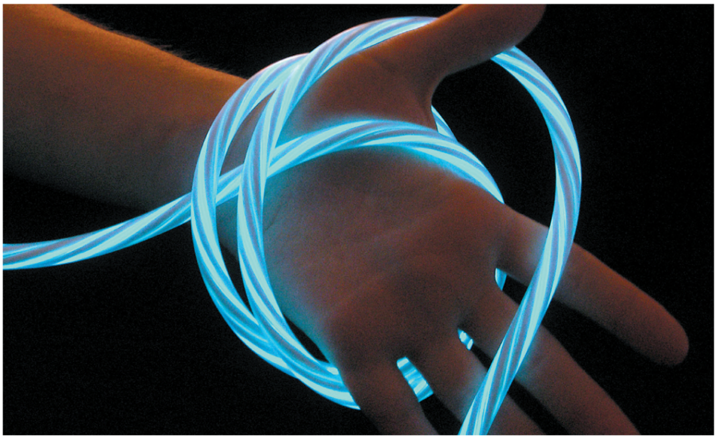
UNIVERSITY OF GOTHENBURG

Positive Persuasion

Designing enjoyable energy feedback experiences in the home

Anton Gustafsson

Ph.D. thesis



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Abstract

The world currently faces huge challenges in terms of our excessive use of energy. Energy conservation – a topic that has been on the agenda since the energy crisis in the 1970s – has for this reason once again become a very central issue in our society. In this thesis, we explore how interface design can be employed to address the increasing energy use in our homes. By creating a number of mobile phone services and computer augmented artifacts, we try to provide both fun and interesting ways to engage with concrete energy consumption issues and problems in a domestic everyday context. While design of technology in the home seeks to conceal our everyday use of energy, we here look at how we can reveal it. Consequently, in this thesis we ask how energy use can be visualized, and how playful and social design features can be employed to generate interest and make energy more noticeable in our lives.

This thesis relates mainly to the fields of persuasive technology and sustainable HCI, but also makes use of theoretical constructs and practical examples from ubiquitous computing and serious-games research. We argue that when designing persuasive technology, a key thing to consider is its use context and the experiences it provides to its users. Like any other product, a persuasive-technology artifact or service must often be bought or downloaded. But persuasive technology must also be used in order to be effective. For this reason, it needs to offer its user something that can compete with other activities in its use context.

The starting point of our investigation has therefore not only been how to change people's attitudes and behaviors, but also how the artifacts and services created to this end can offer meaningful and engaging experiences that fit into a home context. Since persuasive technology arguments always will be judged based on, among other things, the message and the ethics they convey, we argue that they are often limited to a context where people already have a positive attitude towards the subject. Through what we refer to as a *positive persuasion strategy* we accordingly try to provide people, who on some level already are either curious or concerned about their energy habits, with fun and interesting means to explore their energy consumption.

By combining concepts from both ubiquitous computing and so-called serious games, we specifically address how a persuasive-technology argument can offer a rewarding experience and how the different parts of this offering can be integrated, but also how the offering itself can be integrated into the home. By utilizing the rich complexity surrounding electric appliances and their use of energy as well as the social context around them as a design resource, we illustrate how interacting with our energy use can be made intrinsically fun and enjoyable.

Based on the findings from our research we argue that the role of feedback on energy use often is misunderstood. While existing energy feedback solutions focus on conveying accurate information in terms of kilowatts and cost, we argue that this problem needs to be addressed as a question of stimulating attention rather than of providing information. Consequently, energy feedback designs should focus on how feedback cues remind us of and reframe our energy use. This involves a focus on the spatial, temporal, and esthetic aspects of the feedback. We also argue that the primary function of the information conveyed by these energy feedback cues is to motivate rather than to inform. Rather than being simple and abstract, the information will therefore benefit from being detailed, expressive, and complex. Rather than being neutral and objective, it will also benefit from being conspicuous and challenging in its form.

Keywords: Energy conservation, energy awareness, persuasive technology, sustainable HCI, ambient displays, pervasive games, serious games, engaging interaction.

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Part 1

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Chapter 1

Introduction

While the use of energy has brought tremendous improvements to human living conditions throughout history, in recent years we have also had to realize the challenges we face due to our extensive use of this vital resource. The environmental problem of global warming (Solomon et al. 2007) and the economic problem of a diminishing supply of fossil fuels (IEA 2009) are each examples of this. Energy conservation, a topic that has been on the agenda since the energy crisis in the 1970s, has for this reason once again become a very central issue in our society.

This new and evidently far more serious energy crisis is often depicted as a battle against time. It has been concluded that the sooner we are able to avert these threats by changing to more sustainable ways of living, the less the impact will be in terms of the economic (Stern 2006), ecological, and humanitarian effects (Solomon et al. 2007). But one question still remains: How do we motivate people to change their habits when energy and other resources are still abundant and cheap, and the signs of disasters are for many people still only reports of distant events on the news?

The answer that we offer in this thesis is: By making the concern for energy use in our homes more fun and interesting. While there is growing anxiety about problems like global warming, it can still be hard to find room in our daily lives to address these concerns in terms of concrete action. In this thesis we accordingly investigate how IT and design in the form of services and artifacts, can be used to encourage energy conservation in the home in both playful and engaging ways.

Our particular focus on the home has in this case been motivated by the very critical role it plays in addressing resource use in our society as well as the current consumption trends in this area. While the industrial sector, for instance, since the 1970s in many ways has been very successful at reducing energy and resource consumption through energy efficient technology the domestic sector still largely remains unaffected. In most parts of the world, the households are instead characterized by a continuous increase in energy consumption. In the OECD countries, this has amounted to a 160% rise in domestic electricity use during the 40 years since the last energy crisis (IEA 2008, p II.43).

Furthermore, it can be argued that the gain from energy and resource-saving measures in the commercial sector is small as long as we do not first address resource use in the home. Because energy savings in the commercial sector tend over time to lead to cheaper products, the end result often stimulates additional consumption of goods. As this often means that we bring more energy-consuming devices into our homes, a net effect of savings in a commercial setting can in this regard even become an overall increase in the use of both energy and resources. The resource use in the commercial sector should in this regard therefore be seen as a function of the activities in our homes (Carlsson-Kanyama et al. 2007).

The home is also a very interesting example of how technology, through its persuasive (Redström 2006) and rhetorical (Buchanan 1989 in Redström 2006) properties, acts to shape our behaviors. We embrace technology and the use of energy due to the many benefits it provides us with. But at the same time, technology also reshapes our lives. While many people express that they are highly motivated to make changes in terms of their use of energy (Logica 2007), they often seem to lack the ability to do so (chapter 10).

The obstacle to beginning to address the routine use of energy and other resources in our homes is often referred to as a lack of understanding of the technology involved. But underlying this inadequate understanding, we argue, there is also a generic lack of attention to its use. The use of energy in our homes, it seems, has through both deliberate as well as accidental technological development, become transparent (Verbeek 1998 p39). By transparent we, in this case, refer to the metaphorical way in which something is so taken for granted that it escapes active reflection, despite being in our immediate presence or even being actively used by us.

While this notion of transparency, suggested by Verbeek (1998 p 39) and based on Heidegger's notion of "ready at hand" (Heidegger 1926 in Verbeek 1998), usually refers to the *use of* a tool, it also seems to adequately describe the *use of* energy. Energy, however, differs from tools by not always being directly observable. While we obviously can see the light from an incandescent light bulb, we can not see the 95% of the energy that escapes from it in terms of waste heat.

One of the main arguments in this thesis is that even if we sometimes do reflect on our use of energy and try to make an effort to reduce it, this is generally not something supported in the design of the technology in our homes. The use of energy and other resources is, on the contrary, often concealed. The physical manifestations of energy itself, such as coal, oil, or water, are transformed into invisible and convenient forms such as electricity or district heating far away from our homes. The technology for utilizing these is furthermore often hidden behind walls or inside the glossy exteriors of products. With the exception of a monthly bill, we are for the most part left with only accidental and ambiguous cues from the interfaces or functions of our appliances to serve as evidence of our consumption. This abstraction of reality that technology brings us naturally limits our ability both to see what constitutes wasteful behavior and recognize the far-reaching effects that our consumption has outside the home.

A second question then comes to mind: How do we provide the tools needed to address our use of energy in terms of both understanding and engagement? In this work we try to specifically address this by finding ways to interface the problems of energy use through the use of digital artifacts and services. The underlying assumption here is that if technology, though its rhetoric, shapes our lives, it can also be used to reshape them (Thackara 2006, Fogg 2003).

We find support for this assumption in earlier research within both the area of domestic energy feedback systems (Socolow 1978, Abrahamse 2005) and the field of persuasive computing (Fogg 2003). Previous research has, for example, shown that frequent feedback on energy use can result in reductions of up to 21% in terms of household electricity consumption (Abrahamse 2005). The results are not, however, entirely conclusive in this regard. Several research studies on energy consumption feedback have, for example, also shown no (Matsukawa 2004) or only very limited effects of these kinds of interventions (Abrahamse 2005).

This implies that there is still a lot of work left to do with regard to understanding the mechanisms involved in this. Most research done so far revolves around different forms of numerical or graphical displays showing consumption or consumption trends. In many cases these systems build on esthetics and designs inherited from systems that were originally devised for controlling industrial processes or debiting for the use of energy, and frame the saving of energy as a mostly an economic task. For this reason, in this thesis we have tried to approach the problem of creating energy awareness through feedback from a different angle, in terms of the esthetic expression. In designing energy feedback systems for the home, we will argue, the specific characteristics of this location need to be taken into account.

As we have learned from findings within the field of Human Computer Interaction (HCI), the notion of usability needs to be broadened as digital artifacts move from a commercial work setting into our everyday lives (Gaver 2007, Carroll 2009). In this regard we need to consider how these visualizations and feedback mechanisms fit into our lives not only in terms of function, but also personal aspirations, esthetics, or social interaction. Design must, for example, support the diversity found in this context.

Furthermore, we argue that consideration also needs to be taken of the ambiguous and often very complex attitudes that people possess towards the topic of energy and energy conservation. Energy, is regarded by many people as difficult to understand and notions of watt or kilowatts are hard to relate to (chapter 10). At the same time we also find a growing environmental concern as well as an ever-present awareness of the economic benefits of saving energy.

Proper feedback in a domestic setting can draw attention to consumption and educate the consumer on the link between, e.g., the use of household appliances and energy consumption. But in our view, feedback systems need to be more than just a tool for showing energy consumption. At the same time energy, through its function of enabling the use of commodities in daily life, self-actualization, entertainment, or amusement, is of course also very important to us. The starting point of our investigation has therefore not only been how to make use of energy feedback in order to create energy awareness, but also how the artifacts and services created to this end also can offer meaningful and engaging experiences in the context of a home. Through what we would like to refer to as a *positive persuasion strategy* we consequently try to provide people, who on some level already are either curious or concerned in regard to their energy habits, with fun and interesting ways to interface and interact with their consumption.

To do this we incorporate notions from the fields of persuasive technologies, ubiquitous computing, and games research. By combining concepts from both ubiquitous computing and so-called serious games, we specifically address how an offer in terms of an experience can be created in terms of a persuasive argument and how this offer can be integrated into both the home as well as an attitude context.

The design proposals presented in this thesis can in many ways be considered as examples of persuasive technology (Fogg 2003). The theoretical framework of this field formulates a number of strategies by which these artifacts can be understood. However these proposed strategies many times disregard very central aspects of persuasion such as the use experience from these persuasive arguments (Bogost 2008). As our contribution to this field we will therefore specifically address the use context of the persuasive technology argument.

Some of the most important aspects of this context involve the social and physical context, in our case the home, as well as the message–receiver relation, that is, the attitude people have towards the intent of the designer. First of all we stress that a user or receiver-oriented perspective that takes these factors into account is needed in the theoretical framework underpinning the persuasive technology field.

Secondly, we argue that since use experience is a determining factor for these kinds of interventions the usefulness of persuasive technology most of the time is limited to situations where people are very open to persuasion or where it might be more a matter of supporting than persuading. As a result of the above we also come to the conclusion that the perceived ethical problems surrounding persuasive technology are of limited importance.

Apart from the persuasive technology field this work can also be said to relate to the closely related research field of so-called sustainable HCI (DiSalvo et al. 2010).

The design space in this study is explored by on the one hand looking at how existing interfaces in domestic appliances, such as electric radiators or power strips, can be redesigned and, on the other hand, how experiences can be created around central metering in the home. In line with this, we present four different prototypes which map out the design space in terms of persuasive and experience-based domestic energy feedback.

In the Power Awarecord prototype we explore how a power strip that visualizes the electric current running through the device as a flow of blue light in the cord can be used both as a tool for an enjoyable exploration of the home, as well as a continuous reminder over time to reframe energy use. In this prototype electricity itself has been given a visual form. By using a metaphor inspired by the common use of flowing water to describe the workings of electricity, we visualize high-resolution real-time measurements of the electric flow through a power strip. Through this design, we provide an expressive simulation of how electricity would behave if it was visible.

With the use of the Element prototype, which is an electric radiator made out of ordinary incandescent light bulbs, we explore how artificial feedback cues can be integrated into existing product interfaces to produce both engagement and awareness without requiring the additional use of energy. By using light bulbs, instead of ordinary heating filaments, the heat radiation is radiated in the form of visible light (instead of invisible infrared light). The intensity of the light, and at the same time the amount of heat produced, is controlled by an electronic temperature sensor. Because the Element dynamically reacts to drafts and other conditions in the room, thereby becoming a highly visible and engaging center-point in the surrounding home setting, it acquires something of the expressivity and social function of a fireplace.

