Creating Persuasive Technologies for Sustainability – Identifying Barriers Limiting Target Behavior

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ABSTRACT
At an early stage of designing persuasive technologies there is the challenge of selecting a target behavior and examining variables that prevent it. Within our research we are forming sustainability related persuasive technologies in the context of domestic energy consumption. In this paper we present different types of barriers preventing people from the desired energy efficient behavior. In an explorative field study 48 participants received the task to selfmonitor their energy consumption behavior over one week. A qualitative analysis of daily statements revealed eight underlying categories of behavioral barriers. The most common observed barriers relate to Lack of Attention followed by Comfort. On the basis of these results, we formulated four guidelines for sustainability related persuasive technologies.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g.,HCI): Miscellaneous.

General Terms
Measurement, Design, Experimentation, Human Factors.

Keywords
Sustainability, behavioral barriers, domestic energy consumption

1. INTRODUCTION
Domestic energy consumption is responsible for about 40% of the overall energy demands of our society [10]. Supporting pro-environmental behavior in this context therefore is one of the main goals these days. Widespread political and marketing efforts are made to promote behavior change towards more sustainable lifestyles. Besides information campaigns, recently also new technological approaches have been introduced to promote and support a more sustainable lifestyle. A typical example for such a system is Show-me [22], which provides real-time feedback about water consumption in the shower. Similar systems are available with regard to feedback on electric energy consumption e.g. [18]. Research showed that these systems have potential to support users in behaving pro-environmentally [15].

In order to strengthen the impact of those technologies, design should be (and has been) based on findings from different research areas, especially behavior research, environmental psychology and persuasion. Helpful guidelines – named persuasive strategies – have been formulated to support the design process [7], [11], [29], [34]. Examples are reduction of complexity or providing the opportunity for social comparison. Oinas-Kukkonen & Harjumaa [29] provide a comprehensive overview on persuasive strategies applied by different researchers.

However, designing persuasive technology is not a simple task at all. The process of behavior change is very complex and influenced by several manifest and latent variables [4]. For an early stage of designing persuasive technology, Fogg [11] formulates an eight-step process, which aims to guide designers. One important step in the suggested process is to identify variables preventing the targeted behavior with the goal to find ways to overcome or minimize these restricting factors.

We are currently working on designing persuasive technologies for reducing domestic energy consumption. To be able to tailor the persuasive strategies to the needs of the application context we aim to understand consumer practices and habits regarding energy consumption in the context home in more detail. The present study especially aims at identifying barriers preventing individuals to engage in an energy-efficient behavior. We want to understand the involved factors and dynamics defining these barriers in detail, and develop design ideas and strategies for persuasive technologies helping individuals in overcoming the barriers.

To answer these questions by analyzing the domestic context, we applied an exploratory field study. We asked 48 participants to observe their energy consumption over one week and identify situations in which they do not behave in an energy-efficient manner. We differentiated between four energy-areas participants were asked to focus on namely electricity, entertainment electronics, heating and water consumption. Every day participants were requested to fill in an online questionnaire regarding the reasons and circumstances for their behavior. Analyzing these statements we are able to identify types of barriers as well as their frequency.

Within the next section we introduce research in sustainability related persuasive system design. We describe existing approaches, the process of creating persuasive systems as well as guidelines for it. Furthermore we present research on behavioral barriers including theoretical models as well as empirical findings. Section three presents the applied method by describing the used methodology, the tested sample, the procedure and the materials used in the study. The resulting types of barriers are presented in section four, and section five presents the derived guidelines for

creating persuasive technology for sustainability. Finally, we discuss our findings in relation to the state of the art and limitations of our study.

2. RELATED WORK

Within the following section we discuss different approaches used in persuasive technologies in the context of energy-related behavior. We then discuss design strategies for creating persuasive systems and analyze the specific role of variables preventing the target behavior. We next present models describing types of behavioral barriers, as well as existing empirical findings in the targeted context of domestic energy consumption.

2.1 Persuasive Technologies for Sustainability

Persuasive technologies aim to influence users' attitudes and behavior in a desired direction. They have already been successfully applied in various contexts such as health [16] or safety [30]. In the last few years persuasive technologies promoting sustainable behavior received increasing attention.

2.1.1 Classification of available systems

Numerous systems following different approaches have been developed. Table 1 offers an overview of such technologies. The systems use different approaches for the reduction of energy consumption. One approach mainly relies on informing users about their energy consumption (e.g. Google Power Meter, Microsoft Hohm). Such systems provide the possibility to compare actual energy consumption with the previous. The second approach is the usage of stimulative visualizations which catches the users' attention within specific situations (e.g. Power Aware Cord). The third approach, especially addressing the younger population, employs computer-based games (e.g. PowerHouse, Power Agent) to teach and encourage energy efficient behavior. Finally, in the fourth approach, emotional attachment to certain avatars is created. Well-being of these avatars is linked with the target behavior, hence creating pressure towards the desired user behavior (e.g. Ecoisland, Virtual Polar Bear).

Hence all mentioned approached have the opportunity to influence behavior. According to Fogg, the first step of designing persuasive technologies should consist of defining a specific target behavior [13]. However, most of the observed systems lack adequate definitions of their targeted behavior. Their aim can only be described as reduction of energy-consumption in general. Only Show-me as well as the Waterbot system specify specific target behaviors, in both cases is the water consumption in the shower.

