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. September 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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Wien, 1. September 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 feedback 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.
Thanks to everyone who spared time to test the mobile application which was developed within this thesis. Your feedback was very helpful and contributed a lot to its further development. Finally, thanks to my friends during my study time for the mutual support.

Kurzfassung

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Abstract

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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 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. 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. To create something useful out of this amount of data is a big task. [3]

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 application and the application should be beneficial for the user. 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 an App developer of course wants to develop an application that serves as much 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 gamification approach. On the other hand, for someone who is easy on these types of measurement a visualization with colors 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 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 users 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 shall be investigated.

We evaluate different types of users and their preferred way of gathering information. Ranging from the ones who only show interest in their overall behavior, meaning if they are better or worse than the average, over others, who want to know their power consumption more detailed but still can't grasp the measurement of one kilowatt hour, up to users, who are deep into the topic and are keen on extensive figures.

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

1.3 Aim of the work

The overall goal of this thesis is to identify different type of users, to evaluate existing applications and to identify the benefits or even drawbacks of providing a user interface in a mobile application tailored to a user type. We want to investigate if a user makes use of different visualizations or the presented way is excepted and therefore an adaptation of the user to the application takes place.
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) a catalog of criteria of design principles for tailoring visualizations containing information of consumption data.

The central research question is the following:

What are the effects on knowledge acquisition in mobile applications when providing visualizations tailored to users' knowledge?

The central research question can be answered after having found a solution to the sub-questions:

(a) What are the characteristics of a user group with the same state of knowledge? In order to answer this research question we first conduct a literature review in the area, followed by a user survey detecting the state of knowledge in the field of electricity units of measurements, i.e. the size of one kilowatt hour, one kilogram of CO_2. These findings will help in identifying groups and their characteristics.

(b) Which criteria do questions have to meet, that shall identify the type of a user? The findings of the sub-research question (a) will have an influence on the questionnaire needed for defining which group a user can be assigned to. This questionnaire will be the first contact point in the mobile application.

(c) What are the design possibilities when it comes to tailoring interfaces to a users' state of knowledge in the scope of electricity consumption data? This question can be answered by conducting a literature review and considering the characteristics of a user group.

(d) Do the characteristics of user groups correlate with the users' preferred type of visualization? The results elicited for research question a) are the foundation for defining the correlation between groups of users and their preferred type of visualization. Assuming the favorite type of visualization is the most used one, allows to identify the preferred type of visualization by asking the user for his or her preferred type of visualization.

1.4 Methodological Approach

In order to fulfill 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 a 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.

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 this 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 increase awareness?
   - How do these applications handle the users' level of education concerning energy units of measurements, such as kWh?

3. **Elicitation of requirements with Paper Prototyping**
   The second step is to do "Paper Prototyping" in order to elicit the requirements for the graphical user interfaces and overall for the CO2 awareness 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 a group of people containing at least one user for each user type will be put together. Next, hand-sketched drafts will be drawn, showing the application with menus, dialog boxes, notifications and buttons. Then, different tasks that can be done with the app shall be defined. These tasks are then conducted by the users. The feedback from the users show what they expect from the app which is of great value for the implementation later on [Sny03].

4. **Architectural Design of the CO2 awareness mobile application**
   The insights from the previous steps will influence the architecture and the designs of the CO2 awareness mobile application. With focus on design and usability an architectural design will be developed including a development plan. At this step,

the different data resources for the computation of the personal CO2 emission, such as power consumption, water consumption, nutrition lifestyle, transportation habits, size of the living space, place of living, family situation etc. must be considered.

The app shall be usable for all users but will be particularly useful for inhabitants of the Aspern Seestadt in Vienna, as we have a database for the dwellers of the student dorm, the schoolhouse and one residential building. This data comes from the Aspern Smart City Research[4] (ASCR) project where Siemens plays an essential role in collaboration research.

5. **Usability Tests**
   In order to avoid distorting of the research results the graphical user interface will be tested empirically with 4-5 usability tests, that means the usability is accessed by testing the interface with real users [Nie94b].

6. **User study**
   The design of the user study will follow the seminal guidelines for conducting case study research in software engineering as proposed by Runeson et al. [RHRR12]. The target group will consist of at least one user for each type of energy user. The study protocol will follow the check-lists for reading and reviewing case studies from Höst and Runeson [HR07].

