
Evaluation	Success

Table 8.15: Evaluation of Privacy Requirement 1

Chapter 9

Software Architecture

This chapter presents the primary architectural and design patterns used in Smiling Earth. Even though the application's design is based on the previous versions of Smiling Earth, the software architecture and code is built from the ground up. Some parts of the old java code have been converted to flutter code, while others have been updated, added, or deleted. The chapter also describes how the background services used in the application.

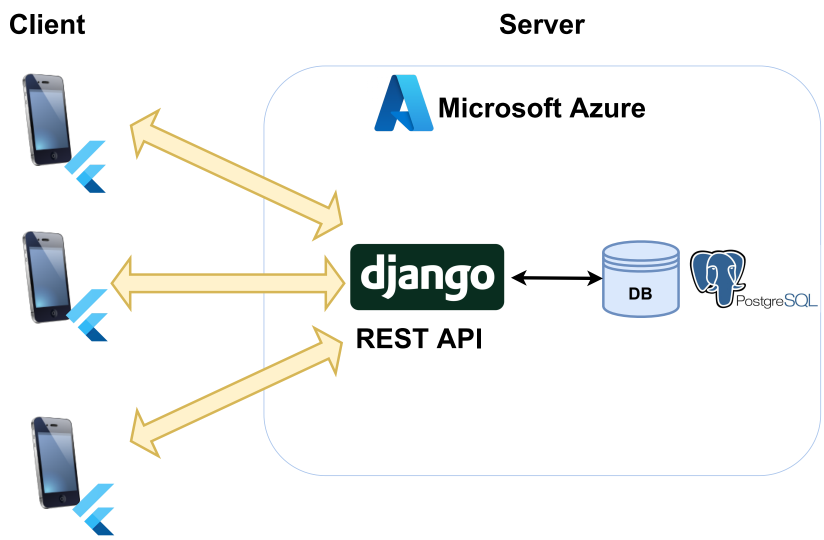


Figure 9.1: Overview of the Client Server Architecture of the application. Each client is running the Flutter Application, and connected to the backend by a Django REST API and a PostgresSQL database. Both the API and Database is hosted on Microsoft Azure

9.1 Client-Server

The main software architecture for the application is the Client-Server Pattern. The architecture is described in Figure 9.1 and consists of two parts, namely the *Client(s)* and the *Server*. Many different clients are running the Smiling Earth mobile application. Each communicates with the server via HTTPS requests to the Django REST API, then reads or writes to the PostgreSQL Database. The HTTP request can either be a GET, POST, DELETE or PUT request. The Django applications and database are hosted on Microsoft Azure but running on two separate virtual machines. Only the Django application is able to connect to the database, and all modifications of the database are done through the API or Admin panel as described in Section 4.6.3.

9.1.1 Backend

The backend architecture is described in detail in Figure 9.2. First, HTTPS requests are received by the Django applications, which looks up the address header of the request in urls.py and redirects it to the correct *view*. The view analyses that the sender of the request is an authenticated user and processes the request by doing a CRUD (Create, Read, Update, Delete) operation on the *Model*. The Model is a python description of a table in the database and is connected to the database. If the request is a Read operation, the object is converted from a python object to a JSON object through the *Serializer* and returned to Client as the body of an HTTPS Response sent by the view. If the client's request is declined or consists of an unknown URL address, an error message is returned.

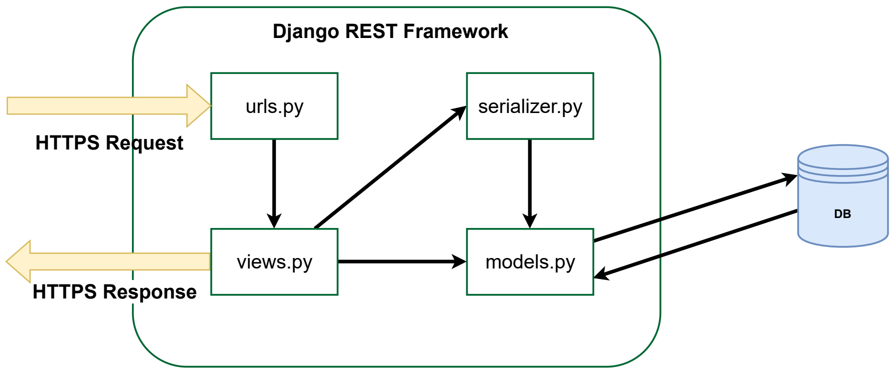


Figure 9.2: The architecture of the backend application. HTTPS requests are received by the applications and redirected to the correct endpoint (view) by looking up the address in the URLs file. The view processes the request and does a CRUD operation on the database via the Model. The returned object is converted from Python to JSON using the serializer and returned to the client as an HTTPS Response.

9.1.2 Database

Table Name	Purpose
user_user	Stores basic user information such as username, user ID, password
user_profile	Stores the user's name, biography and information about their avatar
user_follow	Stores all relations (following) between users
challenge_challenge	Stores all the challenges
challenge_user	A relations table that stores all challenges the users has joined
challenge_team	A relations table that stores all challenges the teams has joined
activity_activity	Stores all published activities
teams_teams	Stores all the teams
teams_member	A relations table that stores all teams the users has joined
teams_rival	Stores relations (rivalries) between teams
pledge_pledge	Stores all pledges
pledge_user	A relations table that stores all pledges the users has made
pledge_team	A relations table that stores all pledges teams has made
emissions_emission	Stores the weekly emissions the users has emitted ($CO2$)
notifications	Stores all notifications
post_post	Stores all posts
post_like	Stores all likes made on posts
post_comment	Stores all the comments commented on posts

Table 9.1: A short description of the tables in the Database and their purpose

The database comprises 17 tables, and their purpose is described in Table 9.1. Additionally, Entity Relation(ER) Diagram is visualized in Figure 9.3, and shows how the different tables relate to the user table. As this version introduces a social network, most tables relate to the user table—the two missing tables in the diagram concern team rivalries and team pledges.

9.1.3 Frontend

The frontend, or client, is running a Flutter application. Even though this version works on the previous version, all code had to be rewritten from traditional android structure to flutter. The main architecture pattern used in the frontend application is the Model-View-Controller(MVC).

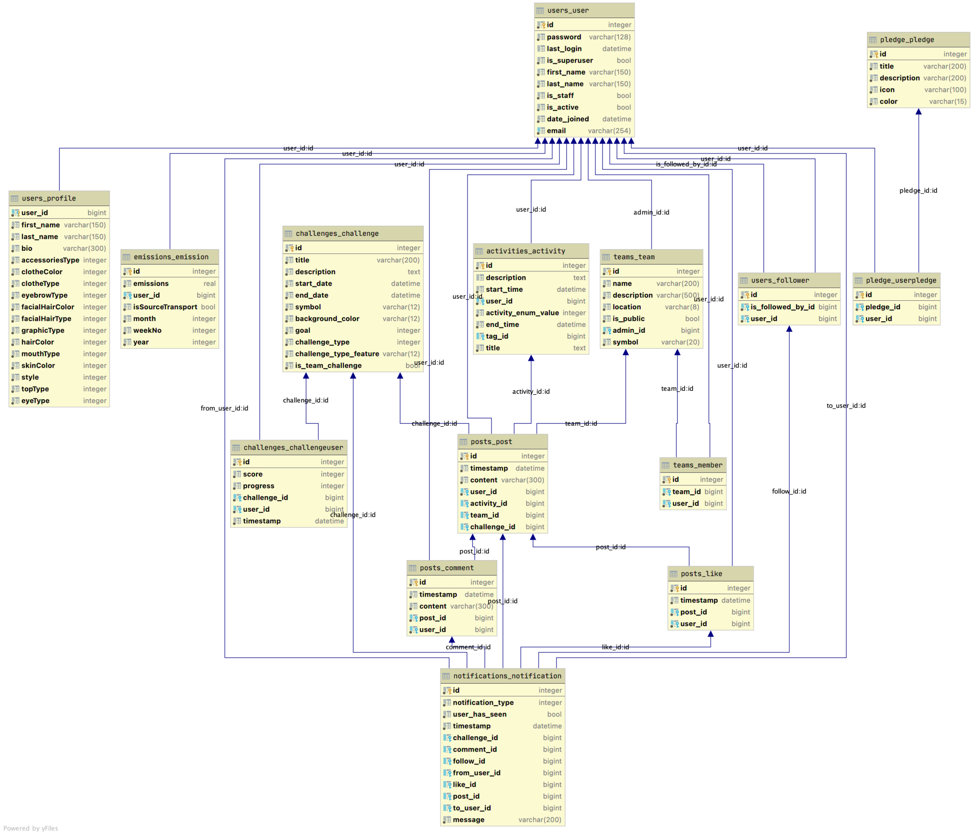


Figure 9.3: Database ER diagram of tables related to the user

Model-View-Controller

As the name suggests, the Model View Controller pattern divides the application into three components, *Model*, *View*, and *Controller*. The Model contains data objects that temporarily store data from the server or local databases. The view is what the user is presented with and visualizes the data stored in the Model. When the user interacts with the view, they activate the controller, which alters the Model, which in turn is updated to the view. Using this architectural pattern increases the modifiability of the applications by reducing the coupling of components and increasing the cohesion of the system [88].

Local Databases

Each application contains four local databases that the model interacts with. The first is the Energy Database, which stores the recorded energy usages of the users. Next is the activity database. This database contains all the registered activities that the user has completed. The third is the settings database which includes basic user settings like information about their house, travel habits, and other information the user added during registration. The final database uses the Flutter

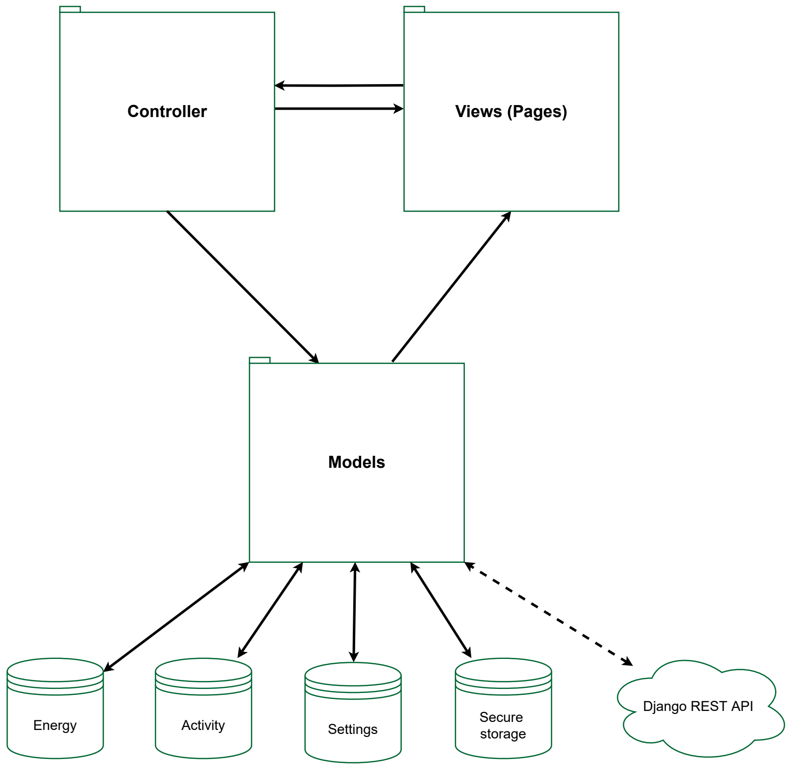


Figure 9.4: The architecture of the backend application. HTTPS request are received by the applications and redirected to the correct endpoint (view) by looking up the address in the urls file. The view processes the request and does a CRUD operation on the database via the Model. The return object is converted from Python to JSON using the serializer and return to the client as a HTTPS Response

Secure Storage solution, which encrypts the data entries and is only available when using this application. This database contains the unique authentications tokens used to confirm the user's identity to the backend server..

Background services

While the participants are using the application, the application runs five tasks in the background. First, the activity recognition detects any movement of the device and tries to estimate the kind of movement and the duration. Then, the last four tasks run periodically. One task updates the user's energy consumption once an hour, while another updates the participant's emission to the backend four times a day. The third task updates the user's progress in the challenges they have joined. This task is called once every 6 hours. The final background service is a daily push notification to prompt the users to open the application.

9.2 Design Patterns

The project architecture includes several kinds of Design Patterns. On the backend side, the most prominent is the *Template method*. Frameworks such as Django Rest Framework come with many pre-built components and classes that we can extend. The patterns can be grouped into two categories in the frontend application: Creational patterns and state patterns. There are two creational patterns used, the singleton and factory pattern. We can ensure that only one instance of an object exists and that all objects interact with the same instance with a singleton. The factory pattern is used to translate JSON objects sent from the Server into Dart objects. In flutter, there are many different ways of handling state. Some components are only interested in their own state. Flutter comes with a pre-build class called stateful widget, which can be extended to handle this. Each time the form is changed, the component will rebuild. This kind of state management fits for smaller components. For more advanced widgets, the Cubit or Bloc Design Patterns were implemented. The bloc pattern is used in the application for the Login and registration process, while the cubit pattern is used for other kinds of requests to the server.

9.3 Summary

This chapter presented the software architecture designed in this application. The main architecture is Client-Server, where the client is the Flutter mobile application, and the server is the Django backend application. Additionally, the PostgreSQL database is described in detail. The Model View Controller (MVC) Architectural patterns were also used, as this is an industry-standard method for structuring software systems, and it supports the overall modifiability of the system.

Chapter 10

Evaluation

This chapter presents how the user evaluation of the application was conducted. It describes how participants were recruited and how the application was distributed. After the application was installed on the participant's phone, the participants were asked to use the application for one week. Before and after the test period, each participant was asked to answer a questionnaire. By the end of the user test, four participants were invited to partake in an interview to retrieve further information about their experiences.

10.1 Evaluation Design

The goal of the evaluation was to test the application and gather data that could help answer the following research questions:

RQ1: *How can social computing enhance the application?*
RQ1.1: *What social functions is most effective to motivate the users to act more sustainable?*
The experiment will gather data to answer RQ1 and RQ1.1 by analyzing if making the application more social has enhanced the user experience. If so, which part of the application has been most important in increasing users' motivation to act more sustainable.

RQ2.1: *Determine which intervention components support the key social cognitive theory constructs*
The evaluation will investigate which part of the application supports the key constructs of Social Cognitive Theory, including Self-efficacy, Collective-efficacy, observational learning, outcome expectations, and self-regulation.

RQ3: *How do theories of online communities contribute to increasing user motivation and promote pro-environmental behavior change?*

The experiment will also evaluate how different online communities based on theoretical communities like the community of practice and community of interest have influenced users to behave more sustainably.

RQ4: *How does anonymity affect the interaction between the users of Smiling Earth?* The fourth and final research question that the experiment will answer is how anonymity has affected user interaction. This includes the willingness and motivation to share content, join groups, follow other users and give likes and comments on other users' posts.

The data generated from the experiment was both quantitative and qualitative. The participants were asked to fill out a pre-test questionnaire before downloading and using the application. During testing, the users generated quantitative data from using the application. After evaluating the application, they were asked to answer a post-test questionnaire. The questionnaires were mainly quantitative but included three textual questions classified as qualitative data. In addition, four of the participants were invited to an interview to gather qualitative data on their experience.

10.2 Participants

The population of this experiment was recruited from the network of the researcher and consisted of friends, family, and co-students who owned an Android device. Additional two participants were recruited via one participant. A total of 20 people showed interest in joining the evaluation. Unfortunately, two declined the offer to join, one because he did not have time and the other was not allowed to download an unlicensed application on their work phone. Thereby the population of this experiment was 18 participants. The different participants were invited based on age, gender, whether they owned a car or not and owned an android device. Each participant was initially contacted either in person or through social media. After the initial contact, communication between researcher and participant was conducted using email.

10.3 Distribution of application

Each participant of the experiment received an email with information about the evaluation, a description of the application, their rights and privacy, and a guide on how to get started with application. The guide included a link to download the APK-file, how to install the file onto their device and their unique username and password to the application. The APK-file was hosted on Microsoft One-Drive, and the mapping between their login credentials and email was stored in an encrypted Excel document. The participant used the application on their own initiative during the test period and the only requirement to participate was to complete the registration and use the application at least one time.

10.4 Questionnaire

The questionnaires were created using Microsoft Form. The questionnaire was mainly answered using Likert scales, and some questions were multiple choice and three optional questions with free-text answers. Both instances of the questionnaires can be viewed in Appendix G.

10.4.1 Pre-test Questionnaire

The first questionnaire was delivered to the participant to be answered before downloading the application. The goal of the questionnaire was to gather some basic information about the participants. The survey consisted of ten questions distributed over four sections. The first and second sections are concerned about demographic data and their attitudes towards climate change and the environment. The third part focused on their transportation habits, while the final part asked about their usage of different social media applications. The participant was asked to enter the anonymous username that was sent to them individually. By submitting their username, it would be possible to compare their answers to their in-app activities and to the post-test questionnaire.

Demographic
This section collected the participant's demographic information, including their age, gender, and username.

Attitude towards Climate Change
This section collected the participant's attitudes concerning Climate Change. This included statements about how worried they are about climate change and their motivation and willingness to act more environmentally friendly. The statements are listed in Table 10.1).

ID	Statement
S1	I am concerned about climate change
S2	I am a environmental conscious person
S3	I want to reduce my carbon footprint
S4	I find it hard to motivate me to take environmentally friendly choices

Table 10.1: Statements about climate change

Transportation Habits
As more sustainable transportation habits are something Smiling Earth tries to

promote, it is important to map the participant's transportation habits. The section consists of two questions and is described in Table 10.2.

ID	Question	Format
Q1	Do you own a car?	Multiple Choice
Q2	Which means of transportation do you use on a daily basis?	Multiple Choice

Table 10.2: Questions about transportation habits

Social Media Habits

Table 10.3 shows the questions regarding participants' social media habits, including what social media they use and how often they publish posts or share content on the different platforms.

ID	Questions	Format
Q3	What Social Medias do you use?	Multiple Choice
Q4	How often do you publish to Social Media Apps	Multiple Choice

Table 10.3: Questions about Social Media Habits

10.4.2 Post-test Questionnaire

After a week of testing the application, the post-test questionnaire was distributed to the participants. The questions consisted of primarily multiple-choice questions, Likert scale statements, and some open text questions to uncover thoughts and feedback on the application. The survey consisted of 58 Statements and 7 questions divided into 10 categories.

General
In the first section, the participant was asked to fill in their username in order to map their answers to their pre-test answers and the data generated during the testing period. Additionally, they were asked if they experienced any issues while testing and described what problems occurred. Next, the users were asked to respond to four statements about their experience using the application. The statements was designed based on Technology Acceptance Model, as described in Section 2.2.7. The model will be used to determine if the application is accepted by the users and compare the results to the previous versions of Smiling Earth. The statements are shown in Table 10.4. They include opinions about the perceived usability and usefulness of the application and whether they would like to use it.

ID	Statement
S1	I think the application was easy to use
S2	I think the application was useful to get an overview of my carbon emissions
S3	I think the application was useful in motivating me to act more sustainable
S4	I would like to user Smiling Earth

Table 10.4: Statements about the users perceived usability, usefulness, and indent of use

Smiling Earth as a Social Application
The next section of the survey included two groups of statements. The first is listed in Table 10.5 and comprises statements about how the participants perceived Smiling Earth as a social application. The second group contained statements concerning which social feature affected the user's motivation to act more environmentally friendly. The statements are listed in Table 10.6.

ID	Statements
S5	Social functions motivated me to open the application
S6	I would ask others I know to download the application and follow my user
S7	Since other people could view my carbon emissions made me motivated to act more environmentally friendly

S8	By viewing other users do environmentally friendly actions motivated me to do the same
S9	The app would have been better without social functionality

Table 10.5: Statements about social functionality

ID	Statements (I get motivated to act environmentally friendly by..)
S10	Sharing a post with my followers
S11	Sharing an activity with my followers
S12	Getting likes on my posts
S13	Getting comments on my posts
S14	Being a member of a community (team)
S15	Comparing my results in a challenge with other users
S16	Comparing my emissions with another user in a duel
S17	Having the lowest emission in any members in a team
S18	Keeping the total emission low in a team
S19	The team joining a team challenge
S20	Other users following me
S21	Following other users
S22	Comparing emissions in a team with a rivaling team
S23	Looking at other users profiles and seeing their activity
S24	Making a pledge to become more environmentally friendly.
S25	Completing a challenge so that I can share it with my followers

Table 10.6: Statements about which social functionality motivated the users

Social Cognitive Theory

The goal of the following sections is to determine which intervention components were most effective in supporting the key constructs of Social Cognitive Theory. This includes statements about the participant's perceived Self-efficacy, Collective-efficacy, Self-regulation, Observational Learning, and Outcome Expectations. The answers will be used to answer Research Question 2 and 2.1.

Self-efficacy

Self-efficacy is the notion of a person's belief in accomplishing a specific task. As discussed in Section 4.1.2, Bandura describes four methods of developing self-efficacy: building on prior experiences, modeling your behavior after someone who already masters the task, enhancing your physical and emotional state, and finally, being persuaded verbally. The statements about self-efficacy are listed in Table 10.7. Statements S26, S27, S28, 30, and S31 concern prior experiences, S30 and S32 regard social modeling, S34 and S35 concerns emotional state, and S29 are about verbal persuasion.

