FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

A Usability Design Approach of Tailored Visualizations for Mobile Applications

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieurin

im Rahmen des Studiums

Wirtschaftsinformatik

eingereicht von

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Wien, 1. Oktober 2018

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DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieurin

in

Business Informatics

by

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to the Faculty of Informatics

at the TU Wien

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Vienna, 1st October, 2018

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Erklärung zur Verfassung der Arbeit

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Wien, 1. Oktober 2018

Romana Jakob

Acknowledgements

I want to thank everyone who has contributed in any way to my study and the making of this thesis. First, I want to thank Margit Pohl, my thesis advisor for her support and not giving up on me, despite longer breaks.

I am grateful to Gerhard Engelbrecht not only for his professional advise but also for the opportunity to write the thesis in cooperation with Siemens. Thanks to my boss at Siemens, Herwig Schreiner, for giving me the freedom to pursue this thesis. A special thanks goes to Siegrun Klug who gave the impulse for the different energy types and was a great help at designing the questionnaire.

I owe thanks to everyone who spared time for the Paper Prototyping sessions. Your feedback was very helpful and contributed a lot to its further evaluation. Finally, thanks to the one and everything in my life. Your love and support is beyond what I could have ever imagined. I am forever grateful.

Kurzfassung

Systeme, die Rückmeldungen zum individuellen oder Gruppenverhalten mit dem Ziel der Reduzierung von Umweltbelastung liefern, reichen mehr als 40 Jahre zurück. Ein historischer Blick auf Technologien, die Öko-Feedback liefern, zeigt das umfangreiche Themenspektrum beginnend bei Verhaltenspsychologie, über persuasive Technologien und Benutzerfreundlichkeit bis hin zu Bildungsthemen. Was jedoch zu fehlen scheint, sind Systeme, die all diese Disziplinen im Auge behalten und sich dennoch an die Eigenschaften und Vorlieben eines Nutzers anpassen.

Um die Darstellungsmöglichkeiten der Benutzeroberfläche einzuschränken, wird in dieser Arbeit eine Segmentierung der Benutzer verwendet. Diese Segmente werden nach der Technikversiertheit und Komfortorientierung der Anwender eingeteilt. Dies impliziert die Notwendigkeit eines Fragebogens, der die Zugehörigkeit zu einem Segment bestimmt, welcher ein Beitrag dieser Arbeit ist. Die zentrale Forschungsfrage ist, ob es sinnvoll ist, auf Nutzersegmente zugeschnittene Visualisierungen anzubieten.

Im Rahmen dieser Arbeit wurde ein Papier Prototyp entwickelt und in Workshops mit den Anwendergruppen evaluiert. Die Ergebnisse dieser wurden analysiert, um die Einflüsse der Anpassung der Oberfläche an die Präferenzen der Nutzer zu identifizieren. Daraus resultierte eine Reihe von Gestaltungsrichtlinien für die Anpassung einer Benutzeroberfläche an verschiedene Arten von Energieverbrauchern. Die Auswertung ergab, dass alle Testnutzer die Anpassung einer mobilen Anwendung an ihre Bedürfnisse und Vorlieben als gut empfanden und die auf ihren Typ angepasste Oberfläche bevorzugten. Das Hauptergebnis dieser Arbeit ist, dass im Bereich des ökologischen Feedbacks bei mobilen Applikationen eine Adaption von Visualisierungen, insbesondere von Maßeinheiten, von großem Wert für die Sensibilisierung ist und die Wahrscheinlichkeit der Umsetzung eines gewünschten Verhaltens erhöht.

Abstract

Technologies providing feedback on individual or group behaviour with the goal of reducing environmental impact dates back to more than 40 years. An historic view on eco-feedback shows the extensive range of topics beginning with environmental psychology, over persuasive technology and usability guidelines to behaviour change and education issues. However, what seems to lack are systems that keep all these disciplines in mind and have a closer look on the characteristics and preferences of users and tailors feedback to these specialities.

In order to limit the possibilities of tailoring interfaces this thesis uses user segments that gather users with the same state of knowledge in energy topics and usage patterns together in groups. This implies the necessity of a questionnaire that determines the type of user, which is a contribution of this thesis. The central research question is whether it is beneficial to provide visualizations tailored to user segments.

A paper prototype was developed in the course of this thesis and evaluated in workshops with the user groups. The results of the prototype sessions were analysed in order to identify the influences of tailoring interfaces to user type preferences. These resulted in a set of design guidelines for adapting an interface to different type of energy users. The evaluation showed that all test users agreed on the idea of tailoring interfaces of a mobile application and that they preferred their proposed screen. The main result of this thesis is that in the field of ecological feedback in mobile application an adoption of visualizations, especially units of measurements is of great value for sensitization and raises the likelihood of applying a target behaviour.

Contents

CHAPTER 1

Introduction

In the age of social media, where information is tailored to users' interests, preferences and state of education, the question arises how to integrate this phenomenon into common mobile applications. Especially when the aim of the application is education or changing a user's behaviour an adoption of the user interface to various requirements might be beneficial.

This thesis investigates whether tailoring the interface of a mobile application to a user's characteristics, preferences and state of knowledge has effects on the usefulness of the application. The state of knowledge and the needs of the users are gathered into user groups, in order to limit the amount of possibilities.

1.1 Motivating Scenario

This thesis is written in cooperation with Siemens AG Austria, within a research project that deals with the Seestadt in Aspern in Viennna. The Seestadt is one of the biggest city development projects in Europe [1]. The Aspern Smart City Research GmbH & Co KG [2] (ASCR) is an exclusive technology partner of Siemens AG. The Aspern project has the overall goal of finding smarter solutions for energy consumption with the help of smart grids, power supplies, building systems, intelligent power grids and communication technologies. Another side goal is an optimal interaction of all these components. The ASCR infrastructure manages the data coming from smart grids and smart buildings such as temperature, energy consumption, water consumption, power demand as well as external data sources such as weather, city events, energy market, traffic reports etc.

[1] https://www.aspern-seestadt.at/ Accessed 10.01.2018
[2] http://www.ascr.at/ Accessed 10.01.2018

[PDE15]. In total 1.5 million values are measured per day [3]. To create something useful out of this amount of data is a big task.

Take, for example, an application that informs you about your electricity consumption. What can be assumed, is that the user wants an easy-to-use and beneficial application. Users are different and so are the motives why someone uses an application, e.g. saving energy, monitoring consumption, pure interest etc. A company or a mobile application developer of course wants to develop an application that serves as many people as possible. But what to do when the target group is defined but consist of people with distinct interests and different level of knowledge?

The problem that we observed is that the majority of users lack the feeling for the size of one kilowatt hour. The same can be witnessed when it comes to CO2 emission. The unit of kilograms of CO2 is an information that mostly only experts can grasp and can relate to.

1.2 Problem Statement

In the field of software development the interaction with the user is important, including the consideration of a user's knowledge. Numerous applications aim at motivating the user to save energy or CO2 but neglect the incomprehensibility of units of measurements one does not deal with on a daily basis. The sense of trying to motivate the user to save energy by displaying the electricity consumption in kilowatt hours, might have less impact than setting it at least in relation to an average consumption of electricity or even visualizing it with a playful approach. On the other hand, for someone who is easy on these types of measurement a visualization with colours or graphs might be too much.

So, the problem we are facing is to develop a mobile application that is beneficial for all types of users, starting from users who do not have a feeling for kilowatt hours or kilograms of CO2 and may not even be interested in energy topics up to users having a great affinity for electricity and carbon-dioxide emission.

To address this bandwidth of user knowledge and visualization possibilities, this thesis investigates the usefulness of tailoring a mobile application to a user's knowledge. Furthermore, design principles and criteria that shall help front-end developers, usability engineers as well as software architects to develop applications customized to a users level of knowledge are developed.

1.3 Aim of the work

The overall goal of this thesis is to identify different types of users, to evaluate existing applications and to analyse the benefits or even drawbacks of providing user interfaces in

[3] http://www.report.at/index.php/energie/wirtschaft-a-politik/item/91884-lebendes-stadtlabor Accessed 10.01.2018

a mobile application tailored to a user type.
This thesis contributes (1) a questionnaire for identifying the energy type of a user (2) an evaluation of a mobile application in the field of consumption data and home automation (3) paper prototypes for a mobile application with interfaces tailored to user types (4) a catalogue of criteria of design principles for tailoring visualizations to eco-feedback

The research questions are the following:

RQ 1: What are the characteristics of a user segment with the same energy consumption interests? In order to answer this research question we conduct a literature review in this area, where we want to find out different user types, the characteristics, the state of knowledge and the preferred way of interaction with them.

RQ 2: Which criteria do questions have to meet, that shall identify the type of a user? The findings of RQ 1 will have an influence on the questionnaire needed for defining which group a user can be assigned to. The questionnaire shall be short and shall precisely identify the type of a user.

RQ 3: What are the design possibilities when it comes to tailoring interfaces to a user segment in the scope of electricity consumption data? This question can be answered by evaluating existing approaches of eco-feedback applications and analysing their approach of trying to change a user's behaviour. One application will be investigated in particular and will be the basis for the paper prototypes.

RQ 4: Do the characteristics of user groups correlate with the users' preferred type of visualization? The results elicited for RQ 1 are the foundation for defining the user groups. The outcome of RQ 3, the paper prototypes, will be presented to the test users found with the questionnaire of RQ 2. The correlation between the groups and their preferred type of visualization will be determined in workshops with the user types.

1.4 Methodological Approach

In order to answer the research questions the methodological approach comprises the following steps:

1. **Literature Review**
   The first step is to dive into the topic of usability engineering, especially different forms of visualizations and graphical user interfaces in the scope of mobile applications. That implies research about paper prototyping, usability testing in the mobile context as well as user classification and evaluation of user interfaces. The goal is to get an insight of all relevant aspects which will serve as foundation for the following steps and also to get a base that shall help at answering the research questions.

2. **Comparative analysis of alternatives and comparison of existing approaches**
   In this step, the market and competition analysis which was done when the problem arose will be done in more depth. The questions that shall be answered in these steps are the following.

   - Which applications are there within the topics of energy saving and CO2 awareness?
   - Which approaches and visualizations do these applications make use of to present feedback?
   - How do these applications tailor their visualizations to different requirements?

3. **Creating a questionnaire for user classification**
   In this step one contribution of this thesis is created, the questionnaire for the identification of the segment a user can be assigned to. This will be a short questionnaire that shall identify the correspondence to the main characteristics of a user segment such as interest in energy topics, typical usage patterns of consumption, technical competence etc. The questions shall help to answer RQ 2. Then the questionnaire will be sent out in order to find at least one person for each user segment.

4. **Design of Paper Prototypes**
   The next step is to create paper prototypes. The prototypes shall follow usability guidelines found out in the previous steps. The whole paper prototyping process will be close to the Step-by-Step guide for creating Paper Prototypes proposed by Arnowitz et al. [AAB10]. This includes first, the definition of the goal followed by identifying the tasks that users shall be able to do with the App. Next, hand-sketched drafts will be drawn, showing the application with menus, dialogue boxes, notifications and buttons.

5. **Elicitation of requirements with Paper Prototyping**
   The fifth step is to do the Paper Prototyping session in order to elicit the requirements for the graphical user interfaces and overall for the app. According to [Lan04] the numerous benefits of early usability studies are vastly superior. It may seem low-tech, but conducting usability tests at this step show what users really expect on a quite detailed level which gives maximum feedback for minimum effort [Wei03].

   At first the people that could be clearly assigned to one user segment will be invited to a paper prototyping workshop. The workshops for each user segment will be held separately in order to avoid the distortion of results and to create a mutual independent outcome. The feedback from the users show what they expect from the app which is of great value for the further design of the app [Sny03] and for the following evaluation.

6. **Evaluation**
   In this step the mobile application from ASCR will be empirically evaluated against

the outcomes of the paper prototyping session and its benefits and drawbacks will be defined. The outcomes of the paper prototype sessions will help to answer RQ 4, which deals with the correlation of user characteristics and the preferred type of visualization

7. **Refinement of design principles catalogue**
   Finally, based on the findings of the evaluation a design principle catalogue will be created. The catalogue will comprise motivations of the user types, requirements definitions and example implementations from the evaluated paper prototypes.

1.5 Structure of the work

The remainder of this thesis is structured as follows: Chapter 2 provides an overview of related work where existing approaches of tailoring user interfaces are discussed beginning with an overview of the foundation of interfaces, the usability. Then the user classification is outlined followed by a dive into paper prototyping topics. This chapter is concluded by a comparison of existing approaches.

Subsequently, in Chapter 3 the methodology is presented, where the guidelines for the survey for user segmentation and a step-by-step guide for paper prototyping is explained and the approach for the definition of design guidelines is outlined.

In Chapter 4 the questionnaire that was developed to identify the type of a user is explained.

Afterwards, in Chapter 5 the main work of this thesis, the paper prototypes, the prototyping workshops and the evaluation of the ASCR mobile application, is presented. Within this chapter implementation-specific details are discussed.

Chapter 6 critically reflects and compares the implementation with related work and discusses open issues.

This thesis is concluded in Chapter 7 with a summary and a discussion on future work.

CHAPTER 2

State of the Art

In the following sections the theoretical background for the topics that this thesis deals with will be presented. In particular, it starts with a general introduction to usability engineering followed by a definition of usability in the mobile context. Then the field of mobile application is continued with a dive into adaptive interfaces. Of particular relevance to this thesis is the work on user segmentation of Smart Cities Demo Aspern on which our user classification is based upon and which is the answer to the following research question:

RQ 1: What are the characteristics of a user segment with the same energy consumption interests?

This chapter goes on with an introduction to paper prototyping containing a comparison of computer-based to paper-based prototypes and outlines paper prototyping as a tool for elicitation of requirements and for usability testing. The use of focus groups is discussed before we compare existing approaches of energy-saving programs including a look at persuasive systems followed by a comparative analysis of used design guidelines in existing approaches.