7. **Evaluation**
   In this step the mobile application from ASCR will be empirically evaluated against a valuation model in a user study to identify its benefits and drawbacks. The evaluation model comprises of numerous Key Performance Indicators (KPIs). An extraction of these KPIs is listed in the following:

   a) More than 50 % of all the users using the app state that the possibility of switching between different ways to display the information is useful

   b) More than 50 % state, that they are more aware of what to do to avoid CO2 than before using the app

   c) More than 50 % of the users state that they understand and get a feeling of how much CO2 they are producing

1.5 Structure of the work

The remainder of this thesis is structured as follows: Chapter 2 provides an overview of related work where the main approaches of tailoring user interfaces are discussed. This chapter is concluded by a comparison of existing approaches.

Subsequently in Chapter 3 the methodology is presented, where a step-by-step guide for Paper Prototyping is explained. This is followed by an example use case, motivating the

[4] http://www.ascr.at/. Accessed 9.11.2017

implementation of this thesis. Then, the conceptional architecture is explained, which is described in more detail in the Data Models and Design Methods section.

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 usability engineering containing the main parts on which this thesis will focus on in the evaluation part. Especially the context of mobile applications will be looked at. That implies a research about paper prototyping, usability testing in the mobile context as well as user segmentation for the definition of user groups. Finally, we will have a look on existing approaches, such as serious games and a comparative analysis of alternatives.

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 [Din98]:

- **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.

Harisson 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 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 programmaticaly 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

[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

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 interactors, 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] discussed the balance of ease of use compared to the ease of learning. A huge emphasis is laid on the first, and according to Weiss, 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

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 range of services. The segmentation into groups also makes communication easier as the used methods of communicaiton 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-centered**: This factor covers aspects like home automation, energy relevant user behavior such as lighting and circulation behavior and hot water usage.
- **Technology-centered**: 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 an big enough group of cases/persons and groups having 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.

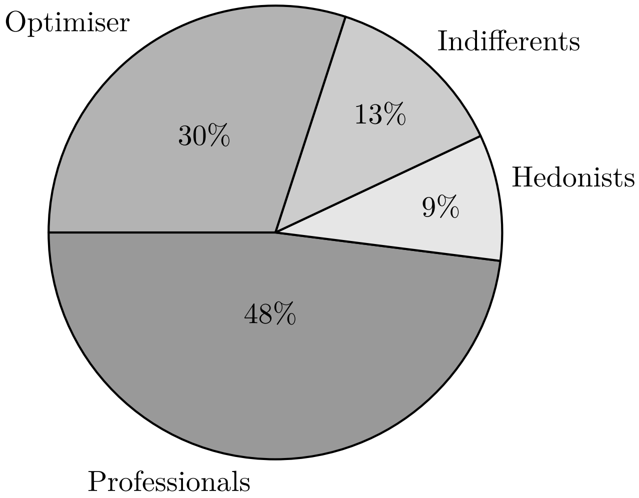

Figure 2.1: Result of the cluster analysis: Four user groups

"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. (Experience with home automation, a quarter has programming skills)
- Interested in sustainability
- Use of media or Internet is primarily for professional purposes

Typical segment behavior 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 behavior 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 very strongly on the following points:

- Clear and concrete instructions for behavior, for example in the form of energy-saving tips or concrete, close to reality explanations and concrete 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 behavior 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 mens, more single households

- Technical competent and partly with programming skills
- Intensive use of mobile Apps and Internet
- Hedonistic use of gaming and social media

Typical segment behavior 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 mobile application with feedback of their energy use. Nevertheless, the motivation to deal with energy topic 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 to experience 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 categorises prototypes according their use case. Prototypes are categorised 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 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 [Nie90].

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-centered design process and argue that at this early stage usability testing is most effective. They married low fidelity paper prototyping with medium fidelity wireframe 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 describe 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 of potential users who talk about their perception, belief, opinion and attitude toward the prototype.

A user-centered model for this type of Web site 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 arenas and is appropriate for applications in varied media.