ID	Statements
S26	The app recording my activities gave me the belief that I could keep overall low carbon emissions.
S27	I observed other users complete a challenge gave me the belief that I could also complete the challenge.
S28	Getting feedback on my climate emissions from the smiling earth on the home screen (smiling earth graph)
S29	Getting a notification when I was more than halfway finished a challenge gave me the belief that I could complete the challenge
S30	Observing that others managed to keep a low emission gave me the belief that I could also manage to keep a low emission
S31	Completing a challenge gave me the belief to take on a new challenge.
S32	By making a pledge, it gave me the belief that I could keep the pledge
S33	Seeing others also make a pledge gave me the belief to keep my pledges
S34	It affected me positively to see the welcome message at the top of the home screen
S35	It affected me positively to see the smiling globe when I kept the emissions low.

Table 10.7: Statements about which intervention components supported the user's self-efficacy

Collective efficacy

As mentioned in Section 4.1.3, the same method for developing self-efficacy can be applied to establish collective efficacy. The statements described in Table 10.8, try to understand which intervention components in the application improved on the user's perceived collective efficacy. S33 and S34 ask about building on prior experiences, while S35 and S36 question social modeling.

ID	Statements
S36	When the team completed a team challenge gave me faith that we could complete a new challenge.
S37	Seeing the group's total CO2 emissions gave me faith that together, we would be able to keep a low emission (less than 4 kg CO2)
S38	By observing other members of the group manage to keep their emissions low gave me faith we could keep a low emission
S39	By observing other rivaling teams having low emissions made me believe that our group could also keep a low emission

Table 10.8: Statements about which intervention components supported collective-efficacy

Self Regulation

Section 4.1.4 describes the six steps in achieving self-regulation. This section tries to analyze how the application supports these steps, and the questions asked to the participants are listed in Table 10.9. All questions are multiple-choice and include a list of features in the application. The participant can select multiple items that they thought helped them. The first to support self-regulation is self-monitoring, which questions Q1 tries to evaluate. Next, Q2 examines the app's ability to support the second step, goal-setting. Question Q3 concerns how the application can return feedback (step No. 3) to the user. The following step is self-reward, which is examined by Q5. Step 5 is self-instruction, when someone talks to themselves when performing a complex behavior. This step is not analyzed in this thesis as it would be too difficult to examine as it would include detailed observations of the users interaction with the application. The last step is the enlistment of Social Support. Question Q4 asks which part of the system the user perceives the application as a source of social enlistment.

ID	Questions	Format
Q1	Choose one or more features of the application that made you monitor your emissions	Multiple Choice
Q2	Choose one or more features of the application that gave you a goal to achieve	Multiple Choice
Q3	Choose one or more features of the application that gave you feedback on how environmentally friendly your actions were	Multiple Choice
Q4	Choose one or more features of the application that made it possible for other users to encourage you to make environmentally friendly choices	Multiple Choice
Q5	Choose one or more features of the application that gave you a kind of reward to work towards	Multiple Choice

Table 10.9: Questions regarding the applications ability to support self-regulation

Observational Learning

Observational learning is the concept of modeling your behavior after other people as outlined in Section 4.1.1. The following statements are about how the application facilitates observational learning. The statements are listed in Table 10.10 and concern the key determinants for observational learning: attention, retention, production, and motivation.

ID	Statements
S40	Seeing other users participate in a challenge led me to join the same challenge
S41	Seeing other users complete a challenge motivated me to complete the same challenge

S42	Seeing other users share an activity they had done motivated me to do a similar activity
S43	Seeing other users make a pledge motivated me to make the same promise
S44	Seeing other users in a team have lower emissions than me motivated me to reduce my emissions
S45	Seeing other users in a challenge achieve better results than me motivated me to improve my results
S46	Seeing other users share a post about an environmentally friendly action motivated me to act more sustainably

Table 10.10: Statements about which intervention components supported observational learning

Outcome Expectation

Outcome expectation is the possible consequences we think can occur from our behavior and is explained in more detail in Section 4.1.5. A goal of the application is to create more awareness around our carbon emissions. Therefore, the next statements, as listed in Table 10.11, analyze which part of the application made the participant aware of their habits' possible outcome on the environment.

ID	Statements
S47	The CO2 emissions from my previous activities made me aware of the consequences of my habits on the environment
S48	Notifications about my progress in a challenge made it visible to me what I had to do to complete the challenge
S49	The change in the Smiling Earth graph on the home screen made me aware of the consequences my habits have on the environment
S50	Posts other users shared made me aware of how my own habits affect the environment

Table 10.11: Statements about which intervention components supported outcome expectations

Anonymity
Research question 4 tries to answer how anonymity affects the users in a social media application like Smiling Earth. The following statement examines how the participants felt about being anonymous and not knowing the other participant's identity. The statements are listed in Table 10.12.

ID	Statements
S51	I find it easier to like posts when I'm anonymous
S52	I find it easier to comment on posts when I'm anonymous
S53	I find it easier to follow other users when I am anonymous
S54	I find it easier to join teams when I am anonymous
S55	I am more motivated to follow other users when I do not know their identity
S56	I'm more motivated to share content with my followers when I'm anonymous
S57	I would have been more motivated to use the app if I could use my own name
S58	I would have been more motivated to use the app if I knew the identities of the other users

Table 10.12: Statements about how anonymity affected the participant's motivation to interact with others and to use the application.

Online Communities
This section asks the participants about how communities were helpful in motivating them to act more sustainably. The results will be used to answer research question 3. The first question asks if the participant believes online communities could support more environmentally friendly habits. Then the section is divided into four sub-sections, one for each type of community evaluated in the application. The different kinds of communities are described in Section 4.3 and include communities with random users, Communities of Interest, Communities of Practice, and location-based communities. Each subsection comprises of same questions as described in Table10.13. First, a question is asked if the participant was a member of one of the communities. If not, why did they not take part in the community? This question tries to expose any limitation of the experiment. Then they are asked to answer three statements concerning if each kind of community is suitable in motivating them to achieve a more environmentally friendly behavior. The statements are listed in Table 10.14

ID	Questions	Format
Q6	Were you a member of a any of these communities: [List the different communities]?	Multiple Choice
Q7	If no, why did you not join any of the communities	Multiple Choice

Table 10.13: Questions about if the users were a part of the listed communities, and why not?

ID	Statements (Teams based on [location/randoms/interests/practice] ...)
S56	are suitable to increase my motivation to act environmentally friendly
S57	are suitable to increase that I changed my habits in a more environmentally friendly direction
S58	made me more motivated to use Smiling Earth

Table 10.14: Statements about how groups could motivate the participants.

Additional Comments to the application

The final section of the post-test questionnaire includes two open-ended questions. The first question asked for additional comments on the user experience of using this version of Smiling Earth, while the second asked for improvements to the application. Both questions can be helpful to highlight faults with the application and ideas for future development.

10.5 Interview

After testing the application, four participants were invited to an interview about their experiences of using the application. The interview was estimated to take about 30 minutes and consisted of 8 questions. The answers are considered qualitative data and will be used to validate the questionnaire results and get more details on each topic. The questions were open and asked in a conversation-like manner. Interviews also open up for follow-up questions about what the users experienced or thought.

First, the participant was informed about the purpose of the interview, that their answer would be anonymous and that they should answer as honestly as possible to mitigate bias towards the researcher. Some of the interviews were conducted in person, while others were online interviews using Zoom. Notes were taken during the interview by the researcher.

The interview questions are described in Table 10.15

#	**Question**
1	How did you like using Smiling Earth
2	Did you meet any issues while testing the application?
3	Do you think making the application social enhanced the application?
4	How did the app affect your motivation to act more sustainable?
5	How do you feel about using it as an anonymous social network?
6	How did you like being a part of a team?
7	Do you think online communities could motivate people to act more environmentally friendly?
8	Do you have any comments on how Smiling Earth could better motivate people to act more environmentally friendly?

Table 10.15: The interview questions

10.6 User Generated Data

During the testing period, the participant will generate data by using the application and sending information to the database through the back-end API. Reviewing the data will give insight into how the application was used. The data that will be stored in the database and analyzed includes:

- Relations between users (follow/following)
- Post that the users created (number of posts and content)
- Which team the user is a member of
- Which challenges the user has joined and their progress in those challenges
- Which team challenges the different teams has joined
- Each users emissions from transportation and electricity
- Likes and comments on posts
- Which pledges the users had made

10.7 Reliability and Validity

This section discusses factors that might have impacted the result of the experiment.

10.7.1 Hawthorne effect

The results from the experiment may be somewhat affected by the Hawthorne effect, which is described as when results depend on the fact that the subjects in a study have been aware that they are part of an experiment and are receiving extra attention as a result [89]. In order to mitigate the Hawthorne effect, the users can use the application on their own devices and over an extended period. This would hopefully reduce the impact of Hawthorne, but it is still not the same as if the users would have downloaded it typically in Google Play Store or Apple App store.

10.7.2 Familiarity bias

Familiarity bias refers to the effect that test users might answer more kindly when asked about their experience using the application because of their connection with the researcher. For this study, the population of the experiment was either recruited from the researcher's network or via one of the participants and thus might be vulnerable to familiarity bias. All participants were asked to answer honestly when asked about their experiences either from questionnaires, observation, or interviews to mitigate the bias.

10.8 Summary

This chapter presented the user evaluation design. The goal of the evaluation is to examine the system's new features and collect data that can be used when answering the research questions. The experiment consists of four data generation sources. First, a pre-test questionnaire was created to understand the evaluation population better. The questionnaire will be distributed to the participant before downloading the application. The evaluation period lasts for one week, during which the participants will get familiar with the application and generate data. After the test period, the participants are again asked to answer a questionnaire. The goal of the post-test questionnaire is to gather enough data to be used to answer the research questions. Additionally, some participants will be invited to an interview to further understand their user experience and triangulate their answers with the responses from the questionnaire. All participants were given a unique user ID that they must enter to sign in to the application and in the questionnaires. Doing this makes it possible to compare their responses before, during, and after they have tested the application. Several measures have been taken to secure their privacy, including applying for an NSD approval, informing the participants about the data collected and their rights, and separating their unique user ID from their contact information, and storing the mapping in an encrypted document. The participants were recruited from the researcher network. A downside of this is the potential for familiarity bias.

Chapter 11

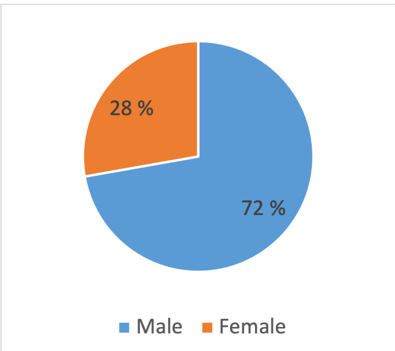
Results

This chapter presents the collected data from the user evaluation of Smiling Earth. First, the chapter presents the quantitative data generated from pre and post-test questionnaires and application usage data. Then the qualitative data from interviews with four of the participants are presented.

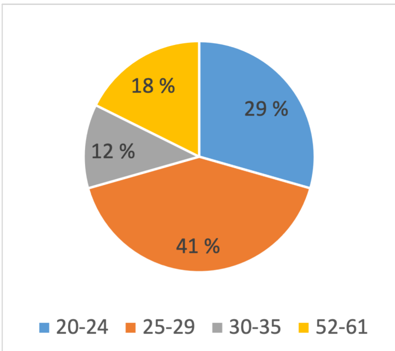
11.1 Demographics

20 people had shown interest and were invited to participate in the evaluation. All participants were recruited from the researcher's network or heard about the project from one of the participants. Unfortunately, two people declined the invitation to join, one because of security restrictions of downloading an unlicensed application on their work phone and another because of the lack of time. So, in the end, the experiment included 18 participants. The results from the pre-test questionnaire are presented in this section.

11.1.1 Gender and Age Distribution



(a) Gender Distribution



(b) Age Distribution

Figure 11.1: Demographic information about the test population

As shown in Figure 11.1.a the total population of the experiment consisted of 18 participants, where 5 were women and 13 men. Figure 11.1.b shows that the majority of the participants were younger than 30 years.

11.1.2 Attitude towards Climate Change

Figure 11.2 illustrates the participant's attitude towards Climate Change and willingness to change to more environmentally friendly habits. Statement S1 and S2 regard views on climate change, while S3 and S4 look at their motivation. Over 90% either agree or strongly agree that they are worried about climate change. 70% of participants say they want to reduce their carbon emissions, while 50% say they find it hard to motivate themselves to act more environmentally friendly.

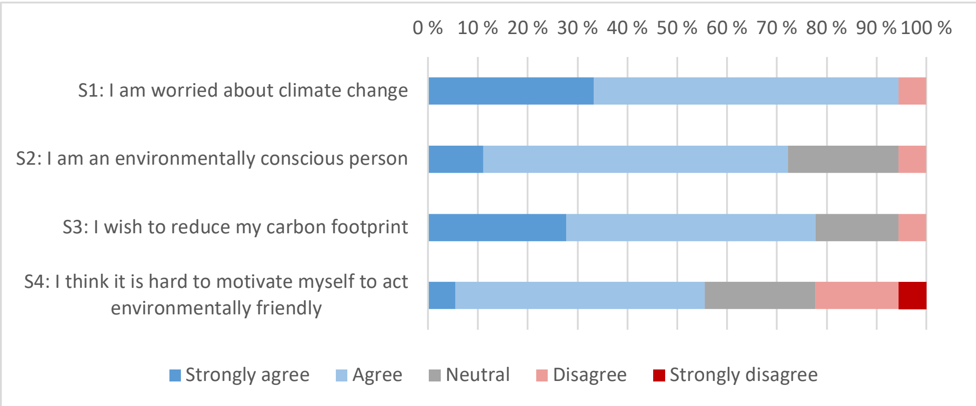


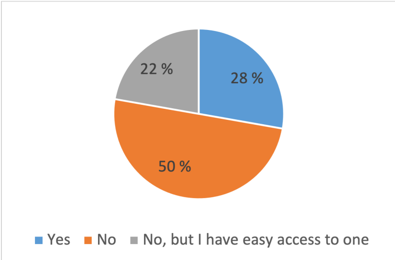
Figure 11.2: The results from statements about the participants attitude towards Climate change

11.1.3 Transportation

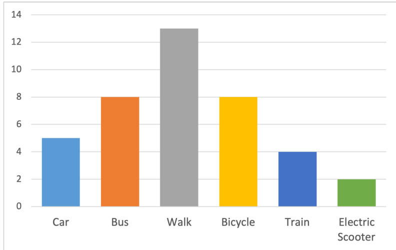
This section tries to examine the user's transportation habits. The results are shown in Figure 11.3.a highlights that half of the users either own or have easy access to a car, and the second halves don't own or have access to a car. There was an option of "No, but I use car-sharing platform on a regular basis (Hyre, VyBil, Nabobil etc.)", but none of the users chose this option.
Figure 11.3.b presents the means of transportation that the participants use on a daily basis. Walking, Bicycle and bus are most popular, followed by driving a car and riding the train.

11.1.4 Social Media Experience

Since the new version of Smiling Earth tries to understand how social computing could promote pro-environmental behavior change, it could be valuable to inspect



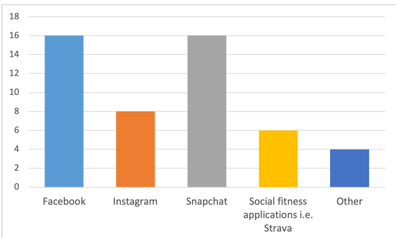
(a) The participants access to a car



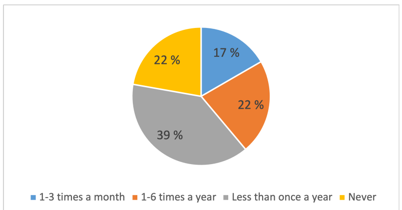
(b) Most common means of transportation

Figure 11.3: The participants transportation habits

the participant's habits when it comes to social media applications. As shown in Figure 11.4.a, the most popular platform is Facebook and Snapchat, followed by Instagram. Six of the participants answered they used Fitness apps like Strava or similar. The other social media applications include Reddit and Tiktok. Figure 11.4.b describe how often the participants publish posts to social media, with the majority publishing less than once a year or less. In social computing, the term *lurker* has been used to address users who join an online community or application but do not post [90].



(a) The most popular social media platform used by the participants



(b) Distribution of how often the participants publish new posts to social media applications

Figure 11.4: The social media habits of the participants

11.2 Application Data

This section describes the results from the generated data produced by the participant using the application. Figure 11.5 shows the distribution of data created during the period. The blue line is the amount of new data entries to the database from the participant creating new posts, liking and commenting on a post, joining challenges, updating emissions. In total, 160 data entries were added to the database, where 84% were either new posts or likes. The remaining 16 % included miscellaneous sources such as comments, user registration, joining teams and challenges. The orange line shows how many new posts were created a day, while the gray line shows the number of daily likes. As one can see from the chart, the number of new entries to the database was highest at the start of the period, followed by a somewhat low period and then a rise of new data entries towards the end of the evaluation. From analyzing the data, it may seem like three participants did not start using the application until the last days of evaluation, thereby causing a rise in new data entries. In addition, it may seem that the participants were a bit more active users of the application during the weekend. Conducting a further evaluation for a more extended period could confirm this assumption

Figure 11.6 illustrates a chart taken from Azure, showing the number of incom-

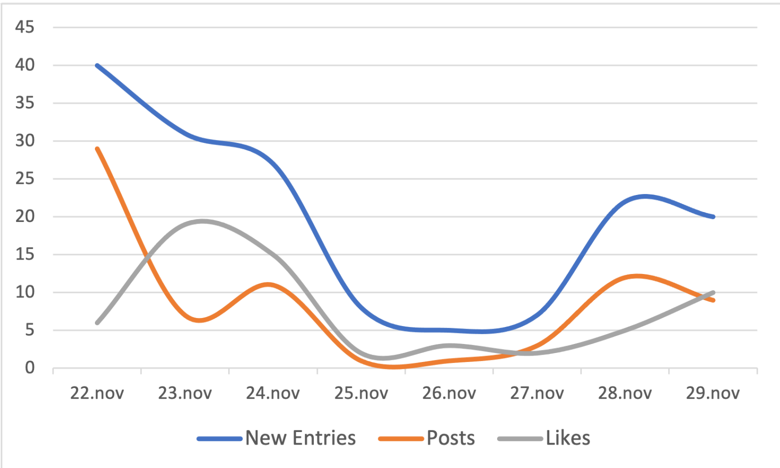


Figure 11.5: The number of new entries to the database per day during the test period

ing requests to the backend server. While Figure 11.5 show new entries to the database, Figure 11.6 indicates all kinds of requests such as GET, POST, PUT, and DELETE. Over 11 000 requests were incoming to the backend server during the evaluation period. The pattern is similar to the one found in Figure 11.5, as being highest during the start of the evaluation followed by a period of lower traffic and an increase towards the end.

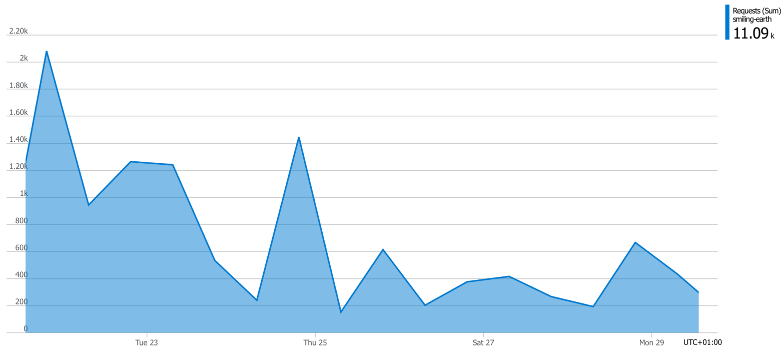


Figure 11.6: The number of requests to the back-end application per day during the test period. Illustration taken from the Azure Portal.

11.2.1 Social Network

The social network that was created between the users is visualized in Figure 11.7. Each node represents a user, with their user ID in the middle of the node. Edges represent a 'follow' from one user to another. Each edge is one-directional. The size of each node means how many followers they had. The bigger the node, the more follower the user had. There were 96 relations (follows) between users of the application, where the most popular users had 11 followers and the least popular had 3 followers.

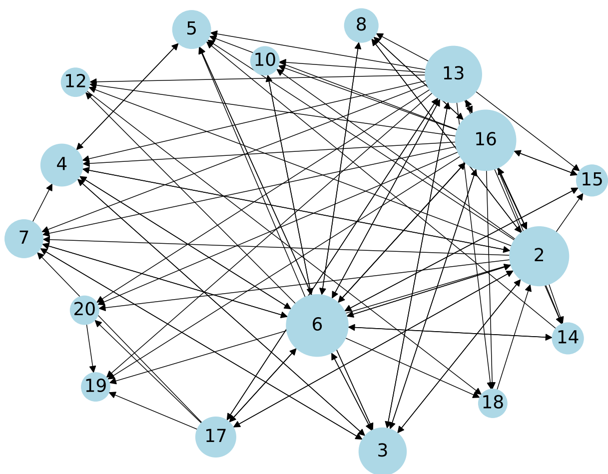


Figure 11.7: The network between users. Each node is a user and the number is their user ID. Each edge represents a 'follow'. The size of the nodes indicates the number of followers the user had.

11.2.2 User

As suggested from the workshop conducted in the specialization project (Section 3.4.1), the participants should have the option to create their own avatars. The avatar would be used to represent the user in the application. A selection of avatars made by the participants is shown in Figure 11.8.