Persuasive System	**Description of the System**	**Reference**
Google Power Meter	PowerMeter by Google, Hohm by Microsoft and Green Pocket are all software solutions for visualizing domestic energy consumption. Those systems present the actual and previous energy consumption by illustrations. However there is the need for cognitive effort, so it is not accessible for all user groups.	www.google.com/powermeter
Microsoft Hohm		www.microsoft-hohm.com
Green Pocket		www.greenpocket.de
Ubigreen	Feedback about transportation behavior is provided by Ubigreen and PEIR. These systems aim at supporting green transportation habits by visualizing the ecological impact.	Froehlich et al., 2009
PEIR		Mun et al., 2009
Energy Orb	Energy orb, Power Aware Cord, Show-me and Wattson are four examples for ambient devices providing energy-relevant information in real-time. Visualizations are used to attract users' attention. Wattson and Waterbot additionally provide the opportunity to compare consumption with others.	www.ambientdevices.com/cat/orb
Power Aware Cord		Gustafsson & Gyllenswärd, 2005
Show-me		Kappel & Grechenig, 2009
Wattson		www.diykyoto.com/uk
Waterbot		Arroyo et al., 2005
PowerHouse	PowerHouse and PowerAgent are two games aiming at motivating domestic energy reduction. The game character should appeal to teenagers and motivate their energy saving behavior.	Bang et al., 2006
Power Agent		Gustafsson & Bang, 2008
Virtual Polar Bear	EcoIsland and Virtual Polar Bear provide feedback about the overall ecological impact using a virtual avatar (the family or a bear). Depending on the environmental behavior the ice floe's size changes, and the water around the isle begins to rise.	Dillahunt et al., 2008
EcoIsland		Takayama & Lehdonvirta, 2009

Table 1: Overview of sustainable-related persuasive technologies

2.1.1 Creating Persuasive Technologies for sustainability

In order to ensure the effectiveness of newly created persuasive technologies, a proper design process should be applied. In the following we discuss the eight-step design process proposed by Fogg [13]. We focus on the first four steps of this framework, as they are in the scope of the study. Additionally, we describe existing guidelines for creation of persuasive technologies and discuss their application on the already mentioned existing systems.

Designing persuasive technologies by eight steps

Fogg suggested eight-step process [13] can be seen as general path of the early stages of designing persuasive technologies. It consists of three main parts: Part one includes step one to four describing preparation activities and definitions. Within part two, including steps five to seven, the major development and inclusion of leanings of other successful systems takes place. Part three, involving step eight, consists of iterating the design and enhancing the success. Within the present paper we focus on part one (steps one to four) of this process (see Figure 1).

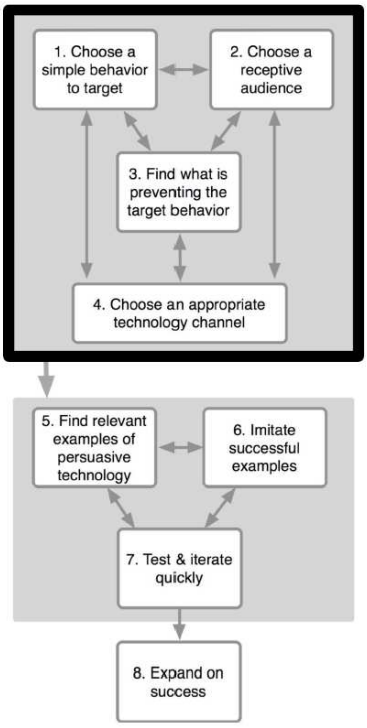

Figure 1: First four steps of the eight-step design process for creating persuasive technology by Fogg [13]

As indicated by the arrows in the figure, all four steps influence each other. Therefore, the sequence is not strictly predefined. The first step suggests choosing a simple target behavior to be changed. For the purpose of the success of the system it is

important to choose the smallest and simplest behavior possible, and avoid being too ambitious. Within step two it is the task to select the right audience for the intervention. The audience should be familiar with technology and should ideally enjoy using technology and trying new things. Before choosing an appropriate technology channel, step three is the most relevant step for the present study. This step deals with variables preventing the audience from performing the target behavior. Determining such barriers for sustainable energy consumption constitutes the core aspect we are address in this research.

Based on his behavioral model [12], Fogg stated that those variables consist of either a lack of motivation, a lack of ability, a lack of a well-timed trigger to perform the behavior or a combination of all three. In our study we aim to discover the types of barriers preventing individuals from eco-friendly behavior. Based on our results we formulate guidelines for sustainability related persuasive technologies. The stated guidelines in the conclusion section of this paper shall supplement already the existing guidelines, supporting persuasive system design, which are described in the next section.

Guiding persuasive system design via persuasive strategies

Strategies to direct persuasive system design have been identified early and formulated by Fogg. [11]. Derived from his functional triad, which consists of the tool, medium and social actor, he suggests seven persuasive strategies: Reduction, Tailoring, Tunneling, Suggestion, Self-monitoring, Surveillance and Conditioning. Similar strategies - however not within the technology context - are formulated by [7]: Liking, Reciprocity, Social Proof, Consistency, Authority, and Scarcity. A comprehensive overview of such strategies and recommendations on how to integrate them in system design is provided by [29] and [34]. Persuasive strategies are more or less used in the systems listed in Table 1. All systems provide the possibility to selfmonitor the individual energy consumption either in real-time or summarized for a defined time-window. This popular usage of feedback leads to the term eco-feedback technology [15]. However, feedback positively influences knowledge and attitude, but does not automatically result in behavior change. This resulting gap between pro-environmental attitudes and pro-environmental behavior is called attitude-action gap [24]. Another popular strategy is social comparison via networks or social media (e.g. Wattson). Individuals have the possibility to share and compare their consumption. The idea is to create social norms and consequently generate social pressure for the target behavior. A third strategy that is successfully used by ambient devices that give real-time feedback is reduction (e.g. Energy Orb, Power Aware Cord or Shower-me). There are also strategies that are neglected, such as tailoring, tunneling and suggestion. Efforts for user groups such as older people or children are mainly ignored. Furthermore, especially the strategies tunneling and suggestion can help to overcome the attitude action gap.