Power Agent, a pervasive mobile phone game developed for an existing automatic meter reading system, is used to explore how one can design energy feedback systems on top of existing infrastructure in the form of people's mobile phones and the automatic meter reading systems installed in homes by the electric utility companies for debiting purposes. In this pervasive computer game, we create an arena for experimentation and social interaction surrounding one's use of energy, as teenagers and their families compete in performing extreme energy saving measures during a period of ten days.

Finally with Power Explorer, a pervasive mobile phone game based on aggregated real-time feedback, we explore how temporary feedback in the home can be used to shape attitudes and promote associative learning in order to change users' energy habits in a long-term perspective. In this more casual version of a pervasive energy saving game, we try to motivate exploration of individual devices by turning the entire home into a game interface. In it, you control the movements and well-being of your game avatar though your energy use.

Chapter 2

The importance of the interface

According to Herbert A. Simon, we live in an artificial world (1969 p. 5). Almost everything that we today surround ourselves with constitutes some form of designed and man-made technology. There is no mystery about why things have become this way, since technology, as a means for controlling and harvesting external energies in our surroundings, has brought tremendous improvements to human living conditions (Moan & Smith 2007 p. 23). Through our use of energy we can today, for example, live comfortably on nearly any part of the planet with endless options in terms of what to eat, what to wear, what to do, what to own, and so on.

But the same technologies that are responsible for improving our living conditions, as the previous chapter pointed out, sometimes also come with unintended side effects. When it comes to the task of designing technology it is a well-known fact that most of the time we cannot find optimal solutions due to the complexity of most problems (Simon 1969 p. 27). Even a relatively simple real-world problem usually exceeds the computing power of any known computer once it includes more than a limited number of variables (ibid).

In technology design we instead simply make do with satisfactory solutions and we learn to accept the side effects of technology, e.g., the smoke, the noise, or the tedious installation procedures, as long as they are in reasonable proportion to the improvement it brings. While our excessive use of non-renewable resources can be viewed as one such side effect, it is clearly not benign, but a quite significant design flaw that needs to be addressed.

Rethinking the way we design technology as a solution to our problems is a compelling idea. But can it really be done? Is it possible to handle the complexities involved in redesigning the technology with an ecological perspective in mind, and can technological progress be controlled on the scale that this implies? While there are plenty of people who believe that we are incapable of doing such a thing (e.g., Lovelock 2010) there are at the same time also many proponents of the view that such a thing is possible (e.g., Thackara 2006).

In the field of eco design, for example, there is general agreement that this could be done, from the designer's point of view, by adopting a holistic view of the environmental impact of a product. Such a view would not only consider the immediate impact of a product, but also more indirect ones (Thackara 2006). In practical terms this is often done by means of so-called life cycle analysis of a product to find the equation that minimizes the total environmental impact (ibid). Making an electric household appliance more durable, for example, might lead to a positive environmental effect. But it might also have the opposite effect if more energy-efficient models could be expected in the near future.

In his book *In the bubble* (2006), Thackara argues that we need to look even more widely than this and also redesign the way in which we use devices. Since the average power tool, as an example, is only used for about ten minutes during its entire lifetime, and consumes many times its own weight in resources in its production, it makes no sense that each and every person should own such devices (Thackara 2006). Hardware like cars, power tools, etc. could instead be shared among several people by turning many of the functions that technology performs for us into services (ibid).

While this idea of Thackara, as well as many other ideas in the field of eco-design that aim to reduce the resource demands of technology no doubt also provide important insights into how to deal with the global problems we presently face, they do not provide a complete answer. As these ideas center on the designer's role they often tend to take a top-down approach. In this way they also rely on an assumption that people's habits and what they want, can be easily understood. They consequently fail to address some of the more central issues such as, for instance, how we as individuals prioritize among the different aspects of design, and how we can motivate people to change their technology.

As Simon, among others, has pointed out, we are rarely rational in our behavior as rationality is bounded (Simon 1982). Decision making is limited by factors such as the information we have available, our cognitive limitations, the time we have available for making the decisions, and so on. Due to our dependence on the commodities that our artificial world brings, and the transparency of their use, which conceals our consumption of resources, we for example often lack the knowledge or focus required to change and update values and behaviors.

In other words, redesigning the world involves a lot more than just mechanically replacing bad technologies with better ones. We also need to provide the tools for people to determine what is good and bad design as well as provide opportunities for them to reflect on energy use. In this thesis, we argue for interface design as an important piece in this puzzle, as a means to empower people and emphasize aspects of energy use in design.

The relevance of interfaces in a broad sense has been discussed by, among others, Herbert A. Simon and Albert Borgmann. According to Simon the artificial in our world resides in the interface of objects (1969). Because both the internal and external environments of, for example, a mechanical device follow natural laws, they cannot in that respect be seen as unnatural or artificial. The artificial instead arises within the design process in the effort to accomplish a goal or fill a function by adapting the inner world of a device to its outer world.

On the border between the artifact and its surroundings, we create our own logic in terms of cause and effect. In this way the interface can also be seen as an abstraction of the system involved and the reality in which it is placed. For example, we do not need to know all the complexities of an elevator in order to use one. The task of going to another floor is reduced by the elevator's interface to stepping through a door and pressing a button. This abstraction is what makes the elevator artificial and is also what turns it into a convenient commodity. But what follows from this is that as we construct interfaces or artifacts we also reshape our reality. Interfaces, in other words, change how we perceive the world and, as a consequence, also what we perceive to be important.

In this abstraction performed by technology, it is inevitable that certain values are often lost to us. According to the philosopher Albert Borgmann, technology often becomes disengaging when designed from a functional perspective. As an example he refers to the task of heating a house. While this used to be a highly engaging task, including elements such as finding wood, preparing it, maintaining the fire, cleaning the hearth and socially coordinating the tasks, it has through technology become a task of simply adjusting a knob. In this way, we also go from *using* energy to *consuming* it, i.e., to a less thoughtful use of our resources (Borgmann 1984 p 41-42).

In this view, Thackara's idea of an environmentally optimized society based on service design might in some instances even be counterproductive as it would increase the transparency surrounding energy use. An unquestionably important issue is therefore how we, at the same time as we redesign the world, also can redesign its artificial properties to empower people in their thought and keep important issues such as resource consumption a focal point in people's interaction with technology. In other words how do we interface our problems?

This does not in any way oppose notions of resource efficiency through service design as part of a solution. It merely suggests that before, or possibly at the same time as we present new sustainable designs, we might also need to embed arguments for their rationale in their interface, that is, to create new interfaces or augment old ones with properties that both engage users and promote awareness of resource usage. Only then can we change what people perceive as important in design and motivate a shift in terms of our technology use.

In this thesis we explore how interface design of services or artifacts, designed with a persuasive technology approach can be used to generate engagement and awareness in regard to electricity consumption. In this approach we also borrow notions from the fields of game design and ubiquitous computing concerning how to integrate this technology into our homes as well as how to design for experience in addition to function.

In the remainder of this chapter we look specifically at the field of persuasive technology and to what extent the theoretical approach in this area can be applied to the specific task of addressing energy use in the home through interface design. Based on this discussion, we will then suggest a more comprehensive persuasive design strategy appropriate for our explicit purpose.

Persuasive technology

In its broadest sense, the research field of persuasive technology is defined as the study of how technology can be used to influence people's attitudes or behaviors (IJsselsteijn et al. 2006). The term technology, however, is by most authorities in the area considered to refer to computer technology in particular. This body of research is therefore often synonymously referred to as persuasive computing. The scope of this research community is, however, still the subject of some debate.

As Redström puts it, when a new field such as the Persuasive Technology emerges it needs to both build on what already is, and differentiate itself from its surroundings, to justify its existence (2006). While some, such as Redström, currently advocate a wider definition of the area, others, such as Fogg (2003), and even more so, Bogost (2008), advocate a more narrow scope. These positions are in many respects influenced by the ethical concerns surrounding the field.

We will here provide a brief account of these three general approaches to persuasive computing as well as discuss how they map on to our work. As the first approach to this research area we will discuss the original view as conceived by Fogg (2003).

Persuasive technology as "usability"

Persuasive technology is defined by Fogg as: "Any interactive computing system designed to change people's attitudes or behaviours." (Fogg 2003, p 5). He further defines the study of persuasive technology by first of all limiting the meaning of the word persuasion to "an attempt to change attitudes or behaviors or both (without using coercion or deception)" (2002 p. 20), and secondly, by limiting the word technology to refer to "interactive computer products" (p. 5).

In Fogg's view, there needs to be intent in order for a system to be considered persuasive. But at the same time Fogg also states that persuasion does not need to be the sole purpose of a piece of software or a computer system in order for it to be conceived as persuasive. The study of persuasive technology can also apply to small tasks within computer software which serve to promote specific behaviors, such as for example completing a work task efficiently and accurately, or continuing to use the software. When any persuasion element is not the main purpose of a program or a system he refers to it as micro persuasion. If there is an overall persuasion goal in a program or a system he refers to it as macro persuasion.

This effort to, on the one hand, limit the study of this field to systems with a persuasive intent and, on the other hand, include almost any level of intent can at first seem to be a bit confusing. It could, however, be interpreted as an attempt by Fogg to maintain a practical view on the subject, i.e., as a way to focus on knowledge that to a wider extent can be applied outside of the academy. Fogg is, in other words, not interested in the traditional scientific approach where all kinds of knowledge of the subject would be sought, but rather that which has commercial value.

Fogg's definition is also a way to distance himself from potentially unethical implications. By excluding coercion and deception from his definition of the research, he aims to avoid these implications. This also seems to imply a practical rather than scientific view on his part. If we view the task from the point of view of a practitioner, this way of distancing oneself from coercion and deception might make sense. As a researcher, however, it does not. In this regard it is rather the opposite, since performing research to critically review the persuasive elements within technology has the potential to expose manipulative or unethical uses of the technology by exposing such strategies (Redström 2006).

What Fogg says with this limitation is, in other words, that he is not at all interested in addressing the ethical concerns in this area. His research instead takes on the very business-oriented viewpoint of a practitioner, focusing on the perceived potentials of this technology. From a methodological perspective his work is optimized for measurable effects on attitude and behavior, and in most cases involves transferring known theories in psychology from a human-versus-human context to a human-versus-computer context.

Fogg also adds the quite peculiar limitation to his definition that persuasive technology research should be limited to human–computer interaction and not human-mediated interaction (Fogg 2003). From this limitation Fogg's business-centered perspective becomes even more apparent as he seems to be viewing this area as a new kind of marketing strategy, one whose effectiveness derives from human persuaders being replaced by computers.

From these studies he concludes that there are three ways in which computers can work to persuade people. The first is by acting *as a tool* to increase the user's capabilities. In this way computers can facilitate a behavior by making it easier to do, but also by providing feedback on progress in relation to a goal. The second way is by acting *as a medium* in order to provide a persuasive experience to the user. This can be accomplished, for example, in simulations where cause-and-effect relations can be explored. The third way in which computers can persuade is *as a social actor* – in one way or another mimicking social behavior among humans. These three categories are in turn divided into a number of subcategories. Concerning computers as *tools,* Fogg has identified the following subcategories:

- **reduction** – i.e., making something easier to do,
- **tunneling** – e.g., guiding users through processes,
- **tailoring** – that is, providing information relevant to the user (i.e., context-aware computing),
- **suggestion** – systems that intervene at the right time,
- **self-monitoring** – tools to keep track of one's own physical or psychological state,
- **surveillance** – having one's behavior judged by others, and finally
- **conditioning** – low level associative learning through rewards (or punishment).

In addition to this taxonomy, Fogg also mentions *credibility* as an overall important factor in persuasion. Fogg observes that computers today often have high credibility due to that they often mistakeingly are perceived as being objective. This, he admits, is likely to change in the future as these technologies come to be exploited for more or less dubious purposes. A crucial aspect of designing for persuasion therefore becomes to address these dynamic and changing conditions of credibility. This also points out perhaps the largest limitation in Fogg's work, namely that the effects of persuasive technology in this regard are bound to be temporary.

Although criticized in almost every respect (Atkinson 2006, Redström 2006, Bogost 2008), the work of Fogg provides a useful framework for the many roles computational technology can play in the human–computer relation. These roles encompass different viewpoints that provide persuasive design with insights into how to structure a persuasive argument. These insights are, however, for the most part limited to the sender's perspective and do not, with the exception of the discussion of credibility, tell us anything about the receiver's perspective. In this regard, they do not provide much insight into the outcome of the persuasive argument. Credibility is only one aspect among many of the context in which the persuasive message will be received and within which it will be judged by its users.

For the purpose of this thesis we would also want to know, for example, what it would be like to live with these kinds of persuasive technologies in a wider meaning. A parallel could here be made to the field of HCI and its original focus on usability (Carroll 2009). The initially quite functional approach towards what meant good usability, which was often measured by clocking the performance of different tasks, has in recent years been challenged. This is a result of computer technology changing from being something that occupied us during our workdays, into something that came to extend to all parts of our lives (Carroll 2003, Gaver 2004).