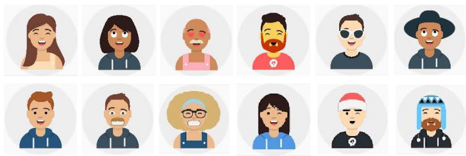


Figure 11.8: A selection of the avatars created by the participants in the application

Each participant made on average 6 pledges that they would commit to. The distribution of pledges is shown in Figure 11.9, with the most popular pledge being to "reduce consumption", followed by "Riding my bike", "Stop wasting food" and "Electric car".

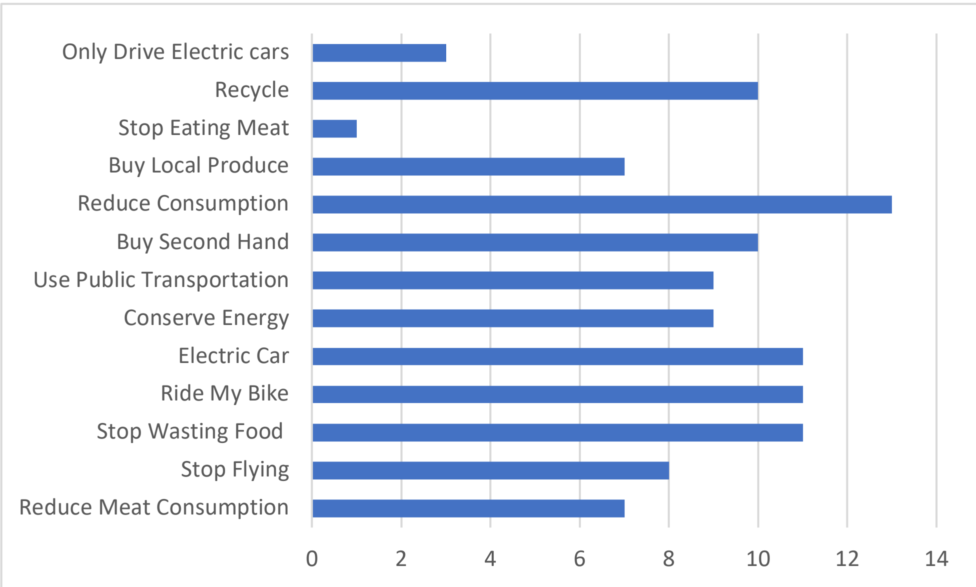


Figure 11.9: The most popular pledges made by the participants. The X axis represents number of participants

11.2.3 Challenges

During the user test, 33 challenges were joined, and 10 challenges were completed. The most popular challenge was *Walk for one hour*, followed by *Walk for* *five hours*, and *car-free week*. The number of participants who joined each challenge is illustrated in Figure 11.10. Teams' challenges were not as popular, with four teams joining the *Team walking challenge*, while only one team joined *Team: Zero Emission Commute*. From reviewing the database, there seems to have been a problem with the background services running on many participants' devices. As described in Section 9.1.3, the background services should run multiple times a day. However, only 5 users updated their emissions during the test period, and 7 users updated their progress in a challenge, indicating the background service was not running as intended on all devices. This may have affected the user's motivation to complete tasks as their progress was not updated.

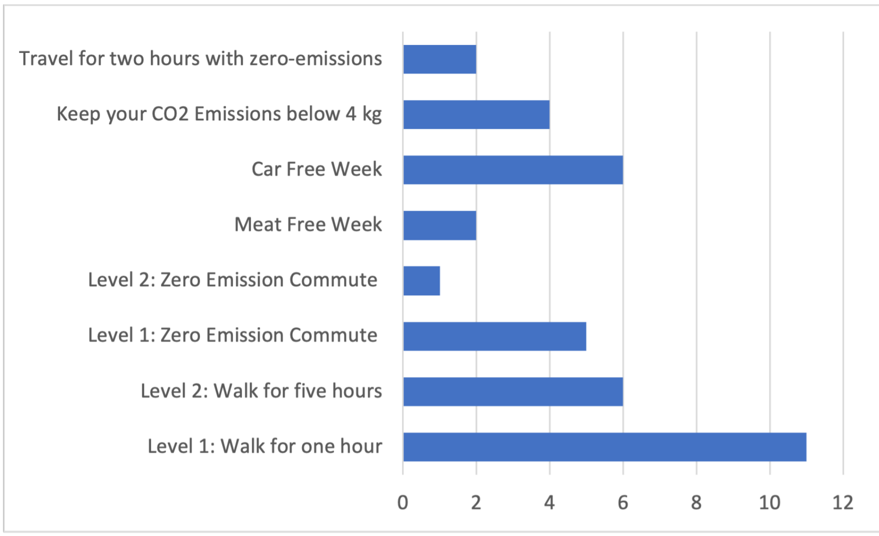


Figure 11.10: The most popular challenges joined by the participants. The X axis represents number of participants

11.2.4 Teams

Figure 11.11 shows the most popular teams in terms of the number of members. On average, each participant was a member of two teams, with 6 participants only being a member of one team. Participants automatically joined the teams "Smiling Earth Group 1,2, or 3" after registering. While in the other teams, the users had to join the teams actively. The most popular teams where the participants had to actively join the team is *Oslo* with 6 members, followed by *Trondheim* with 3 members.

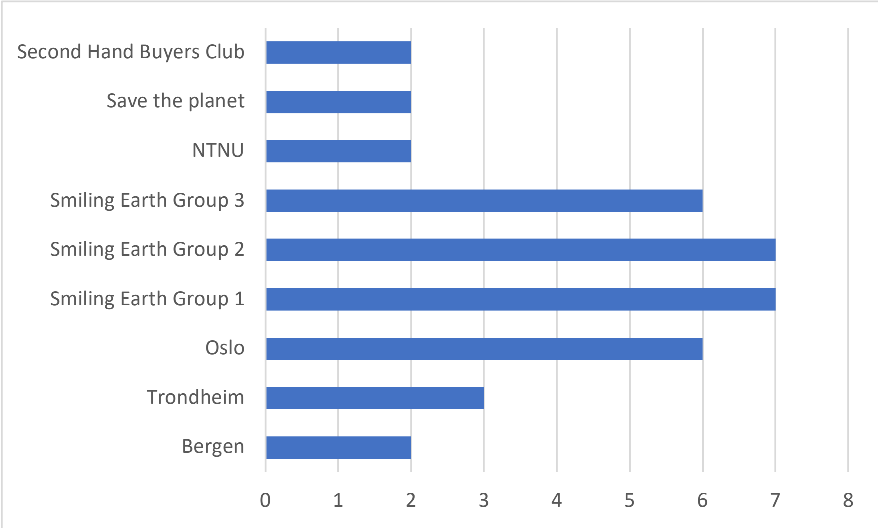


Figure 11.11: The most popular teams. The X axis represents number of participants.

11.3 Post-Test Questionnaire

This section presents the data collected from the post-test questionnaire. The goal of the test was to show how the application worked to promote more sustainable behavior and what effect the application had on the participant's motivation to act more environmentally friendly. It was not possible to reach out to 2 of participants out of 18, thereby the population of the post-test questionnaire is 16.

11.3.1 Technology Acceptance Model

Figure 11.12 presents the results from Statements S1 to S4. The goal of these statements is to evaluate some general views the participants had about the application. Statement S1 concerns the usability of the application. The responses show that over 90% either agree or strongly agree that the application was easy to use, while the rest were neutral. S2 and S3 want to know the perceived usefulness of the application. The results show that over 80% found the application useful in creating awareness about their emission or motivating them to act more sustainable. The last statement, S4, looks at the intention to use the application, with a majority (>70%) agreeing that they would like to use Smiling Earth. The results from these statements will be used in a Technology Acceptance Model analysis in the next chapter.

Subgroups

We can divide the evaluation population into two subgroups, *drivers* and *non-drivers*. The first group includes the participants who answered they either owned

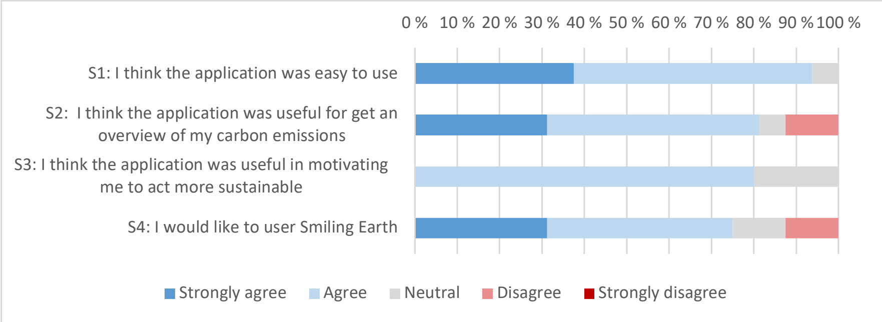


Figure 11.12: General statements about the perceived usability and usefulness of the application and intend of use

a car or had easy access to one. The results presented in Section 11.1.3 showed that 28% of the participants owned a car, and 22% had easy access to one, leaving 50 % not driving a car. In this section, we evaluate Statement S1 to S4 concerning different subgroups. As there was one participant not joining the post-test evaluation, the population of the driving group was n=7, and the other group was n=9. The Likert scale used in the questionnaire was converted into numeric values, where 1 indicates *Strongly disagree* and 5 equals *Strongly agree*. Table 11.1 shows the median value (m), the average value (avg), and the standard deviation (σ) of the subgroup's response to each statement.
To test the technology acceptance statements on the two subgroups, the *Mann-Whitney* [9] test was used as a non-parametric test for significance for drivers vs. non-drivers. The final column in Table 11.1 indicates the p-value from the Mann-Whitney test. The p-value of Statement S2 and S4 are highlighted in green as their value is less than the significance level α of 0.05. This indicates that S2 and S4 have a *statistically significant* difference between the responses of the two groups.

Statement	**Subgroup**	m	avg.	σ	p
S1: I think the application was easy to use	Drivers	5	4.42	0.79	0.40
	Non-Drivers	4	4.22	0.44	
S2: I think the application was useful for get an overview of my carbon emissions	Drivers	5	4.57	0.53	0.033
	Non-Drivers	4	3.55	1.01	
S3: I think the application was useful in motivating me to act more sustainable	Drivers	5	4.57	0.53	0.115
	Non-Drivers	4	4.00	0.71	
S4: I would like to user Smiling Earth	Drivers	5	4.71	0.49	0.003
	Non-Drivers	4	3.33	0.87	

Table 11.1: Statement S1 to S4 based on the subgroups *drivers* and *non-drivers*

11.3.2 Smiling Earth as a Social Application

This section presents the participants' responses towards Smiling Earth as a social application and some general statements about how they liked it.

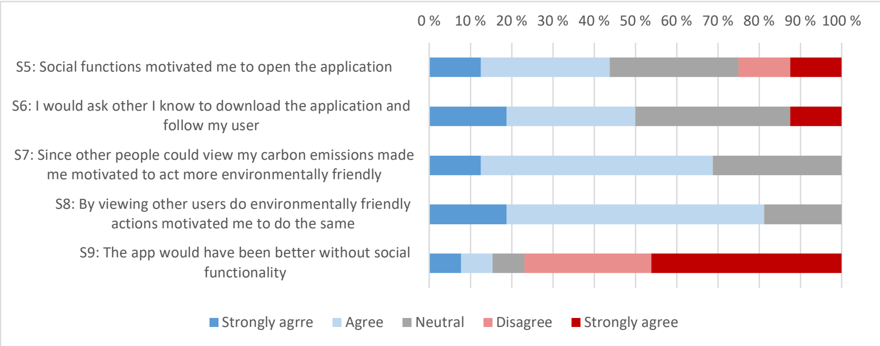


Figure 11.13: Statements about Smiling Earth as a social application

Figure 11.13 illustrates the response to statements regarding the addition of social features to the application. The results from Statement S5 indicate that social features may not have been the primary source of motivation to use the application for everyone. However, over 75% of the participants disagree with statement S9 - the application would have been better without the social functionality. The majority also say that being a social application could motivate them to act more sustainably by observing others (Statement S7) or that other users can view their actions (Statement S8). An additional factor of being a social application is promoting the application using word of mouth. From Statement S6, 50% of the participants stated they would ask their friends to download the application and follow their users.

The next statements are about which social feature in the application was most effective in motivating users to act more environmentally friendly. The section included 15 statements and Figure 11.14 presents the results from each statement. The results indicate that S15 - Comparing results with other users in a Duel was most effective, closely followed by S24 - making a pledge, and S25 - competing in the challenge.

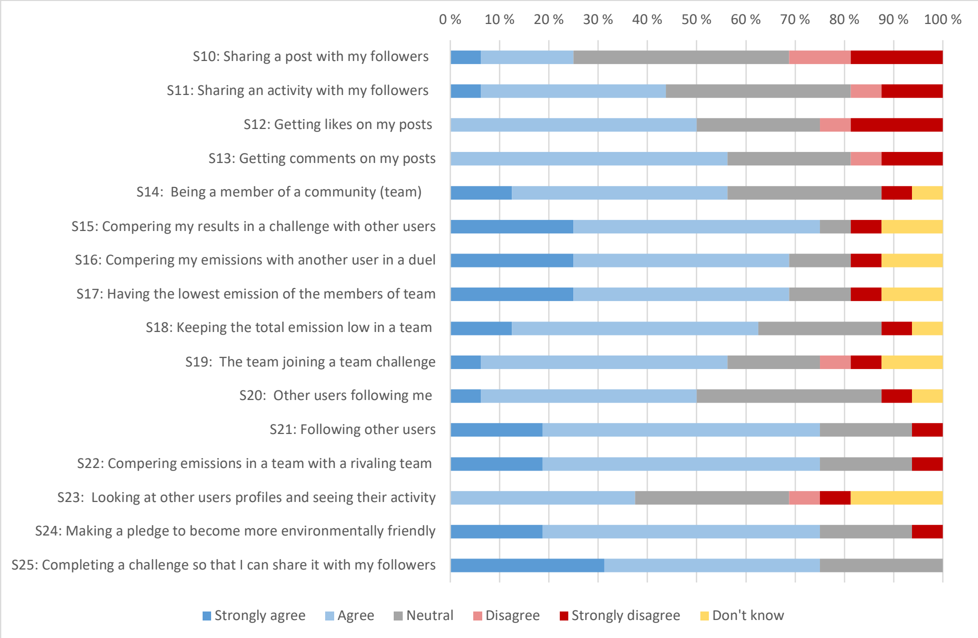


Figure 11.14: A review of the social feature's effect on users motivation to act environmentally friendly

11.3.3 Social Cognitive Theory

This section displays the results from statements about how the applications support the primary constructs of Social Cognitive Theory and includes Self and Collective efficacy, Self-regulation, observational learning, and outcome expectations.

Self-efficacy

The questionnaire contained ten statements about how the application affected the user's self-efficacy. The results are shown in Figure 11.15. Overall, the participants found that the app supported self-efficacy in many different aspects. 90% of participants agreed or strongly agreed with Statement S32, and 80 % with S26 and S28, which indicates that the most compelling feature of the application support self-efficacy is "pledging to take climate action (S32)", "the overview of my activities (S26)" and "the smiling earth diagram on the home screen (S28)."

Collective Efficacy

Four statements were created to examine the application's effect on the users' perceived collective efficacy. Compared to the results from self-efficacy, the impact for supporting collective efficacy is not as strong. As illustrated in Figure 11.16, not many participants disagree with the statements, but a majority are neutral. This could be because they did not use the team features too much or that the feature did not affect their view on collective efficacy. The same participants who

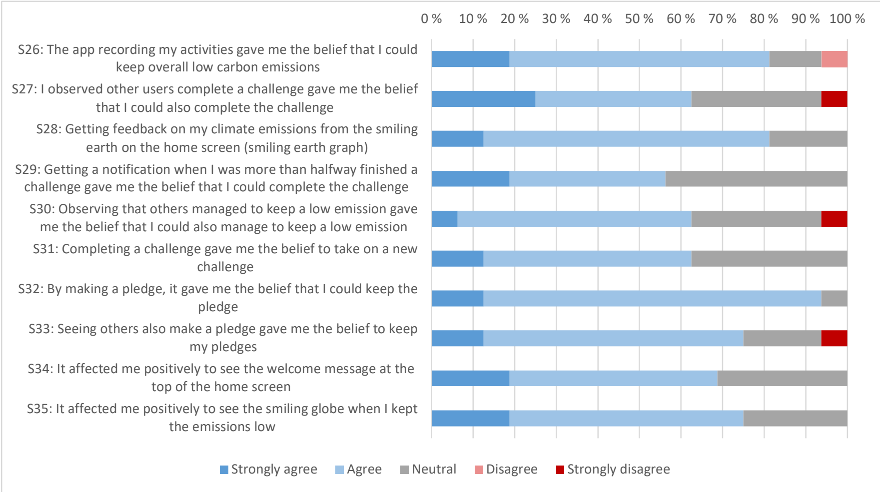


Figure 11.15: Results from the post-test questionnaire about how the application supports self-efficacy

agree with statements S36 also mostly agree with statements S37, S38, S39.

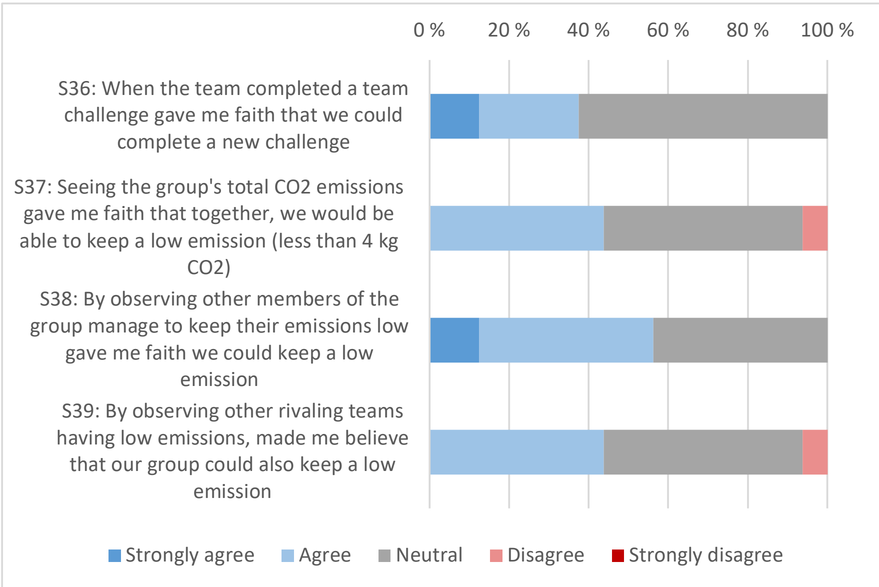


Figure 11.16: Results from the post-test statement about how the application supports collective-efficacy

Self Regulation

As mentioned in Section 4.1.4, Self-regulation consists of different steps, including self-monitoring, goal settings, feedback, reward, and social encouragement. In the post-test questionnaire, the participants were given a list of components from the application and asked to select those that affected the different steps. The results are visualized in Figure 11.17 and Figure 11.18. The smiling earth diagram was the most effective in terms of self-monitoring, goal setting, feedback, and reward. In most steps, climate action pledges and challenges were also popular choices.

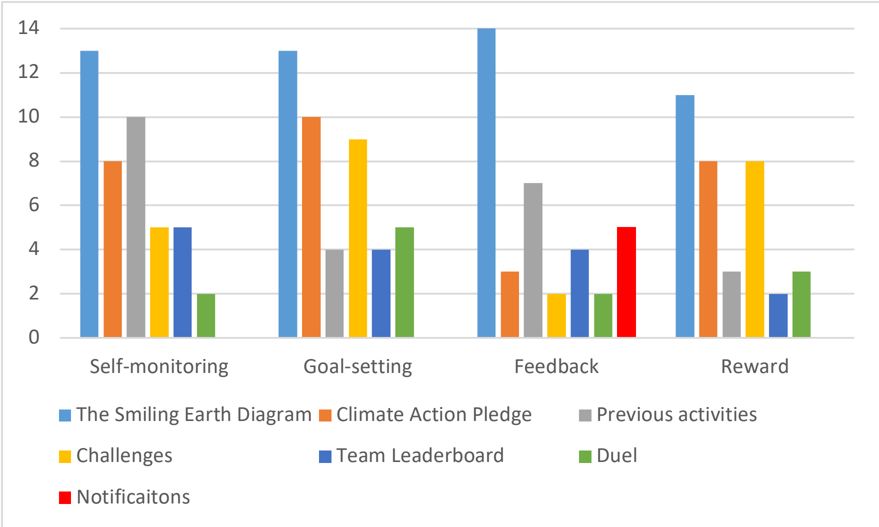


Figure 11.17: Score of the different components of the application in the key constructs of Self-regulation

Figure 11.18 lists the most effective components that facilitate social encouragement from other users. The data indicates that likes on posts and joining a community are the best sources for encouragement from others to act more environmentally friendly.