2.1 General Definition of Usability

The International Organization for Standardization (ISO) defines usability as the "Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [Bev98]. This definition comprises three measurable attributes which are the following [Sta98]:

- **Effectiveness**: Accuracy and completeness with which users achieve specified goals.

- **Efficiency**: Resources expended in relation to the accuracy and completeness with which users achieve goals.
- **Satisfaction**: Freedom from discomfort, and positive attitudes towards the use of the product.

The ISO standard also identifies three factors that should be considered when evaluating usability, which are the user, the goal and the context of use. The user is the person who interacts with the product. The goal is the intended outcome and the context of use applies to users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used.

In addition to the above ones Nielsen [Nie94a] identified five attributes of usability and factors having an impact on how the user interacts with a system:

- **Learnability**: The user should get work done rapidly which is possible if the system is easy to use.
- **Efficiency**: Once the user has learned to operate with the system, the productivity should be high.
- **Memorability**: In case a user does not use the system in a longer period, it should, nevertheless, be easy remembered without having to learn everything all over again.
- **Errors**: When using the system, the user makes few errors and is able to return and recover easily after an error. Further, catastrophic errors must not occur.
- **Satisfaction**: The system is highly accepted as the user has positive attitudes towards the system and finds it pleasant to use.

2.1.1 Mobile definition of usability

The focus on usability and interaction between human and hand-held electronic devices has its origin within the emergence of mobile devices. With the emergence and rapid deployment of mobile technologies a number of additional studies like [Ryu05] and [Gaf09] have focused on the usability of mobile devices. The approach of Nielsen, mentioned above, was expanded with the scope of mobile applications by Zhang and Adipat [ZA05] who highlighted a number of issues by the advent of mobile devices. The issues mentioned are:

- mobile context
- connectivity
- small screen

- different display resolution
- limited processing capability and power and
- data entry methods

They mention that these restrictions are especially a problem when it comes to usability testing methods, as all these issues must be considered in order to select an appropriate research methodology. It must be kept in mind that contextual factors on perceived usability can occur when they are not considered in a study [ZA05].

Almost concurrently, mobile device manufacturers have been developing their own usability constraints, such as Google and Apple. The Apple iOS Human Interface Guidelines[1] states the iOS design principles that should be considered during the application development process, such as: aesthetic integrity, consistency, direct manipulation, feedback, metaphors and user control.

Also, Google has developed Android user interface guidelines[2], which guide developers to take into account the following guidelines: the icon design guidelines including the size and location of icons and buttons, contextual menus and their responsiveness, simplicity, size, and format of text and the widget design guidelines that describe how to design widgets that fit with others on the home screen. These guidelines also explain how these characteristics should be considered during the development and testing of Android applications.

Harrison et al. [HFD13] build up on the terms mentioned before and introduced a PACMAD (People At the Centre of Mobile Application Development) model which was designed to address the limitations of existing usability models when applied to mobile devices. PACMAD extends the theories of usability with more aspects such as *user task* and *context of use*. The existing usability models such as those proposed by Nielsen [Nie94b] and ISO [Bev98] also recognize these factors as crucial parts on which the successfulness of the usability of an application depends. The difference is that PACMAD includes all the factors into one model to ensure a complete usability evaluation.

2.1.2 Adaptive interfaces in mobile applications

Deka [Dek16] discusses how data-driven approaches are tools for mobile app design. They state that designing mobile apps is a complex layered process that affects researchers, designers, and developers who work together to identify user needs, create user flows, determine layout of UI elements, define visual and interactive properties with the help of design prototypes, and evaluate effectiveness of designs both heuristically and with extensive user testing. His approach is to simplify the app design with a more data-driven process by leveraging design data from the vast array of already existing apps. Deka

[1] https://developer.apple.com/design/human-interface-guidelines/ios/overview/themes/. Accessed 06.08.2018

[2] https://developer.android.com/guide/practices/ui_guidelines . Accessed 06.08.2018

advocates interaction mining that captures the static part, such as layouts and visual details, as well as the dynamic part, like user flows and motion details, of app design. His approach is in contrast to design mining approaches that mainly have focused on mining static UI layouts and visual details [KST+13, AY15].

Fogarty and Hudson [FH03] presented a programmatic approach for the optimization problem of usability interfaces. Their approach is numerical optimization and they provide an experimental toolkit to support optimization for interface and display generation.

The decades of research in adaptive user interfaces were summarized by Gajos et al. [GWW08]. They conclude that personalized user interfaces have the ability to improve user satisfaction and performance, when the interface is adapted to the device, task, preferences and abilities of a person. To automatically generate user interfaces they use decision-theoretic optimization which includes functional specifications of the interface, constraints of the devices e.g. screen size and a list of available inter-actors, a typical usage trace and a cost function. The cost function holds user preferences and the expected speed of operation. Gajos et al. especially focus on the preferred UI elements of a user. As this thesis aims at finding interfaces for users that fit different types we first need to classify users into different user segments.

2.2 User Classification

Weiss [Wei03] laid a huge emphasis on the first, and according to him, the most important step in the design and development process, the understanding of the audience. The purpose of the audience definition is to describe the target group, its' traits and ranges.

2.2.1 User Segmentation according to Smart Cities Demo Aspern [KG]

Aspern Smart City Research GmbH & Co KG (ASCR) also lays emphasis on understanding the user. The research group defines a smart user as a person who has the knowledge for sustainable decisions in relation to his or her lifestyle. Saving CO2 and energy should be the overall goals of a smart user.

Nevertheless, not all smart users are the same and not all share the same state of knowledge or interest. Therefore, in 2015 ASCR conducted a socio-scientific study to find out how much know-how a smart user has in the field of technology and energy and also how much interest they have in the topics of energy and sustainability. The research was done in an apartment block named D12, where the possibility to test solutions is given, as the apartments in this block are equipped with systems that collect data including

- electricity consumption
- room temperature

- warm/cold water consumption and
- air quality.

Over half of the households in the apartment block D12 agreed on making their data available for research purposes and to participate in surveys and workshops. In total, 85 households took part in the study in 2015. In the starting phase two studies were done. At first a qualitative study with personal interviews with selected tenants of the building D12 was done followed by a quantitative study with written questionnaires. One outcome of these studies was the segmentation of users into groups. Different types of users were clustered into four segments according to their state of knowledge and their interest in technology and energy. The user groups also serve as target groups for the development of new technology solutions such as home automation, mobile application and for the development of a range of services. The segmentation into groups also makes communication easier as the used methods of communication can be tailored to the needs of a group.

The qualitative study with its interviews was done before the tenants moved into the apartments in Seestadt. Surprisingly the majority stated that it has basic knowledge for the interpretation of the energy consumption and energy data in general. Often they stated that they do not know how much one kilowatt hour is. In most cases the main source of information for energy topics is the energy consumption calculation. Unfortunately the calculation does not state the behaviour or the devices which use up the most energy. Exactly these two aspects are the most wished information for the users when it comes to saving energy.

The aim of a segmentation in its statistical way is to find distinct groups with significant differences [PS83]. Within a group the characteristics should be homogeneous. An established way for segmentation in statistics is to do two statistic procedures, beginning with a factor analysis, followed by a cluster analysis [Tuf11].

The factor analysis reduces dimensions [WOB10]. In the quantitative questionnaires multiple variables are collected and in the factor analysis these variables are reduced to so called latent variables or factors. Therefore, the factor analysis shows which dimensions are underlying the whole questionnaire.

In the socio-economic study of ASCR an explorative non-rotating factor analysis was calculated. Afterwards the scree test showed the amount of factors, which was in this case four. In terms of content the analysis of the factor showed the following dimensions:

- **Comfort-centred**: This factor covers aspects like home automation, energy relevant user behaviour such as lighting and circulation behaviour and hot water usage.
- **Technology-centred**: Also covers aspects like home automation but more with the sense of interest in the technology rather than the comfort aspect.

- **Data sensibility**: Concerns regarding the further use of the collected data.
- **Living in Seestadt**: The aspect of living in the Seestadt as an extra dimension shows that it is some kind of prestige to live there.

Finally, a cluster analysis was done to identify the user segments. Cluster analysis is an exploratory process with the aim of finding groups of similar objects [Tuf11]. Different hierarchical analysis were calculated to find an appropriate amount of clusters. Appropriate means in this case having a big enough group of cases/persons and groups with distinct features. The data set comprised 121 handed back questionnaires and the cluster analysis could identify four clusters. The four clusters correspond to the four user groups. The result of the cluster analysis is shown in 2.1 and explained in the following.

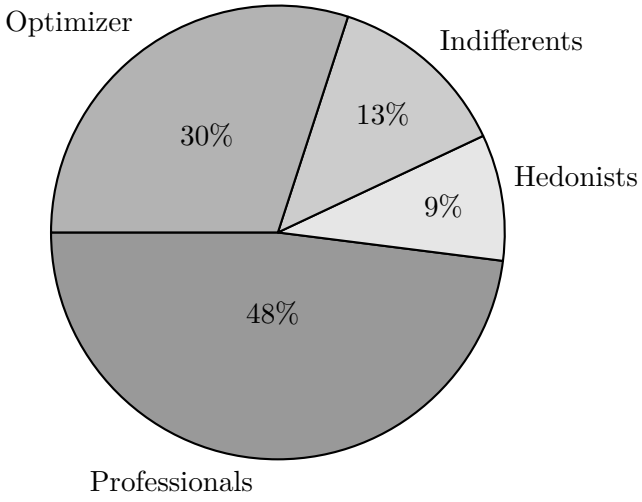


Figure 2.1: Result of the cluster analysis: Four user groups

"Professionals" (48 %):

The Professionals are the biggest group. The members of this group are technically competent and interested in topics concerning energy.

The main characteristics are:

- High proportion of persons having an abitur or university graduates
- Highest proportion of people in managerial positions, a quarter works (also) at home
- All household sizes (also households with children)
- Knowledge about energy

- High technical competence and interest in technology. Technical competence in this sense means experience with home automation or programming skills.
- Interested in sustainability
- Use of media or Internet is primarily for professional purposes

Typical segment behaviour regarding home equipment:

- "Reasonable" use of hot water ("I do not shower longer than necessary")
- "Reasonable" use of lighting ("I turn down the light when I leave a room")
- Make use of the "ECO-Button" (installed tool in the apartments of D12 which helps to save energy) when leaving the apartment

Due to their technical expertise, their experience with home automation and their interest in energy issues they are the most appropriate target group for home automation and mobile application solutions. Rationally justified explanations and instructions for use meet their information style. Professionals also expect more detailed information in individual offers such as energy feedback.

"Optimizer" (30 %):

The second largest segment comprises people who primarily aim to optimize energy costs. Optimizer have little knowledge about energy and are no technophiles.

The main characteristics are:

- High proportion of persons having an abitur or university graduates
- Highest proportion of people in managerial positions
- More women
- All household sizes (also households with children)
- Interested in sustainability
- Little to no knowledge about home automation
- No technophiles
- Use of media or Internet is not very noticeable

Typical segment behaviour regarding home equipment:

- Prefer to air manually rather than to make use of the automatic ventilation system

- A quarter never uses the "ECO-Button"

The use of the home furnishings indicates a poor understanding of their usability or less time of interaction with them. Due to their much lower competence in energy and technology compared to the professionals, the planned solutions and measures should focus on the following points:

- Clear and concrete instructions for behaviour, for example in the form of energy-saving tips or concrete, close to reality explanations and benefits.
- Avoid technical language in communication and use personalized examples.
- Reduce energy feedback to essential information. Optimizer do not need detailed explanations.
- Enable trouble shooting: Optimizer want a quick solution to an energy problem, as they do not want to spend lot of time on energy topics.

"Indifferents" (13 %):

The Indifferents have low competence in energy and technology and no interest in energy topics or sustainability.

The main characteristics are:

- Young segment
- High proportion of non-workers
- No interest in sustainability
- Low technical competence (no experience with home automation)
- Information research and streaming is above average

Typical segment behaviour regarding home equipment:

- Hedonistic use of hot water: They enjoy taking long showers and baths
- Smallest number on different device types
- Little satisfaction with the provided air ventilation

The Indifferents have low interest in the research topic and it's solution in general. To address this group with the necessary knowledge and to awaken their interest for energy and sustainability, a bigger effort has to be done than for the above groups. A typical representative of this group is a person who has just moved out from the parental home and who now has to organize the household on his/her own and to develop independence.

"Hedonists" (9 %):

The Hedonists are technical competent but are indifferent to energy and sustainability topics.

The main characteristics are:

- Young segment
- More men, more single households
- Technical competent and partly with programming skills
- Intensive use of mobile Applications and the Internet
- Hedonistic use of gaming and social media

Typical segment behaviour regarding home equipment:

- Highest number on different device types
- Carefree use of lighting and hedonistic use of hot water
- Frequent use of "ECO-Button"
- High satisfaction with the provided air ventilation
- Weak identification with Seestadt

The youngest segment has good preconditions to make a good use of a mobile application with feedback of their energy use. Nevertheless, the motivation to deal with energy topics is rather low. The hedonistic lifestyle with its strong convenience and comfort orientation is in the foreground. Despite the high usage of Apps it may be difficult to win them around for energy feedback. The comfort gain is of great relevance.

2.3 Paper Prototyping

With the knowledge of the characteristics of the different user groups, the next step, the paper prototyping can be done more easily. It may seem low-tech, but conducting usability tests at such an early stage show what users really expect on a quite detailed level which gives maximum feedback for minimum effort [Wei03].

According to [Lan04] the numerous benefits of early usability studies are vastly superior. Besides saving time and money by solving problems before the implementation even begins, paper prototyping stimulates creativity as it allows experimenting with different ideas before committing to one [Sny03].

Different types of prototypes for different purposes in software engineering exist. Leffingwell and Widrig [LW] proposed a classification tree for prototype selection that categorizes prototypes according their use case. Prototypes are categorized as throwaway versus evolutionary, horizontal versus vertical and architectural versus requirements prototypes. Prototypes can also be categorized according to their representation into textual and visual prototypes, whereby Asur and Hufnagel [AH93] define rapid prototyping as the use of tools for quick prototype construction. A division into executable and non-executable prototypes can also be made as mentioned from Kotonya and Sommerville [KS98] and Wiegers [WB13].