In addition to these general strategies, guidelines have been formulated for the sustainability context by Kim et al., 2010 [23]. The authors strengthen the idea of providing the possibility for self-monitoring, as this maintains the targeting state. Secondly, they also suggest including the functionality to share and compare own values through networks or social media. Finally, they agree with the strategy of suggestion by assuming personalized feedback for initiation of action.

2.2 Barriers Preventing the Target Behavior

In order to discover types of barriers preventing the target behavior, we suggest to first of all understand behavior and especially the change process in more detail. Several existing theoretical models describing this process have been developed so far. Besides those theoretical approaches, we suggest looking at existing empirical findings that describe types of barriers for the environmental context.

2.2.1 Theoretical Models describing influencing variables

There are several theoretical models which describe the process of behavioral change. The aim of these is to predict and explain human behavior in a specific context by describing influencing variables. Defined variables can either support a behavioral change or prevent it. Some examples are the theory of planned behavior [1], theory of reasoned action [2], norm activation model [31] or several models for pro-environmental behavior [4], [21]. Collections of these models are provided by [15], [20], [24]. We will now introduce two selected models that are most relevant for our use case and describe them in detail. The theory of planned behavior [1] is probably the most citied model describing behavioral change. Secondly the model of Kollmus & Agyeman [24] describes behavioral change for environmental issues. In addition to describing variables influencing pro-environmental behavior, the authors formulated possible barriers for a behavioral change.

Theory of planned behavior

The theory of planned behavior by Ajzen [1] is an extension of the theory of reasoned action formulated Ajzen & Fishbein [2]. The theory describes four main factors that influence behavior: intention, perceived behavioral control, attitude toward the behavior and social norms. It formulates the intention to perform a given behavior as a main predictor of behavior. Intentions describe the motivational factor, how hard people are willing to try to perform the behavior. The stronger the intention the higher is the probability to perform a given behavior. This central factor has been widely adopted for several other models (e.g. [4], [24]) and is also important to hold in mind while creating persuasive technologies. Ajzen describes three conceptually independent determinants of intention: Perceived behavioral control, attitude toward the behavior and subjective norm (see Figure 2).

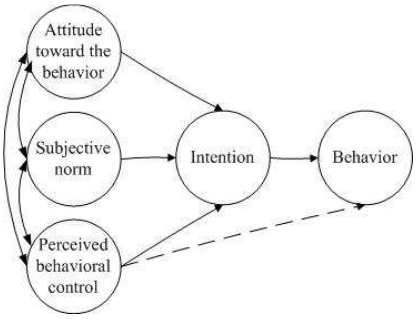

Figure 1: Theory of planned behavior (Ajzen, 1990)

Behavioral intention can always find expression in behavior if the person has the actual control over the behavior, which means that he/she has the required opportunities and resources in doing so. In other words, performing the behavior is mostly dependent on the motivation (intention) and the ability (behavioral control). This is also congruent with Foggs' Behavioral Model [12], which describes the possibility of a behavior by the variables ability, motivation and trigger.

The authors argue that more important than the actual behavioral control is the perception of behavioral control. This variable is an important part of the theory and the direct connection to behavior is the main extension of the theory of reasoned action. Perceived behavioral control is defined as people's perception of the ease or difficulty of performing the behavior of interest. Besides perceived behavioral control, there is the variable attitude toward the behavior. This variable represents the degree to which a person has a positive or negative attitude towards the behavior. Attitude is not directly linked to behavior but partly predicts the intention. Finally, the third variable, which influences intention, is a social one, defined social norms. It is described through the perceived social pressure to perform a target behavior. The present model focuses on behavior in general. The other two models we mention focus on pro-environmental behavior.

Meta model of pro-environmental behavior including behavioral barriers

Taking several theoretical models as foundation, Kollmuss & Agyeman [24] have theoretically extracted factors that influence positive or negative pro-environmental behavior. They developed a model of pro-environmental behavior by also taking behavioral barriers into account. They identify eleven behavioral barriers, which are named: Existing values prevent learning, Existing knowledge contradict environmental values, Lack of knowledge, Emotional blocking of environmental values/attitudes, Existing values prevent emotional involvement, Emotional blocking of new knowledge, Lack of external possibilities and incentives, Lack of internal incentives, Lack of environmental consciousness, old behavior patterns and negative or insufficient feedback about behavior. This model described pro-environmental behavior in general and does not make any statements about what barrier is more important than others.

Within this paper we focus on energy-efficient behavior in the domestic context. The following section describes three approaches to cover behavioral barriers within this context.

2.2.1.1 Empirical Evidence for Behavioral Barriers

As compared to theoretical approaches, only few efforts to create empirical evidence for existing barriers to energy saving behavior can be found.

Recently Hargreave et al. (2010) equipped 275 households in United Kingdom with smart energy monitors which give direct feedback about energy consumption. They monitored their energy consuming behavior over one year. Besides gathering quantitative data about energy consumption they interviewed 15 households, asking them questions about motivations, usage, behavioral change and barriers of behavioral change. They highlighted four categories describing types of barriers for a behavioral change.

Firstly, they report that some appliances, although they are greedy, are necessary to the user and cannot be discarded. Examples differ between households and are mentioned from fishtanks to kettles and fridges. Furthermore participants state that they have to use energy for several individual reasons like e.g. heating the household on a high level because of medical conditions. Within this type of barrier participants have the feeling that they do not have the control over all appliances.