As a result, the term usability now includes a range of other aspects such as fun, well-being, collective efficacy, aesthetic tension, enhanced creativity, support for human development, and many others (Carroll 2009). This has also led to new approaches in terms of methodology for design and evaluation within HCI (Zimmerman et al. 2007). Our conclusion is that for the persuasive technology field it will be just as important to address this issue, by dealing with the specific aspects of the domestic context, as will be done in this study.

Another argument that can be made in regard to Fogg's framework is that the message itself is an integral part of the persuasion and can therefore not be treated separately from the persuasion strategy used. In Fogg's different concepts all messages are treated equally. There is however a great difference between the situation of trying to persuade someone to quit smoking who wants to quit smoking and trying to persuade someone who does not.

A popular example in the persuasion technology field, which is also mentioned by Fogg, is Amazon's book-suggestion algorithm, which presumably persuades people to buy more books (Fogg 2003). At the same time, as Atkins points out, this notion can be turned around (2006). It is equally true to say that what this system is doing is simply providing messages that are of relevance to the receiver and which satisfy the user's needs. If this were not true the system would not work. Even if we do not go so far as to claim, with Atkins, that there is no persuasion in this context, it should be clear that the main task in this case is to find the message of persuasion rather than the means for it; or as one could also put it, in this case, to a large extent, the message itself is the means for persuasion.

Persuasive technology as a social science

In a critique of Fogg's approach, Redström argues that all design can be seen as intentionally persuasive. Design becomes intentional as the designers formulate notions of how their imagined users will behave and inscribe these visions into artifacts. These inscribed visions will then act as persuasion towards this particular behavior (Buchanan 1989 in Redström 2006).

In this way Redström recognizes that persuasion is something very pervasive in the human world, not only in terms of social interactions but also in terms of interactions with our artificial man-made environment. As an implication of this observation, he then suggests that the field of persuasive technology has an even greater role to play than imagined by Fogg. Redström accordingly argues for including all forms of technology in the definition of this field and provides the following vision for the field of persuasive technology:

> We should try to avoid developing persuasive design into a very specialised area like so many areas of technology development have become, but instead build on the observation that this research deals with central aspects of what design is about... Not primarily because we want to persuade people, but because we need to understand the persuasive dimension of the dialogue between object and user that seems to be going on as we use things. Otherwise we will never fully understand the difference between "using" and "being used". (Redström 2006)

Regardless of whether one fully agrees with this vision, it seems as if the notion of intentionality as provided by Fogg is of little use to us since almost every design seems to exhibit some form of intention or another, if not on a macro level then at least on a micro level. We can also agree with Redström that persuasion is a pervasive element in the artificial world. In Fogg's defense, one could point out that persuasive design contains different levels of intentionality. Intentionality is a dimension that ranges all the way from conscious to subconscious acts. But using this as a limiting factor for the scope of the field is, of course, still problematic.

With Redström's view of the persuasive technology field (a field not primarily for persuading people, but rather for gaining knowledge about issues related to persuasion), the field risks instead being turned into something primarily theoretical rather than pragmatic. While we are not saying that the field of persuasive technology is not in need of such a theory of the artificial, it should be apparent that this kind of research already exists in many branches of social science.

Single-mindedly pursuing such an approach within persuasive technology would be unfortunate, since it would severely limit the usefulness of the field by turning it into a descriptive rather than an applied science. Redström does not, however, entirely lack an applied approach. To investigate this problem he proposes critical design as a method. Critical design can be said to be design that through its form or function questions some aspect of a situation.

As an example of this, Redström (2006) mentions the placebo objects created by Dunne and Raby (1999). By creating a number of objects designed to give the appearance of shielding the user from invisible electric smog in the home, they managed to effectively concretize these hidden properties of electric devices for a group of users. Another example provided by Redström is the Erratic Radio (Ernevi et al. 2005). This is a dysfunctional radio that detunes as electric fields around it fluctuate. In this way it reacts to electricity consumption in its vicinity. While all of these artifacts undoubtedly help to raise questions in the user's mind, they are perhaps less helpful in supporting informed decision-making or creating understanding of these hidden dimensions while the user interacts with them in a daily use context.

These are designs that seem to fit better within an artistic or academic use context then in the home, as their form encompasses intellectual arguments rather than practical functions. Designing for understanding rather than for persuading, as Redström proposes, seems to mean to design for another context, a context of philosophical argumentation instead of everyday life in the home. The artifacts in this sense also become harmless means for acquiring information or embodying arguments, rather than something truly persuasive. In this way, Redström also to avoid the ethical dilemmas present in the examples he provides. If we were to view these objects in a real-world use context they could very well be seen as both coercive and manipulative, the radio for punishing you for using too much electricity and the placebo object by playing on latent fears of technology. But perhaps it is these very provoking aspects of the design that in this case make the intellectual arguments surrounding them interesting. However, by being designed for an academic context, these objects instead become more of a foray into the philosophical domain. For this reason it becomes necessary to ask if these objects really can be used tell us something about the everyday situations in, for example, our homes.

As concretizations of abstract ideas, these kinds of objects can of course still have an appeal, and also do persuasively capture people's attention and thoughts. However it should be clear that these objects need the right framing in order for people to interpret them not as the functional, and in this case cohesive objects they might appear to be, but rather as the intellectual arguments they, through their dysfunctional properties, become. These objects require that a story be communicated alongside them, a story that perhaps causes them to lose some of their autonomy as physical arguments, since it could in fact be argued that the story itself is the primary argument, while the objects are illustrations or tokens extending this argument.

Persuasive technology as a fine art

Another target for criticism in regard to Fogg's "usability" approach has been his choice of methods. Ethics, as previously pointed out, is an obvious concern when it comes to persuasion. This is, for example, expressed by Fogg when he states that: "Although I don't find Captology [i.e., the study of computers as persuasive technology, author's remark] immoral, I acknowledge that persuasive technology can be used in unethical ways in an attempt to change people's attitudes and behaviours" (2002). To distance himself from these "unethical ways" he, as we saw earlier, excludes the cohesive and deceptive use of persuasion in his definition of the field. According to Bogost, this does not help, as the unethical outcomes can be viewed as inherent to the method used by Fogg (Bogost 2008).

The current focus on quantitative results in the area, in the form of applied psychology theories – a focus on the end rather than the means, as Bogost expresses it – has a tendency to leads towards cohesion. This is especially so, he points out, if it is used in conjunction with a political or economic agenda. To remedy this he instead suggests the use of methods from the fine arts.

These methods, which Bogost refers to as "fine processing" when applied to computational technology, focus more on the experiences that someone has of computational artifacts than the actual outcome. This shift in focus will, according to him, yield less manipulative designs.

Unfortunately, this again seems to necessitate that we abandon trying to obtain measurable effects. But unlike Redström's view of an all-inclusive field, Bogost instead envisions a specialized area dealing with properties specific only to computer technology. According to him, this is something that Fogg's approach of transferring theories from human–human contexts to computer–human contexts does not do (Bogost 2008).

The suggestion that artistic methods could be used to address the ethical concerns raised by persuasive technology can be questioned with the same arguments that we addressed with regard to the critical design examples presented by Redström. This is merely a method of avoiding it. Furthermore one could also question how artistic methods *per se* would ensure ethical persuasion, as even art has been misused for propaganda purposes throughout history (Karlsson 1999).

Nevertheless, two important points are made here by Bogost. First of all, persuasive technologies do need to offer the user something in terms of experience, as art installations often do. Secondly, in order to avoid becoming cohesive, persuasive technology needs to allow for people to disagree with the message, something that is easily forgotten when looking for statistically measurable and viable results.

Summary

To briefly recapitulate the discussion so far, we can say that there is an unresolved issue concerning ethics when it comes to the field of persuasive technology. This issue does not seem to be dealt with in a way relevant to the topic of energy conservation in the homes by either redefining the area or changing the methods used in the field. There also seems to be a lack of attention to the importance of accounting for the user's context in the design. Two important aspects of the context that we highlight here involve the use context – in our case the home – and the message–receiver relation, i.e., the attitude the user has towards the persuasive technology argument.

A contextual view on persuasion

In this section we will offer further insights into the field of persuasive technology by extrapolating on the discussions in the previous section. We will argue that the ethical concerns can be tied to a neglect of use context. We will also show how we, as a result of taking this context into account, need to reevaluate the usefulness of persuasive technology. As our contribution to the field of persuasive technology we will then formulate a strategy for how persuasive technology applications could be more efficiently designed by accounting for the context and user experience.

Ethical concerns

Our first argument to be made is that the perceived ethical concerns regarding persuasive technology are a minor issue. They are a minor issue because designing IT for persuasion is in no essential way socially different from persuasion at large. As concluded in the previous section, persuasion is an integral and pervasive part of our lives. It is something that we encounter every day in negotiations and interactions with our surroundings and in, for example, commercial advertising or product design. In this sense handling persuasion in all its forms is something with which we as individuals, as well as society at large, are very familiar. What ensures good ethics in this regard is not primarily methods in the design, as suggested by Bogost, but rather the social codes or juridical laws on which our society is based. This is not to say that the ethics of persuasive technology are of no concern at all. However the risk of not taking these concerns into account is not that unscrupulous people will utilize these strategies for unethical persuasion, but rather that we, as our second point will show, will simply do more harm than good in terms of our attempts to persuade.

Our second point here is that a key component in the success of persuasive technology is that it must gain some form of acceptance from its users. For this to happen, we argue, persuasive technology needs to match the preferences of its intended audience both in terms of ethics and other respects as well.

Here one could argue that if the persuasion were hidden (i.e., deceptive) or imposed on us (i.e., coercive) this would not be necessary. Persuasion can of course be hard to spot, which can potentially be exploited as a deceptive persuasion strategy. The transparency surrounding energy consumption is an example of this. However, it should be clear that in this specific case the persuasion builds on many of the aspects of this design being taken for granted. This provides no momentum for changing opinions in this case, i.e., persuading people. In other words we can only persuade by changing the things we take for granted, in which case they will stop being taken for granted.

In this regard Fogg also speaks of how one can make use of the inherently high credibility that people attribute to computers as a strategy in persuasion (2003 p. 213). But even in this case we argue that the effects are limited, as strategies that build on the novelty of the technology only provide a very temporary solution (which Fogg also admits in his discussion). People constantly adapt to these strategies and quickly find ways to avoid and filter unwanted messages. This can, for instance, be seen in familiar examples such as spam email or adware. While people might be fooled the first time they encounter one of these annoyances, they quickly becomes skilled at exposing and discarding these attempts at persuasion with a minimal use of attention (McCollough & Vogel 2008).

As for persuasive technology being imposed on us, there are, of course, many examples of this including different forms of surveillance with the aim of keeping people from resorting to, for example, criminal actions. But even in these cases the technology needs to abide by the general ethics of society or the rules associated with the space it occupies in order to be accepted.

Another example of a persuasion strategy in terms of persuasive computing being imposed on us, and one that is perhaps more suited to the context addressed here, namely the home, involves what Fogg refers to as the persuasive potential of the persistence of computer systems (2003 p. 216). While this might sound like a tempting capability to incorporate into a persuasive computing strategy, it should be clear that open-ended persistence is the same as coercion. In this regard we instead argue that the challenge (as also Bogost implies) rather lies in avoiding this phenomenon. Computer systems tend to have an inherent tendency to become coercive since, unlike a human being, they cannot use ethics or social skills to adapt their programming to the context, unless of course they are explicitly programmed to do so. As Atkinson (2006) puts it, computers are not "sociable." They can only simulate social behaviors. If a software application wants you to register and presents you with only a yes button on the screen, you usually do not have much of a choice.

But even in this case people find ways to avoid these coercive strategies. To avoid revealing personal information, counter strategies have evolved. These include examples such as filling in nonsense in the registration form or using services like mailinator.com to allow you to confirm fake email addresses in registration procedures. We do this because if there is something that we generally do not like, it is being coerced into something against our will. So even with deceptive and coercive methods, persuasive technology does not work well unless it takes into account the context in which it will be applied. However, it is not the methods *per se* that in this case cause the persuasion to fail.

As our third point, we will here argue that the ethics of a persuasive technology argument cannot be determined by the method used. Even coercion and deception can be legitimate components of persuasive technology. As long as the argument conforms to the ethics of its receiver, these methods can even offer a vital resource for creating experiences. In the case of the Erratic radio, the example used by Redström, one might for instance find its coercive nature liberating, justified, or even fun, depending on what kind of attitude one has towards consumerism or saving energy. One might, of course, equally find it provoking or annoying. Being deceived or tricked in a humorous context can similarly be enjoyable.

Coercion or deception in persuasive design does not, in other words, automatically lead to unethical applications, as being coerced or deceived does not always violate the ethics of the receiver. At the same time, the absence of these elements likewise does not in any way ensure the good ethics of an argument. Whether it is ethical is instead determined by the preferences of the user, i.e., the context of the argument.

The limits of persuasive technology

We argue that behind the ethical concerns regarding the use of persuasive technology lies a serious overestimation of the power of these strategies over the human intellect. This overestimation stems from a tendency to make the discussion abstract and view this persuasion out of context. The usefulness of persuasive technology, contrary to what is often envisioned in this field, is quite limited.

We have argued that in order for persuasive technology to be effective, it needs to gain the acceptance of its intended recipients. How a persuasive argument is judged depends, of course, on a combination of many factors. The underlying message that the argument carries is, without doubt, one of the more important of these factors. For this reason it is unlikely that a persuasive technology argument will be effective if the user does not already from the beginning have a positive, or at least neutral attitude toward the message or the ethics it conveys. This is particularly true in the context of one's own home where we rarely accept things we do not fully approve of. Our fourth point will therefore be that the usefulness of persuasive technologies in most cases, and especially in a domestic context, is limited.