2.3.1 Computer-based versus paper-based Prototypes

Nielsen [Nie90] has compared the effectiveness of using interactive prototypes with static paper prototypes. The result of this study showed that evaluators discovered significantly more problems with the high-fidelity prototype than with the low-fidelity prototype.

Sefelin et al. [STG03] builds up on the same approach as Nielsen and also investigated the differences between computer-based and paper-based low-fidelity prototypes. In contrast to Nielsen, they discovered that both types lead to almost the same quantity and quality of critical user statements although users prefer the comfort of computer prototypes. Similarly, Virzi et al. [VSK96] claimed that the sensitivity to find usability problems does not differ between low- and high-fidelity prototyping.

However, there are still a lot of reasons, as discussed by Rudd et al. [RSI96], to implement a paper prototype for example when the available prototyping tools do not support the components and ideas, which shall be implemented. Another benefit of a paper prototype is the low fidelity, as no software skills are needed for paper prototyping. Besides that, paper prototyping leads to a lot of drawings which can contain more ideas than predefined computer-based prototypes. For requirements engineering Vijayan and Raju [VR11] recommend a throwaway paper prototype rather than expensive prototypes. One reason for that is also the absence of the technology barrier.

Lim et al. [LPPA06] concretized the comparison of high- and low-fidelity prototypes to mobile applications. They figured out that major usability issues were identified by all the three types of prototypes, namely, the fully-functional prototype, the computer-based low-fidelity prototype and the paper-based. The major issues especially in the mobile context are unclear meanings of labels, icon/symbol/graphical representation issues, locating appropriate interface elements, mental model mismatch and appearance/look of the product.

A highly recommended introduction into effective prototyping is provided by Arnowitz et al. [AAB10] as well as by Bernard and Summers [BS10] who inducted into dynamic

prototyping. Dynamic prototyping is some kind of mixture between sketches, drawing of ideas and real prototypes, which builds the bridge from low-fidelity to high-fidelity prototyping.

2.3.2 Elicitation of Requirements with Paper Prototyping

Research has shown that paper prototypes are beneficial for many users for articulating their requirements as they already see some possible interface elements [VR11]. Clients have a hard time, even sometimes with the help of a software developer, specifying completely, exactly and correctly the exact requirements of a software before seeing some versions of a product [HD98].

Vijayan and Raju propose a new approach to requirements elicitation using paper prototype [VR11]. Their case study indicated that the paper prototype method is a suitable method for requirements elicitation for small and medium-sized projects. They describe a paper prototype as a visual representation of what a system will look like which can be drawn or created with graphics programs. Their approach is divided into the following steps:

- Domain knowledge acquisition
- System understanding
- Requirements elicitation
- Prototype validation
- Requirements stabilization

In contrast to many systems' development methodologies who address the problem of identifying user requirements but generally focus on the analysis of user requirements Vijayan and Raju argue that paper prototyping focuses more on the elicitation of requirements from the users [VR11]. Sharma and Pandey [SP13] revisited requirements elicitation techniques and listed throwaway paper prototyping as an innovative technique under the numerous other elicitation tools. They conclude that despite the common use case of usability testing, with paper prototyping satisfactory results in requirements elicitation can be obtained.

The parallel activity of prototyping and requirements gathering is described by Caspers [Jon98]. He even says that especially in agile development methods, the prototypes may even substitute other forms of requirements gathering. Young [You02] also recommended numerous requirements gathering practices. Among the preferred ones are storyboards. As they are multiple drawings depicting a set of user activities that occur in an existing or envisioned system or capability they are very close to or even a kind of paper prototyping. Users and developers draw what they think the interfaces should look like and continued until real requirements and details can be discussed and agreed upon. Being so close to

paper prototypes storyboards are also inexpensive and eliminate risks and higher costs of prototyping.

2.3.3 Paper Prototyping as a Usability Testing Technique

Still and Morris [SM10] re-emphasize the importance of usability testing in the user-centred design process and argue that at this early stage usability testing is most effective. They married low fidelity paper prototyping with medium fidelity wire-frame prototyping and called this blank-page technique. Meaning that the user navigate to dead-ends and has the task to describe and create what they would expect there. This technique allows insights into users' mental models regarding site content and design which provides developers with useful data concerning how users conceptualized the information encountered. This more substantial early influence of users almost always translates to better usability. The blank-page technique is described from Maguire and Began [MB02] as brainstorming. Nevertheless, they additionally list paper prototyping as a quick and easy way to detect usability issues in response to user feedback.

Focusing on the quickness and risk management of paper prototyping Cynder [Sny96] showed how only six days of doing paper prototyping lowers risk. They spent two days usability testing the paper prototype. For each test session two people were used who matched the profile of a typical user. Their approach in the session was to somehow let the user alone with the prototype without giving a demo or explaining how to use the interface. The only thing they did, was to observe the user at interacting with the prototype. Cynder describes that the team was surprised by many of the issues they saw. In some cases, aspects about which the developers strongly argued the users didn't even notice. At the same time, huge problems that no one had anticipated were uncovered. Summarizing Cynder writes that usability testing with the help of paper prototyping gave everyone on the team a sense of what the real issues that would affect the success of the next release were.

Grady [Gra00] describes usability testing with paper prototypes as a win-win situation for both the designer and the end user. The study revealed how beneficial paper prototyping is for usability issues, as a lot of problems were released even in the first usability test session. The second usability test run allowed a more in-depth evaluation of the fundamental structure of the site and additionally uncovered issues that were missed during the first usability test. The third usability test on the full-blown site revealed even fewer problems than the previous tests.

2.4 Focus Groups

Dumas et al. [DDR99] describe a typical focus group as a discussion among multiple real users which is led by a moderator. They argue that focus groups provide information about users' opinions, attitudes, interests, preferences and a self report about their performance. What focus groups usually don't do is giving you an insight into how

they behave with the product. The people are carefully chosen, as in usability tests, to represent the potential users of the product.

An experimental prototyping method for play testing was evaluated by Eladhari and Ollila [EO12]. They used focus tests as a type of play test. In a focus test questions are asked in an interactive group setting which comprises potential users who talk about their perception, belief, opinion and attitude toward the prototype.

A user-centred model for this type of Website design was developed by Kinzie et al. [KCJK02]. The model includes techniques for needs assessment, goal and task analysis, user interface design and rapid prototyping. The model includes document review, interviews, focus groups, surveys and observation and is proven as effective across diverse content areas and is appropriate for applications in varied media.

2.5 Existing Approaches of energy-saving Applications

Providing households with better feedback on their energy consumption behaviour has been identified as an important tool for achieving sustainable behaviour change. But understanding why people engage in environmentally responsible behaviour is a complex topic over many disciplines beginning from education to economics over sociology, psychology and philosophy [FFL10]. Feedback on individual or group behaviour with the goal of reducing environmental impact is called eco-feedback technology [MM98, HKH+04, FFL10]. Eco-feedback builds up on a variety of domains such as energy consumption [Hol07], water usage [ABS05], transportation [FDK+09, TSF12] and waste disposal practices [HKH+04].

A lot of people lack awareness of energy wasting in their homes. Making people aware about inefficiencies in their energy consumption behaviours could contribute to large energy savings at city level. In course of this assumption Mohammadmoradi [MGM+17] designed several intentionally simple energy-saving activities with the goal of a high user engagement. They argue that often users do not understand what to do exactly to save energy, so they tried to help citizens to understand how they use energy and even to find more ways to do so. One activity per week was given to the users. The activities ranged from counting all lights, appliances and electronics in the home over finding the appliances that consume the most energy to turning all lights off and enjoy the evening with the family. An interesting point of their evaluation was, that to increase the amount of saving activities should focus on evening hours. To summarize the approach of Mohammadmoradi we can say their main principle for the design of eco-feedback is simplicity.

Eco-feedback has similar roots as persuasive systems and it may seem as an extension of the research in persuasive technology but actually it dates back much further to the research in environmental psychology. Models of pro-environmental behaviour provide a philosophical approach on which to base the designs of eco-feedback technology, as they explain the why of the behaviour but often they lack specific strategies for changing

behaviour. Froehlich et al. [FFL10] bridges the gap between findings from environmental psychology and the design and evaluation of eco-feedback systems.

2.5.1 Persuasive Systems

Of particular relevance in the field of persuasive systems is the work from Fogg [Fog02] who introduced computers to be persuasive social actors. In order to let the computer be persuasive, psychological cues are proposed, such as preferences, motivations and/or personality, in short the computer should seem to have personality. This can be achieved by text messages that convey empathy, e.g. "I'm sorry that...", or icons that portray emotions. In the area of psychological cues, one of the most powerful persuasion principles is similarity [Taj10]. The greater the similarity, the greater the potential to persuade, so the more people feel similar to the computer technology products the more they are readily persuaded [Fog02].

Influencing can also happen through language. Whether asking questions ("Do you want to continue the installation?"), offering congratulations for completing a task ("Congratulations! You won!") or reminding the user to update software written or spoken language can lead people to infer that the computing product is animated in some way. Especially, persuading through praise, with the help of language, photos, symbols or sound effects can lead users to be more open to persuasion [Fog02].

Fogg's [Fog02] functional triad and the design principles presented in it constitute the first and so far most utilized conceptualization of persuasive technology. Nevertheless, there is a weakness of this model as it does not explain how the suggested design principles can be transformed into software requirements and implemented as system features.

2.5.2 Comparison of persuasive system design principles in existing approaches

Tailoring and personalizing the content to the potential needs, interests, usage context or other factors is outlined by [OKH09] in the context of a persuasive system. They studied how a persuasive system must be designed with tailored and personalized content to maximize the change in the user's behaviour.

Design principles for primary tasks

The weakness of Fogg's model, the absence of concrete realization of the proposed design principles in software requirements, was overcome by Oinas-Kukkonen and Harjuma [OKH09]. Their design principles for the primary task support are explained in the following and we added further example approaches which implemented the proposed design principles and should explain the guidelines even better.

- **Reduction:** The system should reduce the time and effort that a user needs to spend on performing the target behaviour.

An example for a mobile application that makes use of this design principle is Matkahupi, which automatically tracks the transportation modes and CO2 emissions of the trips of the user and utilizes this information to present a set of actionable mobility challenges to the user [JNS+13].

Another mobile application that helps to reduce the time for performing a special behaviour is PmEB. It supports healthier eating habits by listing proper food choices at fast food restaurants [LTG+06] and therefore also helps at behaving as wanted by providing support.

- **Tunnelling:** Guiding users through an attitude change process by providing means for action brings them closer to the target behaviour.

  Spagnolli et al. [SCG+11] proposed EnergyLife, a mobile application with a gamification approach that provides different levels which are adapted to the current state of knowledge.

- **Tailoring:** The system should provide information tailored to potential needs, interests, personality, usage context or other relevant factors for the user group.

  Gamberini et al. [GSC+12] focuses on feedback tailored to users' consumption behaviour and giving according recommendations for behaviour change.

- **Personalization:** If a system offers personalized content and services for its users it has a greater capability for persuasion.

  PEIR, the Personal Environmental Impact Report [MRS+09] offers personalized estimates of environmental impact and exposure.

- **Self-monitoring:** System should provide means for users to track their own performance or status to support the user in achieving goals.

  Power Advisor, a mobile application developed by Kjeldskov et al. [KSPP12] provides self-monitoring through personalized information about the user's power consumption.

- **Simulation:** System should provide means for observing the link between the cause and effect with regard to users' behaviour.

  McCalley and Midden [MM02] proposed a computerized machine washing simulation. Feedback on consumption was given after each wash and in combination with self-chosen or assigned goals 21% less energy than the control group was used.

- **Rehearsal:** A system that provide means for rehearsing a target behaviour enables people to change their attitudes or behaviour in the real world.

  PowerAgent is a mobile application that let the users first play a simulation game to learn wanted behaviours and then let them enact and rehearse these behaviours at home in the family context [BGK07].

Design principles for dialogue support

An interactive system should of course provide system feedback to a user. Oinas-Kukkonen and Harjumaa also proposed several design principles related to implementing computer-human dialogue support in a manner that helps users keep moving towards their goal or target behaviour [OKH09]:

- **Praise:** Praising users can make them more open to change their behaviour.

  Petkov et al. [PGKK12] found out that people prefer positive rather than negative reinforcements in persuasive applications.

- **Rewards:** When the target behaviour is rewarded a user is given credit for performing the target behaviour.

  The Energy Piggy Bank gives users virtual badges and points when performing the target activities [BLWM17].

- **Reminders:** By reminding the user of the wished target behaviour it becomes more likely that the user achieves his goals.

  The participants in the study of Kjeldskov et al. [KSPP12] mentioned that it was very important to keep reminding them about their own goals.

  Helen et al. [HGH10] recommend presenting prompts at opportune times to remind individuals to take specific actions and to establish habits. As the habit becomes well instantiated, these prompts can gradually disappear.

- **Suggestion:** Offering fitting suggestions about how to behave provides the system with greater persuasive powers.

  One of the main techniques of the Energy Piggy Bank, is the habit formation that encourage to do a specific activity during a time period [BLWM17].

- **Similarity:** People are more ready to change their behaviour when a system somehow reminds them of themselves in some meaningful way.

  In the pervasive game PowerAgent the person playing has the role of a secret agent and the phone has the role of the boss, the mysterious Mr. Q who gives the player special missions to save the planet from the energy crisis. As the user and Mr. Q, the person in the phone have the same mission, the user share similar goals and therefore similarity is here implemented in one of the best ways [BGK07].

- **Liking:** A visually appealing system is more likely to change a user's behaviour.

  The 7000 Oaks and Counting project [Hol07] uses an animation of a series of tree images to show the estimated number of trees needed to offset the emitted CO2.