2.5 Existing approaches of energy-saving programs

Understanding why people engage in environmentally responsible behavior 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 often may seem as an extension of research in persuasive technology, as explained in 2.5.1, it dates back much further to over 50 years of research in environmental psychology.

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 ("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 animate 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.

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. Oinas proposed design principles for the primary task support which are the following:

- **Reduction:** System should reduce the time and effort that a user needs to spend on performing the target behavior.
- **Tunneling:** System should guide users through an attitude change process by providing means for action that brings them closer to the target behavior.

- **Tailoring:** System should provide information tailored to potential needs, interests, personality, usage context or other relevant factors for the user group.
- **Personalization:** System should offer personalized content and services for its users to habe a greater capability for persuasion.
- **Self-monitoring:** System should provide means for users to track their own performance or status to support the user in achieving goals.
- **Simulation:** System should provide means for observing the link between the cause and effect with regard to users' behavior.
- **Rehearsal** System should provide means for rehearsing a target behavior that enables people to change their attitudes or behavior in the real world.

Although numerous theoretical models of proenvironmental behaviors have been developed and discussed, no definitive explanation has yet been found [KA02]. The previous mentioned studys of [FFL10], [KA02] focus primarily on the why of behaviour aspects and therefore the more theoretical approach of behavioural changes and should serve as base for the design of eco-feedback technology.

While models of proenvironmental behavior provide a philosophical approach on which to base designs, they lack specific strategies for changing behavior whereby Froehlich et al. [FFL10] bridge the gap between findings from environmental psychology and the design and evaluation of eco-feedback systems.

Providing households with better feedback on their energy consumption behaviour has been identified as an important tool for achieving sustainable behaviour change (Froehlich et al. 2010) and represents a popular target for interaction design (Schwartz et al. 2013)

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.

wasted energy in their homes and

Apps die beim Energie sparen helfen

2.6 Serious games

The Energy Piggy Bank - A Serious Game for Energy Conservation

Serious games are games that educate, train, and inform

Serious games are gaining importance recently. These games aim at behavior change and education.

Hedin et al. [BLWM17] describe a serious game that shall help people learn more about their energy consumption. They designed the game according to the taxonomy of Bartles Player Types that constitute of four Types having different motivation for playing games.

They also evaluated the behaviour

self-assessed future behaviour change

The outcome of the work is a strong correlation between self-assessed future behavior change and perceived value/usevulness of the application independent of the player type.

Bartle Player Types

Serious games have attracted much attention recently and are used to in an engaging way support for example education and behavior change. In this paper, we present a serious game designed for helping people learn about their own energy consumption and to support behavior change towards more sustainable energy habits. We have designed the game for all the four Bartle Player Types, a taxonomy used to identify different motivations for playing games. Engagement of the participants has been evaluated using the Intrinsic Motivation Inventory, and we have measured self-assessed future behavior change. We found a statistically significant positive correlation between self-assessed future behavior change and perceived value/usefulness of the application independent of player type. Our study indicates the player type “Achievers” might perform better using this type of application and find it more enjoyable, but that it can be useful for learning energy conserving behavior independent of player type

2.7 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 this 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 increase awareness?
- How do these applications handle the users’ level of education concerning energy units of measurements, such as kWh?

[JNAH08]

CHAPTER 3

Methodology

In this chapter the methodology including the used concepts such as survey for user segmentation, paper prototyping is described. Firstly, the approach is outlined, followed by the use-case description. Then, the conceptional architecture is explained, which is described in more detail in the Design Methods section.

3.1 User segmentation

3.1.1 Questionnaire

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

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 for 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 may result in the inventory of user interface.

2. **Revise inventory UI elements**. Until now maybe multiple run throughs 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 checklist. Developing a set of UI elements for cases that you did not anticipate may be also useful.

3. **Create UI elements**.

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**.

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

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 ore 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 an 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 Guidelines

CHAPTER 4

Implementation

4.1 Questionnaire for user segmentation

To find test users for each of the four user segments as explained in 2.2.1 we conducted a user survey. 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-centered, Technology-centered, Data Sensibility and Living in Seestadt. The following cluster analysis found out four segments. For the definition of the segments only two of the four factors were really 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 all the questions of the original questionnaire which answers were identified by the cluster analysis to be significant for the user segmentation. From the 48 questions of the original questionnaire only ten were relevant for allocating a user to a user segment.