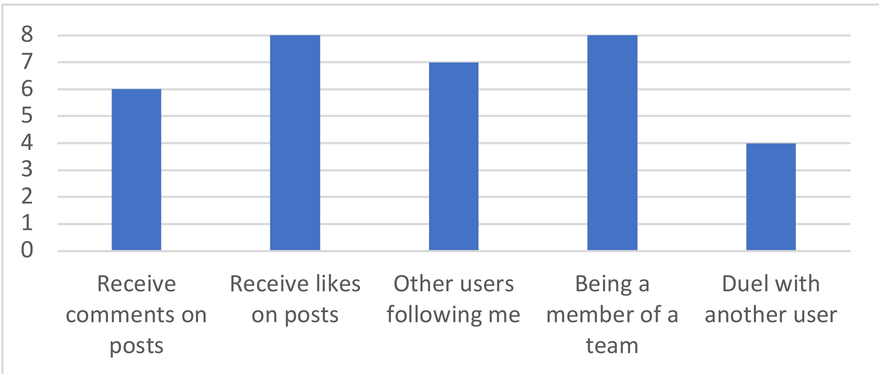


Figure 11.18: The components of the application that support social encouragement

Observational Learning

Already in Statement S8 (see Section 11.3.2), it was stated that 80% of the participants agreed that observing others could motivate them to act more environmentally friendly. This section tries to figure out which application components aided observational learning the most. The results are presented in Figure 11.19, and the majority (>50%) agrees that many of the listed features facilitate observational learning. The statement that most agreed with was Statement S46, regarding observing other users join a challenge, led them to join the same challenge

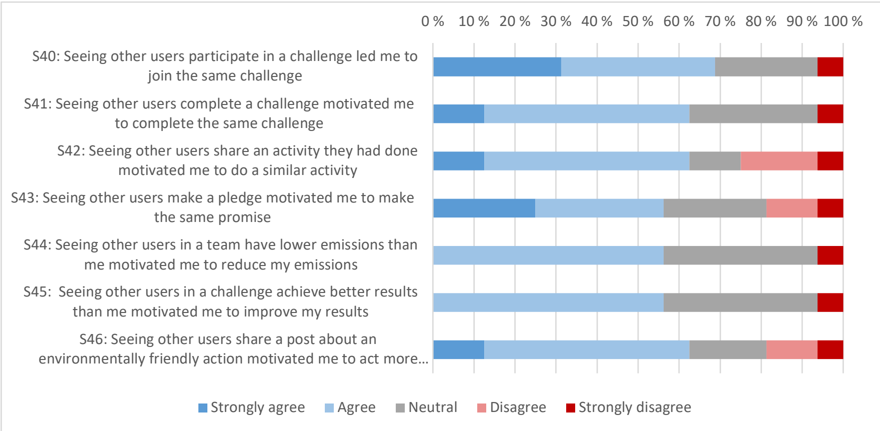


Figure 11.19: Statements about different components effect on observational learning

Outcome Expectations

The results from the subsequent four statements about outcome expectation are illustrated in Figure 11.20. The results state that the majority (> 70%) either agree or strongly agree with statements S47 and S49, which say how the activity page and smiling earth diagram help make the participants more aware of their transportation and energy habits consequences on the environment. S48, concerning notifications, also seems to assist in some regard, with 50% of the answers either agreeing or strongly agreeing. Posts, on the other hand, appear to have little impact on the user's outcome expectations based on Statement S50.

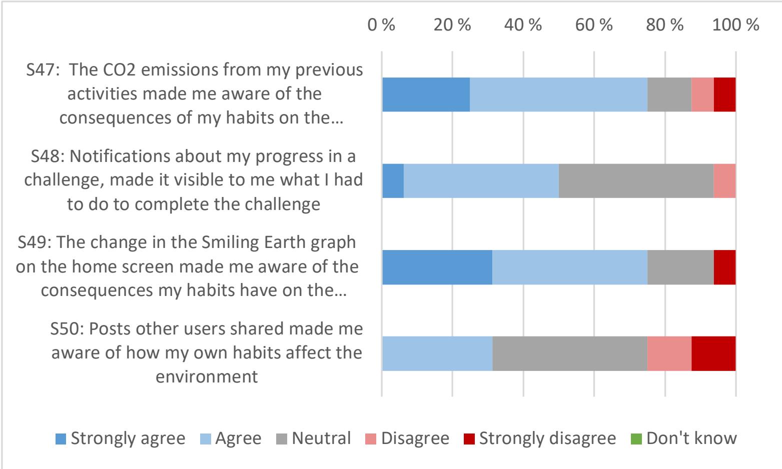


Figure 11.20: Statements about different components effect on outcome expectation

11.3.4 Anonymity

Eight statements were created to analyze how the users felt about Smiling Earth being an anonymous platform. Figure 11.21 presents the results from the statements. In Statements S51, S52, and S53, most (over 60 %) of the users either agree or strongly agree that anonymity made it easier to interact with the other users. On the other hand, 50% disagree with Statement S54 - motivation to follow others when I don't know their identity. 43% of the participants agree with Statement S58 and S57, saying they would have been more motivated to use smiling earth if they were not anonymous, while 30 % disagree with S57 and 12% with S58.

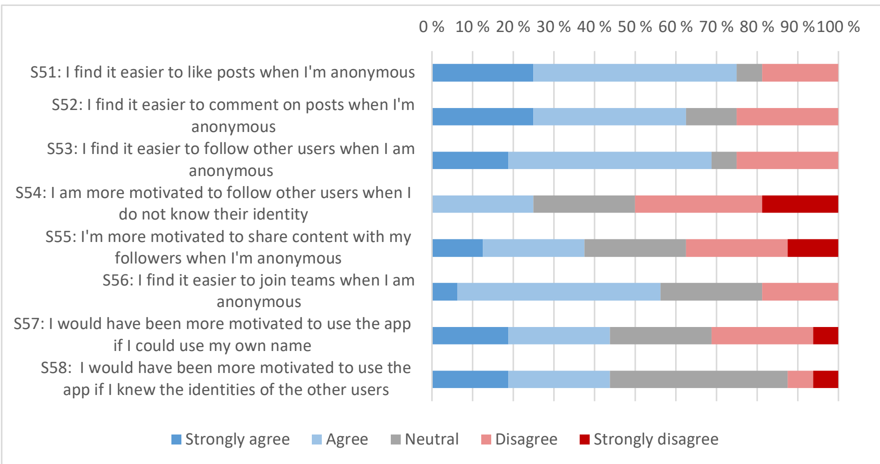


Figure 11.21: Statements about Smiling Earth as a anonymous social platform

11.3.5 Online Communities

This section describes the results from the statements regarding online communities. The section is divided into three parts, one for each statements. Each statement was asked four times, one per type of online communities supported in the application. This includes how different communities affect the users motivation to act more environmentally friendly, behaviour change and their motivation to use Smiling Earth. As mentioned in Section 11.2.4, each participant was on average member of two teams. When asked why they did not want to join any more teams, the most common answer was that none of the alternatives fitted them or that the participant did know the teams existed.

Motivation to act environmentally friendly

For Statement S56 about how the different communities affect the users motivation to act environmentally friendly 68 % agree that communities based on location is the most suited. 62% agree that communities of practise is suited and 50% found communities of interest motivating. Only 20% found communities with random users motivating and additional 30% expressed they did not find it motivating.

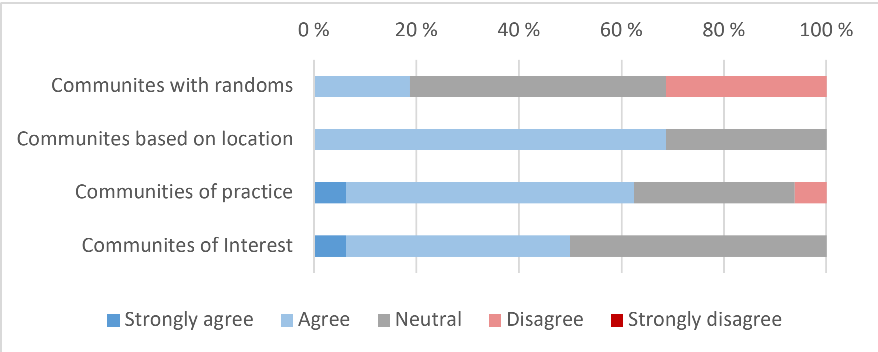


Figure 11.22: Statement S56: Communities based on [randoms/locations/interest/practice] are **suitable to increase my motivation to act environmentally friendly**

Behaviour Change

Communities based on[randoms/ locations/ interest/ practice] are suitable to support me to change my habits in a more environmentally friendly direction

Motivation to use the application

When asked how the different communities affected their motivation to use Smiling Earth (see Figure11.24), 62% agreed that Communities of Interest 56% agreed that communities of practice and 50% could motivate them to use application.

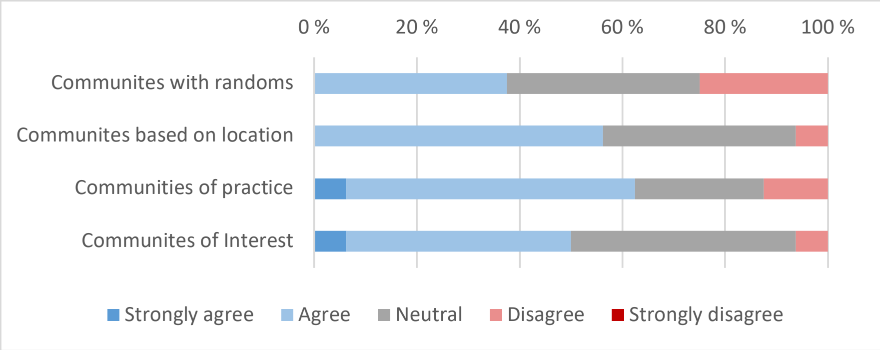


Figure 11.23: Statement S57: Communities based on[randoms/ locations/ interest/ practice] are **suitable to support me to change my habits in a more environmentally friendly direction**

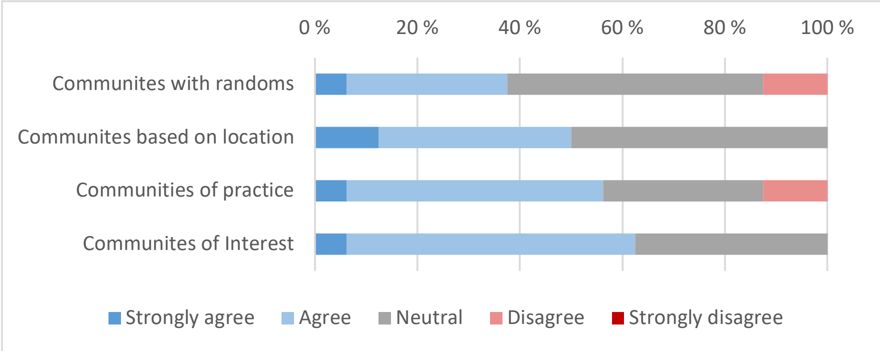


Figure 11.24: Statement S58: Communities based on [randoms/locations/interest/practice] **made me more motivated to use Smiling Earth**

11.3.6 Additional results

In the final section of the post-test questionnaire, the participant could add additional comments and feedback on their experience of using the application. The results are presented in the following three sections, comments, technical issues, and improvements to Smiling Earth.

Technical Issues

First, the participants were asked if they experienced any technical issues during the period. 31% answered they had technical problems, 25% answered they experienced some minor issues, and 44 % said the app worked fine. Some users experienced the app crashing but working again after restarting the application. Others experienced that the app either did not track anything or sometimes registered the same trip multiple times. One user thought the calculation of how many calories burned was too high. This might be linked to the app logging the same trip numerous times, or the calculation is not accurate enough. The issues described by the participants are listed in Table 11.2.

#	**Comments**
1	The app registered that I walked the same trip multiple times
2	The app crashed once every day, but when I restarted the app, it worked for a while
3	Some of my trips did not register in the application
4	Logging the same trip multiple times
5	More clarity about what my emissions mean and how it is calculated. Compare my results with an average emission.
6	The calories calculation seems too high
7	Notifications wont go away after I opened the notification screen

Table 11.2: Technical issues

Comments
Table 11.3 contains comments made by the participants on the concept and user experience of using Smiling Earth. Many users found the concept and the app to work well. Others wanted the app to be able to support more sources of emissions like from shopping for clothes and from their diet. As mentioned in Section 11.2.3, there seems to have been a problem with the background service running on some of the devices. One user commented that he did not understand how to progress in the challenges and thereby was not so motivating to complete them. Another participant felt the application was slow and thereby hard to navigate and use.

#	**Comment**
1	I thought the app worked well and was fun to use
2	I found the app slow and therefore thought it was challenging to navigate. The focus on calories and money saved was not helpful for me.
3	A cool concept!
4	I must say it's really interesting and a very nice idea.
5	I'm not a big fan of social media
6	Instead of only focusing on your carbon footprint, could it be an idea to highlight climate-hostile companies and motivate the users not to use their services or products.
7	Add support for more sources of emissions like food and shopping. It could also have more challenges
8	I thought the concept was fun, and the app worked well most of the time. I would like to see the duel concept completed
9	I did not understand what I had to do to complete a challenge. I never got any information about my progress in a challenge.
10	Instead of only focusing on your carbon footprint, could it be an idea to highlight climate-hostile companies and motivate the users not to use their services or products.

Table 11.3: Comments on the concept and user experience

Improvements

The final question of the post-test evaluation regarded any improvement and additional features that the participants felt were missing or not functioning as expected. The answers are listed in Table 11.4. For example, some participants asked for more sources of carbon to be added to the application. Other users wanted the application to be faster. One user enjoyed the Duel concept but would have liked it to be completed.

#	**Comment**
1	I thought the duel concept seemed fun and should be completed in the future. I would also like that the app would be faster. Additional registration of carbon emissions from i.e. food, cloths or other source
2	Make the app not anonymous and faster. More focus on sharing experiences. Add the functionality to share images of e.g., things you have bought second hand or made a vegetarian dinner
3	It would be interesting to see more carbon emissions sources, like online shopping and from shipping packages.
4	Integration with other sources, like seeing how much electricity you use, and the price of the electricity
5	More clarity about what my emissions mean and how it is calculated. Compare my results with an average emission.

6	Instead of only focusing on your carbon footprint, could it be an idea to highlight climate-hostile companies and motivate the users not to use their services or products.
7	Add support for more sources of emissions like food and shopping. It could also have more challenges

Table 11.4: Feedback on how to further improve the application

11.4 Interviews

1. How did you like using Smiling Earth
All users stated that they enjoyed using the application. Two of the users said they especially liked that the application tracked their activities automatically. The same two users were active users of Starava and compared the application with it. Another user said they liked the concept very much but were generally not a big fan of social media applications. However, the same users also mentioned that they would still like to use the app and only not follow a handful of people they are close with.

2. Did you meet any issues while testing the application?
Two users said they experienced the application tracking the same activity multiple times. One mentioned that even though it tracked the same activity twice or more, the tracked activity seemed correct in duration and distance. Another user mentioned that they did not experience any issues, but they found the application very slow at times.

3. Do you think making the application social enhanced the user experience?

All participants agreed that they preferred the application with social aspects. Even though some stated they were not big fans of social media applications in general, they found that it is still a nice feature. One participant said they believed that making the application social was key to keeping users active on the platform over a longer time. The participant continued by saying that they had been using different fitness tracking applications, but they chose Strava because of the social network it offers. Another user said they would enjoy the social aspects more if they were not anonymous.

4. How did the app affect your motivation to act more sustainable?
Three of the participants said they felt the application could contribute to them traveling more environmentally friendly, but that they were not traveling so much during the test period. One of the participants said they were working from home and thereby was not traveling to work as they usually did. The fourth participant

said the app had an effect on their motivation. As the participant was traveling a lot during work, it did affect their transportation habits in the work environment, but in their spare time, they thought more about taking the bus instead of driving their car.

5. How do you feel about using it as an anonymous social network?
One participant mentioned they did not mind being anonymous but liked the app more if other people were not unknown. They suggested that being anonymous could have been optional or made the app less anonymous by adding more users' descriptions. The same users stated that they liked creating an avatar that represented them and found the feature very important in an anonymous application. The other participants said they would have liked the application more if it was not anonymous and as one participant said "I did find it a lot easier to react to others' posts and to publish new ones, but I found the motivation to do so very low as I did not know the other person".

6. How did you like being a part of a team?
The participant who was traveling a lot during work was not such a bit fan of teams, as they quote "felt they were letting the team down by increasing the total emission in the team". He/she would rather have liked to just compare their results with the different members of the community. Another user said they were members of three teams but felt that the teams were missing some functionality like adding images. The two other users said they found the feature OK, but it was not their primary motivation to use the app. One suggested creating a team with people at work or friends.

7. Do you think online communities could motivate people to act more environmentally friendly?
All participants agreed that they thought communities could contribute to making people more sustainable. One user stated that they got motivated by observing what others are doing and getting inspiration from them. Two participants said it would be better if the members of the community could use their real names.

8. Did you find the application easy to use
All users agreed that they found the application easy to use. One user said they liked the design but sometimes found each page a bit too similar and was a bit confused on which page they were on. They suggested adding a different color or something to symbolize the various pages. Two users said they had minor problems navigating the app and recommended adding more back arrows/buttons instead of opening the navigation drawer each time. In general, all participants said they liked the design.

9. Do you have any comments on how Smiling Earth could be better in motivating people to act more environmentally friendly?

Three users suggested making the application faster. Two of them stated they would like more sources of carbon emissions. Another user said the app could try to track more activity automatically. For example, instead of manually adding air travel, the app should do it automatically. Another user said it would have been cool to collaborate with businesses or maybe the municipality. The fourth user said they found the calculation of money and calories not helpful and would like the app to focus more on one area.

Chapter 12

Discussion

This chapter presents the discussion of the results in regard to the Research Questions.

12.1 RQ1: How can social computing enhance the application

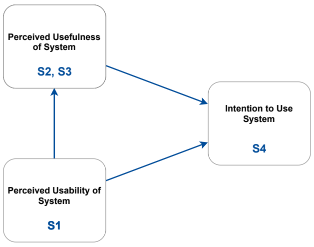
Section 11.3.2 presented how users responded to the new social features added to the application. The response on Statement S10 (see Section 11.3.2) shows that most users preferred the application with social functionality. Statement S6 indicates that being a social platform could assist in recruiting new users to the application. The results from the other Statements S5, S7, and S8 also highlight that connecting and interacting with other users could positively impact the user motivation to act more sustainable and environmentally friendly. This is further supported from the interviews (see Section 11.4), as all of the participants found the social aspects fun and motivating.

The following sections evaluate how well the Smiling Earth is accepted by the users using the Technology Acceptance Model. The evaluation also compared the results to the different subgroups of the experiment populations and the previous versions of Smiling Earth without social computing.

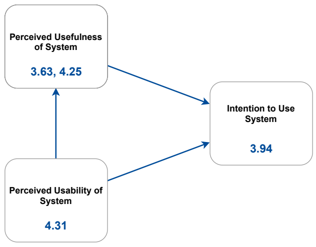
Technology Acceptance Model

The Technology Acceptance Model, as described in Section 2.2.7, is a method of evaluating the user's perceived usefulness, usability, and intention to use a system. The TAM used in this thesis consist of these four statements:

- **S1:** I think the application was easy to use
- **S2:** I think the application was useful to get an overview of my carbon emissions
- **S3:** I think the application was useful in motivating me to act more sustainable
- **S4:** I would like to use Smiling Earth



(a) Technology Acceptance Model(TAM)



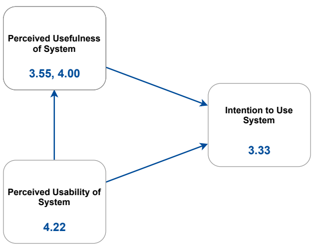
(b) Results from TAM evaluation

Figure 12.1: Technology Acceptance Model

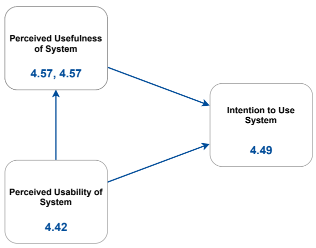
Figure 12.1.a shows the adoption of TAM used. By taking the average results from each statement, we get the result of the categories in TAM on a scale from 1-5, corresponding to the Likert scale used in the post-test questionnaire. 1 means *Strongly disagree* while 5 means *Strongly agree*. Figure 12.1.b illustrates the TAM with the average scores presented in Section 11.3.2. The results show that the application scores high in each category. Most users agree that the application was easy to use, which is an important construct of TAM, as it supports both perceived usefulness and intention to use. The average score in the two other constructs shows that most users agree that they find Smiling Earth useful and would intend to use the app.

The effect on the subgroups

When dividing the participants into groups of *drivers* (those who own or have easy access to a car) and *non-drivers*, we see a difference in their technology acceptance models, as shown in Figure 12.2. From Section 11.3.1 it was found when examining the responses of each group that the drivers overall agreed more with the statements regarding the perceived usefulness, usability, and intend of using the application. The drivers had a higher average value and a median value of 5 in each statement, indicating Strongly Agree. From the Mann-Whitney test shown in Table 11.1, Statement S2 and S4 were considered statistically significant. This indicates a difference between the two groups and suggests that Smiling Earth is most useful and intended for people with easy access or who owns a car.



(a) TAM for *non-drivers*



(b) TAM for *drivers*

Figure 12.2: Technology Acceptance Model of drivers vs non-drivers

Compared to previous version
Table 12.1 shows the average score on Statement S1 and S4 compared to the two previous versions of Smiling Earth. The Likert values have been converted to a scale from 0 to 4 to be comparable to the results from the previous versions, where 0 equals *Strongly disagrees*, and 4 equals *Strongly agree*. The results indicate an increase in both statements, meaning the app has improved its usability, and the users are more eager to use the application. The increase in usability is especially significant since the application has become much more complex in this version of Smiling Earth. The new complexity of the system also seems to have increased the user's intention to use the application, as stated by Statment S4. The usability score could have been even better if the backend server had been running on a server with better specifications to increase the application's performance. As mentioned in the questionnaire feedback (see Section 11.3.6), and in from the interview (see Section 11.4), some users found the application slow, which may have influenced their perceived usability of the application.