  The users of PEIR, the Personal Environmental Impact Report, proposed by [MRS+09] see green icons of trees appear if impact and exposure are low relative to friends, and smokey and smoggy icons appear if impact and exposure are high.

Stepgreen [PQNB12] is a system that presents the information colour-coded and changes according to the household consumption, varying from light green when consumption is low to dark red when the consumption reaches abnormal levels.

- **Social role:** If a system adopts a social role, the system is more likely to persuade.

  The ECO project approach is a learning framework with a network in background that [BMM+14] proposed. The learning experience is marked by social interactions and participation.

Design principles for system social support

In the social support category the design principles make use of leveraging social influence that shall help at persuading the user's behaviour.

- **Social learning:** If a person can observe the outcomes of others who perform the target behaviour (s)he will be more motivated to do the same.

  The feedback of the data monitoring system developed by Petersen et al. [PSJ+07] implemented social learning strategies as each dormitory could see how other dormitories were doing during the competition.

- **Social comparison:** By providing means for comparing one's own performance with others the system users have a greater motivation to also perform the target behaviour.

  EnergyWiz, a mobile application that enables users to compare with their past performance, neighbours, social media contacts and other EnergyWiz users [PKFK11].

- **Normative influence:** If a system leverages normative influence or peer pressure the likelihood that a person will adopt the behaviour of its peers increases.

  Normative messages put in hotel rooms saying, "The majority of guests in this room reuse their towels." increased the likelihood of towel reuse by hotel guests by 33% [GCG08].

- **Social facilitation:** A system that provides means for discerning other users who are performing the target behaviour, system users are more likely to be persuaded.

  Users of the Energy Piggy Bank Game [BLWM17] can recognize how many users are trying to save energy at the same time as them.

- **Cooperation:** A system can make use of the natural drive to co-operate by providing means for co-operation, which increases the motivation of a system user to adopt a target attitude or behaviour.

  The mobile application EnergyWiz [PKFK11] provided a group on Facebook which shows the users that they are not alone in energy saving and allowed them to discuss energy saving topics.

- **Competition:** A system can make use of the natural drive to compete by providing means for competing, which increases the motivation of a system user to adopt a target attitude or behaviour.

  The Energy Piggy Bank Game [BLWM17] offers a leader-board with all the names of the competing users and their points.

- **Recognition:** By offering public recognition for users who perform the target behaviour to increase the likelihood that users will adopt a target behaviour.

  In the Energy Piggy Bank Game each team member's contribution to the group's score is visualized and the number of activities done by each group member is clearly visible in the group area [BLWM17].

2.5.3 Comparison of further design guidelines in existing approaches

The "one-size-fits-all" approach that the majority of energy feedback technologies makes use of is criticized by Helen et al. [HGH10]. Providing the same feedback to differently motivated individuals at different stages of knowledge, readiness and willingness to change is not beneficial. In their paper, they develop a motivational framework based on the transtheoretical model. So, the design guideline they used for eco-feedback are stages of behaviour change. The different stages are precontemplation, contemplation, preparation, action and the last stage is maintenance, relapse and recycling. Criticism to this model is that rather than being in one stage, users can be at a different stages for each action [MPV83].

Fischer [Fis08] specialized on feedback on household electricity consumption and examined which kind of feedback is most successful. Her research concluded the following recommendations for feedback.

In order to be successful, meaning, effective in persuading and satisfying for the users' feedback should

- be based on actual consumption data
- be given frequently (daily or more) and over a longer period
- have the possibility to interact and choose
- involve appliance-specific breakdown
- involve historical or normative comparisons
- be presented in an understandable and appealing way

Nevertheless, attention should be paid, as not all recommendations may hold for all target groups.

A critical survey of interaction design for eco-visualization was done by Pierce et al. [POB08]. Their paper described feedback types and use-contexts for classifying eco-visualizations and also strategies for designing effective eco-feedback visualizations. They offer two strategies to support conservations goals. The first strategy is to offer behavioural cues and indicators and the second is to provide tools for analysis. Both should provide clear and useful information or feedback. Two strategies are proposed for creating incentives to conserve, especially for the contexts where financial incentives are not present. As monetary incentives are not possible they suggest to creating social incentives and to connect behaviour to material impacts of consumption. They also offer strategies that focus on more experimental aspects for visualizing consumption. The first strategy should encourage playful engagement and exploration with energy. The second should cultivate sustainable lifestyles and values. Thirdly, public awareness should be raised and discussion should be facilitated. The final strategy should stimulate critical reflection.

CHAPTER 3

Methodology

In this chapter the methodology including the used concepts such as survey for user segmentation, paper prototyping for usability testing and elicitation of requirements is described. Finally, we describe the design methods for the catalogue of design principles.

3.1 Survey for User Segmentation

The questionnaire that we created for finding test users for the paper prototyping session follows the design guidelines of Andrews et al. [ANP07]. The guidelines say that electronic surveys should be designed to...

- support multiple browsers and platforms [YT00]
- prevent submitting multiple times [YT00]
- to present questions in an adaptive or logical manner [KPM97]
- allow saving the work in long questionnaires with more than 50 questions [Smi97]
- collect both quantified selection option answers and narrative type question answers [YT00]
- have the possibility to thank the users for completing the survey [Smi97].

Google Form is a web application out of the Google Web Apps that follows all these guidelines, which was the reason for choosing it for our survey.

As the motivation to find subjects who complete a survey increases as the question difficulty increases [ANP07], when the aim is to have numerous replied questionnaires the survey should comprise simple and not too many questions.

In general, online survey platforms offer convenient and reliable data management [CB00]. By design, Google Form protects against the loss of data and facilitates data transfer into a database, in this case Google Spreadsheets for analysis.

Before sending out the survey and after deciding on the survey tools, contents and platforms it is very important to carry out a pilot [Lum07].

3.1.1 Evaluation of the Questionnaires

The user segments on which this thesis builds upon are described in 2.2.1. Smart Cities Demo Aspern did a survey and used cluster analysis to define clusters. These clusters had distinct features. The answer of one user of the questionnaire can then be evaluated against each user segment with its distinct features. This evaluation amounts to a correspondence of one answer set to a user segment.

According to Kazi and Khalid [KK12] there are three types of validity, which is the degree to which an assessment measures what it is supposed to measure. The three types are content validity, criterion-related validity and construct validity. The validation technique for identifying the correspondence of a user to a user segment is the criterion-related validity as it best describes the equivalence to the segment characteristics.

3.2 Elicitation of Requirements with Paper Prototyping

For the paper prototype a Step-by-Step guide proposed by Arnowitz et al. [AAB10] is used. To create a paper prototype the following steps should be done:

1. **Create scenario**. Before starting to draw anything the main user goals and tasks have to be portrayed. This can be done in a scenario narration.

2. **Inventory UI elements**. The next step is to make a checklist of all UI elements that may be needed to support the scenario.

3. **Create UI elements**. All the UI elements from the checklist from the previous step are now created in paper form. There are a lot of tools and materials that can come in handy at this step. The following list of materials might help the process: paper, sticky notes, whiteboard, sketchbook, notebook, napkin, cards, overhead sheet, cardboard, carton, scissors, markers, UI stencil, correction fluid and tape and transparency sheet. We experienced that paper, scissors, a pen and coloured pencils were sufficient for our paper prototypes.

4. **Run through scenario**. In this step a dry-run through the scenario with the paper prototype should be done and missing parts should be found and recreated.

5. **Internal review**. The last step in the first round is the internal review with the team where the audience is defined, the goals for each version of the prototype are

reviewed, the expectation of the reviewers are found out and the next steps are planned.

We partly did this step before, as the test users were already found out with the survey.

The next Step-By-Step Guide is following the first. It was also proposed by Arnowitz et al. [AAB10] and is for testing the paper prototype:

1. **Revise scenario**. The internal review may have uncovered some tweaks that you want to change. Be careful with changes at the scenario as it may cause a ripple effect which can lead to necessary changes in user interface elements or even new screens. Keeping changes to minimum is recommended. If changes are necessary keep in mind that this can lead to non comparable results in the end.
2. **Revise inventory UI elements**. Until now maybe multiple runs through the prototype have been done and you noticed that some vital pieces of the interface are missing. Now is a good time to check completeness of the UI elements check-list. Developing a set of UI elements for cases that you did not anticipate may be also useful.
3. **Create UI elements**. Check if the collection of the UI elements is still complete and create some more if needed.
4. **Pilot run through scenario**. Before presenting the prototype to the user, it has to be tried out first. You can give the Prototype to anyone, e.g. a team member, to try it out. The aim here is to find missing pieces to be prepared for everything they do. The run through will ensure that you haven't created a half-baked prototype.
5. **Internal review**. In this step the scenario and the prototype supplies are revised again with the team. Also, the goals and the expectation of the reviewers are revised.
6. **Prepare Kit**. Before running the prototype session, the papers have to be arranged in a way that makes it easy to find the various UI elements. Also, blank paper, sticky notes and pens should be prepared for further ideas.
7. **The Prototype Session**. The user study session is an interactive process where one or more participants and a facilitator are involved. In a dialogue the participant completes tasks provided by the facilitator. The session is used to get user opinions about early design and task flow ideas represented on paper. The sessions are typically recorded for later examination. The feedback from the users show what they expect from the app which is of great value for the implementation later on [Sny03]. Weiss[Wei03, p. 144] proposes to invite not only one, but two respondents at a time for paper prototype usability tests. He mentions that two respondents feel more comfortable in the casual environment that paper prototyping creates, whereas one single respondent can easily become overwhelmed by the experience.

8. **Reiterate**. After each prototype session a review and evaluation about what went good and what bad can be done. Although it might be tempting to change things after each session, it is better to wait until all the planned user sessions are done to do an overall comparative review at the end.

3.3 Creating a Catalogue of Design Guidelines

A common challenge is to interpret the results of empirical studies and derive design guidelines which are not too specific but also not too general to make them applicable without additional interpretation effort. The methodology for the deduction of design guidelines for this thesis is inspired by De Bruijn's and Spence's [DBS08] framework for theory-based interaction design.

ID	DA1
Title	Maximisation of information exposure
Description	Expose users to as many representations of information items as possible commensurate with maximising the likelihood of those representations being correctly interpreted in terms of the information being represented.
Effect	The more of these items being presented to the user the greater the likelihood will be that one is perceived that is a relevant to a user's interests.
Upside	(1) Queries need not be explicitly formulated, as the relevant items will be recognized as such when encountered. (2) Irrelevant items will be forgotten with no cost in cognitive effort
Downside	Any display area is finite, giving rise to a trade-off between the number and size of items being presented simultaneously, and their presentation duration.
Issues	Comment is often made concerning the effects of information overload. This is not so relevant here, because no additional cognitive effort is involved in perceiving, interpreting and then forgetting information that is irrelevant. However, any action triggered does require focused attention. It is therefore important that this DA be applied to situations in which the likelihood of encountering a relevant item is relatively small. If multiple items of interest are likely to be encountered, then it is important that either a) the items can be easily prioritised, or b) the items can be dealt with sequentially.
Theory	Current theory suggests that irrelevant information is rapidly forgotten at no additional cost.

Figure 3.1: Exemplary design action of De Bruijn and Spence [DBS08]

The design action is headed by an **identifier** and a **title** indicating as clearly as possible the expected result of applying the design action. The **description** clarifies the brief title, followed by the **effect** that the design action will have. The design action further includes an **upside** and **downside** section that describes advantage and trade-offs respectively. The **issues** sections considers issues that are neither positive nor negative. In the last part of the design action the **theory** is provided as an opportunity for the designer to dive deeper. Nevertheless, the designer does not necessarily need to understand it in order to apply the guideline.

CHAPTER 4

Questionnaire for user segmentation

In the State of the Art chapter the User Segmentation 2.2.1 from Smart Cities Demo Aspern on which this thesis builds up upon is explained. With regard to the Paper Prototyping session we need users that clearly can be allocated to a user segment. To find users for each user segment we created a questionnaire. This questionnaire answers the second research question:

RQ 2: Which criteria do questions have to meet, that shall identify the type of a user?

The user survey leaned on to the first questionnaire of the quantitative study of Aspern Smart City Research. The original questionnaire of ASCR comprised of 48 questions. The factor analysis of the returned questionnaire identified the four dimensions: Comfort-centred, Technology-centred, Data Sensibility and Living in Seestadt. The following cluster analysis found out four segments. By analysing the results of the qualitative and quantitative study from Smart Cities Demo Aspern we realized, that for the definition of the segments only two of the four factors were relevant for describing the characteristics of a user group. For our study we focused on these two factors which are the comfort and the technology orientation. So, we took the questions of the original questionnaire which answers were identified by the cluster analysis to be significant for the user segmentation. Out of the 48 questions of the original questionnaire ten were relevant for allocating a user to a user segment. These ten were then reworded, as some of them did not make sense any more as they ware taken out of context. Some answer options also have to be adopted to guarantee more clarity. The questions were also resorted and grouped into categories to provide a better comprehensibility.

For creating and sending the survey we used Google Forms. As the motivation to find subjects who complete a survey increases as the question difficulty increases [ANP07],

our questionnaire only comprised of ten questions and the average time for answering the whole questionnaire only took one minute. We sent the questionnaire to 57 people, trying to have a good distribution of different ages, educational levels, jobs and interests. 41 questionnaires were returned.

For evaluating the response we used Google Spreadsheet and Microsoft Excel. The answers of each person were evaluated against the characteristics of each of the four user segments. Of course not every user could easily be assigned to exactly one user segment. For each user the correspondence to each of the four user segments was calculated and expressed in percent. The ones who had a clear correspondence of more than 50 % to one user type were chosen as test users for the paper prototyping session. So at least one user for each user type was chosen.