This is easily illustrated by the persuasive technology artifacts or services suggested in this thesis, as they need to find their way into your home, either by your buying or being given them. Furthermore they need to be accepted and used in order to work. The really interesting applications in this field, in our view, therefore lie not in forcing opinions or behaviors onto people, but rather in the far more powerful situation where someone is already positively disposed toward the message, and where the persuasion situation has something to offer the person.

As a way to address design in persuasive technology, we will therefore argue that instead of looking for the right methods, as a means to create effective persuasion in interactive systems, one should instead address the context of the argument by asking what the persuasive argument has to offer its users. With regard to what we call a *positive persuasion* strategy, we will later discuss what we see persuasive technology as being able to offer the user in terms of both function and experience in a home context. Before we do this, however, we need to gain an understanding of the specific context surrounding an energy conservation argument in the home.

Chapter 3

Energy in the home

We have previously argued that persuasion always appears in a context, and that in designing for positive persuasion we need to account for the social practices operating in a particular setting as well as people's relation to the subject. In this chapter, we will discuss the context selected for this study: energy and its use in our homes. We will briefly provide some historical background of the growing energy consumption as well as the concerns surrounding it. We will also look at the sociology of consumption, what the current attitudes towards energy conservation are, and finally, how the topic of energy conservation is addressed in our homes today. But first we will briefly provide the background and definitions of some of the more technical terms used in regard to energy, the most central of these being *energy conservation*.

Energy

As a first step, we will need to frame our use of the word "energy". Energy encompasses different meanings depending on the situation in which it is used. In this thesis, it will be used in both its technical and its more informal everyday sense (Moan & Smith 2007, Wikipedia 2009). Energy is technically defined as a scalar quantity describing the amount of work that can be performed by a force (Moan & Smith 2007). According to the law of conservation of energy and its physical definition, energy cannot be destroyed. It can only be transformed or converted into other forms of energy (ibid). The term *energy consumption* could in this regard seem a bit strange, as it would appear to violate this law.

In its informal sense, however, the term usually implicitly refers to particular forms of energy that are easily accessible and controllable, such as electricity. Energy can also refer to the physical matter which is the source of the energy, such as wood, coal, or oil. In this regard, the term *energy consumption* makes perfect sense as referring to the consumption of a particular form of energy or matter. Consuming energy, in other words, refers to the process of utilizing easily accessible energy for a purpose, and during this process it is transformed into some less usable form of energy (typically waste heat).

Different forms of energy are also valued differently depending on how versatile and useful they are to us. On this scale, heat energy is the least valued since it is very easy to produce from other forms of energy, but hard to convert into *higher forms of energy*. At the top of the scale we find electricity. Electricity can easily and efficiently be transformed into light, heat, and motion – or even information and logical processing for that matter.

A distinction is often made between the *primary energy* source, such as coal, oil, or water and the *secondary energy* source, such as electricity or heat. *Energy production,* like energy consumption, also refers to the process of transforming one particular form or energy into another. In this case, however, it refers to the task of transforming an already accessible primary energy source into an even more accessible secondary form of energy. In this way, consuming a primary energy source can often be the same thing as producing a secondary one.

Efficiency

Whenever energy is transformed, for example when coal is burned to produce electricity or electricity is consumed by using a computer, some of it is inevitably lost in the form of waste heat. The term *thermal efficiency* is in this case used to describe the efficiency of an energy conversion system. A gasoline engine typically has a thermal efficiency of 25%, meaning that only 25% of the energy contained in the fuel becomes motion, while the remaining 75% instead becomes heat. In a incandescent light bulb, the thermal efficiency is even worse. Only between 5–10% of the electricity becomes visible light while the remainder becomes heat or infrared light. The concept of *energy conservation* refers both to a more moderate consumption of energy as well as increased *efficiency* in its use (Moan & Smith 2007).

The home in a global context

Since the beginning of the industrial revolution, the global demand for energy has constantly been increasing. The primary source of energy today is still oil, followed by coal and gas. While the use of energy has meant many positive things in human history, the adoption of fossil fuels during the industrial revolution has unfortunately led to our now collectively facing what may be our greatest crisis ever (Moan & Smith 2007). This crisis could be said to consist of two parts. First of all, since fossil fuels are a finite resource, we are at risk of running out of this vital resource in the very near future. Secondly, the pollution from burning coal and oil has proven to have severe and irreversible effects on the global environment.

With regard to the first problem it has been predicted that we today have used about half of the world's total oil reserves. The problem, however, is much more pressing than this would seem to imply. The term "peak oil" is often used to refer to the tipping point where oil production will go from increasing to decreasing. It is predicted that when this occurs it will have devastating effects on the global economy. IEA in their latest report estimate that an energy crisis before 2015 cannot be ruled out (IEA 2009).

But oil consumption also needs to be placed in the context of the second problem of global warming. Global warming is a result of the changing concentration of certain gases in the atmosphere, which traps heat radiation in the atmosphere causing temperatures to rise globally. A rising global temperature, it has been predicted, will ultimately lead to many severe and irreversible effects such as rising sea levels as ice in the polar regions melts, as well as more severe weather conditions due to the greater amount of energy in the weather systems, and thereby cause many forms of ecological crises.

The UN climate committees, which report on the subject, have established that climate change is a real and serious threat and that it is caused by human use of fossil fuel (Solomon et al. 2007). Unfortunately global energy consumption in the world today is still increasing overall, as is the use of coal, oil, and gas (IEA 2008). Currently we globally release about 28 billion tons of carbon dioxide per year with a 3% yearly growth rate (UN statistics 2009).

While the large scale of these problems might cause the effect of our homes to appear small in comparison, what we do in the home does make a difference. In this regard, households arguably play a growing role, as a major portion of the global increase in energy use can be traced to the domestic sector. In terms of the direct use of electrical energy, the domestic sector in OECD countries has, for example, during the last 40–

50 years more than doubled from 1,082 TWh in 1973 to 2,814 TWh in 2006, a 160% increase (IEA 2008, table 2.14). This constitutes a significantly larger increase than the industry sector which during the same time period increased its consumption from 1,836 TWh in 1973 to 3,086 TWh in 2006 in the same countries, a mere 60% increase in electricity use (ibid).

If we also include the indirect use of energy, by taking into account the energy being used to produce the many products consumed by the households, the domestic sector can said to be responsible for a lot more. A Swedish report recently estimated that Swedish households are indirectly as well as directly responsible for 87–89% of all the CO_2 emissions caused by the entire country (Carlsson-Kanyama & Assefa 2007). Finding means to address the energy use in our homes is therefore of the utmost importance.

But to do this we of course need to understand what motivates and drives energy use in the homes. It is clear that while the energy conservation strategy implemented by the commercial sector – the use of more energy efficient technology – has so far been very successful, such measures have worked less well in the domestic setting. We will now turn to a more specific discussion of the energy use in our homes in order to look for a possible explanation of this.

Consumption in the home

Our homes today are full of electric appliances. In any average home we therefore need only to look around us in order to perceive our dependence on energy. But how did this situation emerge? Is it by design or is it a natural development stemming from our basic needs?

Our dependency on energy is clearly not new. Ever since humans learned how to use fire, some 0.5–2 million years ago, energy has been vital to our survival (Wikipedia 2010). The use of fire enhanced human abilities so that more kinds of food could be eaten and places previously too cold to inhabit could be settled. But it is perhaps not these properties of energy that are in focus in today's homes.

As technology – our tools for using energy – evolved, so did human use of energy. The most notable change in this regard took place during the last 160 years (Moan & Smith 2007), after the start of the industrial revolution. During this time, advances in technology, such as the steam engine, gave humans the ability to mechanize labor. This also led to a huge increase in the demand for energy, which in turn led to a shift towards the use of fossil fuels.

This increase in energy demand was at the time mainly driven by the industry sector. Energy consumption in the homes at the beginning of the twentieth century still mostly served very basic functions such as heating, cooking, and providing light. But with the introduction of electric light, and later kitchen appliances, this gradually started to change.

Energy companies at the time had similar problems as energy companies today. Since the demand for electricity can be quite high during certain, hours and low during others, the companies needed to maintain a high and costly production capacity on stand-by during many hours of the day. However by promoting the use of electric kitchen appliances, electric companies such as AEG hoped to be able to increase the demand for electricity during the daytime.

Considered to be the first industrial designer ever, Peter Behrens, a German artist and architect, has been credited as the initiator of this development (Raizman 2003). In 1907 he was employed by AEG to develop electrical appliances and promotional materials for this purpose. In a hugely successful strategy, consisting of a combination of branding and design, he managed to boost the demand for electric kitchen appliances.

In the Behrens series of kitchen appliances, materials, finish, and handles could all be varied in accordance with customer choice due to a modular design approach. This enabled AEG to offer appliances for a wider range of customers with many different kinds of taste and preferences, while the core elements in the devices remained the same.

The ever-growing range of domestic electric appliances today not only includes kitchen appliances but also computers, TVs, mobile phones, and all sorts of other gadgets supporting a wide range of needs including self-realization, entertainment, and social interaction (Raizman 2003). While the ulterior motive of increasing energy use might no longer be the goal of manufacturers of electric appliances, the mission of promoting the desire for their products still very much is. The modular design approach, making products configurable to fit all kinds of preferences, is still being practiced on a broad scale. Design has without doubt become an important tool not only for finding solutions to problems, but also for stimulating our desire to buy commodities.

Tying back in to the previous chapter, we can recall that technology is inherently persuasive, as both Redström (2006) and Buchanan (1989) have pointed out. In Peter Behrens's example we can see just how intentional this persuasion can be. Reframing products through design to show them from their best side often conceals their energy use, as energy use *per se* is not usually seen as adding value to a product. This is the case despite the fact that increasing the demand for energy is no longer an ulterior motive. Because manufacturers naturally want to focus on the benefits provided by their products, operational costs associated with energy use are not something accentuated in design. (Of course, this concealment is also to some extent related to safety issues).

The values emphasized in the design of a product are, however, also a reflection of our values as consumers. As public opinion and regulations are starting to change, we also see a growing need for companies to communicate the benefits of a product in terms of, for example, its low energy consumption. So far, however, this has mostly been achieved through different forms of certification or branding rather than through the interface or design of products.

The social perspective on consumption

An additional factor that might partly explain the abundance of electric devices as well as increased energy consumption in the home is the social context. Materialism is often connected to notions of luxury, excess, and hedonism (Miller 1995 in Shove & Warde 1998). In sociology, it has also been argued that so-called *conspicuous consumption,* i.e., lavish spending to impress the surroundings can be explained as stemming from individuals' generic need to attain or maintain social status (Veblen 1899). The materialism that results from this striving is generally considered to contribute to resource waste (Gabriel & Lang 1995 in Shove & Warde 1998).

Lower-class social groups will, for example, try to achieve higher status by imitating social groups higher up the ladder in terms of consumption and activities. Because groups with higher social status will in turn try to find new possessions and practices to differentiate themselves from the lower classes, an endless consumption loop is created, in which new items must always be acquired and discarded to maintain the status quo (Hirsch 1978 in Shove & Warde 1998).

With this in mind, the importance of addressing the home becomes apparent. As any resource saving measures applied by industry are likely to mean that goods can be sold more cheaply, there is a risk of increasing the total energy use. This is because individuals will then have the ability to consume and use more products to indicate social status. In this connection it could, of course, also be argued that energy saving measures targeting the home will only free resources to be spent on other forms of consumption. Energy saving measures will, in other words, only reallocate resource use.

This view on the sociology of consumption is, however, as Shove and Warde point out, an oversimplification. To begin with it could be questioned in terms of its view of a one-dimensional hierarchy. While this might have been more true a hundred years ago, when Veblen first coined the term conspicuous consumption, we today find ourselves in a much more pluralistic society. There are also plenty of examples of practices trickling up in the hierarchy rather than down (Shove & Warde 1998).

In this regard it can be argued that we today have many different groups with their own preferences and value systems competing as to which is superior (Bourdieu 1984 in Shove & Warde 1998). While comparing does still go on, both within and between groups, it seems, as Shove and Warde put it, to be less serious and more playful in nature. There are also no self-evident environmental consequences of social comparison. For example, social groups exist such as vegans, neo-greens (Wired 2006), or grungers whose ideals and preferences generally have neutral or even positive effects in regard to resource use.

The overall argument that social interactions play a key role in shaping consumption behavior is, however, still the same in this regard, but through this more detailed understanding of the sociology of consumption we find insights into how the increased energy use in our homes might better be addressed. For instance it points towards the importance of addressing resource use as not only an economic problem.

Apart from *social comparison* we can also understand the mechanisms behind resource consumption (in a conspicuous context) through theories involving *identity* – that is, how who we are is communicated through what kinds of goods we own. The way we engage in carefully decorating and designing our homes is an example of this. Social comparisons aside, becoming a green consumer can, of course, also be understood as an identity-building factor.

But, as Shove and Warde also point out, the mechanisms involved in both social comparison and social identity are more useful for acquisition or display of the objects than their daily use. One could, of course, argue that using one's car could be a way of showing off and gaining status. However this does not generally translate into how we use domestic appliances. We do not normally heat excessive amounts of water on the stove, or lower the temperature in our fridge, just to show off.

