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An Usability Design Approach of Tailored Visualizations for Mobile Applications

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An Usability Design Approach of Tailored Visualizations for Mobile Applications

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Erklärung zur Verfassung der Arbeit

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Wien, 1. Mai 2018

Romana Jakob

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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 eduation or changing a user's behaviour an adaption 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 which shows the power consumption in an understandable way. 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 show only 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.

1.3 Aim of the work

The overall goal of this thesis is to identify the benefits or even drawbacks of providing a user interface in a mobile application with various possibilities of presenting information

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

to switch between. 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 prototype of a mobile application aiming at increasing CO2 awareness with the help of customized visualizations and (2) 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 CO2. 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 favourite type of visualization is the most used one, allows to identify the preferred type of visualization by analysing the log files.

(e) Does a user switch between various screens showing the same information represented in different ways? We answer this by looking at the log files and also by observing the interaction with the mobile application in the usability tests.

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 carbon dioxide awareness. 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 app 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. **Technical Implementation of the CO2 awareness mobile application**
According to the architecture description from step 4 the mobile application will be implemented using an agile software development process and a fully native approach targeting Android Devices.

6. **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].

7. **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].

8. **Evaluation**
In this step the developed mobile app will be empirically evaluated against a valuation model in a user study to identify the success of the research. 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

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

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 with the existing approaches.

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, 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 for the definition of user groups and carbon dioxide awareness in general. Finally, we will have a look on existing approaches, such as serious games and a comparative analysis of alternatives.

2.1 Usability engineering

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:

- **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:

- **User**: Person who interacts with the product.
- **Goal**: Intended outcome.
- **Context of use**: Users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used.

Nielsen [Nie94b] also identified five attributes of usability and factors having an impact on how the user interacts with a system. In addition to the above ones Nielsen [Nie94a] states:

- **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 Usability engineering in the context of mobile applications

The focus on usability and interaction between human and hand-held electronic devices has its origin within the emergence 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

Zhang et al. 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.

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.

Deka [Dek16] discusses how data-driven approaches are tools for mobile app design. A relevant field mentioned is 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.

Fogarty and Hudson [FH03] presented an experimental toolkit to support optimization for interface and display generation. This approach

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 interactors, a typical usage trace and a cost function. The cost function holds user preferences and the expected speed of operation.

2.2 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].

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2.3 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.

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 the apartment block D12, where the possibility to test solutions is given, as this block is 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 to participate in surveys and workshops and to make their data available for research purposes. 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 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 Segmentation

Professionals

Optimiser

Indifferents

Hedonists

2.4 Usability Tests

mobile context 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].

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2. More than 50 % state, that they are more aware of what to do to avoid CO2 than before using the app
3. More than 50 % of the users state that they understand and get a feeling of how much CO2 they are producing

Carbon dioxide awareness

[MGM+17]

2.7 Existing approaches

2.8 Comparative analysis of alternatives and comparison of existing approaches

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

2.9 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

2.10 Persuasive System

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. Although the outcome on the behaviour change is not relevant, the findings on the tailor aspects are highly interesting for the proposed thesis.

x

x

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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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