Since the previous versions of Smiling Earth did not have a functioning backend server, the improvement from the response on Statement S4 from 2.40 to 2.93 (an increase of 20%) indicates that adding Social features to the application enhanced the user experience.

	V1	**V2**	**V3**
S1: I think the app was easy to use	Disagree (1.20)	Agree(3.00)	Agree(3.31)
S4: I would like to use Smiling Earth	-	Neutral(2.40)	Agree(2.94)

Table 12.1: Evolution of the perceived ease of use and willingness to use Smiling Earth

12.1.1 RQ1.1: What social functions is most effective to motivate the users to act more sustainable

The response on statements S10 to S25 is used to answer this research question. The results is presented in Section 11.3.2, Figure 11.14. An interesting finding from the survey is that sharing a post with your followers receives quite a low score, while getting a like or comment on the post received a high score. Another observation from the results is all statements regarding comparing habits and results to other users scored high. This could suggest that most participants find the concept of comparing their emissions to others users motivating. The results also indicate that most users enjoyed taking climate actions in some way. The application supported two main methods of taking action, making a pledge to change a habit, or joining and completing challenges. Both features seem to have positively affected the participant's motivation.
From the results, we can create a list of the most effective social functions in the

application based on the percentage of Agree and Strongly Agree responses to each statement.
The Top 10 most effective social features added to the application was found to be:

1. Comparing my results to others in a competition
2. Completing a challenge so that I can share it with my followers
3. Making a pledge to become more environmentally friendly
4. Comparing the team's emissions to rivaling teams
5. Following other users
6. Compering my emissions to other team members
7. Compering my emissions to other users in a Duel
8. Being a member of a community
9. Receiving a Comment on a post
10. Receiving a Like on a post

12.2 RQ2: How can social cognitive theory be used in the application?

The literature review includes a study of Social Cognitive Theory. As discussed in Section 4.1, the theory seemed fitting as it focuses on behavior change with the help of social encouragement, support, and recognition and thereby been suggested for moderns social application. It also describes how to obtain behavior change as a community, and the theory has been used in many mobile health applications. Behavior change is obtained in social cognitive theory with the help of five primary constructs; Self-efficacy, self-regulation, observational learning, and outcome expectations. In addition, the theory includes the construct collective efficacy to describe behavior change as a group or community. Finally, the theory was applied when designing the system and creating functional requirements for implementing the application.

12.2.1 RQ2.1: Determine which intervention components support the key social cognitive theory constructs?

This section will answer the research question by highlighting how each key construct is supported by the application and assessed from the user evaluation results.

Self-efficacy
As described in the literature review, Bandura described four methods of improving one's self-efficacy: building on previous experience, social modeling, improving physical and emotional state, and verbal persuasion. From Section 11.3.3 the results show that most participants found the application to support these methods.

Statements S26 and S28 try to make the user more aware of their habits' consequences on the environment and how this affects their self-efficacy. This is related to the method of building on prior experience. The results show that by being more aware of their carbon emission, the user is also more inclined to believe that they can keep a low carbon emission lifestyle. Over 80% agreed with statements S26 and S28, meaning that the activity history page and the smiling earth diagram positively influence their self-efficacy.

The results also showed that social modeling positively affected the users' perceived self-efficacy. Over 60% agreed with the three statements (S27, S30, S33) regarding social modeling.
Verbal persuasion was only supported in the application by sending notifications to the users. Statement S29 concerned receiving a notification on the user's progress in a challenge. The responses show that this statement received the lowest score (56% agreed) of this section. As mentioned in Section 11.2.3, there was a problem updating some of the participant's progress in challenges, which meant many users never received a notification about their progress. This meant that verbal persuasion was only supported by a handful of users, and thereby, the statement was not so relevant for most of the participants.

The final method to improve self-efficacy is to enhance the physical or emotional state of the user. The app tries to enhance the participants' physical health by showing how walking or cycling could burn more calories and reduce emissions. When opening the app, the users are presented with a welcome message (as shown in appendix C). From Section 11.3.3, 68% of the users said that this message had a positive effect on them (Statement S34), and additionally, 75 % responded that keeping the earth happy had a positive impact (Statement S35).
In the past years, there have been many reports on social media's negative effect on people's emotional states, especially young people [91]. However, the results here indicate that the app could enhance the user's physical and emotional state; the negative effect of adding social computing to the network has not been examined.

Collective-efficacy
The same methods for enhancing self-efficacy were used to improve the collective-efficacy. During development, the application was enhanced by adding the ability to create teams, team challenges, a chart of the group's combined emission, facilitating social modeling by adding a team leaderboard and a leaderboard for rivaling teams. The results on how this feature affected the user is presented in Section 11.3.3. Based on the results, only the team leaderboard seemed to be somewhat effective on the collective efficacy as 50% agreed with the Statement S38. 40% decided with the other statements (S36, S37, S39), while the majority were neutral. From the interviews with some of the participants, many said

they did not find the competition part of teams that exciting and the fact that all members were anonymous. One interviewee said that they would have liked to have more ability to share more content and interact with the team members. The results make it hard to conclude that the different features supported collective efficacy for every participant. However, there is some evidence that the functions did support some participants' collective efficacy in some way—especially, Social modeling, by comparing and observing other members' emissions.

Self Regulation

Bandura described six steps to improve one self-regulation (see Section 4.1.4). Five of them were present in the application and included Self-monitoring, Goal-setting, feedback, reward, and social encouragement. Each step was examined in the post-test questionnaire, where users could select one or more features in the application that they felt supported the different stages. For self-monitoring, the most popular was the smiling earth chart on the home screen, listing previous activities, and making a climate action pledge. The same was also chosen by most in the goal-setting step, in addition to challenges. In the feedback step, the Smiling earth chart, the previous activities, and notifications were selected as the most effective. While, for obtaining a reward, the challenges, climate action pledge, and smiling earth chart were the most popular choices. For the final step, social encouragement, the results were more even. The participants felt that receiving comments and likes on a post, other users following them, being a member of the teams were all sources of social encouragement from other users.

Observational Learning

Observational learning is closely related to social modeling. For measuring the effect, the components had on supporting observational learning; six statements were created (S40 to S46). From a review of the results presented in Section 11.3.3, over 50% of the participants agreed with every statement, indicating there are many sources for observational learning in the application. This includes observing other users taking climate action pledge, having a lower carbon footprint, joining and completing a challenge, and sharing activity.

Outcome Expectation

The final construct of Social Cognitive Theory is Outcome expectations, which refers to what people believe the potential consequence from action is. The results showed that two primary components of the application affected the users' outcome expectations. First, the list of recorded activities, which included the duration of the activity, the number of calories burned, money saved, and CO_2 emitted. Secondly, the changes in the smiling earth diagram on the home screen made the users more aware of the outcome of their actions. The results from self-monitoring, discussed in the previous sections, show similar responses. The two are closely related as the outcome of your previous actions are often used to predict the future outcome.

12.3 RQ3: How do theories of online communities contribute to increase user motivation and promote pro-environmental behavior change

This research question explores how different communities could motivate users to act more sustainably and develop environmentally-friendly habits. Section 11.3.5 describes the result from the post-test questionnaire about online communities. When asked, "do you think being a member of online communities could contribute to making your habits more environmentally friendly", 75% answered "Yes" or "yes, somewhat," and 12% answered "No", while 13% answered, "I don't know". Additionally, from the statements about social features in the application, 56% agreed that being a member of a community motivated them to act more eco-friendly (Statement S14).

Next, when evaluating which kind of online communities worked the best, the questionnaire was divided into three parts, "motivation to act environmentally friendly", "motivation to change behavior," and "motivation to use the application". For the first question, communities of practice and communities based on location scored 62% and 68% agreeing. The two kinds of communities were the only ones to score more than the more general statement about online communities, Statement S14. The results from the second question indicate that communities of practice (62% agree) and communities based on location (56% agree) are also the most suited for obtaining behavior change, followed by communities of interests (50% agree). However, when evaluating the third question, motivation to use the Smiling Earth, Communities of interest are the most popular, with 62% saying it could motivate them to use the application, followed by communities of practice with 58% and communities based on location with 50%. In every statement, communities with random users score the lowest.
Looking at which communities were most popular, the location-based teams had the most members. At least when not including communities with randoms, as all participants were placed randomly in these teams.

When asked why the participants were not members of the other teams, the most common answer was "none of them fitted me", indicating that there could have been more diversity in the number of teams. From the interviews, some of the participants found the community feature lacking more ways of interacting with each other and exchanging experiences, like sharing articles and images. Additionally, some participants found it hard to motivate themselves to interact with the users when they did not know their identity.

To answer the research question, the kind of online communities to motivate the users the most were communities based on location, followed by Communities of Practice. The importance of communities and locations was also found in the review by Wang et al. [92] of the anonymous social media application Whisper.

The results from Wang showed that users are more likely to join communities in a region near themselves and that locality plays an essential role in the formation of Whisper's communities.

12.4 RQ4: How does anonymity affect the interaction between the users of Smiling Earth?

The results shown in Section 11.3.4 states that most participants find it easier to interact with others when they are anonymous. This includes giving likes and comments on posts and following other users. These results support the research done by Peddinit et al. [93], where they reviewed anonymous users on Twitter. Their study found that anonymous users are generally less inhibited to be active participants than other users. However, as one participant quoted in the interview (see Section 11.4), "I did find it a lot easier to react to others' posts and to publish new ones, but I found the motivation to do so very low as I did not know the other person". This is also reinforced from the responses to statements about motivation to interact with others in the app, as only 25% found it more motivating to follow others when not knowing their identity. Similar results were found in a study by Wang et al. [92] on the anonymous social media application Whisper. Their findings showed that without strong user identities or persistent social links between users leads to weak ties in the application. Weak connections between users weaken the network effect of the application and the overall *stickiness* of the network, leading to challenges in long-term user engagement.

In order to support some kind of representation of each participant, they could create their own avatar. A selection of the avatars created is shown in Sections 11.2.1. One interview subject said that having an avatar to represent yourself was very helpful and suggested that adding more information about yourself while still anonymous could improve the experience. This is further supported by Kang et al. [94] where they evaluated how the degree of avatar realism in anonymous applications supports Social Copresence. It was found that the higher degree of realism of the avatars, the larger increase in social copresence in the application. Also, lower realism graphic avatars, as the kind used in Smiling Earth, were shown to improve the social copresence, but not as much as higher realistic avatars. If the application still supports anonymity, future work should evaluate how the user can have an identity in the system while still being anonymous.

12.5 RQ5: How to implement a persuasive and social mobile application with support for both individuals and communities with existing technologies and methodology?

A crucial part of creating a system is to make a solid foundation to build upon. Since the system would be a continuation of the previous version of Smiling Earth, an examination of the state of the app was done in the begging. From reviewing the code and the reports of the earlier versions, it was found that there were three main issues:

1. The tracking of users' movement was faulty and had to be improved.
2. The application lacked a backend solution and thereby had no support for social aspects.
3. It was recommended to improve the structure of the application.

Before implementation could start, a review of possible technologies and solutions had to be evaluated. For three reasons, Flutter was chosen to be the framework of choice for the mobile application. Firstly it supported cross-platform development, meaning there is the possibility of creating an iOS version and a version for the web in the future. Second, it is a modern framework with increasing popularity. Thirdly, it has a great developer experience and community with support for many different pre-build plugins and components. For example, we used a pre-build plugin called Activity Recognition and Google's Activity Recognition API to make the app persuasive. Using a tested and well-known plugin improved the accuracy of tracking the user's movement. The review concluded that many different potential frameworks exist for the backend solution, and most offer the same functionality. The choice of using Django Rest Framework was based on the research's prior experiences with the framework, the philosophy of having loose coupling and high cohesion, which reinforces the modifiability of the system, and that the framework comes with an admin panel for managing data in the system. The final step in the technology review included a study of different hosting solutions for the backend application. The choice was made to use Heroku as the development server since it offers a free basic server for Django Applications, while Microsoft Azure was chosen to be used as the release server as it complies with NTNU's data storing policies.

After settling on the technologies, a wireframed prototype was created using Figma. The prototype could be used to try out new ideas quickly, create a system structure, and figure out what functionality could work. The design was made with constructs of Social Cognitive Theory in mind, in addition to the results from the user evaluation of the previous version of the application and the outcome from a co-design workshop executed in the specialization project. Creating the design was an iterative process, including discussions with my supervisor and conducting a usability evaluation with potential users of the system.

The next step was to structure further the application's functional requirements and quality attributes based on the design and usability evaluation. The requirements were prioritized according to how crucial it was for the operation of the application. Prioritizing the requirements was useful when planning which component to complete first. The quality attributes described the non-functional requirements in the system. The main quality attributes were modifiability, usability, availability, security, and privacy. The systems architecture was designed based on standard practices used in the chosen technologies and the quality attributes. The main architecture for the system was Client-Server. Additionally, other patterns were used, such as the Model View Controller, Singelton, and Template method, which all supports the overall modifiability of the system.

Finally, it was time to implement the system. Using standard development methodologies was an excellent way of structuring the process. This included elements from Scrum like creating a kanban board to track progress and issues, bi-weekly standups with my supervisor, and dividing the process into sprints. Additionally, Continuous Integration and Continuous Development CI/CD, a standard method from DevOps, was used to rapidly test and deploy the system.

12.6 Limitations

The work done and the data generated in this thesis are affected by four main limitations. Firstly, the duration of the test period should have been longer to evaluate the long-term effect the application has on the participants. One week may be enough to get a feeling of using the app and the concept but not long enough to fully evaluate the change in behavior and motivation in the long run.

Secondly, doing the same evaluation with a larger population could affect the results additionally. As social media applications increase their network value with the growth of the number of members [95], a more real-world result could be achieved with more participants.

Thirdly, the experiment should be tested with a more variety of participants. For example, was the test population in this evaluation already somewhat concerned about the climate and motivated to change behavior. From reviews of similar health applications like Strava, it has been found that the application works well on people who have already engaged with physical activities but is not well suited to first engagements with physical activity [96]. The same could also be present with pro-environmental applications such as Smiling Earth.

Finally, there is some limitation in the design of the application. Many participants stated they would not join the different communities because they did not find any of them suitable. More time should have been used to create diverse communities that applied for more users. Additionally, as mentioned in the interview section, many participants would have liked more community functionality, such as better ways of sharing content and exchanging experiences. Also, since some participants experienced bugs during the evaluation and found the system somewhat slow, this may have affected their experience of using the application.

12.7 Lessons Learned

The process of creating this application has been an educational experience. During the last year, I've had to use all the knowledge attained from courses taken at NTNU and acquire new knowledge. Running a workshop, talking with users, conducting the evaluation of the application with real users, and basing the application on theory were all new experiences. Also, creating an application from the ground up, from designing the prototype, eliciting requirements, creating a software architecture, developing both a server and client application, and deploying the application to a server has been a real challenge and very motivating to work with.

In hindsight, it would have been better to work on this project as a team of two or more developers to even out the workload and discuss the different solutions. Additionally, I would recommend testing the applications on more devices before releasing the system, as the Android ecosystem contains many different versions of the OS and devices. The user evaluation showed that not every function worked as intended on all devices.

Chapter 13

Conclusion

13.1 Conclusion

The aim of this project was to examine user perception of a mobile social application based on the theoretical framework of Social Cognitive Theory. The application was created to motivate, promote and engage citizens to reduce their carbon emissions both individually and as a community. The thesis contributes by enhancing the application Smiling Earth and researching social computing based on social cognitive behavior. This included how social computing can be used in the application employing the research strategies Design and Creation, and Experiment as defined by Oates [7].

The Design and creation period consisted of first doing a background study on the application's state (Smiling Earth) and a literature and technology review to find new features to be implemented. Then a workshop was conducted during the specialization, and a list of requirements and quality attributes was created. The requirements worked as the basis for the design of a new prototype. A usability evaluation was conducted with potential users to expose any design flaws and receive feedback. Finally, the implementation of the design could begin, and by utilizing agile methodology from Scrum and DevOps, a proof-of-concept application was created within four months.

In order to answer the research questions, the next phase was to conduct an experiment with the application and potential real-world users. First, the participants were given a unique anonymous username and asked to install the application on their android device. The experiment lasted for a week, and afterward, they were requested to answer a questionnaire regarding their experience of using the application. The data was then analyzed and used to answer the research questions.

The results showed that the participant liked the social aspects of the application and would prefer having social features rather than using the application without them. The results also showed an increase in users' willingness to use the application compared to the previous versions without social features. Additionally, the experiment population was divided into two groups, drivers and non-drivers. By analyzing the results from each group, signs showed that both groups enjoyed using the application and found it motivating to act more sustainably. However, the driver's groups found the application more useful than the non-drivers. This suggests that the application is most useful for people who have easy access or own a car

The participants also answered statements about which social features motivated them the most, which was used to create a ranked list of the most effective social features to encourage users to act more eco-friendly.

The application was also evaluated on how well it supported the different primary constructs of Social Cognitive Theory. The results indicated that application was most helpful in increasing self-efficacy, observational learning, and self-regulation. Additionally, some users found it to support collective efficacy, but the majority were neutral, suggesting that the application could further improve to support online communities.

Due to privacy concerns, the application's users had to be anonymous. From the results of the post-test questionnaire and interviews with participants, the majority state they found it easier to interact with others when being anonymous. Still, while many found it easier to interact, most felt that being anonymous affected their motivations to interact with other users.

A contribution to the system was adding the ability to create and join communities in the application. The literature review discovered many different kinds of online communities. Three types were added for participants to join, communities interests, communities of practice, and communities based on location. Additionally, to have a control group to test against, all users were randomly placed into one of three groups. The results showed that participants found being in a group with random users the least useful. Communities of location were the most popular, while communities of practice were stated to be the most fitting for increasing users' motivation and suited for supporting behavior change. On average, the participants were members of two groups. When asked why they did not join any other teams, the most common answer was that the other teams did not fit them. For future experiments with Smiling Earth, it could be interesting to use more time to create more suitable groups for the participants.

13.2 Further work

Due to the time limitation of this thesis, some features were not implemented in time for the user evaluation. For example, only a preview of the duel feature was implemented. As the participants found this feature very intriguing, it should be prioritized to complete in future versions of the application. Additionally, some of the features from the previous version, like Earth coins, were not implemented due to time restrictions. Some participants experienced bugs like the app crashing during the user evaluation, or some activities were tracked multiple times. The participants also suggested that the application should have more carbon emission sources, such as shopping and food consumption emissions.

From the anonymity results, most of the users said they would like the application better if they could not be anonymous and could know the other participants' identities. A future version of the application could enhance data storage security to support participants in using their real names to further evaluate the social aspects and compare the results to the ones presented in this thesis.

Another idea that was suggested from the workshop is to enable crowd-sourcing in the application. This means that users can contribute to the application, e.g., creating their own challenges, teams, etc. From the review of the related application, these features seem not to be present in any other systems.

As the system now has a functioning backend, it opens up for adding more types of users to the system. As of now, the application only focuses on the citizen in a city. In order to create a more sustainable city, it could be interesting to add different roles in the city hierarchy that could examine and use the user-generated data to improve the city further or to interact with the citizen. Additionally, the user could have various roles within a community. For example, you could be a team leader that can administrate and arrange events in a community. From the additional comments and further development section in the results, some users also suggested adding more ways of interacting within a community.
Since the mobile client is creating using Flutter, the application can now also be converted to iOS. Creating a version for iPhone can assist in the recruitment of more participants to join the evaluation of new features as 58 % of Norway's population uses iPhone [97].

The thesis has based the theoretical framework for behavior change on Social Cognitive Theory. The results showed that the applications successfully supported many aspects of Social Cognitive Theory. However, it did not evaluate the degree of effect the application had on the participants. Therefore, a future evaluation should examine how well the application promotes pro-environmental behavior. This could be done by evaluating the participant's attitude toward climate change and environmentally friendly behavior before and after using the application.

As described in Section 11.1, the majority of the population in the evaluation could be described as *Lurkers*, a term used in Social Computing to address users who don't actively interact in the application or community. Due to time limitations, analyzing their results and comparing them to non-lurkers was not completed. However, it could be interesting to explore the difference in terms of Smiling Earth as discussed by Wagner et al. [90] there are significant differences between people who lurk and those who post in an online community. Additionally, examine how to promote more active participation in the application and within communities.