The second aspect deals with situations in which participants see use of energy justifiable and reasonable. It is important for them that it is comfortable and warm in the house. They also mention that 'life is for living'. Furthermore they stated that they are not willing to change nature rhythms like energy consumption in the morning. Some participants also stated that they would need high incentives to change their time of certain practices.

Third the authors reported social aspects as a possible barrier for changing behavior. Participants stated that they have talked about possibilities for energy savings with the household members, which leads to conflicts. They discussed the question about who is more responsible for savings and cut its consumption.

Finally, participants feel unsupported in behaving energy-efficient by the social and polity context. Information about what appliances are energy-efficient is hardly to understand for laypersons.

Another approach to assess types of barriers was conducted by [33]. They tried to identify barriers to energy-saving solutions within the domestic context, by applying focus groups. The authors additionally aim to specify the strength and relevance of those barriers. Within two focus groups they discussed barriers with one group who was looking for new dwellings and a group of environmentally conscious participants. Barriers that were relevant are called cultural-normative, economic and information.

Finally, we highlight a research study, which uses energy-diaries to assess barriers. Cames & Brohmann conducted the study with the aim to identify possibilities for energy savings [6]. They use energy-diaries in which participants had to note all energy relevant behavior during the day. There were 20 households with about 50 persons participating in the study. They have been asked to describe all their energy consuming behavior over two weeks. Turning the light off and on, opening the fridge or taking a shower are all events they have to note. Through this diary method it was possible to investigate the energy-efficiency of their behavior. Results show that participants already perform an energy-efficient behavior by e.g. opening the window only for a short time or reducing temperature when leaving a room. There are two limitations of this methodology. Firstly, as participants decide on their own to participate, there may be a self-selection regarding individuals with an already positive attitude to environmental issues. Secondly, we suggest that social desirability plays a main role, which negatively influence the validity of the study.

Our present study takes into account several aspects of the mentioned studies. Like in the studies before we aim to examine types of behavioral barriers by applying qualitative analyses methods. In contrast to interviews and focus groups we applied a methodology similar to the energy-diary published by [6]. In contrast to their energy diary, we asked participants not to notice all energy behavior, but to identify situations in which they waste energy. Every day over a whole week, we reminded them to fill out an online questionnaire. Like [33] we are aware that environmental attitudes can influence results of the study. Consequently we also describe environmental attitudes of the presented study and their perceived energy consuming behavior. In contrast to [19], we assessed limitations before conducting a comparative study, as we aim to integrate results directly within system design.

2.3 Identification of Barriers Preventing Energy Efficient Behavior

Resuming the current state of research, the study at hand addresses the following research question: What are types of barriers that prevent people from acting energy-efficient in the domestic context and how likely are these types to prevent the target behavior in daily life. The necessity to identify such barriers is justified in the discussed design process for persuasive technologies. Beside a broad range of theoretical models for behavioral barriers we address the lack empirical evidence for such barriers in the context of energy consumption.

Based on our empirical findings we complement the presented guidelines for persuasive systems design with guidelines for creating persuasive systems targeting energy efficient behavior.

3. METHOD

To answer these research questions we conducted an explorative field study. Participants were asked to observe their energy related behavior over one week and fill out an online survey every day. Their task was to identify situations in which they did not act energy-efficiently and additionally think about reasons for that. Within the following sections we explain the study design, the tested sample and its characteristics, the procedure of the study as well as used materials in detail.

3.1 Study Design

The present study took place in Vienna during the month of November 2010. All participants have been asked to self-observe their energy-related behavior over each day and retrospectively think about situations in which they did not act energy-efficient. As energy consumption is a widely used term and self-observation requires cognitive effort, we decided to reduce this by defining four special areas of energy use, participants should mainly put their attention on. We decided to differentiate between the four following groups (see also Table 2): A first group was requested to focus on electricity consumed by entertainment electronics such as the TV, laptops or PCs, smartphones or audio equipment. A second group had the task to focus on electricity related to the daily needs, used by the refrigerator or other appliances in the kitchen, the hairdryer as well as lights. A third group focused on heating and the fourth group focused on water consumption.

Although each group had its specified focus, participants were instructed to describe all situations that came to their mind, including situations outside their predefined focus.

3.2 Participants

The present study was conducted as a field study that takes place at the participant's homes. The precondition to join the study was daily access to internet as participants had to fill out an online questionnaire every day. We recruited 48 participants, where we tried to balance them between areas according to three variables: housing situation, gender (male, female) and age (younger than 28 and older than 28). We differentiated between three housing situations: single person, living with a child and shared apartment. We used this distinction as we thought that different barriers might be relevant for different housing situations. The final sample consisted of 38 persons i.e. those participants who filled out the questionnaire all seven days. Table 2 summarizes the distribution of the participants over the variables focus and housing situation (data for one participant missing).

Table 2. Distribution of participants over variables

		Housing Situation			
		Single person	Living with a child	Shared apartment	
Area	Electricity	3	5	3	11
	Entertainment electronics	3	1	5	9
	Water	4	3	3	10
	Heating	3	4	0	7
		13	13	11	37

Out of those participants, 20 were male and 18 were female. Their age ranged from 19 to 70 (Mean: 37.45, SD: 12.92). Participants had different types of employment situations from unemployment to students and part-time to full-time employees. At the first part of the study, we also asked participants to self-assess their level of energy saving behavior on a seven-point Likert scale (1=high energy saving behavior to 7=low energy saving behavior). People assessed themselves as average with 3.42 (SD: 1.43, Min: 1, Max: 7). Thus, the tested sample was also balanced within this variable.