Given the answer of the first research questions and the results of the survey we can give a conclusive answer to RQ2. The questions shall concern the main characteristics of every user type regarding the factors technology and comfort. This means the survey should include questions that:

- check the interest in energy
- investigate the knowledge of the consumption of electric devices
- detect the importance of saving at energy costs
- determine whether a user programs from time to time
- find out if home automation possibilities are used
- examine the pattern of showering or taking a bath
- check the behaviour of switching out the light when leaving a room
- ask if the light is sometimes forgotten to be switched off when leaving the apartment
- ask for the preferred use of lighting

Additionally, the questions shall be short, comprehensive and easy to answer, as mentioned in 3.1. The whole questionnaire can be found in Appendix A.

CHAPTER 5

Design and evaluation of the Paper Prototype

This chapter describes the design and the evaluation of the paper prototype. The design was done on paper and with the knowledge of usability issues in mind. The existing approaches of eco-feedback applications have been evaluated in the section 2.5. Especially the design principles were the basis for the hand-sketched drafts. The evaluation was done in a paper prototype session with the users found with the questionnaire. The workshops were held not only to test usability but also to answer the following research question:

RQ 4: Do the characteristics of user groups correlate with the users' preferred type of visualization?

The Smart Home Control mobile application from ASCR will be investigated in particular and will be the basis for the paper prototypes. As described before in 2.3.2 we follow the Step-by-Step guide of Arnowitz et al. [AAB10] to create a Paper Prototype. The first task of the Step-by-Step guide is to define the tasks in a scenario narration.

Scenario narration The main goal of the mobile application for which the paper prototype is sketched is to give eco-feedback. This feedback shall primarily focus on the consumption of electricity, water and heating and the emission of carbon-dioxide. So the history consumption rate of these data shall be available to look into. A comparison of the consumption during different time intervals shall also be possible. This comparison can be drawn to one's own consumption rate but also to a comparable household, to an average consumption rate of the neighbours, your city or the European Union. On a dashboard the current measured values, the consumption of the day and some current settings shall be shown. The management of the home automation system shall also be possible with the app. Tips for saving money by saving energy shall also be given. Energy saving-tips shall be tailored to the characteristics of a user type. Especially for

Hedonists the menu item "Project" will be interesting. Here projects are listed, which show possible further home automation items that can help at energy saving. A user can read frequently asked questions in the FAQ section when questions or problems occur.

5.1 Design of Paper Prototypes

We designed multiple versions of the paper prototype that resulted from several runs through the Step-by-Step guide for the creation of a paper prototype of Arnowitz et al. [AAB10].

5.1.1 Menu navigation

We developed a navigation drawer that shows the app's main navigation menu. The menu items are adapted to the requirements of each user type, as shown in Figure 5.1. The sorting of the menu items was adapted to the main motivation why a user uses the app. This motivation was taken from the outcomes of the survey from Aspern Smart City Research [KG]. The main motivation for a Professional to use the app is to monitor the consumption rate, which is shown in the dashboard. For the Optimizer it is to save money and to see how much money can be saved. So for the Optimizer the "Sparen" which means the Saving is the second item, below the dashboard. This is because the dashboard for the Optimizer also already shows a quick overview of the previous savings. According to [KG] the Indifferents primarily use the app for fun. So the "Aktuelles" which shows the latest topics containing gamification elements is shown as the first menu item for the Indifferents. The gamer under the user segments, the Hedonists, primarily use the app to manage their home automation gadgets, because of that the "Aktuelles" is adapted to that and shown as the first menu item to the Hedonists.

5.1.2 Dashboard

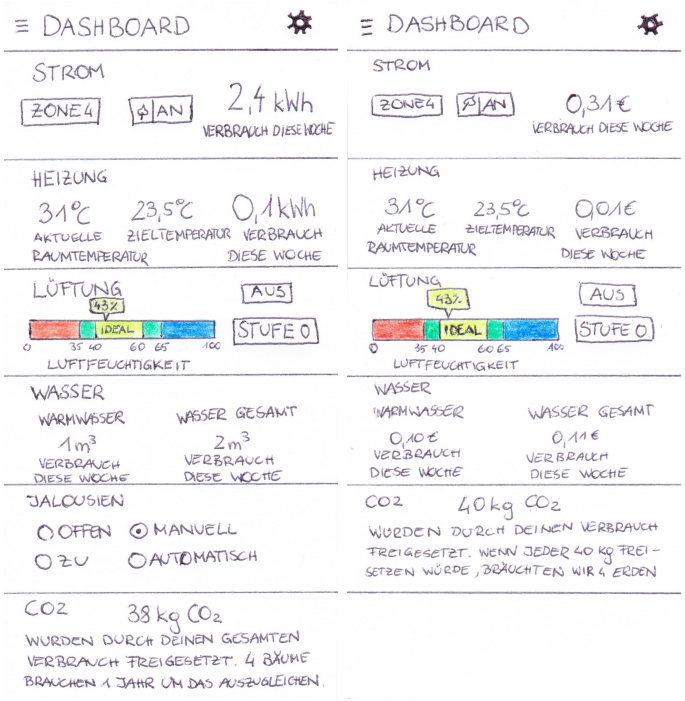
The dashboard was based on the one from the ASCR application. As visible in 5.2, the main difference is the use of kWh for Professionals and Hedonists and the use of Euro for Optimizer and Indifferents. Again we based our assumptions on the findings from the survey from [KG]. We assumed that Professionals and Hedonists prefer units of energy or consumption to monetary units and Optimizers and Indifferents are contrary, meaning they prefer monetary units to units of energy or consumption. Additionally, we introduced a scale for air humidity to make it more appealing and better comprehensible.

5.1.3 Latest topics

In the latest topics section, shown in Figure 5.3, a user can see informations that are daily new. Professionals and Hedonists are given the "Project" item and Optimizer and Indifferents have an overview of the current level and the trophies earned. The latest figures such as "Did you know that...", "Figure of the day...", "Energy-saving tip of the day..." and "Lifehack of the day..." shall motivate the user to use the app daily.

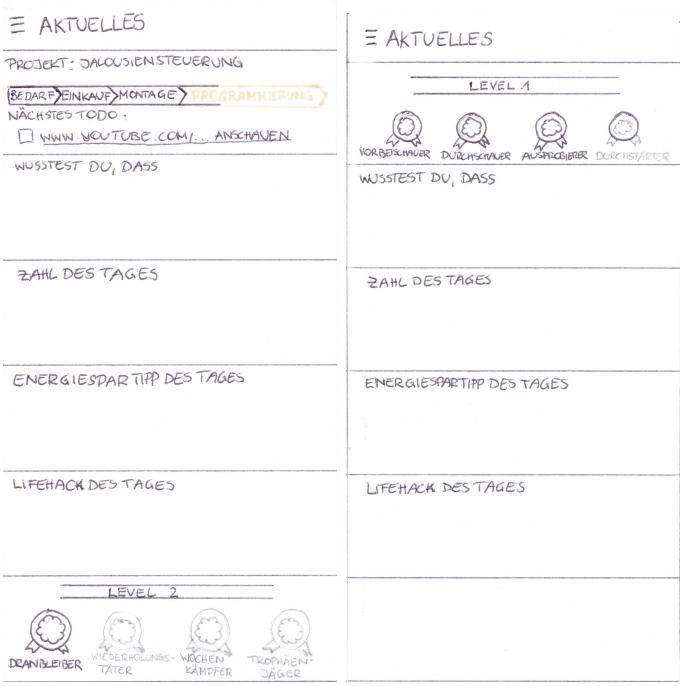
(a) Professional (b) Optimizer (c) Indifferent (d) Hedonist

Figure 5.1: Proposed screens for the navigation drawer



(a) Professional and Hedonist (b) Optimizer and Indifferent

Figure 5.2: Sketches of the dashboard



(a) Professional and Hedonist (b) Optimizer and Indifferent

Figure 5.3: The proposed screen for the latest topics

5.1.4 Statistics

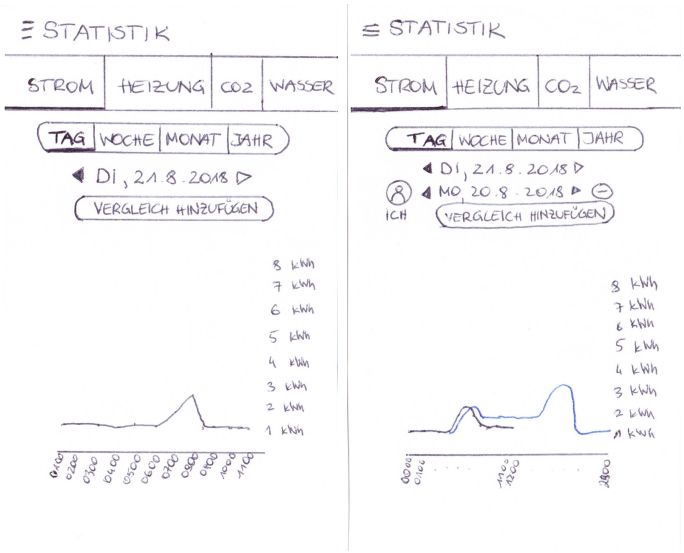
Figure 5.4 shows the statistics screens where a user can monitor the latest consumption of electricity, heating, water and the emitted CO2 value. Day, week, month or year are periods of time that can be selected. In every period values can be compared to previous consumption rates, see Figure 5.4b.

5.1.5 Equipment control

All the manageable tools are grouped in the equipment control. The ones that are managed are active and the other ones are greyed out, as pictured in Figure 5.5a. Profiles can be selected and are adaptable.

5.1.6 Comparison of Savings

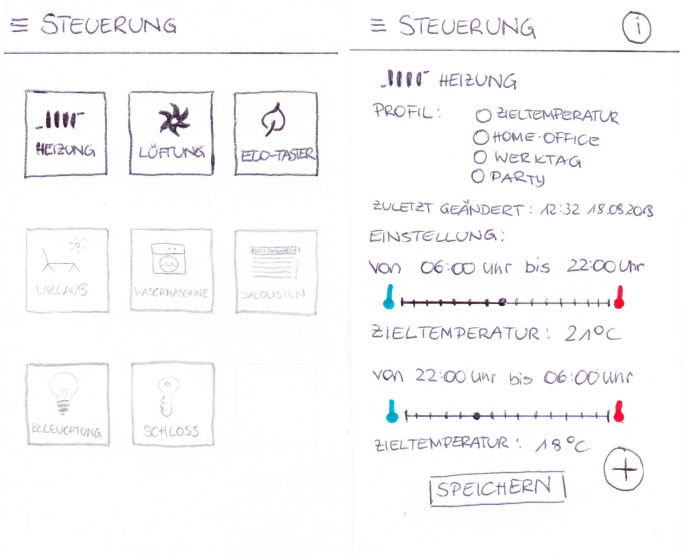
Figure 5.6 shows the screens for the comparison of savings for all user types. The screen for the Professionals, see Figure 5.6a, provides the possibility to compare yourself to the average of your neighbours, to one friend and to see yourself on a rank table. For Optimizers the screen in Figure 5.6b shows that they can set themselves a goal with which they are then compared, leaning on the design principle self-monitoring. Also the total savings of the time interval are shown and an example is given of what can be bought



(a) Statistics of electricity consumption of a day

(b) Comparison of electricity consumptions of two days

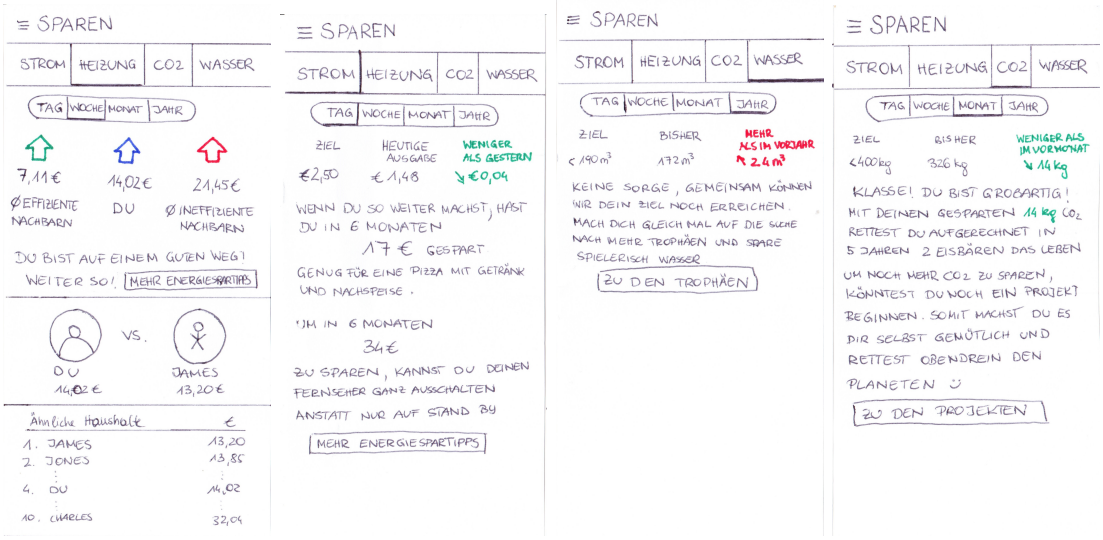
Figure 5.4: Sketches for statistics



(a) Overview of control possibilities

(b) Control of heating with profiles

Figure 5.5: The proposed screens for equipment control



(a) Professional (b) Optimizer (c) Indifferent (d) Hedonist

Figure 5.6: The paper prototype screens for comparison of savings for all four user segments

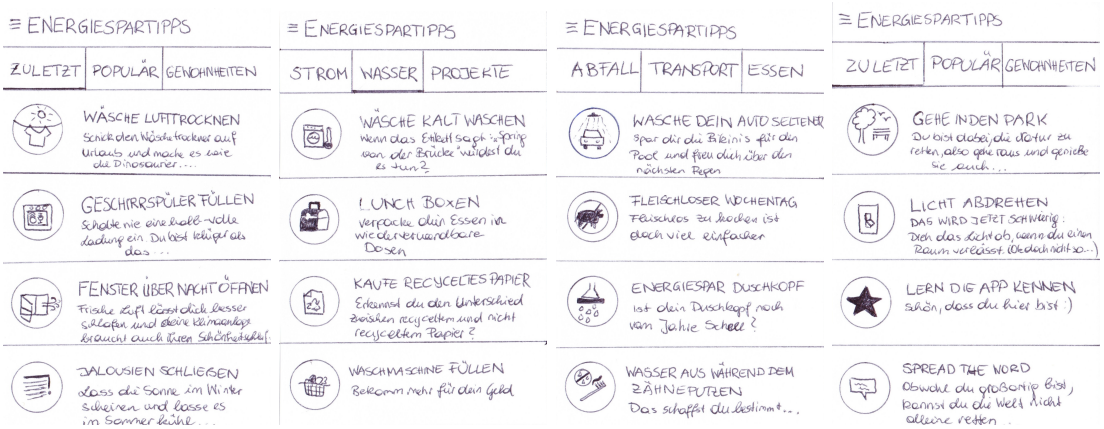
from that amount. A motivation is given by showing the amount that can be saved when the target behaviour is maintained which orientates to the design principle rehearsal. The screen for the Indifferents, pictured in Figure 5.6c, also includes a comparison of the aim and the current value and animates to search for more trophies. Similarly, Hedonists can also see their current value compared to their goal, see Figure 5.6d. Hedonists are then motivated to start or go on with existing projects.