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Appendix A

Workshop Scenarios

Template

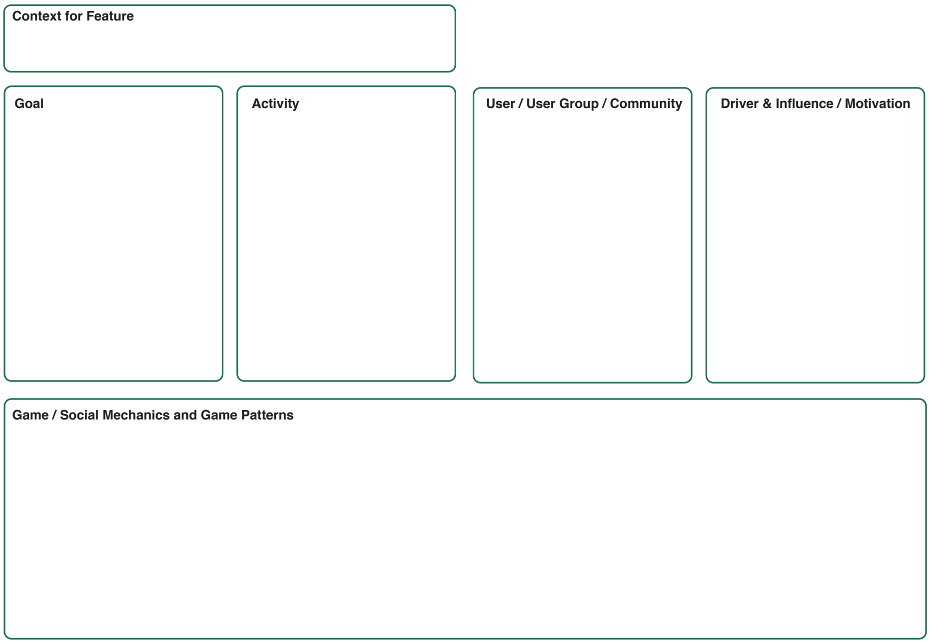


Figure A.1: Template created to represent a user scenario derived from the workshop

Scenarios

This section includes the scenarios created in the co-design workshop. On the left side is a picture taken of the boards created, and the right-side includes a digital version of the board.

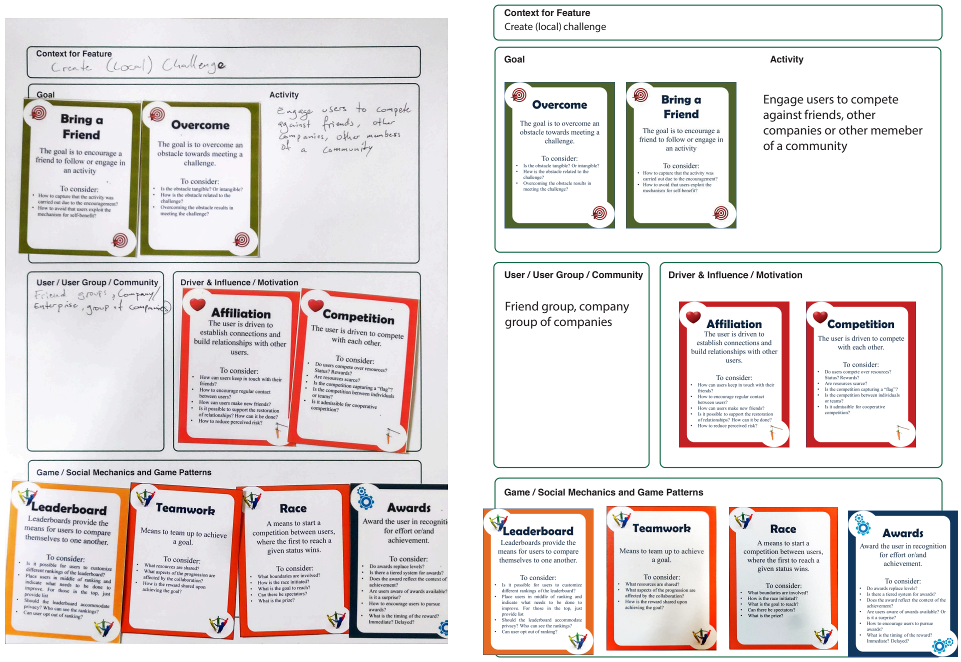


Figure A.2: Boards created to represent creating challenges between users or communities

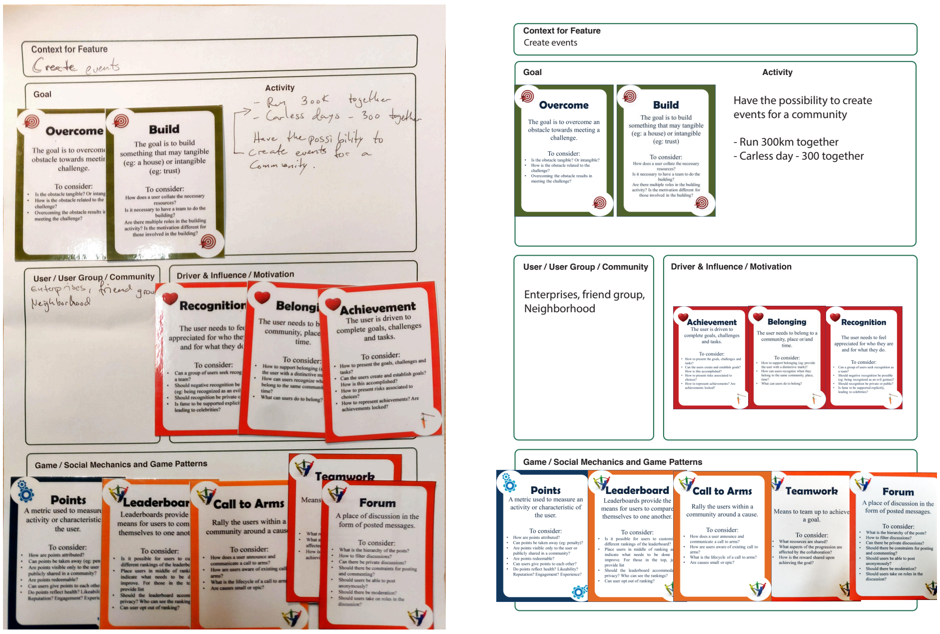


Figure A.3: Boards created to represent attending events for everyone or within a community

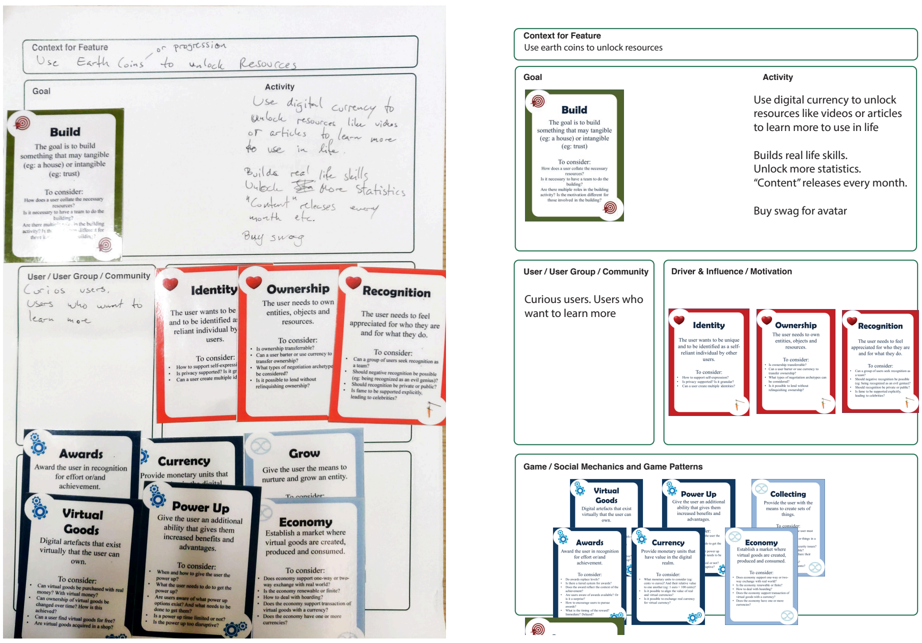


Figure A.4: Boards representing using earth coins to buy virtual goods or content

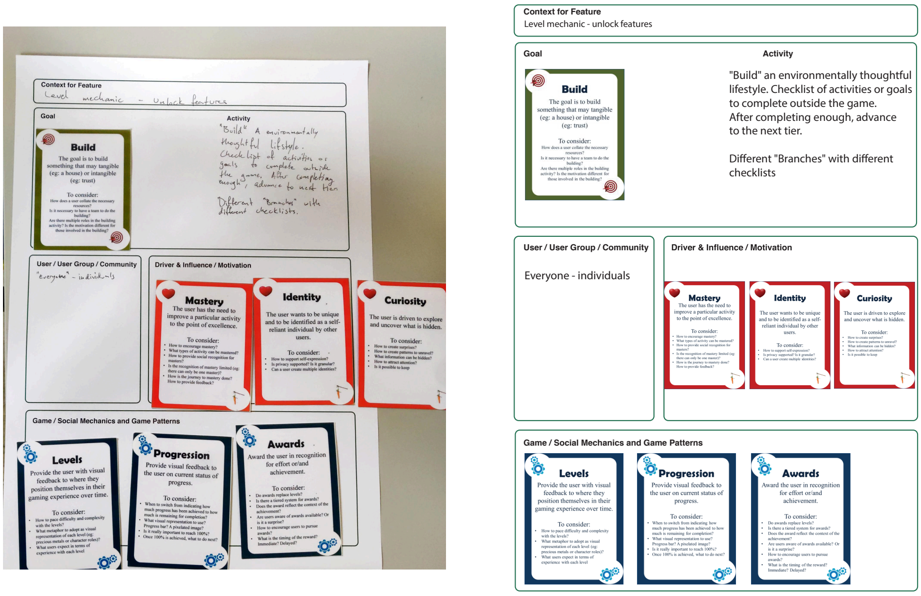


Figure A.5: Boards representing unlockable items(challenges, eventsm etc) by completing other challenges or attending events

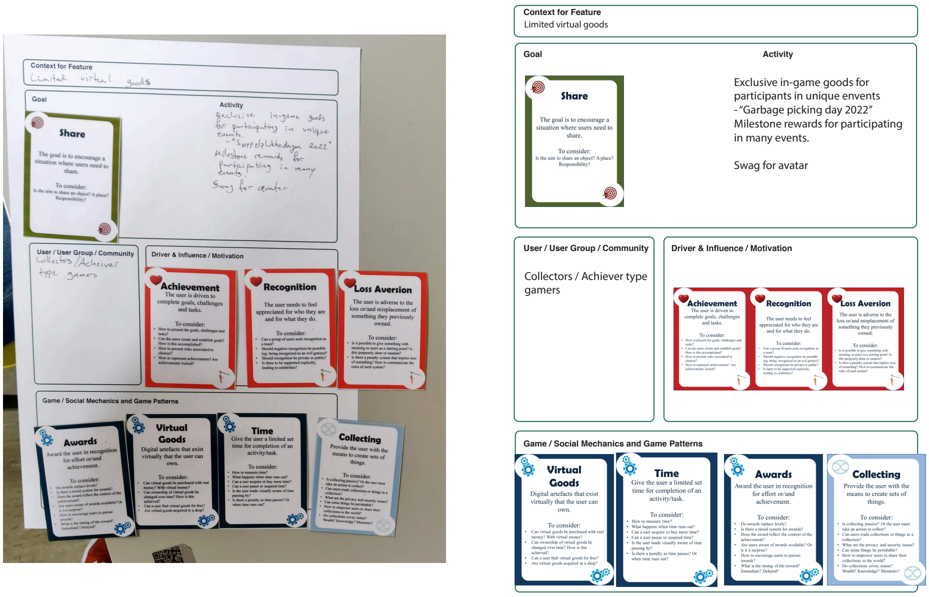
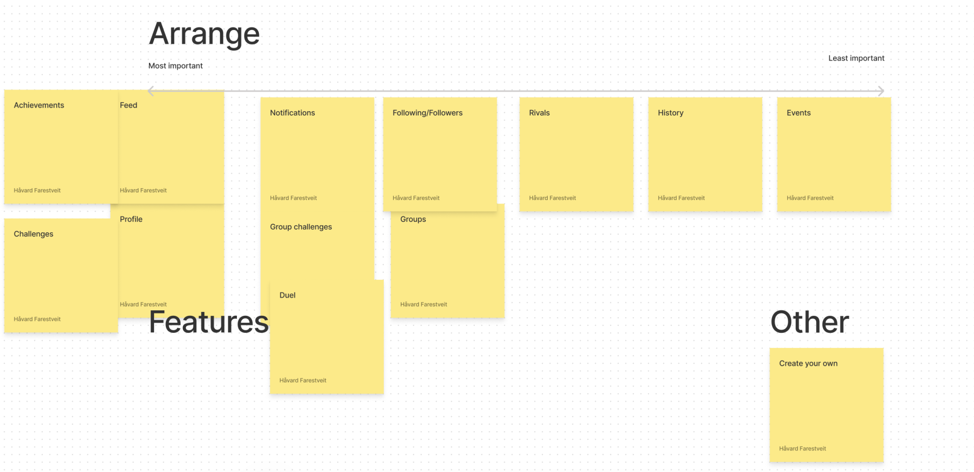
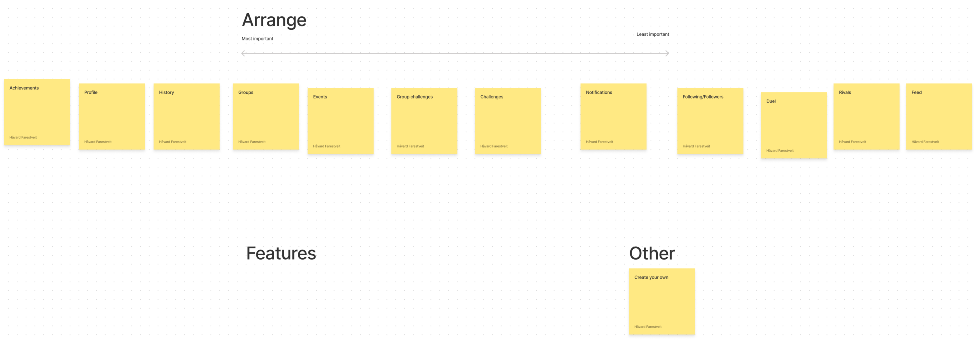


Figure A.6: Boards representing the users can obtain virtual goods that are limited to a specific challenge or event

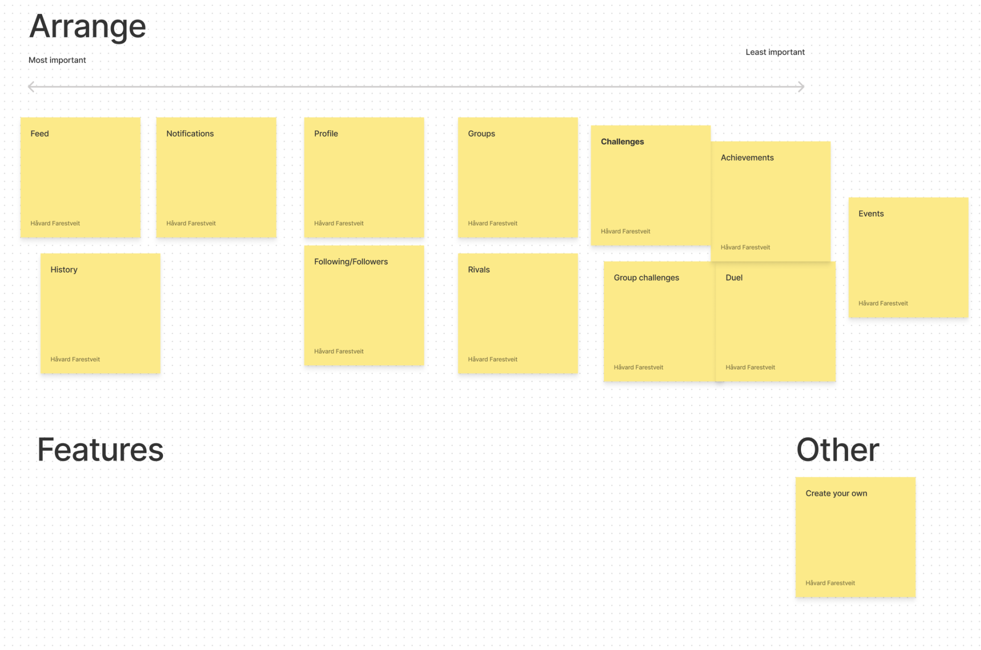
Appendix B

Boards






Arrange
Most important
Least important
Following/Followers
Groups
Profile
Rivals
Feed
History
Notifications
Group challenges
Achievements
Duel
Events
Challenges
Features
Other
Create your own


Arrange
Most important
Least important
Feed
Notifications
Profile
Groups
Challenges
Achievements
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Following/Followers
Rivals
Group challenges
Duel
Features
Other
Create your own

Arrange
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Least important
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Groups
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Profile
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Group challenges
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Feed
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History
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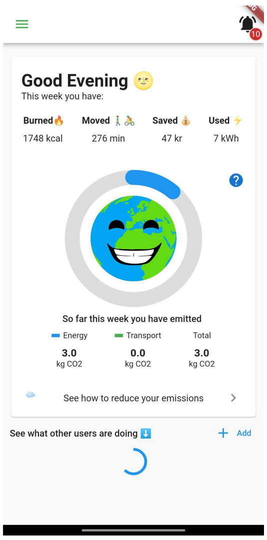
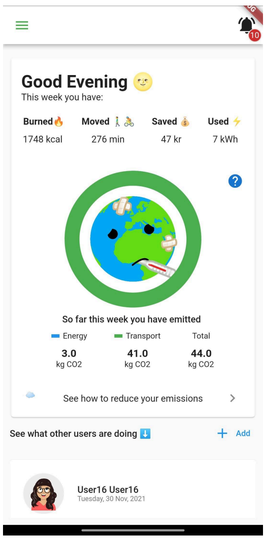
Other
Create your own
Håvard Farestveit

Appendix C

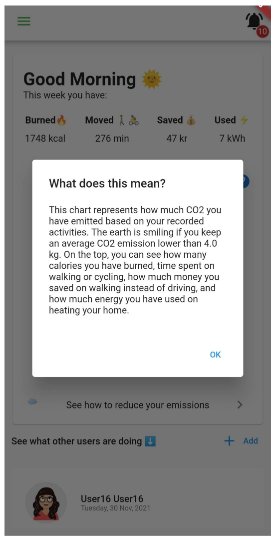
Screenshots of the Smiling Earth Client



(a) The home screen w/ low emissions

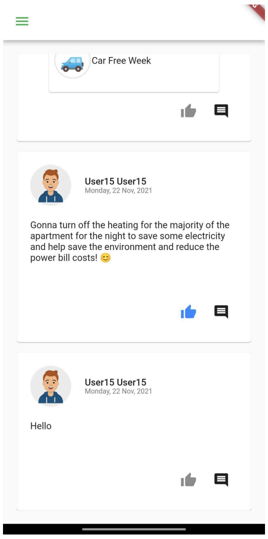


(b) The home screen w/ high emissions

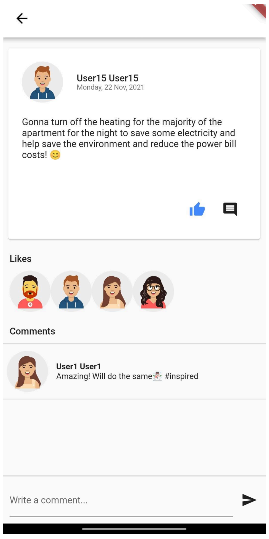


(c) Modal opening after pressing the question mark button

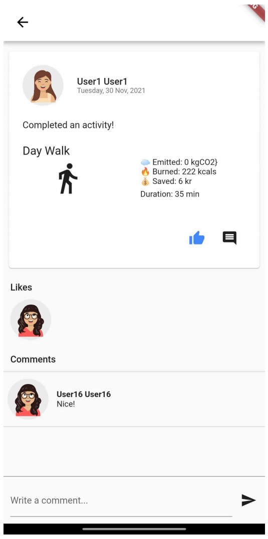
Figure C.1: Screenshots of the home screen in the new versions of Smiling Earth



(a) News feed

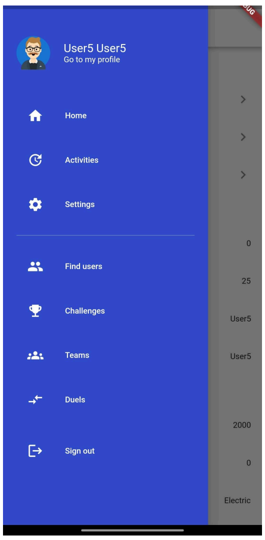


(b) Detailed view of a post

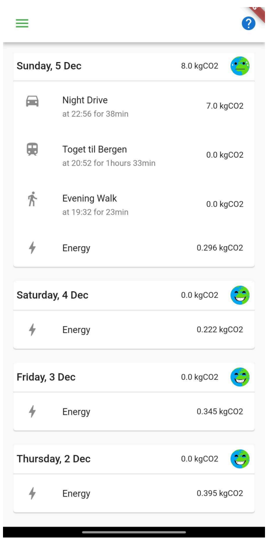


(c) Detailed view of a shared activity

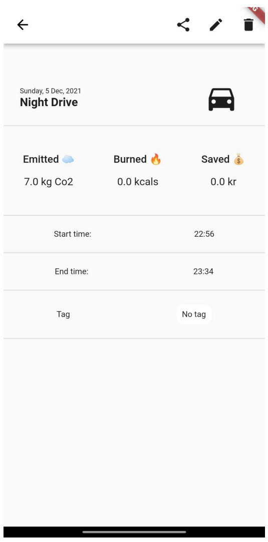
Figure C.2: Screenshots from the news feed. The feed is found below the home screen