3.3 Procedure of the study

The present study consisted of three parts. The first part was conducted as group testing, whereas there was one group for each energy-area. Within this part we first of all introduced the topic of sustainability related persuasive technology to increase commitment during the study. Afterwards we introduced the study and the tasks for the next seven days. As the study situation was conducted at home without a present researcher, who can answer questions, we went through the online questionnaire to avoid misunderstandings. Finally, we asked participants to sign a declaration of consent, and additionally to fill out two questionnaires consisting of a sociodemographical questionnaire, and the environmental attitude inventory (EAI) [26]. Those questionnaires are described in detail in the next section. Altogether we conducted one group session for each energy-area. These sessions lasted about 30 minutes to one hour depending on how fast participants completed the questionnaires. During the second part participants had to self-observe their energy consuming behavior at home and to fill out the online questionnaire every day. They received an email reminder every day at five o'clock. Finally, in the last part people had to fill out the EAI again. As a token of appreciation, all participants that finished the study received 40 Euro.

3.4 Materials

Materials that were used during the study consisted of an instruction, a declaration of consent, as well as three questionnaires collecting demographic data, environmental attitudes and descriptions about daily situations. To guarantee anonymity, each participant had a code assigned which had to be typed in before filling out each questionnaire. We will now describe the three questionnaires in more detail.

Questionnaire gathering demographical data. Participants had to answer questions about their age, gender, housing situation and, occupation as well as their perceived energy saving behavior.

Environmental Attitude Inventory (EAI). [26]. We used the EAI to collect data about environmental attitudes. Self-reporting techniques, such as scales and inventories, are currently the most widely used methods for measuring environmental attitudes. The EAI assesses perceptions regarding the natural environment by twelve specific facets. The long version of the EAI consists of 120 items, 10 items for each scale. Besides this long version there is a short one with 24 items and a middle one with 72 items. For our study we used the 72 items version, to minimize effort Reliabilities for each scale are between .53 for the scale anthropocentric concern and .92 for environmental activism. At present there are no norms available so we cannot compare individual values with norms.

Questionnaire for describing target situations. Within the present study participants had to self-observe their energy-related behavior and to fill out a questionnaire each 4day describing defined situations. This questionnaire was developed as an online survey via Lime Survey[1]. First, participants had to type in their individual code so that we could match the data while retaining anonymity. Afterwards they have to describe the situation occurred during their day at home, in which they do not act energy-efficient. For the respective situation they had to formulate reasons for their behavior within the next item. Additionally we asked them about ideas of technologies that can support them within the respective situation. Participants had the possibility to fill out the questionnaire for as many situations as they wanted by opening the link again.

3.5 Data Analysis

We applied a summarizing qualitative content analysis [25] based on situational descriptions and related reasons. Formulated reasons alone are not completely understandable without reading the description about the assigned situation. Our procedure started with paraphrasing the statements, which means that we restated the text by using other words to make it understandable for everyone. In a next step we summarized the reasons on a more abstract level until a small set of categories that describes the essence of original statements has been extracted. There was the need of three rounds of categorization to achieve a number of eight categories.

4. RESULTS OF THE STUDY

Within this section we present the results of our study. We first of all describe environmental attitudes of the tested sample. Then, we describe the result of the summarizing qualitative content analysis resulting in eight types of barriers. We describe their overall incidence and also incidences separate for the household situation and the energy areas. Finally, we present ideas of technologies participants like to have to reduce energy consumption.

4.1 Environmental Attitudes

Assessing the environmental attitudes of participants is twofold relevant for the study. First because there is the assumption that environmentally aware people would rather participate and second because different patterns of environmental awareness can influence the results of the study. Consequently we asked participants to fill out a questionnaire capturing environmental attitudes (EAI–Environmental Attitude Inventory) [26]. Figure 3 describes the average values (including standard deviations) in the scales of the environmental attitude inventory of all participants. On the axis of abscissas the twelve subscales of the EAI, representing environmental attitudes are listed.

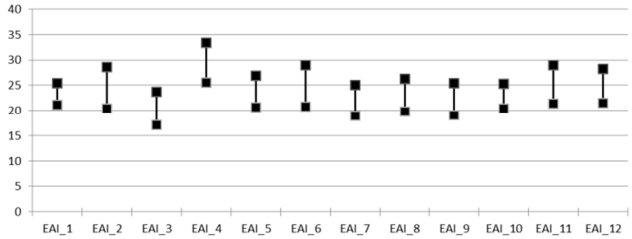

Figure 2: Average values of environmental attitudes

As can be seen from the figure the highest values are reported in the scale EAI_4 (*Conservation motivated by anthropocentric*

[1] http://www.limesurvey.org

concern). High values of this scale describe a support for conservation policies motivated by anthropocentric concern. Low values describe a support for such policies motivated by concern for nature. The scale on which participants have on average the lowest values is EAI_3 (*Environmental movement activism*). High values of this scale describe a person's readiness to get involved in action for environmental protection. Low values describe a disinterest in such support. Currently there are no norms available, so we cannot compare the values with the population.

We asked participants fill out the EAI two times: at the beginning and the end of the study. As we hypothesized that self-observation itself might cause a change of environmental attitudes, we compared the values of environmental attitudes before and after the self-observation session. However, this comparison does not result in statistical significance.