5.1.7 Energy-Saving Tips

The energy-saving tips are subdivided into categories which can be scrolled horizontally as shown in Figure 5.7. The interface is the same for all user types but the tips are tailored to the specific preferences. A Hedonist does not get tips that limit comfort, see Figure 5.7d. An Optimizer should not get tips that are written in technical language. According to [KG] Professionals prefer deeper information about a tip and the consequences of applying a special behaviour. For Hedonists tips for saving energy or CO2 should not concern longer usage of laptops or entertainment screens, as streaming and use of social media is an important leisure activity for them.

5.1.8 Gamification approach

Gamification is the application of game theory concepts and techniques to activities that normally don't contain gaming elements. The Gamification elements shall help attract consumers to more efficient energy management. The elements proposed by this thesis



(a) Professional (b) Optimizer (c) Indifferent (d) Hedonist

Figure 5.7: The paper prototype screen for energy saving tips

are trophies, as shown in Figure 5.8. For earning a trophy a special behaviour has to be done. To increase in levels a special amount of trophies need to be saved.

5.1.9 Trouble Shooting

A suggestion how an FAQ screen can look like is shown in Figure 5.9. We assumed that the Professionals, Hedonists and Indifferents like the possibility to read frequently asked questions first, but the Optimizer prefer to call first. We did not find it necessary to adapt this screen to all types as we assume it covers the needs for all types.

5.1.10 Communication

Any interactive system provides some system feedback to the users, mostly via verbal information. The dialogue between the application and the user shall help at moving towards goal or target behaviour. One design principle that [OKH09] mentioned is praise, which we also tried to use in our application.

We also assume that the Optimizer prefer less time of interaction and rather like unclear instructions. Notifications and energy-saving tips should give concrete, clear and close to reality handling instructions on how to apply the target behaviour. "Reduction", more deeply described in Design principles for primary tasks, is the design principle that applies here, as it reduces effort to perform the target behaviour.

5.2 Description of the evaluation method

As mentioned before, in this thesis we focus on the four user types: Professionals, Optimizer, Hedonists and Indifferents. For each of the four user types a session with at least one test user was held. The test users were found by evaluating the returned

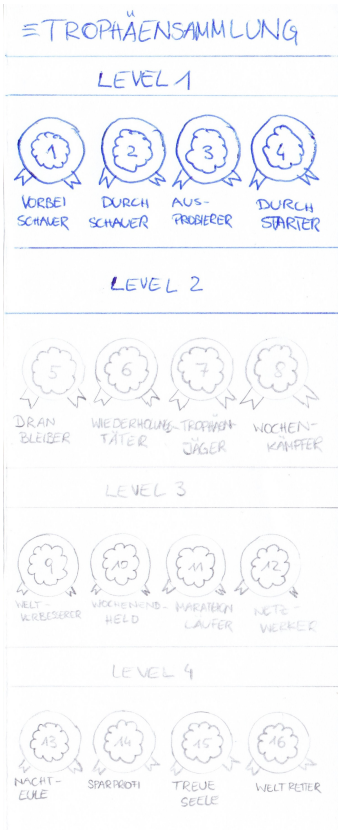


Figure 5.8: Sketch of collection of trophies

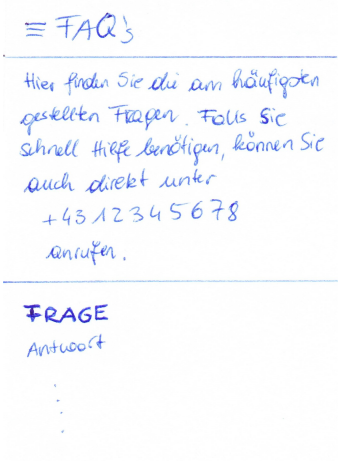


Figure 5.9: The proposed screens for Trouble shooting

questionnaires. The persons that corresponded the most, which means more than 50 % to one user type were invited for the workshops. In total five test users took part in the four paper prototype sessions.From the five test users two were men and three women. Two of the five test users were workers and the other three were students. As the users corresponded to the user groups, they shared their characteristics. Meaning, the Professionals had experience in energy topics, the Optimizer had interest in optimizing energy costs, the Indifferent did not have interest in energy topics and the Hedonists was a passionate user of different device types and gaming gadgets. The age of the test users also were appropriate to the characteristics of the respective user group. The average age of the test users is 30.8 years. The Hedonists, Optimizer and Indifferents were the youngest group with 25 years and the Professionals were in average 39.5 years.

Each of the sessions took approximately two hours, where 30 minutes were spend on the explanation, introduction and evaluation of the ASCR application and 90 minutes for the evaluation of the paper prototypes. For the Professionals we found two test users, who perfectly could be identified as Professionals. The paper prototype session with the Professionals can be declared as "Focus group". This session took about ten minutes longer than the ones with the other user groups, as we let them discuss the topic of energy saving and feedback on behaviour first. This discussion took approximately ten minutes. The other sessions with the Optimizer, Indifferents and Hedonists were held with one test user each, which can be called interview.

5.2.1 Session protocol

We developed an agenda for the paper prototype sessions with the test users so each session could follow the same procedure. The agenda covered the following points:

1. Introduction with explanation of the aim of the workshop
2. Explanation of user segments
3. Review of the existing ASCR mobile Application
4. Review of the paper prototypes

The paper prototype sessions were started with an introduction to the topic, where the main goal of the session was explained which was the evaluation of the ASCR Smart Home Control application and the evaluation of the paper prototypes. After that an explanation of the user segments followed. The users did not know to which user group they were assigned to by the questionnaire. So the users did not know their user type and were asked to have a guess, after the explanation of the user segments. All the, in total five users, guessed their user type right. The users were also asked if they could identify with the characteristics of the user group they were assigned to by the questionnaire, which was also true for all the test users. Then the ASCR Smart Home Control App was given to the users on an mobile phone. The phone that we used was the Samsung Galaxy

S5. The Thinking-Aloud-Protocol was explained and the users were asked to apply this technique to evaluate the usability. After the discussion on improvements for the ASCR app, the paper prototypes were shown and the users' opinions were noted. The users were presented all the different possibilities for one screen an were asked which one they prefer and why they prefer it. They were never told which screen was designed for them to get unbiased results. The user stories that were defined beforehand were analysed against their validity, which means the users were asked questions to find out whether the user story is true for the user. The answer and it's explanation was noted done in the protocol.

Arnowitz et al. [AAB10] proposed that one team member shall keep the minutes during a session. In every paper prototype session there was one person who took notes. This person was given an explanation of what to do and of what to write down. The sessions were also recorded in case uncertainties occur in the evaluation afterwards. A template for a protocol was also developed so taking notes was easier. The template included the agenda for the session, so for the person who took notes it was easier to follow the session and to keep up with the writing. For the analysis section of the existing ASCR app the protocol included yes/no questions with answers that were asked in the sessions. The protocol allowed to tick or cross the given answer by the test user to limit the amount of writing but always included a "Why?" where the explanation that the user gave was noted down. The questions concerned usability issues such as the following:

- Is the app appealing?
- Is the app clearly structured?
- Is the app easy to comprehend?
- Do you fear to unintentionally adjust something?
- Do you wish for other measurement units?

Additionally the protocol included a section for improvements, that were mentioned by the test users. Concerning the evaluation part of the paper prototypes the protocol and therefore also the sessions were subdivided into topics. These topics correspond to the different screens of the applications and were chosen on the basis of the ASCR Smart Home application and the requirements that we found out for an application that help users at saving energy and raising awareness. For each topic we developed user stories on the basis of the findings from the previous survey of Aspern Smart City Research. These user stories were tested against their validity with questions. The topics including the user stories and the asked questions are listed the following.

Menu navigation

User stories tested against their validity:

- As a Professional I primarily use the app to monitor my consumption rate.
- As an Optimizer I primarily use the app to save money.
- As an Indifferent I primarily use the app for fun.
- As a Hedonist I primarily use the app to manage my home automation gadgets.

Question:

- Think about a mobile application that shows your consumption rate, has the possibility to manage your home automation gadgets, shows information of how to save energy and money and has gaming elements for dealing with the topic of energy saving. What is your main motivation to use such a mobile application?

Dashboard including units of measurements

User stories tested against their validity:

- As a Professional I prefer units of energy or consumption to monetary units.
- As an Optimizer I prefer monetary units to units of energy or consumption.
- As an Indifferent I prefer monetary units to units of energy or consumption.
- As a Hedonist I prefer units of energy or consumption to monetary units.

Question:

- Do you prefer units of energy or consumption to monetary units?

Latest topics

User stories tested against their validity:

- As a Hedonist I love to do projects where I can save energy in the long run.

Question:

- Are you interested in starting projects that may last longer and require some skills to save energy?

Statistics

User stories tested against their validity:

- As a Professional I want to compare my consumption data with others.

Question:

- Are you interested in comparing your consumption data to others?

Equipment control

User stories tested against their validity:

- As a Hedonist I primarily use the app to manage my home automation gadgets.

Question:

- Do you want to use the application mainly for controlling your home gadgets?

Comparison of savings

User stories tested against their validity:

- As a Professional I am interested in comparing my consumption rate to others
- As an Optimizer I am interested in comparing my consumption rate to others

Question:

- Are you interested in comparing your consumption rate to others?

Energy saving tips

User stories tested against their validity:

- As a Hedonist I do not want energy-saving tips that limit my comfort.
- As a Professional I want to have deeper information for energy-saving tips.

Questions:

- How do you like the idea of getting energy saving tips on a regular basis?
- Do you want to have deeper information about energy saving tips?

Gamification approach

User stories tested against their validity:

- As a Hedonist I want to be rewarded with game progress for applying a target behaviour.

Questions:

- How do you like the idea of a gamification approach in such a mobile application?
- Would you be motivated to apply a certain behaviour when gaining trophies?

Trouble shooting

User stories tested against their validity:

- As a Professional I would read the FAQs first
- As an Optimizer I want to have help immediately when a problem arises

Question:

- When a problem occurs do you read the FAQs or call the hotline first?

Communication

User stories tested against their validity:

- I like it when the application praises me
- As a Professional I prefer deeper information to energy topics
- As an Optimizer I want clear instructions of what to do

Questions:

- Do you like it when the application praises you or is it too much for you?
- Do you like information that goes into depth?

Every user story included a section for notes and improvements in the protocol where further information could be gathered which was of great value for the following evaluation.

5.3 Results of the Paper Prototype sessions

In this section we provide a summary of the main results of the evaluation containing detailed guidelines for front-end developers. We took statements from the Thinking-Aloud-Protocol and put them into a more readable form without changing the sense behind the statements.

ASCR app evaluation

Every session also included the evaluation of the ASCR Smart Home Control app. Some of the statements of the interviews are stated in the following.

Benefits

- Professional 1: "It (the dashboard) is simple."
- Professional 2: "The text is clear and the big numbers are good"
- Professional 2: "The statistic is very interesting"
- Indifferent: "In general it looks appealing to me. Not the colours but the overview"
- Optimizer: "The numbers are not clear"
- Hedonist: "After some time of orientation, it is clear to me what the numbers mean"
- Hedonist: "I do not wish for other units"
- Hedonist: "The design and the colours are appealing"

Improvements

- Professional 1: "Monotonous. It (all the numbers) is all on one side"
- Professional 2: "What does target mean in the heating section?"
- Professional 2: "A cancel button is missing. I am afraid to do something wrong"
- Optimizer: "The numbers are not clear"
- Optimizer: "The design is boring"
- Optimizer: "Community would be interesting. Who else uses the app?"
- Indifferent: "I am a bit scared to unintentionally adjust something. For example: Electricity. I am scared to switch of electricity"
- Indifferent: "I am confused which value is the current one"

- Indifferent: "I can not say how much water I did consume"
- Indifferent: "What does Zone 2 mean?"
- Indifferent: "The colours should be adapted to the prices of the Zones."
- Hedonist: "The text is too small and the design is not uniform"
- Hedonist: "The loading time takes so long that it is not funny anymore"

The loading time was a problem when testing. Sometimes it took two minutes until figures appeared, which made the application not very usable. The problem that was stated the most often, is that it the latest consumption is not clear. May it be due to the missing information or to measurement units that are not appropriate to the user type.

Menu navigation

Benefits

- Professional 1: "I am actually only interested in statistic figures"
- Professional 2: "... that (the overview of consumption figures) interests me the most"
- Optimizer: "If I could really save money, I would use it".
- Indifferent: In the context of looking at the trophies and explaining the gamification approach "I am the perfect type for that"
- Indifferent: "A menu that adapts itself is very customer-orientated"
- Indifferent: "I really like the idea of a tailored navigation menu"
- Hedonist: "I would not want to adapt the menu myself but I would adapt to it"

Improvements

- Professional 1: "Changing the order would be good"
- Optimizer: "I recommend the use of more colours and symbols"
- Indifferent: "Drag and Drop for the menu items would be nice"

The test user from the Optimizer and Indifferent user section stated that a drag and drop function to resort the items would be a nice-to-have feature. One Optimizer suggested using a different colour for each menu item to make it visually more appealing. Also the use of icons was highly recommended, especially from the Optimizer.