In this way it also becomes important to talk about the mechanisms behind inconspicuous consumption (Shove & Warde 1998). While the use of washing machines and the frequency with which we shower admittedly can be points of comparison, they are so only to a certain degree (ibid). And while plumbed bathtubs and washing machines were once a novelty, they are now the norm in most western countries, and therefore less important from a social comparison point of view. According to Shove & Warde (1998) the inconspicuous use of energy is more often a trade-off between time and resource. In the way our use of energy replaces the once manual tasks of chopping wood, etc., with flipping a switch it also creates convenience and frees up time for other forms of activities (Shove & Warde).

Once again connecting back to Redström and Buchanan (Redström 2006), we can say that the promise that technology today brings to our homes is very much that of saving time and effort to allow us to engage in other more fulfilling tasks. But at the same time we now also have an entirely new class of energy consuming appliances offering the very opposite of saving time, for example, by providing means for leisure. People amuse themselves by engaging in different forms or playful and experience-centered activities such as playing computer games, watching movies, taking care of their gardens, and so on. The leisure class as Veblen refered to nowadays incoperate most people in the develop countries (1899). If we simplify this a bit, we can even go as far as to say that the core argument of technology design in our home today is to provide means or opportunities for leisure. This can either be by saving us the time we need for it, or by providing the leisure activities to spend the time saved.

Of course in reality these two categories, saving time or providing means for leisure, often merge in design. Many functional appliances in our homes possess both esthetic and engaging qualities alongside the functions they fulfill (chapter 11). But from the perspective of designing for energy awareness, perhaps this division makes it clear why it could be more suitable to frame energy feedback design as leisure time activities. While awareness requires attention, it rarely saves us time.

Another conclusion from this discussion is how visualizing something can reshape its social context by turning it into a point of comparison or an identity communicating factor. Shove & Warde use the example of cavity wall insulation versus double glazing to illustrate how visible energy conserving measures are preferred over non-visible measures. Even though cavity wall insulation is more cost effective in terms of reducing energy use, people still tend to a larger extent to install double glass windows, which we can speculate also has the ability to fill a social function (Shove & Warde 1998).

While the inability to address our resource use of electricity is often explained as due to a lack of knowledge (e.g., Pierce et al. 2008, Matsukawa 2004), we can, with a sociological perspective and the example of double glazing, also argue that the lack of interest is a result of the very inconspicuous role resource use plays in our social life. In other words, it is not that that energy is difficult to understand as a result of its concealment that makes it hard to address, but rather that it, because of being concealed, becomes uninteresting from a social perspective.

What we can conclude from the discussion so far is that when it comes to designing for energy awareness, social aspects will play a crucial role in how the design acts to attract our interest, shape behaviors, and form identities. When visualizing energy we consequently need to address these social dynamics in order to make the design fit into a home context in terms of what it offers, but also in order to achieve the intended persuasive effects. From this observation we will now look at how energy conservation is dealt with in the home today.

Conserving energy in the home

The energy crisis in the 1970's generated an increased interest in energy conservation. In many countries, this led to research being conducted in the area, as well as rules and regulations to promote energy efficiency. A lot of the work regarding energy efficiency focused on the technology aspects of the problem, i.e., inventing more efficient machines, better building materials, and so on. While these measures have been successful in some segments of our energy use, such as for example in the sector of white goods (Harrington & Brown 2007), they have so far still failed to address the overall consumption trend of increasing energy use in the homes (IEA 2008).

In the pioneering work of the so-called Twin River project (Socolow et al. 1978), people's behavior was also investigated as an important factor for energy consumption in domestic housing. This multidisciplinary project found that the inhabitants' behavior could play an even larger part in energy consumption than, for example, the materials from which the house was built. In additional studies it could also be shown that giving the inhabitants of a house feedback on their energy consumption had a positive impact on their behavior. After having received feedback in the form of written notes posted in a slot outside their kitchen window, participants in the Twin River study saved between 10–15%.

Due to the current crisis, conserving energy is now once again a very pressing issue. The topic is currently being addressed in several ways, such as through information campaigns and legislation. The European Union has, for example, introduced legislation regulating the use of electricity during stand-by mode in products, as well as the use of energy inefficient technology such as incandescent light bulbs. Other measures being discussed include the use of global CO_2 taxes.

There is also a very dramatic shift in public opinion going on in regard to energy consumption. While global warming and peak oil used to mostly be a concern of the traditional environmental movement or climate researcher, we have in recent years seen a lot of engagement start to appear among both public and commercial interests (e.g., Stern 2006). Concern for the environment has in a sense become trendy.

With the explosion of ecological goods in many parts of the world, new social groups are emerging whose conspicuous consumption is directed towards green commodities such as hybrid cars, ecological clothing, and trendy, energy-efficient houses with photovoltaic power generation and so on (Wired 2006). Concern for the global climate has without doubt become a point of social comparison or an identity-shaping topic (e.g., Tengvard & Palm 2009).

In response to this, and of course also to the more serious debate surrounding global warming and the ethics of our resource use, we find rapidly growing concern in the general opinion worldwide. In a European study, 80% of the participants claimed to be worried about climate change (Logica 2007). In a global survey in connection with the international climate conference in Copenhagen 2009, about two-thirds of the participants stated that they found the issue of global warming to be “very serious” (Globescan 2009). In a British study with 2,000 participants, commissioned by a provider of so-called smart metering systems, about 75% also claimed to be willing to change their lifestyle in response to global warming and rising energy prices (Future foundations 2006). About 50% expressed that they could even go so far as to actually change their everyday habits.

Despite the evident concerns of home owners concerning energy use, and the possibilities available for them to address these concerns, we have yet to break the trend of increasing consumption in our homes. In other words, there is still quite a large gap between people’s opinions and their actual behavior. This gap can be explained by factors we have already discussed such as a lack of understanding, the transparency surrounding the use of energy, the lack of social focus on resource consumption or the ambiguity of our use of energy.

While most of these factors seem to point towards visualization or feedback in some form, the reasons for these feedback systems are, of course, of importance in terms of the design of such appliances or services. If saving energy were just about reducing the amount of electricity used, this design would be very easy. This task, however, is in many respects a very complex one involving the delicate matter of finding a balance between energy saved and many of the benefits its use brings us in our daily lives. This task requires both our attention and our thoughtful consideration. In terms of performing these measures it involves finding those situations where these actions make the most sense and incorporating them into our daily routines. It requires changing our energy behavior to coexist with both everyday needs and personal aspirations.

When it comes to energy feedback systems, we can see today a number of commercial examples emerging. To conclude this chapter we will provide a few examples of such systems to use as a starting point in our discussion of energy feedback design.

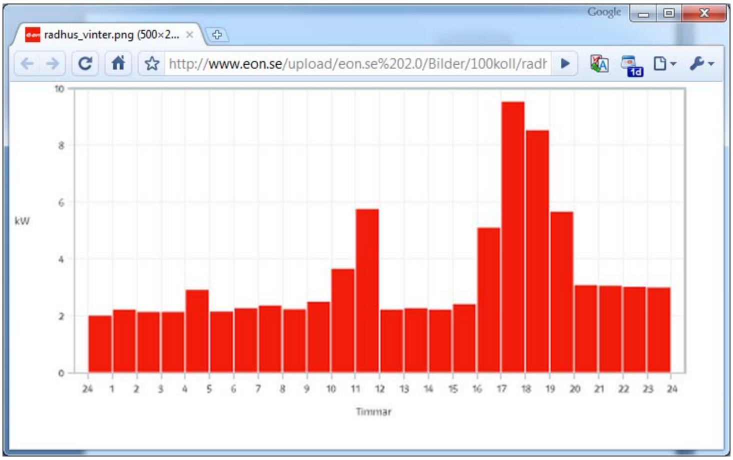


Figure 1. Web service for feedback on energy use by E.ON.

Figure 2. Left: Electrisave an wireless consumption monitor for overall energy use in the home. Right: A plug in consumption meter for measuring a specific device.

These examples encompass the typical energy service provided by the electric utility company (see Figure 1) that builds on so-called automatic meter reading system (AMR, also referred to as smart metering). AMR is a system installed by electric utility companies to automatically monitor the energy use of their customers for debiting purposes. Due to the limitations of the AMR network, these services typically provide hourly resolution with the customer able to view the energy use the day after it occurred. These services generally display energy consumption in terms of cost and kilowatt-hours. The feedback is normally accessed through the electric utility companies' webpage by logging in with a customer ID and password.

We also provide two examples of physical displays designed for use in the home. These function by either measuring the combined use of energy with a centrally placed sensor (see Figure 2 left) or individual consumption of appliance though a plug-in design (see Figure 2 right). The feedback in these displays is given in kilowatt-hours, but often with a design focus on the cost associated with the consumption. In some cases they can also provide an estimate of resulting CO_2 emissions.

Common to all three examples is that they in their form and function are framed as utilitarian tools, tools that are constructed to make it an objective as well as simple task to measure consumption (Pierce et al. 2008). In this way they can clearly be seen as form of persuasive technology filling the function of a *reductive tool* (Fogg 2003). The persuasive effect of these systems can, however, be questioned.

In a statistical survey performed on the commercial web service provided as an example here, as well as two other similar commercial services, no indication of reduced energy consumption could be found as a result of their use (Ersson & Pyrko 2009ab, Pyrko 2009). In a Japanese research study on a non-commercial system that in a similar fashion employed graphs of consumption with hourly updates, it was also concluded that no effect on energy consumption could be measured (Matsukawa 2004).

In order to change behavior with regard to energy use we obviously need to provide something more than just a measurement of consumption. In the context of the home the products or services provided as examples here, we argue, offer little in terms of experience. By being designed from a utilitarian perspective, both in terms of form and function, they become abstract and simplistic and in many regards uninteresting. In this way they also fail to bring attention to energy use.

Chapter 4

A positive persuasion strategy

Based on our knowledge of the context of the persuasive-technology argument we can now start to outline what incentives our persuasive-technology argument might offer the user. This offering is made both through the function as well as the experience the persuasive-technology argument brings. We will here start by addressing the function of the argument, i.e., its role as a *tool* (Fogg 2003) to address some already existing concerns among its users.

We have concluded that as the argument is judged, among other things, according to the message and ethics it conveys, that it for this reason is limited to a context where the intended users at least to some extent approve of its message. As we saw in the previous chapter, we also find broad concern among people in regard to the topic of energy conservation which motivates the use of persuasive technology in this context. But what exactly is it that persuasive technology offers in terms of its function, and can one really speak of persuasion in this case, when people clearly already have concerns in this matter?

Atkins (2006) has, for example, questioned the notion of persuasive technology as a tool (Fogg 2003) on the grounds that one, according to her, cannot persuade oneself. But this view, we would argue, encompasses a very simplified perspective on the matter that disregards the many complexities involved in opinions we hold and choices we make in daily life. When it comes to our use of energy, there are obviously several opposing needs or ambitions involved. Although most people seem to have a quite positive attitude towards saving energy (Logica 2007) it might not be their top priority in daily life. In reality, a task such as saving energy might collide with everyday concerns like picking the kids up at school, making dinner, or doing the laundry, or with leisure activities such as playing computer games or watching a movie.

Our attitudes are often both complex and ambiguous (Albarracín et al. 2005). They are ongoing evaluations based on the current situation, our knowledge, previous thoughts on the subject, social pressures, and identity, as well as several other factors (Albarracín et al. 2005 p II.79–125). We can therefore possess multiple and even opposing attitudes towards an issue (ibid). In the flora of needs and concerns surrounding a topic such as energy consumption, persuasive technology in positive persuasion contexts can no doubt play an important part in helping us to find a balance between needs and concerns. In this regard persuasive technology offers a way to reshape our lives into something we perceive as better. The prototypes suggested in this thesis all perform the function of revealing and reframing energy use and consequently also become tools for people to do precisely this.

In the particular context dealt with in this thesis we have argued that this function performed by the prototypes is perhaps more a task of bringing attention to our use of energy rather than providing quantitative information about it. It is, in other words, mostly a question of timing cues and providing a "top of mind" effect, and not so much a problem of providing objective measurements of the kilowatts used. But attention is also important here for a more general reason, when it comes to persuasive technology.

A basic condition for a persuasive-technology argument to work is that it needs to be used. To motivate use in a home it consequently needs to be able to compete with other forms of activities in this setting. Two important questions therefore become: What is it that a persuasive-technology argument has to compete with and what is it that can make a persuasive-technology interesting in the context of a home along with its function to address a concern of some sort?

As we saw in the previous chapter, we can find a number of things that can be said to be more or less distinguishable for the context of the home. These include the focus on leisure and identity-building activities such as playing computer games or decorating one's home. The home is, of course, also a social arena where we spend time with family and friends as we engage in these activities.

On a general level, what a persuasive technology has to offer could, as suggested by Redström, be something intellectual or, as suggested by Bogost, be an opportunity for experience. A comparison between rhetoric and persuasive technology is sometimes also made (Tørning

2008). Viewed from a positive persuasion perspective, a rhetorical situation can in many cases also be regarded as an intellectual experience. The persuasive argument might in other words offer a way to try out one's beliefs when a person is unsure of his or her own position on a matter. It might in a similar way offer a means to address curiosity and stimulate exploration. An offering framed in an intellectual manner can in this way become both a leisure activity and a form of identity building, while at the same time educating users about energy use.