4.2 Types of Barriers Preventing Target Behavior

Within the present study we were able to collect 388 valid statements about situations in which individuals are prevented to act energy efficient. Having a first look at the data we realized that there are statements which describe energy consumption that is necessary to use for the participants. This was the case for 29 statements. Let us clarify this by three examples:

> *I used an electrical toothbrush because it is better for my teeth.* [2]

> *I turned on the PC, because I have to upload photos on a server for four hours. As this is part of my business I have to do this.*

> *Today I took a shower two times. In my mind it is necessary to take a shower every day. It is also good to take a shower a second time before going out.*

In all three situations participants had the possibility to save additional energy, although it causes limitations of their health, work and hygiene. The aim of our study was to collect situations in which people do not act energy-efficiently, although they subjectively had the possibility to do so. We suggest that for these situations there is the highest potential for persuasive technologies. Consequently we decided to exclude the 29 statements describing statements that have been reasoned as necessary to use by participants.

Remaining data consists of 359 statements. Most statements have been formulated for the focus electronics (132) and entertainment electronics (99). For the focus of water consumption we collected 68 statements and for the focus of heating we collected 60 ones. We summarized these statements by a summative content analysis and extracted eight categories which describe the statements representative. Those categories are interpreted as types of barriers for energy-efficient behavior. They are named: Lack of Attention, Comfort, Quality of Appliances, Habits, Lack of Knowledge, Social Aspects, Resources and Remaining aspects. Figure 4 visualizes absolute frequencies of the different types of barriers.

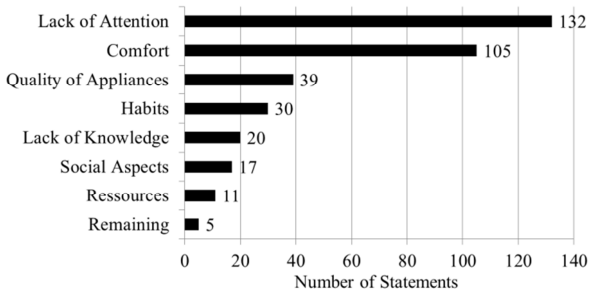

Figure 3: Number of Statements per Category

Most statements can be describes through the variable *Lack of Attention* (132 out of 359 statements). The second most common factor that prevents energy-efficient behavior is called *Comfort* (105 statements). In the following we will describe all types of barriers by examples of the original statements.

Lack of Attention. The main part of the statements (132) is assigned to the variable *Lack of Attention*. In these situations attention is not or no longer focused on energy consumption. This includes situations in which people forget something, do not think about energy, or move their attention for several reasons. Forgetting something was a repeatedly mentioned example.

> *I forgot to turn off the light on the toilet.*

> *Normally I turn off all appliances before going out, but today I forgot to do this.*

Another example describes situations in which people are careless or do not think about the energy aspect.

> *While I was cooking I did not turn off the stove at the proper time to use the remaining heating. The reason was that I did not think about that in this situation.*

> *In the morning I warmed up some water in the electric water jug for my cup of tea. I filled the water jug with about one liter of water, although I needed just a fractional part of it. In this situation I did not realize that this is waste of energy.*

Finally participants describe situations in which they are first focusing on energy consumption, but suddenly this moves outside of their span of attention.

> *While I was looking for something in the fridge the telephone rang. I went to the phone and didn't close the door of the fridge for the duration of the phone call.*

> *I was watching TV in the evening, and suddenly fell asleep. The TV was turned on the whole night.*

Comfort. The second most common type of a barrier describes *Comfort*. The reason why people do not act energy-efficient is because of comfort aspects. In several situations participants state that they are lazy and therefore do not want to invest effort:

> *While taking a bath I did not turn off the TV, because I was too lazy to do so.*

> *I haven't turned off my laptop because I was too lazy to do this.*

[2] Statements are originally in German. The authors have translated them for this paper. Several formulations can differ from the original statement, but the content remains the same.

In other situations people use energy for comfort reasons. In these situations people are aware that they waste energy, but feel comfortable that way:

I always turn on all the lights in my flat even if I am not in a room. I do this because I like the feeling of a very bright flat.

Today I took longer shower than usual. The reason was that the warm water was so pleasant and so I want to enjoy this feeling longer.

Quality of Appliances. Besides psychological aspects concerning the individual itself, the *Quality of Appliances* plays a role. Appliances can be either (partially) broken or be not energy-efficient. Consequently in such situations people are inhibited to save energy. Their possibilities are to bury new ones or repair the remaining. Both are connected with monetary efforts. Examples are written below.

The washing machine keeps getting stuck and so I have to restart it again and again. It is broken and I think it is time to buy a new one.

I have opened the window to let some fresh air in the room. In the meantime the radiator was turned on very high. There is no possibility to regulate the heating on this kind of radiator.

Habits. Another type of a behavioral barrier is described by routines of behavior. In these cases individuals perform the specific behavior because they have always done it like that. Behavior occurs kind of automatically and unnoticed.

My appliances in the kitchen are constantly connected to electricity. I have always done it that way.

After picking up my children from school we went home and everybody went in his room. We all turned on the TVs in each room and even watched the same program. So there are four TVs running with the same program. By joining this study I have to think about the reason why we are doing this and I can only say that this is a stupid habit that we have never questioned.

Lack of Knowledge. Within 20 situations people stated that a *Lack of Knowledge* is the main reason for their energy waste. Individuals do not really know how to save energy or behave energy-efficiently. Examples are presented below:

My refrigerator runs on the coldest setting. I do not know what setting is suitable for my fridge to hold my food fresh enough.

Before taking a bath I usually heat the bathroom by turning on the radiator on the highest level for about one to two hours. I think there are more energy-efficient possibilities to achieve a warm bathroom, but I do not know them.

Social Aspects. Social Aspects as a possible type of barrier, for energy-efficient behavior, that comes up when individuals live together with other ones or animals. There are three main reasons in this context. First there are situations in which participants feel responsible for several humans or pets and therefore energy-savings are of lower priority:

My five-year old child is actually afraid of the dark so I turned on a light for him between 7 pm and 6 am.