Dashboard

Benefits

- Professional 1: "I know how much one kWh is."
- Professional 2: "Of course. I don't think it is possible to transfer it to Euro because of the taxes."
- Optimizer: "I can better estimate and compare the values when they are in Euro."
- Indifferent: "I have absolutely no clue about kWh. I have never taken a closer look to kWh"
- Hedonist: "Yes, I can handle kilowatt hours and cubic meters."

Improvements One critic from a Professional was, that the screen misses, how the quality of the air can be improved. Grouping the measured values to one side and the values that can be controlled to the other side was also suggested by a Professional. The Optimizer again wished for more colours and symbols. A similar scale for CO2 as for the air humidity was mentioned by the Indifferent segment of test users. An extra pop up window for the adjustable values in order not to unintentionally adjust settings was desired from the Hedonist test user.

Latest topics

Benefits

- Professional 1: "Further information is preferable"
- Professional 2: "I prefer small projects to big ones"
- Professional 2: "I would have a look at it in the first days but later on maybe not"
- Optimizer: "I like the concrete instructions of what to do"
- Optimizer: "Energy saving tip of the day or the week are an incentive for me"
- Indifferent: "Gamification would be very cool"
- Indifferent: "The trophies would be the most important topic for me"
- Indifferent: "Oh, how cool!" in the context of "Did you know that, ..."
- Hedonist: "...I've already done projects with YouTube tutorials and love the idea of having them in the mobile app"
- Hedonist: "I would not search for energy tips, when they are not visible at the first sight"

Improvements Some test user mentioned that the information given in the daily news should also be tailored to personal consumption figures. One Professional mentioned that a reminder from time to time for the daily figures would be interesting but at a daily basis it would be annoying. The users of the other segments came to the same conclusion. The Hedonist test user said that for the project overview only the next to-do would be enough and the bread crumbs from the latest steps are not necessary.

Statistics

Benefits

- Professional 1: "Yes, I like the statistics a lot. The comparison with me and others."
- Professional 2: "Very interesting. I would watch especially when the bill comes."
- Optimizer: "I am not very interested in monitoring my energy consumption but I am interested in a comparison with others"
- Indifferent: "Comparisons are cool. Even with others."
- Hedonist: "The comparison is only funny in special situations, e.g. LAN party vs. normal day"

Improvements An improvement mentioned by a Professional was to split up the statistics into consumption statistics and quality statistics. The latest can then e.g. show the room temperature, the air quality in CO2 or the air humidity. The Optimizer wished for a possibility to switch to Euro. Showing an area in the diagram that indicates with colours where the "good" and the "bad" range lies, was wished by an Indifferent test user.

Equipment control

Benefits

- Professional 1: "I like that there is less text. I like that the equipment control is done from the app"
- Professional 2: "The general idea is very nice. But I would wish for more profiles"
- Optimizer: "The tiles overview is much better but I still want to have concrete instructions of what to do. Otherwise I do not know where I should start"
- Indifferent: "I like that the control is in an extra menu point"
- Hedonist: "Controlling my home is what I would really like to do with the app"

Improvements All test users proposed to use other wording for the profile. "Home" instead of "Home-office" because it is not clear that "Home-office" can also be used at weekends or when not working at home. Instead of "Goal temperature" the term "Manually" was mentioned. One Professional noticed an obvious lack of the equipment control: the absence of weekly profiles. The adding of who has changed the value at last time was wished from a Hedonist participant.

Comparison of Savings

Benefits

- Professional 1: "Comparing with others is nice letting data protection aside"
- Professional 1: "I like the structure of screen one, the other ones are not clear for me"
- Professional 2: "I also like the comparison. Especially in an anonymized list."
- Professional 2: "The text of the other screens is not appealing to me"
- Optimizer: "Oh yes, the incentive of saving Euros is extraordinary good".
- Indifferent: "I would prefer a comparison of values from kWh. Such as 1 hour of cooking consumes X kWh. The only thing I know is that a stove needs a lot of kWh."
- Hedonist: ""

Improvements The Professionals expressed their concerns of sharing their data publicly. They would use the feature of comparing with others but are not ready to make their data available to others. Even here the Professionals preferred kWh to Euros. One Professional criticised the use of too much text and suggested structuring the infos better. The Professionals were the only user group who would like only their screen for all the other consumption data. The Optimizer, Indifferents and Hedonists stated that they would like all the four screens for the different tabs and prefer the mixture of text and values. The Indifferent voiced the concern of feeling supervised when the measured time interval is very short.

Energy-Saving Tips

Benefits

- Professional 1: "I really like personalized but also the general tips"
- Professional 2: "I want to know the 'Why?' behind a tip"

- Optimizer: "The symbols motivate me a lot to dive deeper into the topic of energy saving"
- Optimizer: "What I like are concrete instructions that are clear and easy to follow"
- Indifferent: "Negative warnings are also good because they touch me emotionally"
- Hedonist: "In general energy saving tips are interesting, but if they limit me I would ignore them"

Improvements The projects are more logical to be an extra menu item and not a part of the energy-saving tips. The list of tips can be updated from time to time to make them more interesting.

Gamification approach

Benefits

- Professional 1: "This does not interest me. I doubt that someone would change the behaviour because of a game"
- Professional 2: "My app usage will not change because of the trophies"
- Indifferent: "Maybe I will only do certain things to get more trophies"
- Indifferent: "...I am the perfect type for this kind of gamification..."
- Hedonist: "When the trophies correlate with the projects I would also like them"

Improvements An improvement that was mentioned from an Indifferent was to not bind trophies to specific labels but to advance in levels when a special amount of trophies is earned, regardless which trophies. This avoids disappointment when a behaviour was done the whole time but the trophy for it could not be earned because the level was not reached.

Trouble Shooting

Benefits

- Professional 1: "At first I would have a look at the FAQs."
- Professional 1: "The best thing would be a chat"
- Professional 2: "I would not like a chat. I would read the FAQs and then call if I do not find an answer"

- Optimizer: "Definitely a telephone number! I always call, it is much faster".
- Indifferent: "I would use a contact formular or write an E-Mail. I am not that telephone type."
- Hedonist: "I prefer calling to mail. When something doesn't work I would screen the FAQs but then I would call."

In the paper prototyping session with the Optimizer it was wished for a hotline to call immediately when an error occurs. The Hedonist also stated, that calling is preferred to reading the FAQ.

Improvements A chat was proposed by a Professional. In contrast, another Professional would not like a chat. Having the possibility to send an E-mail was categorized as low priority. The telephone number should be at first like in Figure 5.9 for Optimizer but for the other types, the questions are preferably on the first position.

Communication

Benefits

- Professional 1: "Totally wouldn't use an app that tells me all the time what I am doing wrong"
- Professional 2: "I don't want to feel catched by the app. A note is ok, but not a reprimand"
- Optimizer: "I just want to know what I should do".
- Indifferent: "The App should not tell me off or say 'Tututu'. It should be nice to me"
- Hedonist: "If the app praises me like this I would use it more often because it makes me feel good"
- Hedonist: "Funny tips would be the best"

Summarizing, the dialogue between the application and the user should be with positive words and in a positive way.

5.4 Catalogue of Design Guidelines

In the following section a catalogue of design guidelines was developed. The guidelines were derived from the results of the evaluation from the paper prototype sessions.

Guideline 1: Adapt navigation drawer to requirements of user type

Sort the items of the navigation drawer according to the motivation of a user type. An effect would be that a user can quickly interact with the app as the preferred items are on top. The sorting reduces the time a user has to search for his/her primary task. However, the different sorting can be irritating when a user compares the app to a user who is a different type of user and therefore has another sorting of the items.

Evidence The paper prototype session with the professionals has shown that Professionals primarily use the app for monitoring their consumption rate. One professional said "I am actually only interested in statistic figures" and the other one "... that (the overview of consumption figures) interests me the most", therefore "Dashboard" is the first menu item. The main motivation for Optimizer is to save money with the app, as they mentioned "If I could really save money, I would use it". Indifferents primarily use the app because it makes fun which means that their main motivation is supported by the gamification approach. This is proven by the statement of the Indifferent test user "I am the perfect type for that". Hedonists' are especially motivated to use the app, when their drive for programming projects is picked up. The gamification approach and the projects are shown in the first menu item, for that reason the "Dashboard" is on second place for Hedonists and Indifferents. The following user stories were tested in the paper prototype sessions with the according user types and were proven to be appropriate:

- As a Professional I primarily use the app to monitor my consumption rate.
- As an Optimizer I primarily use the app to save money.
- As an Indifferent I primarily use the app for fun.
- As a Hedonist I primarily use the app to manage my home automation gadgets.

Guideline 2: Use monetary units for Optimizers and Indifferents and units of energy or consumption for Professionals and Hedonists

Depending on the user type the measurement unit is changed and the values are converted accordingly. The electricity and heating consumption is shown in kWh for Professionals and Hedonists and in Euro for Optimizers and Indifferents. The same counts for consumption of water. Optimizers and Indifferents prefer the measurement unit Euro to cubic meter.

Evidence Tailoring, as mentioned before in Design principles for primary tasks, is beneficial for persuasion. The tailoring of the measurement unit to the preferences was defined as very beneficial by all user types. It was very clear in all testing sessions that the proposed unit for the particular user group was preferred. "I really like the idea of a tailored navigation menu" was mentioned by the Indifferent. The following user stories were tested to be true:

- As a Professional I prefer units of energy or consumption to monetary units.
- As an Optimizer I prefer monetary units to units of energy or consumption.
- As an Indifferent I prefer monetary units to units of energy or consumption.
- As a Hedonist I prefer units of energy or consumption to monetary units.

Guideline 3: Use the thrive of Hedonists to program and provide projects for them

One characteristic of the hedonist is that they have high interest in technology and programming solutions. The natural thrive of them can be used to make them using the app by providing projects that support their thrive. These projects can compose of multiple steps for installing and programming a home automation gadget, that shall save time, energy and money in the long run. One example is shown in Figure **??**.

Evidence Tunnelling, as mentioned before in Design principles for primary tasks, guides a user through an attitude change process. This design principle is used for the projects, as it shows a Step-by-Step guide of what to do while performing the target behaviour. The test user of the Hedonist user segment very much liked the projects section, "...I've already done projects with YouTube tutorials and love the idea of having them in the mobile app".

- As a Hedonist I love to do projects where I can save energy in the long run.

Guideline 4: Provide diagrams to monitor the consumption rate for Professionals, Optimizer, Indifferents and Hedonists

Making use of diagrams to show consumption and history data and provide the possibility to switch between different time intervals.

Evidence The design principle of Self-monitoring, as explained in Design principles for primary tasks, shall provide users with the possibility to monitor their performance, which is clearly given with diagrams of the latest consumption figures. All of the test users mentioned that they like to have a look on past consumption figures.

Guideline 5: Provide the possibility to compare with others for Professionals

Preparing one's consumption data with other even unknown people is motivating for a Professional.

Evidence The ranking table and the comparison with others is based on the design principles social learning, social comparison, normative influence, competition and recognition, that are described above in the section 2.5.2. In the paper prototype sessions the Professionals also liked their proposed screen the most, e.g. "I like the structure of screen

one, the other ones are not clear for me", "The text of the other screens is not appealing to me". The following user story was derived from the statements of the Professional test users:

- As a Professional I want to compare my consumption data with others.

Guideline 6: Avoid to present comfort limiting energy-saving tips to Hedonists

Hedonists prefer to do projects that save energy for them in the long run and are comfort-oriented. The hedonistic lifestyle with its strong convenience and comfort orientation is in the foreground. In order not to lose them, do not present energy saving tips to Hedonists when they limit comfort.

Evidence As mentioned in the user segmentation section 2.2.1 Hedonists do not want to be limited in comfort, which the Hedonist test users confirmed in the paper prototype session "In general energy saving tips are interesting, but if they limit me I would ignore them". The following user story was derived:

- As a hedonist I do not want energy-saving tips that limit my comfort.

Guideline 7: Provide deeper information for an energy-saving tip for Professionals

Professionals are interested in deeper information for saving tips and want to understand how and why a tip works.

Evidence Based on the findings from the study from SCDA, as mentioned in the User Segmentation Section 2.2.1, Professionals like to dive deeper into the topic: "I want to know why I should apply this". Again the Tailoring design principle is here applied as the other user segments get shorter information to energy-saving tips. The user story for this guideline is:

- As a Professional I want to have deeper information for energy-saving tips.

Guideline 8: Avoid motivating a Professional with gamification elements

Professionals are intrinsically motivated for energy topics and don't need to be sensitized for these topics.

Evidence The professional test user stated that they would not change their behaviour in order to collect trophies, "My app usage will not change because of the trophies". The proceeding in the game does not motivate them to deal with energy topics more deeply. Some said, that it may be interesting to have a look on but the gamification approach is not persuasive for them.

Guideline 9: Provide optimizers with the information of how much money can be saved when following an energy-saving tip

Optimizer also like to know the concrete benefits of a certain behaviour change. The explanations shall be as close to reality as possible and technical language shall be avoided. The energy feedback is reduced to essential information. The saved costs of a behaviour change shall be visible to provide some kind of reward for the new habits.

Evidence The design principle "Simulation" as described in 2.5.2 is the basis for this guideline. The information of how much can be saved is the link between the cause and effect with regard to the user's behaviour. The test user of the Optimizer workshop session also mentioned that they like to know the amount of money that can be saved by following a special tip.

Guideline 10: Reward an Indifferent with game progress for applying a target behaviour

Indifferents want to be rewarded with game progress for applying a target behaviour. The main goal that we had with Indifferents was to sensitize them for the project. This was best possible with a gamification approach that is an additional motivation for other user segments but the main one for Indifferents.