What a persuasive-technology argument could offer obviously might also be provided by means of esthetic experience. The esthetics of a domestic persuasive-technology argument, we argue, plays an important role. This is because apart from motivating the use and exposure of the persuasive-technology argument in the home, it also motivates the artifact being bought and brought into the home in the first place.

While the energy feedback systems presented in the previous section clearly aim for an inconspicuous appearance in terms of their esthetics, they do not fit well into, for example, an identity-communicating home-decoration context. While this design ambition could be seen as an attempt to be both neutral and objective (Pierce et al. 2008) in order to fit into any home, there is of course no such thing as neutral esthetics. Consequently these designs will appeal to a particular kind of user.

A conclusion from the Peter Behrens example is that we will need not one, but many forms of esthetic expressions for energy feedback systems in order to target the multitude of preferences present among users. Still, most energy feedback systems today seems to be aiming for the inconspicuous and objective appearance that we have seen in the examples referred to here. We consequently need to explore new ways in which energy feedback can be conveyed in terms of its visual properties.

From a social perspective there are, of course, also a number of ways in which a persuasive-technology argument can offer an enjoyable experience. This could be as a social conversation piece, something that we can engage with together with family and friends, or something used as an instrument for persuasion among family members. The way the persuasive technology facilitates the social interaction surrounding it is obviously of interest in this matter.

As these incentives combine intellectual, social, and esthetic ingredients, it is also relevant to look at how they can be constructed with an interactive system acting as the medium. As also Bogost has suggested, we need to consider the more specific properties of computer technology in this regard (2008). As an inherent property of any interactive system, we find its ability for manipulation and interactivity (Eskelinen 2001), i.e., the possibility for the user to configure and change elements in a system, to be one of the key components.

While the theoretical framework in the persuasive technology field provides limited insight into how an offering suitable for the home can be integrated with a persuasion goal in an artificial and interactive medium, many of the applications available do. In the area of serious games, researchers and practitioners have, for example, long tried to address precisely this issue. Games are obviously also a common leisure activity in the home, which makes this knowledge even more relevant for a positive persuasion strategy seeking to find the intersecting points between a persuasive interactive medium and activities in the home. In the field of ubiquitous computing, the many examples of how to integrate interactive computational materials into our homes provides additional insight into how this can be done.

In the next section of this chapter we will therefore first look at how the more general field of digital games research combines intellectual, esthetic as well as social aspects to create engaging, playful, and rewarding leisure experiences, i.e. what by Fogg would be referred to as micro persuasion (2002). After this we will then also look specifically at how so-called serious games, with an explicitly persuasive purpose, combine the game experience with a message to form a persuasive argument i.e. macro persuasion. In the last section of this chapter we will then turn to the field of ubiquitous computing to show how approaches from this area can be used to integrate approaches from game research with the physical reality of our homes.

Persuasion in digital games

Digital games are often designed to engage and entertain the player for no other purpose than to provide amusement. In this sense, games research provides a unique understanding of how to not only persuade, but also engage people in a computer context without any utilitarian purpose. Most games accomplish this by following a looping pattern of effort and reward (Salen & Zimmerman 2004). In this process, the effort is tightly connected to the reward in that the reward would not be rewarding if there were no effort.

It is in this, not the concrete graphical representations of rewards such as points gained or resources collected, that constitutes the true incentive for engagement. While these are mere symbols of our actions, it is instead the mental process underlying play and the emotions it creates that turn an experience into something rewarding. In order to begin to understand the persuasion in digital games we consequently need to understand the emotional elements associated with the very fundamental human activity of play.

Elements of play

Since the engaging aspects of play were known long before the arrival of computer games, the research in this area precedes that of digital games. In his book *Homo Ludens,* from 1938, Johan Huizinga, a Dutch historian, addressed this phenomenon and the role that play has in society. As he points out, play holds a central position in both human and animal life and therefore seems be both older and more generic to us than culture at large. He also points towards the non-utilitarian function of play as being part of the very essence of play and criticizes the many attempts of science to find the purpose or function behind games.

Others such as Caillois (1961), in this pre-digital era, also addressed the nature of play. In an attempt to distinguish between different forms of play he divides it into four basic elements (competition, chance, simulation, and vertigo). He also suggests a continuum where different forms of play can be placed. This continuum ranges from at the one end *ludus*, i.e., rule-bound, structured games, which would encompass most of our modern digital games, to at the other end *paidia*, free spontaneous games such as for example playing with a pen while reading.

As computer games became common in the 1980s, the research into the area of digital games grew rapidly. New terms such as flow, immersion, and magic circle were either invented or imported from other areas in order to describe the games and their engaging aspects.

Brigid Costello and Ernest Edmonds (Costello & Edmonds 2007) have recently done a good job of summarizing some of the key concepts in the area of digital game research to derive a comprehensive framework for analyzing and understanding play in interaction design. They do this by

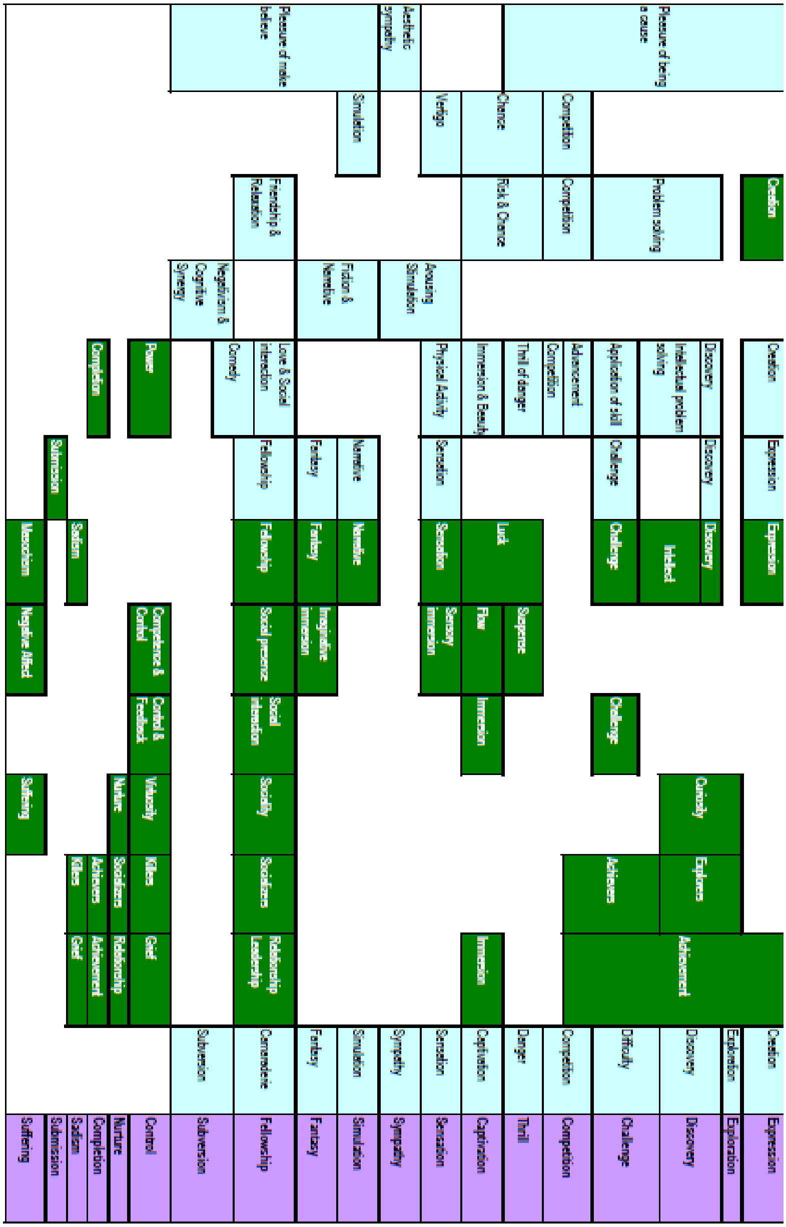


Figure 3. The PLEX model from Korhonen et al. (2009)

combining some of the overlapping concepts found in the literature to finally yield a framework consisting of 13 different elements of game-related pleasures. This framework has later been expanded with another six categories by Korhonen et al. (2009) into the PLEX model (see Figure 3). Both Costello and Edmonds's model and the PLEX model have the categories of expression/creation, exploration, discovery, challenge/difficulty, competition, thrill, captivation, sensation, sympathy, simulation, fantasy, and fellowship.

The PLEX model further adds control, nurture, completion, sadism, submission, and suffering. While many of these categories appear self-explanatory they might however require in-depth understanding based on their origin. One category that it could be argued is missing here, which is of importance in order to understand the limitations of persuasive games, is the emotion of escape. This is the pleasure of escaping from the "must do" of everyday life (Salen & Zimmerman 2004, Royse et al. 2007).

With the proposed framework an interactive experience can be understood as any combination of the suggested emotional elements. In this combination, each of the different elements can have a more or less pronounced role. In terms of the prototypes presented in this thesis, elements such as exploration and discovery are obviously central. We can, however, also find elements such as:

> Expression/Creation – The pleasure of expression is the enjoyment of creating something, expressing oneself, or feeling in control. In our case, the pleasure of viewing the result of one's manipulation.
>
> Captivation – The pleasure of captivation is the enjoyment of being focused on and immersed in the task, causing unawareness of the surroundings.
>
> Sensation – The pleasure of sensation is the enjoyment of tactile interactions with the game.
>
> Simulation – The pleasure of simulation is the enjoyment of observing real-world things recreated in games.

In terms of the more game-oriented prototypes presented in this thesis we also find:

> Competition – The pleasure of competition is the enjoyment of achieving or progressing towards a defined goal.

Challenge/Difficulty – The pleasure of difficulty is the enjoyment of having to develop a skill, to exercise skill, or pushing one's boundaries.

Thrill/Danger – The pleasure of danger is the thrill of being exposed to risky or unpredictable events.

Fantasy – The pleasure of fantasy is the enjoyment of perceiving imaginary things or worlds.

Fellowship/Camaraderie – The pleasure of camaraderie is the enjoyment of developing a sense of friendship with in-game characters or other players.

Subversion – The pleasure of subversion in the enjoyment of breaking rules or seeing them being broken. This can be game rules or real-world rules that are broken in the game world.

As this example shows, a game or interactive and playful design will usually relate to quite a number of the proposed categories. These categories also span over intellectual, social, and esthetical properties in the design, as discussed in the previous section.

While these kinds of abstract frameworks admittedly tend to lose many of the finer details and meanings behind the original concepts on which they are built, they obviously provide a powerful way to interpret the non-functional and persuasive aspects of an interactive situation. Although how to map these emotions onto design is far from self-evident, the different elements also give us clues about how to design for playful experiences.

When it comes to exploration and discovery, for example, the size and richness of the space to be explored is obviously of importance. If we offer nothing to discover, or perhaps only the same or very similar things over and over again, one might expect people to lose interest. Hence, one way to support engagement with regard to energy use is to provide a detailed and expressive form of feedback that displays the unique properties of every device.

To support challenge we must (in line with theories of flow which is one of the theories behind challenge in the PLEX model, Salen & Zimmerman 2004) offer clear goals and ways to determine ones progress in terms of these goals.

In a social context surrounding energy conservation an energy saving game could, for example, also utilize the pleasure of subversion. Some examples of this could be kids getting away with turning off their parents' TV during one of their favorite shows or turning off all the lights in the house as we will later see examples of. But also in the way that people could feel that by saving energy they can rebel against the large, profit-driven energy companies (Tengvard & Palm 2009)

Persuasive games

The power of digital games to engage people has long been recognized by researchers, parents, teachers, and marketers. In so-called educational, serious, or advergames many have sought to harness these powers of computer games and utilize them towards a persuasion goal like getting people to learn certain subjects, practice skills, or develop a positive attitude towards a brand. In this way, digital games have been explored as a means for what Fogg refers to as macro persuasion.

As mentioned earlier, the persuasion approach used in digital games uses a combination of effort and reward to generate a diversity of emotions or a desirable state of mind. In serious, educational, or advergames the effort is directed towards a specific goal. From a designer's perspective, designing educational games therefore often requires that you balance the message and the gameplay, or find a way for them to coexist, something that has often proven to be difficult.

Bruckman (1999) has critically referred to the strategy of using play and fun to reframe a supposedly boring task as a "chocolate covered broccoli" approach. As Bruckman points out, it is important that the game experience be integrated with the learning. In situations where it is not, the learning games can even have negative effects on learning, as the game, by communicating the designers' underlying assumptions, provides students with the message that games are "fun," while learning in contrast is "boring."

Linderoth and Bennerstedt (2007) also criticize the use of computer games as carriers for learning and persuasion on the assumption that the medium is misunderstood from a learning perspective. Playing digital games has traditionally been seen as a task of identifying and making sense of objects as well as constructing meaning. Linderoth and Bennerstedt, however, point out that playing games is more about finding and differentiating between options for how to interact with the game.

This analysis is performed through the use of ecological psychology (Gibson 1986). In other words what is important to the player is not what an object symbolizes, but rather what affordances it possesses in relation to the game mechanics. In a game, a lock could be something that can be opened to progress further into the game, but it could also just be decoration. Since differentiating between the two in this case is very tightly connected to the details and expressions in the medium, the process of transfer (Gagné et al. 1948), i.e., applying knowledge gained in one context to another, becomes difficult. The result is that players tend to learn the medium in terms of graphic details revealing such affordances and not the persuasive message communicated though symbolic or metaphorical meanings.