My cat has rheumatic problems, which are better if the flat is very warm. So I heat more than usual.

Second there is the social phenomenon of a diffusion of responsibility described. In these situations the responsibility for being energy-efficient is not explicitly assigned to one or all individuals within the household.

The radio in the kitchen has been turned on although nobody was in the kitchen. I did not turned it on so I did not feel responsible for turning it off.

Finally there are statements describing the reason to avoid conflict situations with flat mates.

All my children take a bath instead of taking a shower. Additionally, all want to use fresh water which results in a huge waste of water. I have not forbid my children to do this, because I want to avoid conflicts.

Resources. Another category describes a lack of resources consisting of time and money. Individuals state that they do not have the time to think about energy-savings, and also do not have the money to buy energy-efficient appliances.

Today I bought incandescent bulbs for the whole flat. I bought the cheapest ones, although they are the ones that need the most energy.

Remaining aspects. There are also some remaining aspects we were not able to assign to one of these types of barriers. One participant went to the cinema and did not turn the light off in his/her flat, because of security issues. Possibly burglars should not know that he/she is not at home. Another person stated that they are at present preparing a marriage and that no one thinks about energy-savings now. As this situation is not representative for the overall behavior of the individual we put this in the remaining aspect category.

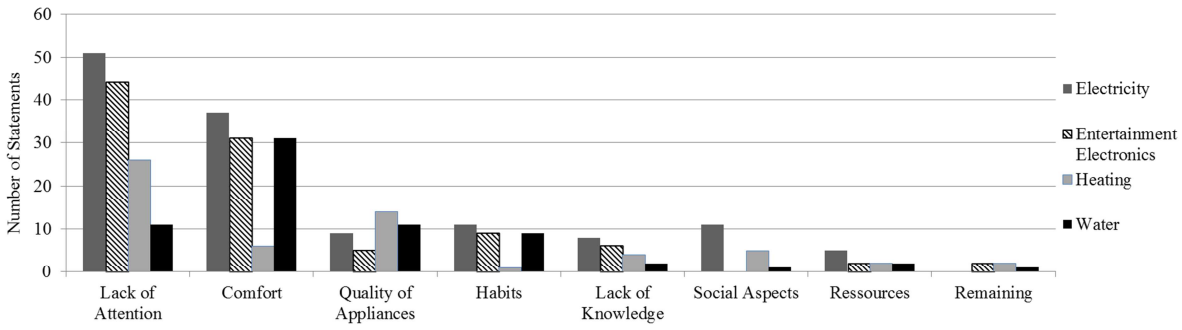

Figure 4: Number of Statements per Category separated for the energy areas

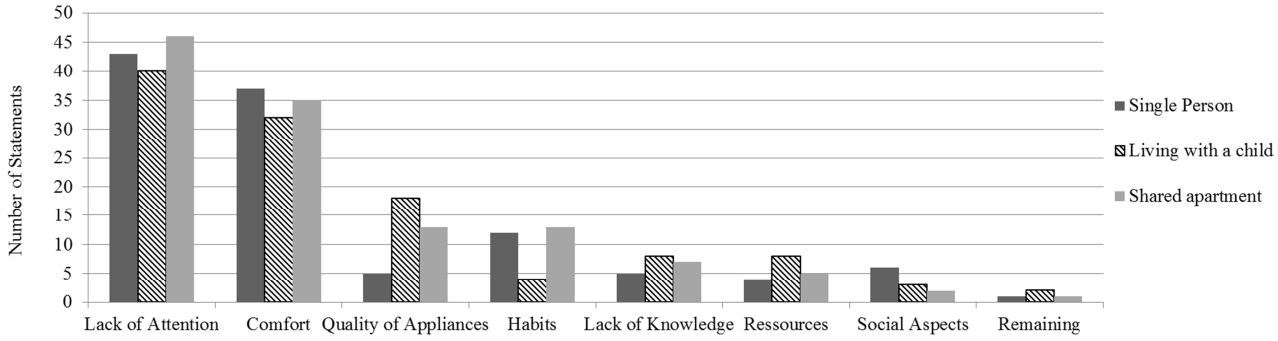

Figure 5: Absolute frequencies for the categories separated for the housing situations

In summary, we extracted eight types of barriers representing variables that prevent people from behaving energy-efficiently within the domestic context. *Lack of Attention* and *Comfort* are the two most common barriers. As we have varied different energy-areas as well as household situations we split the number of statements for those variables represented the two following figures.

Figure 5 presents the frequencies of types of barriers separated for different energy areas. As can be seen from the figure *Lack of Attention* was the variable with the highest frequency for all energy areas except water consumption. People who had the task to focus on water consumption stated *Comfort* as the most frequent type of barrier. As the study has been conducted in winter and water is tightly associated with warm water this makes sense. *Comfort* was also the second most common reason for electricity and entertainment electronics. For the case of heating the second most common reason was *Quality of Appliances*. Together with *Lack of Attention, Quality of Appliances* was the second most common reason preventing participants from energy efficient water consumption.

Besides splitting up the number of statements separated for the energy areas, we also split the categories describing reasons by the housing situation (see Figure 6). Participants who lived alone, with children or in a shared apartment state *Lack of Attention* as the most common reason for not behaving energy-efficiently. As second most common aspect all mentioned *Comfort* as a reason. For people living with a child *Quality of Appliances* is more important than for people living in a shared apartment as well as for those who live alone. In the 'Single person' group the reason *Quality of Appliances* was stated only five times (out of 114 reasons overall). In contrast to the *Quality of Appliances* category the 'Living with a child' group states only four times that *Habits* as a behavioral barrier.