Evidence The design principle "Reward" of the dialogue support 2.5.2 proposes to reward a target behaviour. The best reward for Indifferents to change behaviour is game progress, which was also found out in the paper prototyping sessions with them: "Maybe I will only do certain things to get more trophies".

Guideline 11: Use gamification elements to sensitize Indifferents to energy-topics

The Indifferents have low interest in energy topics in general, so the main requirement of the application for this type of user is in the first run to sensitize them for the topic, to raise awareness and to make electricity and CO2 saving appealing to them. To awaken their interest in energy and sustainability a gamification approach is recommended. When the game also has an addictive quality it may be even more beneficial for sensitization.

Evidence The Indifferent in the user prototype session said "...I am the perfect type for this kind of gamification...". The following user story can be derived from this:

- As a Hedonist I want to be rewarded with game progress for applying a target behaviour.

Guideline 12: Provide a hotline for trouble shooting for Optimizer and Hedonists

For Optimizer trouble shooting shall be easily accessible, in order to reduce the time they are spending with the application and not to loose them on the way.

Evidence In the paper prototyping session with the Optimizer it was wished for a hotline to call immediately when an error occurs. The Hedonist also stated, that calling is preferred to reading the FAQs.

Guideline 13: Provide FAQs for Professionals and Indifferents

Professionals and Indifferents take the time to read frequently asked questions when a problem occurs.

Evidence One Professional stated he would read the FAQs carefully before calling the hotline. The Indifferent said, calling was not preferred at all, reading the FAQs or writing an E-mail would be done before calling.

Guideline 14: Use praise to motivate all energy-users

Make use of praise via words, images, symbols or even the use of colours as a way to provide user feedback information based on previous behaviour.

Evidence The design principle "Praise", mentioned in Design principles for dialogue support, applies here. Also, the paper prototype sessions showed that praise is the most beneficial way to make users open to persuasion. The Hedonist mentioned "If the app praises me like this I would use it more often because it makes me feel good".

Guideline 15: Use concrete instructions and avoid detailed information for Optimizer

Optimizers prefer less time of interaction and rather like unclear instructions. Notifications and energy-saving tips should give concrete, clear and close to reality handling instructions on how to apply the target behaviour.

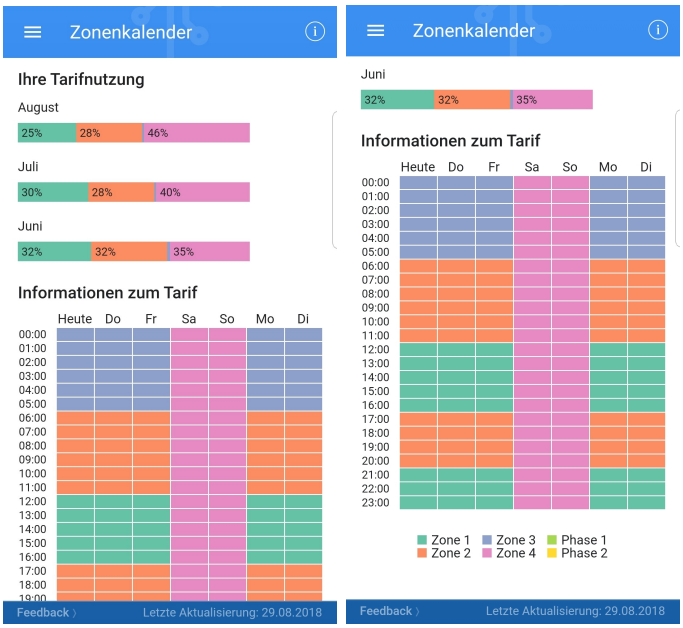
Evidence The paper prototyping session with the Optimizer clearly showed that this user segment favours clear handling instructions to reduce the time of applying the wished behaviour, "I just want to know what I should do". "Reduction", more deeply described in Design principles for primary tasks, is the design principle that applies here, as it reduces effort to perform the target behaviour.

5.5 Recommendations for improving the ASCR App

Part of the paper prototype session with the test user was to evaluate the ASCR App on which the prototype was based upon. The Smart Home Control app developed by ASCR and EMAKINA[1] is available on the Google Play Store[2]. The app provides an overview of energy consumption, along with all apartment control options.

[1] https://www.ascr.at/en/ascrs-smart-home-control-app/. Accessed: 02.09.2018
[2] https://play.google.com/store/apps/details?id=at.ascr.app. Accessed: 02.09.2018

Besides that a time-variable electricity tariff has also been implemented with which users can activate households, e.g. running the dishwasher, ironing, charging batteries, etc., at times when electricity is cheaper. The evaluation of the tariff calendar screen, shown in Figure 5.10a, revealed a lot of improvements possibilities.



(a) Tariff calendar screen on top

(b) Tariff calendar screen underneath (scrolled down)

Figure 5.10: The screens of the tariff calendar

The one thing all the users that first saw the tariff calendar needed was an introduction. The wording could be improved, as "Zone" was generally more associated with a geographical area than tariffs. No test user got the idea of different prices for time zones without clicking on the info button on the right corner on top. Most of the test users did not understand what the bars on top want to show. Overall, it was not clear if the percentage were the time or the money spent in the zones.

In general, the use of colours was recommended very often in the paper prototype sessions, but the used colours in the Smart Home Control app were misleading as they do not represent the costs. An improvement here would be to colour the cheapest zone or tariff in green and use a shading to the most expensive one in red. Phase 1 and Phase 2 were sometimes overseen or not understood. The test users criticised that the knowledge when Phase 1 or Phase 2 occurs is not given. Even when a notification that one of these two Phases will occur, it is not clear when exactly this will be. Getting the information of how much one kWh costs in a tariff was named as ponderous. Every time the info button was clicked and the corresponding information was searched. The wished improvement here was to group the small corners of one tariff together and write in the costs only once

for each block.

Figure 5.11 shows an improvement to the tariff zone calendar. It is the one who was evaluated in the paper prototype sessions. Some of the improvements were mentioned above, under which are the clearer use of colours. Colours should represent as clearly as possible the highness of the prices. The prices are written to often and can be grouped together. Making use of a pie chart was also named to be beneficial, as the use of the different tariffs can be shown clearer. Nevertheless, a Professional stated that comparison would be easier with bar charts, as the can be better listed one below the other.

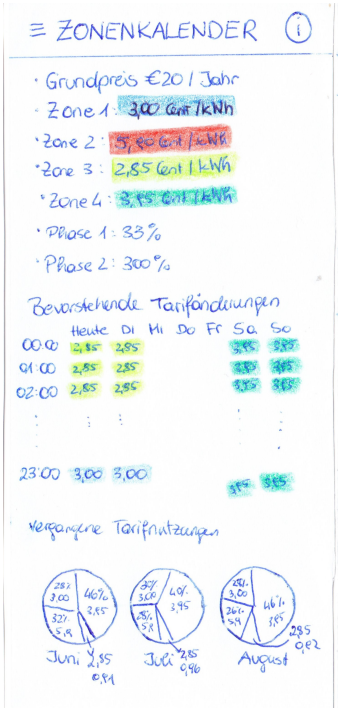


Figure 5.11: A recommendation for the tariff description

CHAPTER 6

Critical reflection

Developing applications that give eco-feedback and are persuasive for behaviour change is not a straightforward but complex task. Different aspects have to be considered, such as usability issues, mobile context restrictions, adaptive interfaces, persuasive technology, environmental psychology, human computer interaction and preferences and characteristics of users.

The usability issues were evaluated against ISO definition and the literature of Nielsen [Nie94a, Nie94b, Nie90], Zhang and Adipat [ZA05], Harisson et al. [HFD13] and Deka [Dek16]. In the paper prototyping sessions usability was also tested. Nevertheless, the focus was on the content of the application and the preferences of the users.

This thesis used the findings from the socio-scientific study of Smart Cities Demo Aspern. The design guidelines were derived from the findings of the user testing sessions. It is questionable whether the results of this thesis apply to other user types. Ware [War12] strongly emphasises that design guidelines are never a substitute for rigorous usability studies. To improve a design one should formally test it with potential users of the target audience. We tested the paper prototypes with at least one representative for each user type. However, for a rigorous usability study tests with more test users should be done.

6.1 Comparison with related work

Deka [Dek16] used a data-driven approach to adapt interfaces in mobile applications. In contrast, design mining approaches from [KST+13, AY15] mine static UI layouts and visual details. Numerically optimizing usability interfaces was proposed by Fogarty and Hudson [FH03]. In comparison to the related work this thesis shows interfaces that are optimized to user types which is a more user-centred than optimization centred approach.

The user interfaces of the paper prototypes shown in this thesis also make use of a lot of design guidelines from Oinas-Kukkonen and Harjuma [OKH09]. Similar to

EnergyLife proposed from Spagnolli et al. [SCG+11] we also make use of gamification approaches that provides different levels which adapt to the current state of knowledge. The tailoring approach is used in literature in the field of eco-feedback very often, amongst it is Gamberini et al. [GSC+12] who tailors feedback to users' consumption behaviour and gives according recommendations for behaviour change. Comparably, the Personal Environmental Impact Report [MRS+09] offered personalized estimates of the environmental footprint.

Helen et al. [HGH10] criticised the "one-size-fits-all" approach of the majority of energy feedback technologies. Multiple mobile application proposed in literature take into account the design guidelines from Oinas-Kukkonen and Harjuma [OKH09] but do not consider conducting a profound user study before implementing. In contrast to this, this thesis made use of the user types found from Smart Cities Demo Aspern.

CHAPTER 7

Summary

A questionnaire for the determination of a user type, paper prototypes for a mobile application that adapts to user types and design guidelines for such a mobile application are the contribution of this thesis. These contributions resulted from answering four research questions.

The first research question that asked for finding user segments and their characteristics was answered by conducting literature research and an evaluation of it in Chapter 2. The user types found by Smart Cities Demo Aspern were taken as target group users. Relevant usability definitions and guidelines are also stated in the second chapter.

The questionnaire for determining the type of a user is the answer to RQ 2. It was taken from the quantitative studies from Smart Cities Demo Aspern and adapted to serve the purpose of finding the correspondence to a user segment. The approach of finding answers to the research questions was explained in Chapter 4.

Design possibilities were found with different ways. Some already crystallized by conducting literature review, others were found in the paper prototype sessions. All of them were evaluated against the other ways, meaning previously found possibilities were proven to be right in the dialogue with the users and the ones found in the user sessions were searched afterwards in existing literature, to strengthen the evidences. These findings were elaborated in Chapter 5 and served as answers for RQ 3, that asked for design possibilities. The correlation of the preferred type of visualization and the characteristic of a user group was also investigated in the paper prototype sessions and it's evaluation answered RQ 4. Finally, in Chapter 6 the results were critically reflected and compared to related work.

7.1 Future work

As every thesis faces limitations, the presented results are not the exception. Thus, to keep within bounds of a Master thesis some restrictions have been undertaken.

As a first constraint, the implementation of the mobile application was not done in order to be able to dive more deeply into the evaluation phase. A well implemented application needs a thorough architectural design. This includes integrating data from different data sources for the computation of personal CO2 emission, such as power consumption, water consumption, nutrition lifestyle, transportation habits, size of the living space, place of living, family situation and further. After the implementation usability tests, in the best case with representatives from all user segments, should be done to assure that the guidelines have been realized correctly.

The paper prototyping sessions were held with at least one user for each user type. In order to do a more profound evaluation, future work could be to do sessions with more users. It would also be interesting to see if the user still prefer their screens as they said, after using the mobile application for a longer time. Future work can also be a long term study that evaluates the impact of the tailoring interfaces on behaviour change.

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Appendix A

Energieinteresse

Wie sehr treffen die folgenden Aussagen auf Sie zu? Stufen Sie ab zwischen 1=trifft sehr zu und 4=trifft gar nicht zu

* Erforderlich

1. **E-Mail-Adresse** *

2. **Ich nehme mir Zeit, um mich mit dem Thema Energie auseinanderzusetzen** *
   Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu	◯	◯	◯	◯	trifft gar nicht zu

3. **Ich weiß, welche Geräte in meinem Haushalt die meiste Energie verbrauchen** *
   Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu	◯	◯	◯	◯	trifft gar nicht zu

4. **Es ist mir sehr wichtig, bei den Energiekosten zu sparen** *
   Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu	◯	◯	◯	◯	trifft gar nicht zu

Selbsteinschätzung

5. **Programmieren Sie gelegentlich selbst in einer Programmiersprache?** *
   Markieren Sie nur ein Oval.
   - ◯ Ja
   - ◯ Nein

6. **Nutzen Sie in Ihrer Wohnung Steuerungs- und Einstellungsmöglichkeiten? (z.B. Heizungsanlage programmiert, TV-Sender eingestellt, Timer-Funktionen genutzt)** *
   Markieren Sie nur ein Oval.
   - ◯ Ja
   - ◯ Nein

7. **Wie würden Sie sich selbst am ehesten einstufen?** *
Markieren Sie nur ein Oval.

- Ich dusche oder bade gerne lange, das ist für mich Erholung und Genuss
- Ich dusche nicht länger als notwendig
- Alles, je nach Situation

Beleuchtung

Wie sehr treffen die folgenden Aussagen auf Sie zu? Stufen Sie ab zwischen 1=trifft sehr zu und 4=trifft gar nicht zu

8. **Ich drehe immer das Licht ab, wenn ich einen Raum verlasse** *
Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu					trifft gar nicht zu

9. **Ich vergesse häufig das Licht abzudrehen, wenn ich die Wohnung verlasse** *
Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu					trifft gar nicht zu

10. **Ich habe gerne möglichst viele Lampen eingeschaltet** *
Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu					trifft gar nicht zu

11. **Es ist mir eher egal wie viele Lampen in der Wohnung eingeschaltet sind** *
Markieren Sie nur ein Oval.

	1	2	3	4	
trifft sehr zu					trifft gar nicht zu