FRAGEBOGEN AN DIESER STELLE EINFÜGEN ODER FRAGEBOGEN IN DEN APPENDIX???

For creating the survey and sending it to different people we used Google Forms. We sent the questionnaire to 57 people, trying to have a good distribution of different ages, educational levels, jobs and interests. 31 questionnaires were returned. Answering the 10 questions only took about one minute.

For evaluating the response we used Google Spreadsheet and Microsoft Excel. The answers of each person was evaluated against the characteristics 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 subjects for the paper prototyping, the usability tests and the user study later on. So at least one user for each user type was chosen. The next step was the Paper Prototype.

The participation in this experiment of different users, from a beginner to an expert, enables us to have different opinions, different reactions, as well as inconsistent feedbacks when using the apps (Nielsen 1994). [MIA16]

4.2 Paper Prototyping

In order to elicit the requirements for the graphical user interfaces and overall for the app we make use of Paper Prototyping.

There, hand-sketched drafts will be drawn, showing the app with menus, dialogue boxes, notifications and buttons. Then, different tasks that can be done with the app shall be defined. These tasks are then conducted by the users.

As described before in 2.3.2 we follow the Step-by-Step guide of Arnowitz et al. [AAB10] to create a Paper Prototype:

1. **Create scenario**.

   The main goal of the mobile application that shall be developed is to give feedback about how much electricity, water and heating a user consumed, how much carbon-dioxide was produced and how the values can be made better. The screens shall be adapted to the user type to make the information and tips more attractive to a user's interests.

   Professionals: The user study revealed that Professionals have high interest in energy issues. As they are deep into the topic and prefer more detailed information in individual offers they can have a look on the energy consumption on a very detailed level, such as a consumption rate on a granularity of minutes.

   - Task: Have a look on your consumption rate of the last week/month/year

   Professionals should have a possibility within the application to compare energy consumptions of different time intervals.

   - Task: Compare your consumption rate of the last week with the consumption rate of the same week one year earlier.

   Professionals also like to compare themselves to others. Comparing his or her average energy consumption to others should also be possible.

   - Task: Compare your consumption rate of the last week with the average consumption rate of your neighbours

Professionals also like rationally justified explanations and instructions for use. Notifications on a daily basis give tips on saving energy or CO2, give concrete instructions for use and provides deeper information in Energy topics.

- Task: Find tips on how to save more energy

Optimizer: Optimizer primarily aim at optimizing energy costs, so the app should give easy to find tips on how to save energy and therefore costs. Optimizers prefer less time of interaction. As Optimizer rather like unclear instructions, the notifications on a daily basis also should give concrete instructions on how to save energy or CO2.

- Task: Find out what to do to save costs for electricity

Professionals like to know the concrete benefits of a certain behavior 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 and the detailed graphs for energy consumption that the Professionals get are not visible at a first glance for an Optimizer. The saved costs after a behaviour change shall also be visible to provide some kind of reward for the new habits.

- Task: Find out how much you have saved in the last week

For Optimizer also 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.

- Task: Report a problem

Indifferents: 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 for energy and sustainability a gamification approach will be used. For opening the application once a day the user earns points. Points are also earned for clicking on notifications and reading the article. 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 Indifferents.

- Task: Earn points by interacting with the App

Hedonists: The youngest segment, the Hedonists, are keen on developing technical solutions. The interest in technology can be used to give instructions for programming technical devices and using home automation. The primary motive for the Hedonists is not to save energy but the interest in technology. This will be considered in the notifications and tips of the day. The hedonistic lifestyle with its strong convenience and comfort orientation is in the foreground.

For a hedonist the comfort gain is of great relevance. Programming and establishing home automation aspects is a great interface between the aim of saving energy and the affinity of technology.

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.
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CHAPTER 5

evaluation

CHAPTER 6

Critical reflection

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Glossary

editor A text editor is a type of program used for editing plain text files.. 5

Acronyms

CTAN Comprehensive TeX Archive Network. 11

FAQ Frequently Asked Questions. 11

PDF Portable Document Format. 6, 10, 11, 15

SVN Subversion. 10

WYSIWYG What You See Is What You Get. 9

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