4.3 Ideas of Technologies Supporting Users

Based on the idea of a user-centered design approach we asked participants for each situation if they have an idea of a technology that can support them. We collected 188 valid statements. Out of them people mentioned 68 times that they like to have appliances that start up or turn themselves off automatically. An amount of 27 statements support the idea of a reminder. Participants stat that they like to have a visual or auditory signal that reminds them about energy consumption. There are also 66 statements that wished to have more energy-efficient appliances.

5. GUIDELINES FOR SUSTAINABLE PERSUASIVE TECHNOLOGIES

The results of our study provide insights into domestic energy consuming behavior. We have derived types of barriers that impede people from acting energy-efficiently and additionally determined their frequency of occurrence. Based on the results we articulate four design guidelines for sustainable persuasive technologies.

The idea of persuasion is to change behavior by influencing the user to actively perform a desired target behavior. The results of our study indicate that there are two major barriers which should be addressed with persuasive technologies.

Navigate the user's attention. We identified *Lack of Attention* as the most common type of barrier for not behaving energy-efficient in the domestic context. To address this issue, technology should navigate the users' attention. This is possible by using acoustical or visual signals. Here, it is important that those signals are not annoying users, otherwise they will quickly turn them off.

Allow people to satisfy their needs for comfort. The second most common type of barrier is named *Comfort*. Energy itself is strongly related with comfort, e.g. warm water, light, or entertainment appliances. For designing technology we think that it is very important to hold this comfort aspect in mind. Technologies should allow people to e.g. take a long warm shower if they want to. What technology can do is remind users about how often they have done this e.g. the month before. And thus regulate energy consumption over a longer period of time. This will help increasing technology acceptance and usage.

Consider individual differences. We recognized for the same situation often different types of barriers exist. People are individual different within their perceptions, motivations, attitudes and priorities. For example people living with a child have other priorities and attitudes as single persons. For most effective usage, technology should be adaptive or be adaptable for specific needs and situations.

Target particular types of barriers. There are several types of barriers that can prevent people to perform the target behavior. Different barriers need different approaches to overcome them. *Lack of Attention* can be addressed with reminding the user. The information content of such technologies can be very simple, and their design very attention-catching. In contrast to that, technologies aiming to overcome the barrier *Lack of Knowledge* should provide detailed energy-related information and consulting. We assume that one technology can provide several

features, which can be used in different situations. The combination of several different approaches in one appliance may therefore increase the resulting effect. This is also in line with Fogg's assumption that persuasive technology requires not only triggering the behavior, but also boosting motivation or facilitating the behavior [12].

In addition to the proposed guidelines for persuasive technologies, where the user has the active role to manage energy consumption, the results of this study indicate, that automation is a potential approach to overcome some barriers. Especially in situations where the actual necessary behavior (e.g. standing up, going to the kitchen and turn off the light) and not the consequences (the kitchen is dark) constitutes the barrier, or the necessary behavior is difficult to perform (choosing the optimal settings for the refrigerator), automation may be an opportunity for efficient energy usage.

6. DISCUSSION

Our study investigated types of barriers preventing energy efficient behavior. Over all Lack of Attention and Comfort are the main reasons for wasting energy. Coming back to the eight-step process formulated by Fogg [13] we deal with step three named "find what is preventing the target behavior". According to Fogg those variables consist of either a lack of motivation, a lack of ability, a lack of well-timed trigger to perform the behavior or a combination of all of these factors. The resulted barrier Lack of Attention can be interpreted as a lack of a well-timed trigger, whereas the Comfort relates to a lack of motivation. Our next steps, within the process of creating persuasive technologies, will be to choose a simple target behavior, the receptive audience as well as an appropriate technology channel. Derived from the results of our study a simple target behavior might be turning appliances off if they are not used anymore (e.g. light when leaving a room) or systems that individually inform users about energy-efficient appliances.

Comparing to existing empirical studies researching barriers, our applied methodology was suitable to detect types of barriers preventing people to act energy-efficient within the domestic context. In contrast to interviews [19], focus groups [33] and energy-diaries [6], we applied a methodology which results in a large amount of situational descriptions. We were able to detect three of four barriers mentioned by [19], which applied face to face interviews with 15 households that have interacted with smart energy monitors one year. Like those authors we were able to state that there are some situations in which people use energy that is necessary for them and has to be used. Additionally we also collected statements describing barriers based on comfort and social aspects.

According to theoretical models, describing the process of behavioral change, the perception of a behavioral control is a core variable influencing behavior. A perception of behavioral control is highly important that behavioral intentions find expression in behavior itself. A lack of attention excludes the control over behavior and behavior is therefore hardly possible. Consequently we suggest focusing on this lack of attention by creating persuasive technology.

There are also some limitations of the study referring to the used methodology, we discuss here. As mentioned before, we focused on situations in which people are aware that they waste energy. Therefore we have excluded statements about energy that is necessary to use for participants. This results in three main limitations. First, people are not always aware about how to behave energy-efficient and what results in a waste of energy. As technology market changes quickly, there also many myths about what is energy-efficient. For example people are not aware about if their charging cables do need energy when they are in the socket but not connected to an e.g. mobile phone. Second, there is the question about what is necessary and unnecessary energy consumption? This brings us back to a very first discussion of our work about what do we expect from people behaving energy efficiently? What's the beginning of comfort and the end of necessary consumption? Finally our used methodology limits the validity of the type of barrier named Lack of knowledge. It is always critical to ask people about how much they do not know, as this is a potential restriction. How should individuals know that there is something they do not know?

Summarizing our study we were able to detect types of barriers for saving energy. Our formulated guidelines can be used for sustainability-related persuasive system design. Further research can extend those guidelines based on additional studies.

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