(a) The new navigation drawer

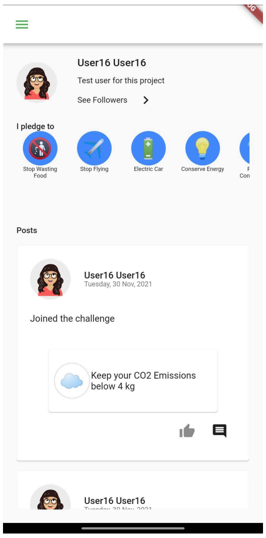


(b) Previous activities

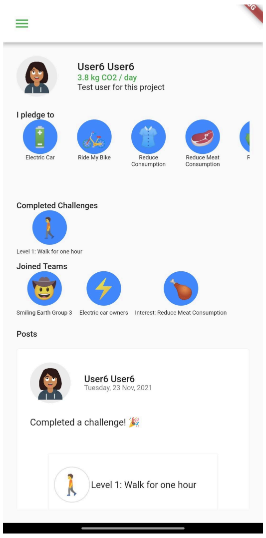


(c) Detailed activity view

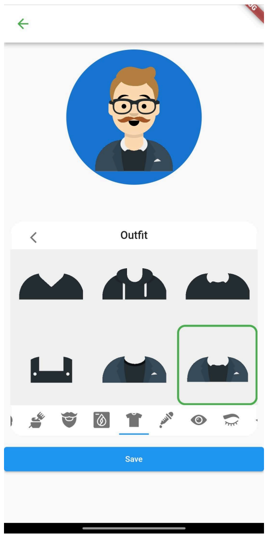
Figure C.3: Screenshots of the new view containing the previous recorded activities. From here the user can create, edit, delete and publish activities



(a) The new profile view

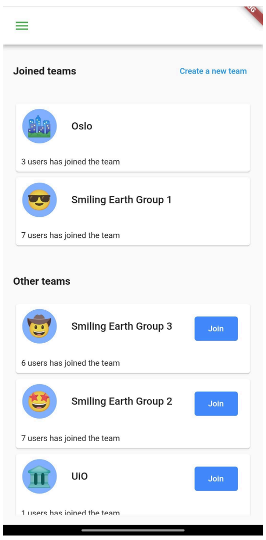


(b) The view of a follower's profile

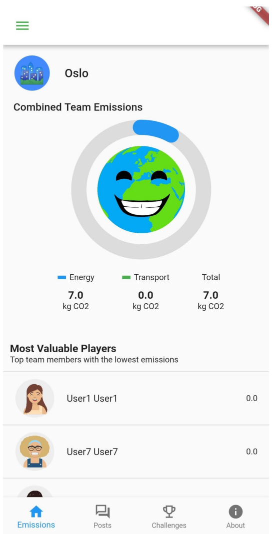


(c) Creating a avatar using Fluttermoji

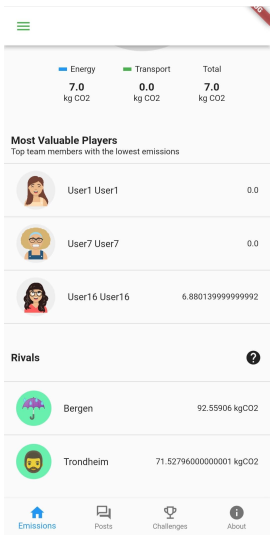
Figure C.4: Screenshots of the profile pages and avatar



(a) Team list page

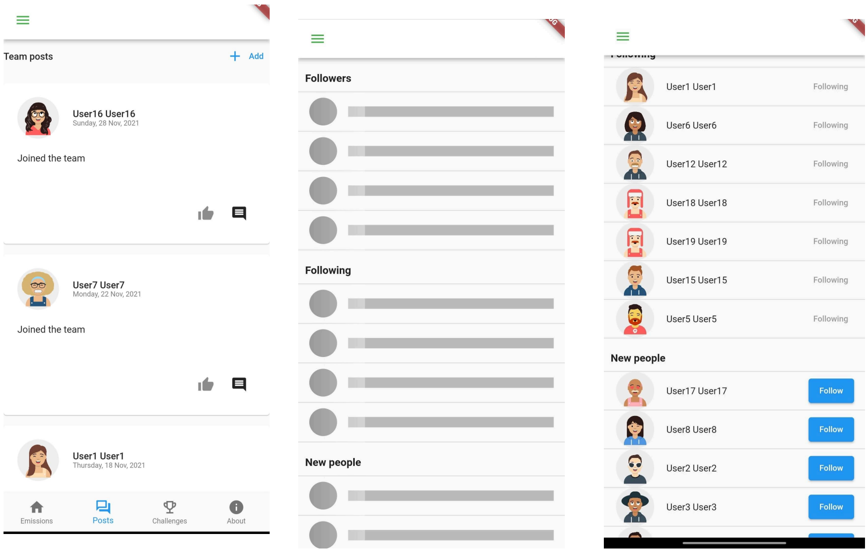


(b) Detailed team page 1



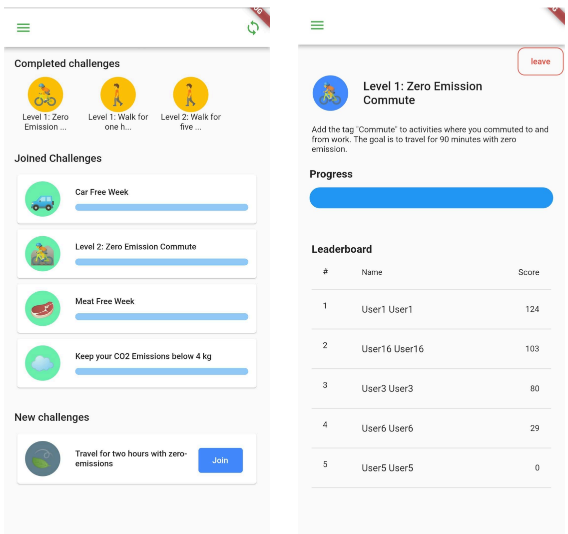
(c) Detailed team page 2

Figure C.5: Screenshots of the new teams page



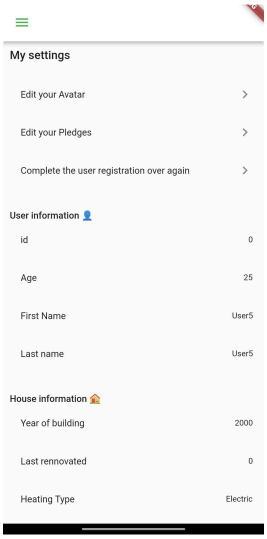
(a) Teams forum page where members can create posts **(b)** Skeleton loading screen **(c)** Follower page

Figure C.6: Screenshots of the teams post forum page and finding users page. A skeleton screen is previewed while the page is loading

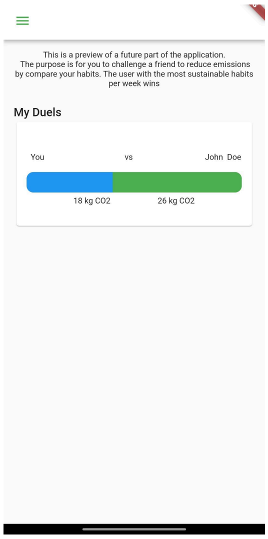


(a) Challenges list view **(b)** Challenge detailed view

Figure C.7: Screenshots of the challenges view



(a) Settings screen



(b) Duel screen

Figure C.8: Screenshots of the settings view and the preview of the duel view

Appendix D

Screenshots of the Django Rest Framework

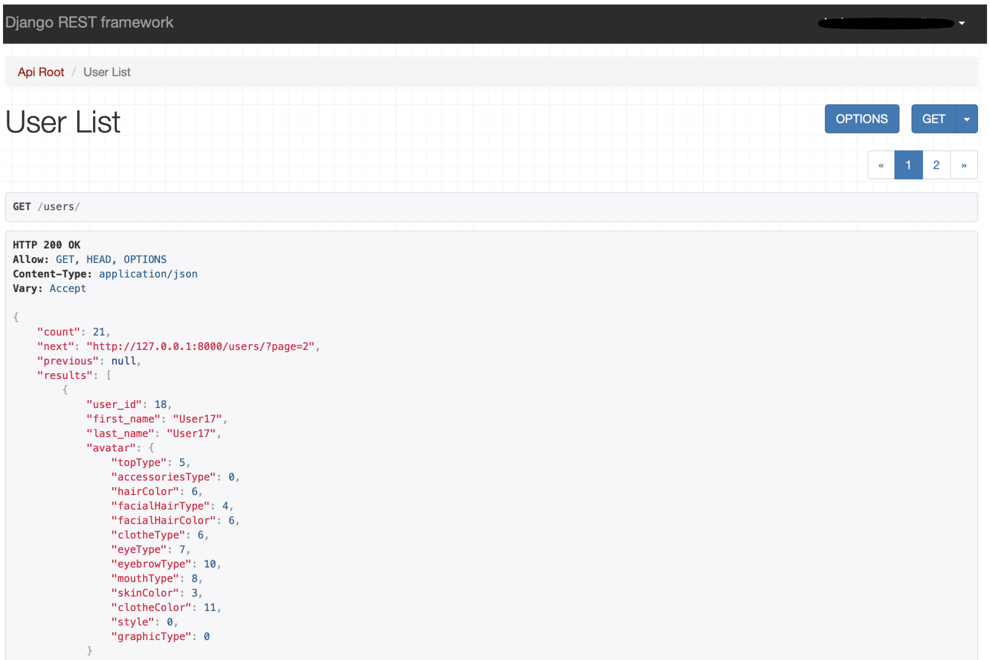


Figure D.1: The built-in API interaction view from Django Rest Framework API

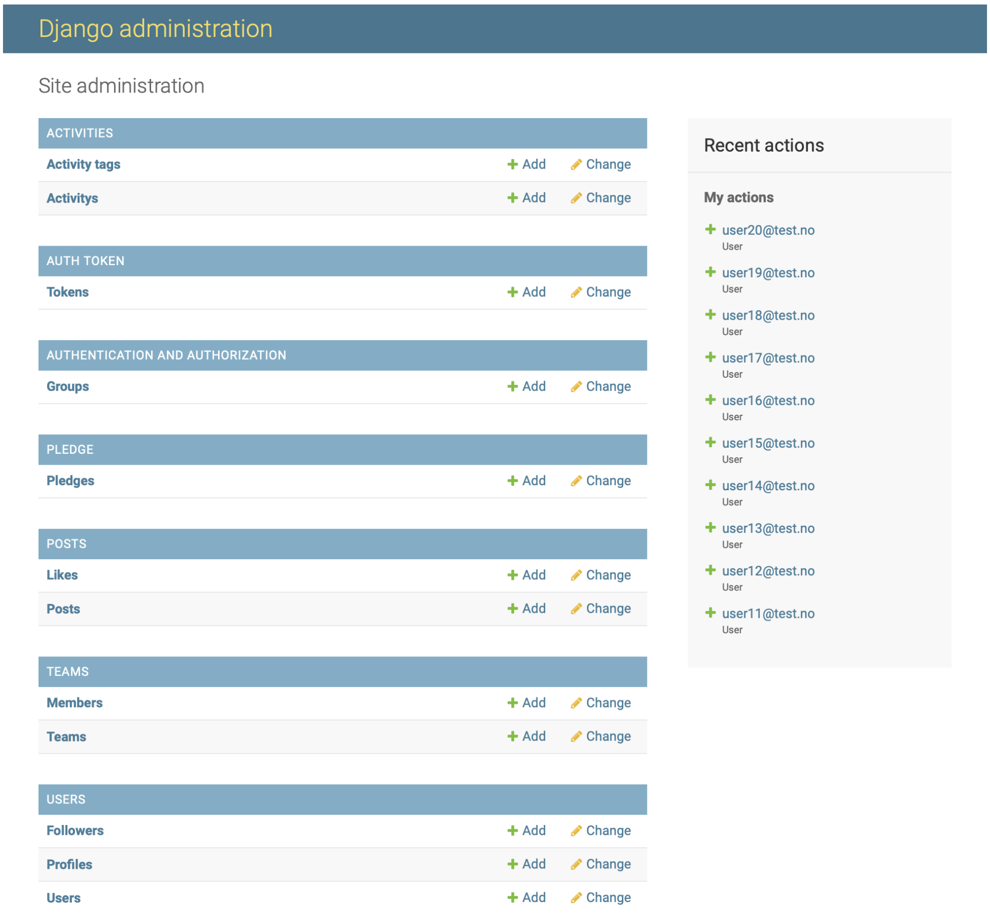


Figure D.2: The built-in Admin view from Django Rest Framework API

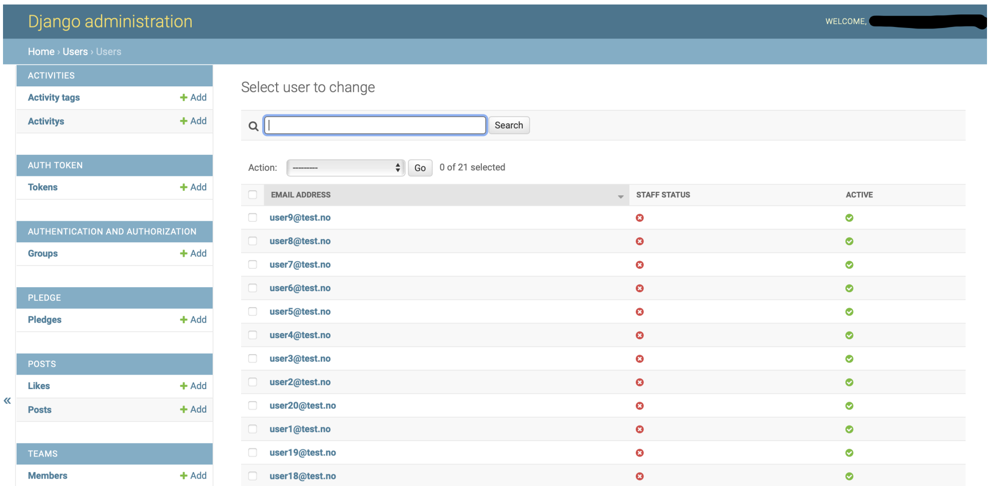


Figure D.3: The admin view for creating, edit and delete users

Appendix E

Calculations

The calculations is the same as used in the previous versions of Smiling Earth, and was first added by Celine Mihn [13].

Appendix C

Calculations

The following document has been written by Peter Ahcin. It describes the calculations used in the app.

C.1 Cost of solar power

The app tries to visualize the impact of investing into a solar installation in an immediate way. All consumption costs and the costs of the user's solar installation are translated into hourly values. Energy consumed is paid for very directly. The electricity company charges the consumer for each kWh of used electricity and the use of the electricity grid (nettleie in Norway), which can be divided generally into fixed charges for billing and with bigger customers for peak load, and per kWh. In Norway, the future trend is toward charging a larger fixed part and a smaller variable per kWh part, since this corresponds better to the actual cost of the distribution system operator. Namely, network costs are predominantly infrastructural costs that depend not on the amount of energy transported but rather on the capacity of the network to support the highest – peak loads that may occur only a few hours in a year.

The cost of energy generated by the solar installation is calculated as the so called Levelised Cost of Electricity generation (LCOE):

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \tag{C.1}$$

Where:

- LCOE – lifetime levelised cost of electricity generation;
- I_t – investment expenditures in the year t;
- M_t - operations and maintenance expenditures in the year t;

- F_t - fuel expenditures in the year t;
- E_t - electricity generation in the year t;
- r - discount rate
- n - economic life of the system.

The above is taken from:

· IRENA: "Solar Photovoltaics" Renewable energy technologies: Cost analysis series, Volume 1: Power Sector Issue 4/5, June 2012.

We take the economic lifetime to be 30 years and a discount rate of 8% which corresponds to the cost of capital for renewable energy projects Europe. The values are calculated with the NREL LCOE calculator[1] and neglect the performance degradation factor. However, due to the high discount factor, this has little effect on the obtained value of LCOE.

C.2 Cost of driving

The cost of driving is estimated using the web service Bilkostnadskalkulator that's available at:
`http://www.smartepenger.no/kalkulatorer/2164-beregn-arlige-bilkostnader-for-bruktl`
The key inputs are:

- current value of the vehicle
- age of the vehicle
- distance on the kilometer counter
- number of years the user will keep the vehicle
- distance driven per year
- fuel consumption per Norwegian mile

The calculator produces a daily cost of the vehicle that includes all variable and fixed costs and an estimate of the marginal cost of every additional kilometer driven. The daily value is divided into an hourly value for the app to which the marginal cost is added for the distance driven every hour.

[1] `http://www.nrel.gov/analysis/tech_lcoe.html`

C.3 Emissions from electricity consumption

The emissions factor for electricity consumption is taken from a SINTEF study[2]. The author's put the value at 157 gCO_2e/kWh. Both consumption and the production of the solar installation use this same factor, with the production obviously having a negative value of -157 gCO_2e/kWh.

C.4 Emissions from driving

Greenhouse gas emissions from driving are calculated from the estimated fuel consumption. For gasoline vehicles the value 2392 gCO_2e/L is used. For diesel vehicles it is 2640 gCO_2e/L[3].

The US EPA uses 2348 gCO_2e per liter of gasoline and 2689 gCO_2e per liter of diesel fuel[4].

For electric vehicles the value used is 157 gCO_2e/kWh.

[2]2 I. Graabak, B.H. Bakken, N. Feilberg: "Zero Emissions Building and Coversion Factors between Eelctricity Consumption and Emissions of Greenhouse Gases in a Long Term Perspective", Environmental and Climate Technologies, 2014.

[3]`http://ecoscore.be/en/info/ecoscore/co2`

[4]"Greenhouse Gas Emissions from a Typical Passenger Vehicle", Office of Transportation and Air Quality, EPA, 2014.

Appendix F

NSD

Vil du delta i forskningsprosjektet
Smiling Earth?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke hvordan en mobilapplikasjon som kalkulere ditt klimautslipp kan gjøre brukeren mer miljøbevisst ved hjelp av funksjoner fra sosial medier. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Dette studiet gjennomføres som en del av en masteroppgave på NTNU.

Målet med studiet er å se hvordan man kan bruke funksjonalitet fra sosial medier i en mobil-applikasjon kalt *smiling earth.* Applikasjon prøver å påvirke brukere til å bli mer miljøbevisste og handle mer miljøvennlig ved å kalkulere ditt klimautslipp basert på ditt aktivitetsmønster og/eller informasjon som brukeren selv legger inn. Hoved fokuset i oppgaven er å se på hvordan digitale interaksjoner mellom brukerene av applikasjon kan påvirke brukerens motivasjon til å handle miljøvennlig. I applikasjonen har brukerene mulighet til å følge andre brukere, dele innlegg med sitt nettverk, delta i konkurranser eller danne og bli medlem i ulike nettsamfunn.

Hvem er ansvarlig for forskningsprosjektet?
Forsøket gjennomføres som del av en masteroppgave ved Institutt for Datateknologi og Informatikk (IDI) på NTNU. Veileder og hovedansvarlig for prosjektet er Sobah Abbas Petersen. Forsøket vil bli gjennomført av studenten Håvard Farestveit.

Hvorfor får du spørsmål om å delta?
I studiet ønsker vi å få tilbakemelding fra personer mellom 18–65 år. Du har blitt spurt om å delta fordi du enten kjenner noen som jobber med prosjektet, eller noen andre som deltar i prosjektet, eller fordi du har hørt om dette prosjektet på noen måte og selv tok kontakt med prosjektansvarlig for å delta.

Hva innebærer det for deg å delta?
Hvis du velger å delta i undersøkelsen innebærer det at du må svare på to spørreundersøkelser og en brukertest av applikasjonen over to uker. Spørreundersøkelsen vil bli fylt ut elektronisk og tar 20-30 minutter. Spørsmålene vil gå ut på din opplevelse av å bruke applikasjonen, samt dine vaner og kunnskap rundt ditt eget klimautslipp.

Det kan hende at du vil bli spurt om å stille på intervju i etterkant av brukertesten, men det vil ikke være nødvendig å intervjue alle deltakerene av undersøkelsen. Deltagelse i intervjuet er helt frivillig. Målet med intervjuet er å få mer informasjon, tanker, problemer eller annet som ikke blir oppdaget i spørreundersøkelsen. Under intervju vil det bli tatt lydopptak.

Under gjennomføring av brukertesten vil data som brukeren selv publisere bli lagret på en server. Alle brukere vil få utdelt en tilfeldig bruker. Det vil ikke være mulig å identifisere brukerens ekte navn ut i fra informasjonen som blir lagret i applikasjon. For mer informasjon se «Ditt personvern - hvordan vi oppbevarer dine opplysninger»

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket

tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket. Det vil ikke være mulig å gjenkjenne deltakere i publikasjonen av masteroppgaven. Det er kun studenten som gjennomfører prosjektet og ansvarlig veileder som vil ha tilgang til opplysninger under dette prosjektet. Under brukertesten vil deltakerens navn og kontaktopplysningene blir erstatte med en kode som lagres på egen navneliste adskilt fra øvrige.

Applikasjonen som blir brukt under prosjektet vil samle inn og lagre følgende data på en server:
- Hvilke grupper/nettsamfunn brukeren har meldt seg inn i
- Hvilke konkurranser brukeren har meldt seg inn i og poengsummen brukeren har oppnådd i konkurransen.
- Hvilke brukere som «følger» hvem (relasjon mellom brukere)
- Innlegg som brukeren selv publisere til sitt nettverk
    - Kan være en tekstmelding (under 300 tegn)
    - Kan være en aktivitet f.eks. en sykkeltur eller en togtur
        - En aktivitet inneholder en aktivitetstype (sykkel, bil, tog osv.), starttidspunkt og varighet
- Interaksjon mellom brukere i form av en kommentar eller «like» på et innlegg som brukeren har publisert.
- Hvilke klimatiltak eller mål brukeren har satt seg (om noen)
- Brukerens klimautslipp basert på brukerens aktivitetsmønster og grunnleggende informasjon om sin bolig.
- Summen av tiden brukeren har brukt på en aktivitetstype per uke.