While Linderoth and Bennerstedt make an important point with their argument, it should be obvious that players of learning games do not always fail to reflect on objects in games. This phenomenon can also be understood through the so-called dual process theories of social psychology models such as the elaboration likelihood model (ELM) or the heuristic-systematic model as Svahn suggests (2009). This model states that there is an elaboration continuum which ranges from low cognitive elaboration (the peripheral route or heuristic processing) to high cognitive elaboration (central route or systematic processing) in terms of how we process things we encounter.

Where the processing of something in our surroundings ends up on this scale depends on factors such as our need to understand it, as well as the cognitive resources we have available in terms of, for example, time or attention. This reasoning is very similar to Simon's notion of bounded rationality (1982). As games, and especially those that are captivating or immersive in nature, tend to put a lot of cognitive strain on the players, this could account for a tendency towards peripheral route processing in games, resulting in the symbols or metaphors in the game not being actively reflected on.

A common solution in serious games to facilitate transfer is to incorporate debriefing sessions or breaks in the gameplay during which more active reflection can be facilitated (Henriksen 2006). These can be integrated into the game structure directly or be initiated by an instructor or teacher after a gaming session.

Svahn (2009) has also suggested a framework using the ELM model, Caillois's notions of ludus and paidia, as well as the level of integration between message and game to predict the effects of a persuasive game argument. In his framework, the cognitive effort that the game requires depends on how structured versus casual a game is. The need to understand something is equally determined by the novelty or unfamiliarity of the object or, alternatively, how well integrated the message is within the gameplay.

Persuasive technology in the form of educational, serious, or advergames provides an interesting proposal for how an interactive and artificial argument can be created by combining play with a goal. The metaphor of "chocolate covered broccoli," coined by Bruckman, was meant primarily as a reference to the many bad examples of learning games. Still even in the good examples this can be identified as the fundamental assumption through which serious games can be understood.

This metaphor can also be applied to the persuasive technology strategy suggested here. The experience offered can, in this case, be seen as the chocolate on top of the energy-conservation broccoli. But as we have argued in this thesis, the persuasion goal is in this case also part of the incentives to some extent. The energy conservation message could in this case in some respects be seen as chocolate as well. What we offer in terms of experience must, of course, also match the users' preferences or it will more or less turn into broccoli.

What is important, of course, is not what is broccoli and what is chocolate, but that the combined properties of our persuasive-technology-argument motivate use by the intended audience. The task of persuading can be said in this regard to be the task of finding a compelling framing for the topic of energy conservation.

Although as pointed out, using this strategy can be hazardous, there seem to be clear rules to avoid potential pitfalls. To avoid sending the wrong message, as Bruckman warns us against doing, we must as designers entertain a positive picture of the subject at hand. We must look for the intrinsic fun in the matter communicated and build our playfulness around this to achieve an argument in which message and experience are tightly integrated. In light of Linderoth and Bennerstedt's argumentation we must also integrate the message into its medium. That is, for example, in line with Svahn's reasoning, to make room for reflection on the players' behalf by stimulating the user's curiosity or providing the time and context needed for consideration of the arguments provided.

These guidelines all tell us that integration of message and experience is very important; otherwise people, as we might put it, may just peel off the chocolate and leave what appears to be the broccoli. To gain further insight into how message and experience, and their medium, can more concretely be integrated we will in the following section approach the field of ubiquitous computing. In this field we find technical concepts that provide examples of how playful, esthetic, and social persuasive-technology arguments can be integrated into the physical space of our homes.

Ubiquitous computing

Ubiquitous computing (Weiser 1991) is a vision in which computer technology has been integrated into our entire artificial world and all artificial things have been seamlessly networked and connected to enable new forms of interaction. In the approach used in this thesis, this research area plays an important role through its endless number of design examples focusing on the home and how technology can be integrated into this environment. In this section we will briefly describe two key concepts from the field of ubiquitous computing that have been of particular inspiration for this work, namely ambient displays and pervasive games.

Ambient displays

An ambient display can be said to be a physical device that communicates simple forms of information though subtle cues in the form of sound, light, or movement. In this way it provides a mode of interaction where it stays present in the periphery of your mind and only receives your full attention when needed. The idea behind the *ambient display* originates from Weiser and Brown's notion of calm technology (1995) although the term ambient was not coined until later in work by Ishii and Ullmer (1997).

With examples such as telephones, pagers, email alerts, and so on Weiser & Brown saw the need for less disruptive forms of information technologies. The way to achieve this, according to them, was to study, as well as mimic, how we interact with the physical things around us. As a good example of how this could be done they discuss an installation called the "Dangling String" created by the artist Natalie Jeremijenko.

The Dangling String consists of a small electric motor connected to the signals of an Ethernet cable and a plastic cable connected to the rotor of the electric motor. As network packets pass the motor the plastic cable will twitch. This means that if network traffic is low, the cable will hang still. When, on the other hand, network traffic is high, the cable violently flaps around to, among other things, create a characteristic noise.

Weiser & Brown explain the function of this prototype as follows:

> The dangling string increases our peripheral reach to the formerly inaccessible network traffic. While screen displays of traffic are common, their symbols require interpretation and attention, and do not peripheralize well. The string, in part because it is actually in the physical world, has a better impedance match with our brain's peripheral nerve centers. (1995)

In later work by Ishii and Ullmer ("Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms" 1997) this concept is taken further by investigating how subtle cues in the form of light, sound, airflow, and water movement in an architectural space can be used to communicate information. In one of their installations a flotation device was used to cause ripples on the surface of the water in an illuminated tank in response to web activities. The ripples in turn produce a play of shadows throughout the room.

There are several ways in which the ambient display concept becomes relevant in terms of a persuasive technology message in the home. In relation to other forms of digital interaction one can say that an ambient display, by connecting the physical and the digital in a very specific manner, provides a form of information economy. This information economy can very effectively be used to extend our awareness by letting us effortlessly monitor and receive simple forms of digital information in a very natural way. Since our attention always needs to be shared among many different activities in the home, this provides us with a powerful way for persuasive technology to fit in and coexist with other things in our homes.

The many examples of ambient displays also provide an interesting approach for how to combine a message with aesthetics. In the two examples provided here, considerable efforts have obviously been made to address esthetic qualities. In the first example, the metaphor of a cable twitching violently as the result of the data flow has an entertaining twist to it. In the second example, by Ishii and Ullmer, involving a flotation device that produces ripples on the water, there is instead a poetic touch to the concept. In a home-decoration context this esthetic approach can obviously have an appeal, while at the same time be strange and dynamic enough to remain engaging.

Pervasive games

Pervasive games (not to be confused with persuasive) are often referred to as games that extend beyond the traditional interface into the real world in some way. The term pervasive computing is often used as a synonym for ubiquitous computing. Pervasive games can therefore be understood as an ubiquitous computing paradigm fitted onto the area of games. While the actual definition of these kinds of games is still under some discussion (Nieuwdorp 2007), these kinds of games typically rely on some form of sensory input connecting the game logic to real-world events beyond ordinary computer interfaces.

One of the more common types of pervasive games are so-called location-based games where the players' location, usually monitored through a GPS system, is used as an input to the game. Montola et al. (2009) have suggested that one can view the reality expansion in pervasive games as consisting of a spatial, temporal, and social expansion. Compared to traditional desktop games, the players of pervasive games are typically less constrained to one place and as they move around they typically encounter non players to a higher degree. Also, these kinds of games tend to be more drawn out in time. These properties are in varying degrees incorporated and made use of as a resource in the game design. Pervasive games can, for example, often rely on the social interactions they create with non-players in the gameplay (Niemi et al. 2005).

A classic commercial example of a pervasive location-based game is Botfighter (Brunnberg 2008). This is a game that you play by sending text messages to a game server from your mobile phone. By sending, for example, a text message with the word "scan" you will receive a list of players currently in you vicinity. You can then move towards these players and, when in range, text the word "shoot" in order to attack them. The other players will however by then have received a proximity alert and might have either fled or taken counter measures.

Pervasive games, like ambient displays, have several properties that make them relevant for persuasion in a domestic context. Because pervasive games though their gameplay have the ability to twist the meaning of objects in reality (Brunnberg 2008), they become powerful from a persuasion perspective. In this way they can reframe our everyday notions and enable us to see things from new perspectives. By actually making reality part of the medium, and at the same time by means of social expansion facilitate and use social interaction in the gameplay, we can also see how pervasive games offer a solution to the problem of transfer in learning. As social game experiences, pervasive games could potentially also fit well into a home context.

Chapter 5

Framing the design space

This thesis aims to investigate how IT and design can be applied to the domain of domestic energy conservation to increase awareness of energy use or promote more sustainable behaviors. The approach chosen here involves the use of persuasive and ubiquitous computer technology with a user- and experience-centered perspective. Our aim has been to both motivate and educate in terms of personal energy consumption building on the intrinsic fun and social values of performing these tasks. In this regard we try to design for intuitive and esthetic understanding of everyday use of energy, playful engagement with feedback on energy use, the reframing of everyday energy-consuming activities, as well as social interaction in regard to resource use. In this chapter we will briefly revisit the discussion from chapters 2–4 before summarizing the central questions in this work.

Approaching the domestic setting

We have so far argued that the home plays a very central role when it comes to addressing global energy consumption. This is because a major part of the global use of energy can directly (IEA 2008) or indirectly (Carlsson-Kanyama et al. 2007) be attributed to the homes, and because current means to address energy consumption in this sector have largely failed (IEA 2008). While these means for energy conservation often focus on the technology and its increased efficiency they fall short of addressing the complexities of a social setting like the home.

As long as the social identity and status is marked by the number of items we own, any energy efficiency measures will have a limited effect as we will always consume in accordance with the resources we possess (Shove & Warde 1998). The increased efficiency achieved in industry will likewise only lead to cheaper products, which in turn leads to increased consumption in the homes, for example, more lamps, more cars, or more computers (Carlsson-Kanyama et al. 2007). To address the use of energy in our homes a perspective focusing on human beings rather than technology is clearly needed.

Interacting with energy in the home

Energy use in the home is often concealed in the design as a result of both our own values and the manufacturers' need to frame products in a persuasive manner. While electricity in itself is invisible, the technology for controlling it also tends to be concealed inside walls or under the designed exteriors of products. Cables are deliberately tucked away behind furniture out of sight since no one likes messy heaps of cables. The production of electricity, i.e., the conversion of a primary energy source such as coal, uranium, or water into a secondary one such as electricity, might in addition be located several hundred kilometers away from our homes. Our usage of electricity is furthermore predicted and compensated for by energy companies bringing us a seemingly endless, flawless, clean, and reliable resource.

In this way our daily use of energy becomes hard to understand, easy to forget, and uninteresting from a social everyday perspective. While the larger questions in regard to resource use seem to engage people, the energy-related questions involved in the hassle of our everyday lives currently often do not (Logica 2007). To address this we have argued for the importance of addressing interface design in a domestic energy context. This is because interfaces, through the abstractions they perform, in many regards shape what we perceive to be important.

In today's homes there are basically two ways in which we interact with energy: through the interfaces and expressions of our electric appliances, and by paying the monthly bill. Neither of these, we argue, provides a means for addressing our use of energy (chapter 10). The monthly electric bills constitute a poor form of feedback since they are both delayed and aggregated, which makes it hard to connect cause and effect in terms of our energy use. Prices might change and are in addition mixed with taxes and fixed rates. By being just a monthly bill it is also a poor means for bringing attention to our daily use of electricity.

The ambiguous feedback from devices also fails to reframe our use of devices as use of energy. Beneath the surface of a product we do not know much about what is going on. When is a product on or off? How does usage of an appliance correlate to consumption? But while current means for providing energy feedback often focus on providing objective measurements (Pierce 2008) of energy consumption, they often do not work well for bringing attention to our energy use. This is because the problem here is more one of timing the feedback and attracting attention to energy use than one of conveying accurate information. We have here argued that the concepts of *transparency* (Verbeek & Kockelkoren 1998) or *ready at hand* (Heidegger in Verbeek & Kockelkoren 1998) used to describe the use of a tool can here be a good way to view this lack of attention in regard to energy use. A vital question to address is therefore how we can design not only to make energy use more visible and understandable in the context of the home, but also to make it more interesting and conspicuous.

An experience centered approach

The approach presented here employs interactive arguments combining elements of both experience and persuasion. In regard to the prevailing techno-rational or Thackara's design-systemic approach (2005), it can be seen as a largely user- and experience-centric approach to the problem. We argue that such an approach within the field of domestic energy conservation is important for the following reasons.

First of all, we argue that such an approach has the potential to better address the gap between the general concern about resource use and our everyday concerns in the home. By occasionally reframing and attracting attention to our resource use, it can bring about a more conscious behavioral change in the homes than the now prevailing approaches. As seen in previous work (Socolow 1978, Abrahamse et al. 2005), directing attention to energy use has considerable potential for reducing its use.

Secondly, with an experience-centered approach, which values a broad set of concerns in addition to economy, it also becomes easier to approach the topic of energy conservation. By turning everyday consumption into a social activity, or reframing it as a fun and interesting experience, values building on shaping one's social identity as well as enjoying a playful or challenging experience can be utilized. This enables these forms of technology for energy feedback to fit better into our homes where the focus often lies on freeing up time for, or performing leisure activities.