Applikasjonen innhenter informasjon om brukerens reisevaner/aktiviteter og bruker dette til å kalkulere hens karbonutslipp. Aktivitetene hentes automatisk via aktivitetssensorer i mobilen dersom brukeren tillater dette eller legges inn manuelt av brukeren. Disse dataene vil bli lagret lokalt på mobilen. Brukeren har selv mulighet til å slette og redigere dataen i applikasjonen.

Når bruker logger inn første gang må hen legge inn litt informasjon om sin bolig (postnummer, byggeår, oppvarmingstype, størrelse og energimerke) og om bilen sin dersom bruker har det. Disse dataene vil bare bli lagret lokalt på mobilen.
All data lagret på mobilen blir slettet når brukeren sletter applikasjonen.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 7.januar 2022. Filene med koblingsnøkkelen mellom navn og brukernavn vil bli slettet ved prosjektslutt og all informasjon vil være ikke-identifiserbar. All data på serveren vil også bli slettet ved prosjektslutt. Det vil ikke være mulig å vite hvem det er som har gitt de ikke-identifiserbare dataene som gjenstår etter prosjektslutt.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og

- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Norges teknisk-naturvitenskapelige universitet / Institutt for datateknologi og informatikk har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Student: Håvard Farestveit, *havard.farestveit@ntnu.no*
- Prosjektansvarlig: Sobah Abbas Petersen, *sap@ntnu.no*
- Vårt personvernombud: Thomas Helgesen, *thomas.helgesen@ntnu.no* (tlf: 93079038)

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Sobah Abbas Petersen
(Forsker/veileder)

Håvard Farestveit
(Student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *[sett inn tittel]*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i spørreundersøkelser og brukertest
- ☐ å delta i intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)

Appendix G

Pre-test Questionnaire

Smiling Earth Spørreundersøkelse

Dette er en spørreundersøkelse som skal besvares før test perioden

* Obligatorisk

Demografisk informasjon

1. Hva var brukernavnet du fikk tilsendt på e-post? *

2. Hvor gammel er du? *

3. Hvilket kjønn er du? *

- ◯ Mann
- ◯ Kvinne
- ◯ Annet
- ◯ Ønsker ikke å oppgi

Ditt forhold til miljø og klimaendringer

4. Hvilke påstander om miljø og klimaendringer stemmer for deg? der 1 er *Helt enig*, og 5 er *Helt uenig* *

	1 Helt enig	2 Enig	3 Hverken eller	4 Uenig	5 Helt uenig	Vet ikke
Jeg er bekymret for klimaendringer	○	○	○	○	○	○
Jeg er en miljøbevisst person	○	○	○	○	○	○
Jeg ønsker å redusere mitt klimafotavtrykk	○	○	○	○	○	○
Jeg synest det er vanskelig å motivere meg til å ta miljøvennlige valg	○	○	○	○	○	○

Informasjon om dine transportvaner

5. Eier du bil? *

- ◯ Ja
- ◯ Nei
- ◯ Nei, men jeg har tilgang til bil når jeg har behov
- ◯ Nei, men jeg benytter meg av bildelingsplatformer som VyBil, Nabobil, Hyre, osv.

6. Hvilke transport-alternativ bruker du til vanlig? *

- ☐ Bil
- ☐ Buss
- ☐ Går
- ☐ Sykkel/El-sykkel
- ☐ Tog
- ☐ Elektrisk sparkesykkel

Informasjon om dine sosiale medier-vaner

7. Hvilke av følgende sosiale medier bruker du?

- ☐ Facebook
- ☐ Instagram
- ☐ Snapchat
- ☐ Twitter
- ☐ Strava eller andre helse/treningsapper
- ☐ TikTok
- ☐ YouTube
- ☐ Andre

8. Hvis "Andre", hvilke andre sosiale medier bruker du?

9. Hvor ofte publisere du noe på sosiale medier? *

- ◯ Mer enn en gang i uken
- ◯ Noen (1-3) ganger i måneden
- ◯ Noen (1-6) ganger i året
- ◯ Sjeldnere
- ◯ Aldri

Appendix H

Post-test Questionnaire

Smiling Earth spørreundersøkelse 2

* Obligatorisk

1. Brukernavn *

   Skriv inn brukernavnet du fikk tilsendt i eposten

2. Opplevde du noen problemer under testingen av applikasjonene? *

   ◯ Ja

   ◯ Nei

   ◯ Noen

3. Hvis ja eller noen, hvilke problemer med appen møtte du på?

4. Dette spørsmålet handler om din opplevelse av å bruke applikasjonen? *

I hvilke grad er du enig i disse påstandene?

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
Jeg synes applikasjonen var enkel å bruke	○	○	○	○	○
Jeg synes applikasjon var nyttig for kartlegge mine utslipp	○	○	○	○	○
Jeg synes applikasjon var nyttig for motivere meg til å ta mer miljøvennlige valg	○	○	○	○	○
Jeg kunne tenke meg å bruke Smiling Earth	○	○	○	○	○

5. Kunne du tenke deg å delta på et kort intervju (30 minutter) om din opplevelse av å bruke appen? *

○ Ja

○ Nei

Sosiale funksjoner

I applikasjonens er det en rekke sosiale funksjoner som f.eks. mulighet forå følge andre, gi likes, kommentere, konkurrere og bli med grupper.
De neste spørsmålene dreie seg om hvilke sosiale funksjoner i applikasjonen som har hatt innvirking på din motivasjon til å ta miljøvennlige valg.

6. I hvilken grad er du enig i følgende påstander? *

	Helt uenig	Litt uenig	Verken enig eller uenig	Enig	Helt enig	Vet ikke
Sosiale funksjoner motiverte meg til å åpne applikasjonen	○	○	○	○	○	○
Jeg vil be andre jeg kjenner om å laste ned applikasjonen og følge min bruker	○	○	○	○	○	○
Det at andre brukere kunne se mine utslipp gjorde at jeg ble motivert til å være mer miljøvennlig	○	○	○	○	○	○
Å se andre brukere gjøre miljøvennlige valg motiverte meg til å gjøre det samme	○	○	○	○	○	○
Appen hadde vert bedre uten sosiale funksjoner	○	○	○	○	○	○

7. Applikasjonen har mange ulike funksjoner. Her skal du vurdere i hvor stor grad du er enig i følgende påstander.
Jeg ble motivert til å ta miljøvennlige valg av...
*

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt Enig	Vet ikke
Å kunne dele et innlegg med mine følgere	◯	◯	◯	◯	◯	◯
Å kunne dele en aktivet jeg har gjort med mine følgere	◯	◯	◯	◯	◯	◯
Å få "likes" på mine innlegg	◯	◯	◯	◯	◯	◯
Å få kommentarer på mine innlegg	◯	◯	◯	◯	◯	◯
Å bli medlem i et lag	◯	◯	◯	◯	◯	◯
Å sammenligne resultater med andre i en utfordring (*challenge)*	◯	◯	◯	◯	◯	◯
Å kunne sammenligne mine vaner med andre brukere i en *duel*	◯	◯	◯	◯	◯	◯
Å ha det laveste utslippet innad et lag (*team*)	◯	◯	◯	◯	◯	◯
Å holde det samlede utslippet innad i laget lavt	◯	◯	◯	◯	◯	◯
Å delta i lag-utfordringer (*team challenges*)	◯	◯	◯	◯	◯	◯
At andre kan følge meg	◯	◯	◯	◯	◯	◯
At jeg kan følge andre	◯	◯	◯	◯	◯	◯

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt Enig	Vet ikke
Å kunne sammenligne utslipp mot andre rivaliserende lag (*rivals*)	○	○	○	○	○	○
Å kunne gå inn på andre sin profil og se hva de har gjort	○	○	○	○	○	○
Å gi et klimaløfte (*pledge*) om å bli mer miljøvennlig	○	○	○	○	○	○
Å fullføre en utfordring (*challenge*) slik at jeg kunne dele det med mine følgere	○	○	○	○	○	○

Mestringstro (Self-efficacy)

Disse spørsmålene dreier seg om din tro på at du kan få til en bestemt oppgave

8. Et mål med applikasjonen er at du skal bli mer bevisst på egen miljøpåvirkning og jobbe mot å bli mer miljøvennlig. Jeg lurer på i hvilken grad du følte at du skulle få til å bli mer miljøvennlig gjennom appen.

   Hvilke deler av applikasjonen påvirket din tro på at du faktisk kunne bli mer miljøvennlig. *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt Enig
Ved at appen registrerte aktivitetene mine, ga det meg troen på at jeg kunne holde et samlet lavt karbonutslipp	○	○	○	○	○
Det at jeg observerte andre brukere fullføre en utfordring (*challenge*), ga meg tro på at jeg også kunne fullføre utfordringen	○	○	○	○	○
Å få tilbakemelding på mine klimautslipp fra den smilende jordkloden på hjemskjermen (smiling earth grafen)	○	○	○	○	○
Å få en melding (*notification)* når jeg var over halvveis i en utfordring (*challenge*), ga meg troen på at jeg kunne fullføre utfordringen	○	○	○	○	○
Å observere at andre klarte å holde et lavt utslipp, ga meg troen på at jeg også kunne klare å holde et lavt utslipp	○	○	○	○	○

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt Enig
Å fullføre en utfordring (*challenge*), ga meg troen på å få til en ny utfordring	○	○	○	○	○
Ved å gi et løfte (*pledge*) ga det meg troen på at jeg kunne holde løftet	○	○	○	○	○
Ved å se andre også gi et løfte (*pledge*) ga det meg troen på å få til mine løfter	○	○	○	○	○
Det påvirket meg positivt å se velkomstmeldingen øverst på hjemskjermen	○	○	○	○	○
Det påvirket meg positivt å se den smilende jordkloden når jeg holdt utslippene lave	○	○	○	○	○

Mestringstro som en gruppe (Collective efficacy)

Disse spørsmålene dreier seg om din tro på at en gruppe kan få til en bestemt oppgave

9. Forrige spørsmål dreide seg om hvilke deler av applikasjonen som påvirket din tro på at du faktisk kunne bli mer miljøvennlig.
   I dette spørsmålet luret jeg på i hvilke deler av lag-funksjonalitet (*teams*) som påvirket din tro på at vi som **en gruppe** kan bli mer miljøvennlig.

   Hvilke deler av lag-aktivitetene påvirket din tro på at gruppen kunne bli mer miljøvennlig.
   *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
At laget fullførte en lag-utfordring (*team challenge*) ga meg tro på at vi kunne fullføre en ny utfordring	◯	◯	◯	◯	◯
Å se gruppens totale CO2-utslipp ga meg tro på at vi sammen skulle klare å holde et lavt utslipp (under 4 kg CO2)	◯	◯	◯	◯	◯
Ved å se andre medlemmer i gruppen klare å holde et lavt utslipp, ga det meg tro på vi kunne holde et lavt utslipp	◯	◯	◯	◯	◯
Ved å observere andre rivaliserende lag ha et lavt utslipp ga det meg tro på at vår gruppe også kunne holde et lavt utslipp	◯	◯	◯	◯	◯

Selvregulering (Self Regulation)

10. Velg én eller flere deler av applikasjonen som gjorde deg observant på ditt eget utslipp. *

- [ ] Smiling Earth grafen (Jordkloden på hjemskjermen)
- [ ] Løfte om å ta klimahandlinger (*Pledge*)
- [ ] Mine tidligere aktiviteter
- [ ] Utfordringer (*challenges*)
- [ ] Lag-utfordringer (*Team Challenge)*
- [ ] Ledertavlen innad i laget (*team leaderboard*)
- [ ] Duell mellom to brukere

11. Velg én eller flere deler av applikasjonen som ga deg et mål å jobbe for. *

- [ ] Smiling Earth grafen (Jordkloden på hjemskjermen)
- [ ] Løfte om å ta klimahandlinger (*Pledge*)
- [ ] Mine tidligere aktiviteter
- [ ] Utfordringer (*challenges*)
- [ ] Lag-utfordringer (*Team Challenge)*
- [ ] Ledertavlen innad i lage (*team leaderboard*)
- [ ] Duell mellom to brukere

12. Velg én eller flere deler av applikasjonen som ga deg tilbakemeldinger om hvor miljøvennlige handliger du har gjort *

- [ ] Smiling Earth grafen (Jordkloden på hjemskjermen)
- [ ] Løfte om å ta klimahandlinger (*Pledge*)
- [ ] Mine tidligere aktiviteter
- [ ] Utfordringer (*Challenge*)
- [ ] Ledertavle i en utfordring (*challenges*)
- [ ] Lag-utfordringer (*Team Challenge)*
- [ ] Ledertavlen innad i ett lag (*team leaderboard*)
- [ ] Duell mellom to brukere
- [ ] Varsel (*notifications*) på progresjonen i utfordring (*challenge*)

13. Velg én eller flere måter applikasjonen gjorde det mulig for andre brukere å oppmuntre deg til å ta miljøvennlige valg *

- [ ] Få en kommentar på et innlegg
- [ ] Få *like* på et innlegg
- [ ] At andre brukere følger meg
- [ ] Å være medlem i et lag
- [ ] Duell mellom to brukere

14. Velg én eller flere deler av applikasjonen som ga deg en form for belønning å jobbe for. *

- [ ] Smiling Earth grafen (Jordkloden på hjemskjermen)
- [ ] Løfte om å ta miljøvennlige valg (*Pledge*)
- [ ] Mine tidligere aktiviteter
- [ ] Fullføre en utfordring (*challenge*)
- [ ] Fullføre en lag-utfordring (*Team Challenge)*
- [ ] Ha lavest utslipp innad et lag
- [ ] Duell mellom to brukere
- [ ] Å kunne publisere en miljøvennlig aktivet

Læring ved å observere andre brukerer

15. I hvilke grad er du enig i disse påstandene?
*

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
Å se andre brukere delta i en utfordring (*challenge*) førte til at jeg ble med i samme utfordringen	◯	◯	◯	◯	◯
Å se andre brukere fullføre en utfordring (*challenge*) motiverte meg til å fullføre den samme utfordringen	◯	◯	◯	◯	◯
Å se andre brukere dele en aktivitet de hadde gjort motiverte meg til å gjøre tilsvarende aktivitet	◯	◯	◯	◯	◯
Å se andre brukere gi et løfte (*make a pledge*) motiverte meg til å ta det samme løftet	◯	◯	◯	◯	◯
Å se andre brukere i et lag ha lavere utslipp enn meg motiverte meg til å redusere utslippene mine	◯	◯	◯	◯	◯
Å se andre brukere i en utfordring (*challenge*) oppnå bedre resultat enn meg motiverte meg til å forbedre mine resultater	◯	◯	◯	◯	◯
Å se andre brukere dele et innlegg om en miljøvennlig handling gjorde meg motivert til handle mer bærekraftig	◯	◯	◯	◯	◯

Forventet utfall av mine handlinger

16. I hvilke grad er du enig i disse påstandene? *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
CO2-utslippene fra mine tidligere aktiviteter gjorde meg klar over hvilke konsekvenser mine vaner har på miljøet	◯	◯	◯	◯	◯
Varslinger (*notification*) om hvordan jeg lå an i en utfordring (*challenge*), synliggjorde for meg hva jeg måtte gjøre for å fullføre den	◯	◯	◯	◯	◯
Endringen i Smiling Earth grafen på hjemskjermen gjorde meg klar over konsekvensene mine vaner har på miljøet	◯	◯	◯	◯	◯
Innlegg andre brukere delte gjorde meg klar over hvordan mine vaner påvirker miljøet	◯	◯	◯	◯	◯

Anonymitet

17. Dette spørsmålet handler om din opplevelse av å være anonym i appen. I hvilke grad er du enig i disse påstandene? *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
Jeg synes det er lettere å gi likes på innlegg når jeg er anonym	○	○	○	○	○
Jeg synes det er lettere å gi kommentarer på innlegg når jeg er anonym	○	○	○	○	○
Jeg synes det er lettere å følge andre brukere når jeg er anonym	○	○	○	○	○
Jeg er mer motivert til å følge andre brukere når jeg ikke kjenner identiteten deres	○	○	○	○	○
Jeg er mer motivert til å dele innhold med følgerene mine når jeg er anonym	○	○	○	○	○
Jeg synes det er lettere å bli medlem i grupper (*teams*) når jeg er anonym	○	○	○	○	○
Jeg hadde blitt mer motivert for å bruke appen dersom jeg kunne brukt mitt eget navn	○	○	○	○	○
Jeg hadde blitt mer motivert til å bruke appen dersom jeg visste identiteten til de andre brukerene	○	○	○	○	○

Grupper - Tilfeldig plassert

Disse spørsmålene dreier seg om din opplevelse av å bli tilfeldig plassert i en gruppe.

18. Tror du deltagelse i nettsamfunn (*online communities*) kan bidra til å gjøre dine vaner mer miljøvennlige? *

- Ja
- Litt
- Hverken eller
- Nei
- Vet ikke

19. Dette spørsmålet handler om å delta i et **nettsamfunn med tilfeldige brukere**.
I hvilke grad er du enig i disse påstandene?
Grupper **med tilfeldig brukere...**
*

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
er egnet til å øke motivasjonen min for å handle miljøvennlig	○	○	○	○	○
er egnet til å øke jeg endret mine vaner i en mer miljøvennlig retning	○	○	○	○	○
gjorde meg mer motivert til å bruke Smiling Earth	○	○	○	○	○

Grupper basert på nærmiljø (geografisk tilnærming)

Disse spørsmålene dreier seg om din opplevelse av å være grupper (lag) basert på ditt nærmiljø (f.eks by, region, nabolag)

20. Var du medlem i en av følgende grupper: Bergen, Oslo, Trondheim? *

- ◯ Ja
- ◯ Nei
- ◯ Husker ikke

21. Hvis Nei, hvorfor ville du ikke bli medlem i en av gruppene

- ☐ Ingen av de passet meg
- ☐ Jeg visste ikke om noen av dem
- ☐ Jeg ønsket ikke å være medlem i flere grupper
- ☐ Andre grunner

22. Dette spørsmålet handler om å delta i et **nettsamfunn med personer i ditt nærmiljø**.
I hvilke grad er du enig i disse påstandene?
Grupper **med brukere fra ditt nærmiljø ...**
*

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
er egnet til å øke motivasjonen min for å handle miljøvennlig	○	○	○	○	○
er egnet til å øke at jeg endret mine vaner i en mer miljøvennlig retning	○	○	○	○	○
gjorde meg mer motivert til å bruke Smiling Earth	○	○	○	○	○

Grupper basert på deling av erfaringer

Disse spørsmålene dreier seg om din opplevelse av å være grupper (lag) som baserer seg på deling av erfaringer

23. Var du medlem i en av følgende grupper: "Electric Car Owners", "We don't fly", "Second Hand Buyers Club", "Group for people who bike to work" ? *

- Ja
- Nei
- Husker ikke

24. Hvis Nei, hvorfor ville du ikke bli medlem i en av gruppene

- Ingen av de passet meg
- Jeg visste ikke om noen av dem
- Jeg ønsket ikke å være medlem i flere grupper
- Andre grunner

25. Dette spørsmålet handler om å delta i et **nettsamfunn for å utveksle erfaringer innenfor et felles tema**.

    I hvilke grad er du enig i disse påstandene?
    Å være en del av grupper **basert på erfaringsutveksling** ..
    *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
er egnet til å øke motivasjonen min for å handle miljøvennlig	○	○	○	○	○
er egnet til å øke at jeg endret mine vaner i en mer miljøvennlig retning	○	○	○	○	○
gjorde meg mer motivert til å bruke Smiling Earth	○	○	○	○	○

Grupper basert på felles interesser

Disse spørsmålene dreier seg om din opplevelse av å være grupper (lag) der medlemmene har en felles interresse

26. Var du medlem i en av følgende grupper: Save the planet, Interest in reducing meat consumption, UiO, NTNU? *

- ◯ Ja
- ◯ Nei
- ◯ Husker ikke

27. Hvis Nei, hvorfor ville du ikke bli medlem i en av gruppene

- ☐ Ingen av de passet meg
- ☐ Jeg visste ikke om noen av dem
- ☐ Jeg ønsket ikke å være medlem i flere grupper
- ☐ Andre grunner

28. Dette spørsmålet handler om å delta i et **nettsamfunn for personer med en felles interesse.**

    I hvilke grad er du enig i disse påstandene?
    Å være en del av grupper **basert på felles interesser...**
    *

	Helt uenig	Uenig	Verken enig eller uenig	Enig	Helt enig
er egnet til å øke motivasjonen min for å handle miljøvennlig	◯	◯	◯	◯	◯
er egnet til å øke at jeg endret mine vaner i en mer miljøvennlig retning	◯	◯	◯	◯	◯
gjorde meg mer motivert til å bruke Smiling Earth	◯	◯	◯	◯	◯

Kommentarer til Smiling Earth

29. Har du noen flere kommentarer til din opplevelse av å bruke Smiling Earth (Frivillig)

30. Har du noe forslag til forbedringer av Smiling Earth? (Frivillig)

NTNU

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