Finally, we also argue that by bringing about an informed and conscious change in the home, an experience-centered approach has the potential to affect the user in a larger context than the specific task for which it is designed. By empowering the user, reinforcing attitudes, and nurturing an interest in the matter, this approach is likely to open doors for other forms of energy conservation technology in the home or behavioral change in a wider context. In this way the approach suggested here can possibly also provide a more holistic view of the problem that, for example, would prevent energy savings in one area from being spent in another area.

Designing for the everyday context

While we view persuasion in the field of persuasive technology to be greatly overrated for the purpose of changing behaviors and attitudes (e.g., Fogg 2003) we still find this approach and some of its methods useful in particular situations, that is, in situations where people are partly, or on some level positive towards the persuasion, as explained earlier.

The key to this is that the arguments provided must also offer the user something interesting enough to compete with other activities in the home. This offering can, as Redström (2006) gives examples of, be intellectual. It can also, as Bogost (2008) has argued, be an opportunity for playful experiences, or as Fogg (2003) suggests, be a tool to address personal concerns. A focus on the use-experience of persuasion technologies in general, as well as when promoting energy awareness in particular, is therefore required.

As we create an offering around our persuasive message we can also learn from the field of serious games both what this offering can be but also how to integrate it with an energy-conserving message into a coherent experience. Within the field of ubiquitous and pervasive computing we can also find additional insights into how this integration in a domestic setting could be performed on a more practical level.

Research questions

Following the above discussion we can now present a detailed set of research questions. In this thesis we will explore how ubiquitous and persuasive computing in regard to the context of use (i.e., the home) and in regard to the context of attitudes and message (i.e., energy conservation) can be used to:

- **Design for positive persuasion –** i.e., how to create a persuasive-technology argument that in an integrated manner offers the *user* something in terms of both function as well as experience.
- **Reveal the transparent and hidden use of energy –** That is, bring attention to energy use by timing cues or reframing everyday activities.
- **Intuitively and esthetically visualize and conceptualize energy usage** – That is, take into account the esthetic and pedagogical aspects of the feedback in order to create understanding and a language for shared experiences. But also how to achieve an esthetical value through interface design related to energy use to motivate engagement.
- **Recreate engagement in regard to energy consumption by means of playfulness** – i.e. how engagement in energy use can be created through means such as playful interaction or gameplay while building on the intrinsic fun of engaging with one's energy use.
- **Stimulate social interaction in regard to energy usage** – That is, to make the use of energy interesting from a social perspective by making it visible and at the same time providing means for interaction and identity-building in relation to this topic.

How to design for positive persuasion

As discussed earlier, a persuasive-technology argument needs to be used in order to be effective. An important question therefore is how to create a persuasive-technology argument that offers the *user* something in terms of experience or personal goals. How a persuasive-technology argument is experienced by the user is, of course, a balance between numerous aspects of the argument in terms of the message it conveys, its esthetics, its pedagogical aspects, who is sender of the argument, how it fits into its context, and so on.

In this thesis we will specifically address how such offerings could be made in the context of the home. In addition to being means to address one's energy use we will here explore how these incentives can be provided through esthetic, social, and playful properties of these interface designs.

A second concern is to explore how the message and the experience can be integrated. A failure in this regard can, as was earlier discussed, lead to no or even counterproductive effects in terms of persuasion (Bruckman 1999, Linderoth & Bennerstedt 2007, Svahn 2009). In this thesis, we will explore design approaches borrowing from ubiquitous computing as a means to achieve this integration.

Revealing the hidden and transparent energy use

In terms of the function that our designs offer, we will in this thesis explore how interface design in the home can be used to reveal hidden and transparent uses of energy. This will be done by, on the one hand, redesigning existing interfaces of physical artifacts in the home, and on the other hand, by utilizing existing metering data to create services in the home that do the same.

Verbeek & Kockelkoren (1998) describe transparency as a property of objects enabling them to be "ready-to-hand" according to the concept introduced by Heidegger (Heidegger in Verbeek & Kockelkoren 1998). We have earlier described the failure to address personal energy use as being the result of, among other things, a lack of attention to its use. As the use of energy is taken for granted in our lives, its use also becomes transparent to us, i.e., "ready to hand." In the case of energy, our attention tends to be directed towards the functions that energy performs rather than its use *per se*.

Feedback directs our attention to the use of energy and in this way acts to reframe our use of energy. Reframing in this sense constitutes the task of getting people to acknowledge their use of electric devices as being a use of energy in addition to being the performance of a task such as doing laundry, watching TV, reading a book, etc. For such a reframing to occur, it is important to look at how feedback is delivered but also how it is expressed.

In order to reframe energy use, consideration needs to be given to, for example:

- the placement of the feedback mechanism,
- the associations created by the visualization,
- whether or not data shown is aggregated consumption information,
- updating the time of consumption,
- the cost of accessing the information,
- the intuitive connection between the display and what is measured,
- and the amount of attention required of the user.

Of course, how these aspects are shaped is often dependent on limitations of the technology involved. And what constitutes the best design in any particular situation is dependent on this context in its entirety.

Mapping the feedback on energy consumption to actual activities is naturally made easier by maintaining a close temporal and spatial connection between use and feedback. But while it might be easy to jump to the conclusion that digital systems capable of delivering hourly updates on consumption might be more effective than the daily update used in the study by Socolow et al., this might not always be the case. While, for example, the study by Socolow et al. (Socolow 1978) produced a savings of 15% in terms of electricity, a more recent Japanese study (Matsukawa 2004) with hourly feedback on a digital display generated only a 0.3% reduction of electric use.

Our available time to focus on a particular interface in the home is limited and has to be shared with many other activities. As attention is a limited resource, energy feedback has to account for this in the design. This might involve finding a balance between being obtrusive and inconspicuous, or a balance between the intensity of an interaction and the length of time it progresses. In the examples above, we can speculate that daily feedback might have better captured the users' attention due to an hourly update requiring too much attention and offering too small a reward to be interesting. Another factor in this is, of course, the cost of accessing the information.

The way that energy feedback is provided, in terms of whether it measures a specific device or the home in its entirety, and whether it measures a period or the usage in the present moment, also acts to shape what kind of activities it is mapped onto. We will here also investigate how these different kinds of feedback, in terms of aggregated or delayed readings, work to reframe energy use in our homes. In addition to this we will also explore how we can design services and artifacts around these different forms of feedback to make the most of the data available.

Intuitively visualizing and conceptualizing energy use

In terms of visualizing energy we will also explore how energy feedback can be designed to have something to offer from both an esthetic as well as a pedagogical perspective. Energy, and notions surrounding it, are often abstract. People consequently often struggle to understand concepts such as watts or kilowatt-hours (chapter 10).

Learning to relate to a concept such as kilowatt-hours can in a way be seen as very similar to learning a foreign currency. What the understanding of our own currency does is to immediately give us an emotional sense of a cost in relation to an offer.

In this thesis we will look at new ways to visualize energy, visualizations that:

- enable quicker routes from a presentation to an intuitive and emotional understanding of a quantity,
- provide a language for mutual understanding among, for example, inhabitants of a home,
- make energy more concrete and its use more graspable,
- and create associations to energy use (as also addressed in the previous question).

At the same time we will also explore how this visualization can be designed in order to add value in term of experience. How can we, in terms of a positive persuasion strategy, offer experiences through the esthetic expression of the persuasive-technology argument as addressed in the first question posed?

Creating engagement with regard to energy consumption by means of playfulness

Motivating use is, as previously addressed, a precondition for persuasive technology being effective. As a means to address this we will in this thesis also investigate how playful design (Gaver 2007, Korhonen et al. 2009) can be used to reframe consideration of resource use as both an interesting and engaging activity. This positive persuasion approach borrows from how serious games reframe extremely tedious learning tasks into enjoyable activities.

As previously discussed, technology design with a functional perspective can be seen as inherently less engaging than the manual tasks it replaces (Borgmann 1984, Verbeek 1998, and Simons 1969). The interfaces in this case often strive towards abstracting or simplifying our world in order to make things easier for us. In terms of experience, however, it is often complexity rather than simplicity that is appreciated and sought (Norman 2004, Stolterman 2008). When designing for engagement, like for instance when designing digital games, the creation of elaborate and artificial complexity to support tasks such as exploration, discovery, and facing challenges is instead a primary activity.

When expanding on the engaging aspects of feedback on personal energy use, a design ambition of the concepts and prototypes presented in this thesis has been to utilize the complexity already inherent in our energy use. In addition to this we will also aim to design for the intrinsic interest we all have in things that relate to ourselves. This we do by providing the means to explore and discover the secret world of energy consumption embedded within our electric appliances, or by exploiting our interest in, for example, a challenge presented to us or the obsession we can develop about a subject once we have invested enough effort into it.

Designing for these kinds of experiences reconnects to concepts from game design such as flow (Csikszentmihalyi 1991 in Salen & Zimmerman 2004). For example, the challenge presented must contain a clear goal and a way to determine one's progress. In similar way, we also borrow the notion of engagement cultivation from game design. Games are often designed in such a way that the player follows a looping pattern of effort and reward, in which the effort is presented as a challenge (Salen & Zimmerman 2004). Typical in game design is that these loops are initially quite small, i.e., contain small efforts and quick rewards. But as the game progresses these loops will expand by providing bigger challenges, more work, and consequently also bigger rewards. In order to facilitate exploration we must furthermore offer a rich versatile information space in terms of the feedback and manipulation.

But finding a balance is a key issue also with regard to this question. By relating to the previously research questions we can see that designing for feedback on energy use encompasses both a functional perspective, i.e., making it easy to understand, and an experience perspective, i.e., making it intriguing and complex. A successful design in this respect therefore needs to combine elements of both simplicity and complexity.

Stimulating social interaction in regard to energy usage

We will also address the social dimension of energy conservation. Can materializing or visualizing energy consumption turn it into a point of social comparison or an identity-building activity? Can the social interaction that arises around these artifacts and services act to stimulate reflection and discussion? How do the esthetical expressions of these kinds of interventions or technological arguments fit into the neighborhood context?

Investigations and constructions of self identity can here be seen as an additional pleasure in terms of playfulness (Shove & Warde 1998), which can be triggered by technology and media (e.g. personality tests in popular magazines). In this thesis we play with the notion that our own use of electricity actually is inherently interesting to us as a way to figure out who we are, if presented in the right way.

In any household with more than one inhabitant conserving energy requires coordination, that is, negotiations and handling of conflicting interests by the inhabitants. As is often done in the pervasive game genre (Montola et al. 2009) these social interactions can be viewed as a resource for experience and be made part of the game design. We explore how these interactions can be facilitated both as part of the gameplay but also as an integrated means for so-called *debriefing* (Henriksen 2006).

We have also explored how shared experiences of energy use can create interaction between homes. In this task, the conceptualization of energy plays a key role in providing people with a language for discussion and information sharing. The engaging and playful framing that we have sought here also provides the driving force for people to use this language to construct and share stories about their experiences or, as in the two game prototypes, interact through their energy use.

Chapter 6

Method

In this chapter we will explain how the questions outlined in the previous chapter are answered in this thesis. The research in this thesis has been conducted with an applied and design-oriented research approach. We will start by providing the context and background of this type of research, before briefly reviewing the problems investigated and the considerations that follow from this. We will then show in more detail how we have chosen to explore the design space by means of two somewhat different approaches and illustrate the methods used in each of them.

Methodological background

This thesis uses an applied and design-oriented research approach common within the field of HCI (Fällman 2005). This method is characterized by the design, implementation, and evaluation of functional prototypes in order to conceive of novel and innovative ways to apply technology, new interaction styles, or new interface solutions.

This methodology has typically been recognized for its strength in addressing so-called *under restraint* or *wicked* problems (Zimmerman et al. 2007), i.e., unsolvable problems with conflicting interests among stakeholders, unknown variables, etc. In this, the design prototype plays a central role, as emergent effects typically make it difficult to isolate certain variables, as in traditional science. The problems instead need to be addressed from a more holistic perspective, through, for example, the use of implemented prototypes (Stolterman 2008, Zimmerman et al. 2007).

In this type of research the prototypes can be viewed as scientific tools for acquiring new knowledge, as vehicles for communicating results, or as in themselves being the research result in the form or “artifacts as theories” (Zimmerman et al. 2007, Fällman 2005, Stolterman 2008).

Zimmerman and colleagues' model

The method used here closely resembles that of research-oriented design as described by Zimmerman et al. (2007). In their model the designer/researcher works by combining the *true,* i.e., behavioral theories and models, with the *how,* i.e., technical knowledge and opportunities, and the *real,* i.e., first-hand experience or anthropological studies of the problem space, into a design artifact. By "ideating, iterating, and critiquing potential solutions" the designer, according to Zimmerman et al., reframes the problem with the goal of transforming the world from its current state into a so called *preferred state.*

As the potential outcomes of this process Zimmerman et al., among others, list:

- new forms of technology or advancements of current technology
- the identification of gaps in existing models
- the discovery of unanticipated effects
- templates for bridging theory and practice (in terms of problem space, use context, and users), but also as arguments facilitating knowledge transfer.

In addition, the prototype itself can also be seen as a result in the way it successfully (or unsuccessfully for that matter) combines different technological elements and reveals both the framing of the problem and how to compromise between its different aspects (Zimmerman et al. 2007).

Because design research prototypes typically differ from designs derived from commercial design practices they also need to be evaluated differently. This difference consists of the prototypes in research typically not needing to take into account variables such as commercial risk and production cost, etc., things that always need to be addressed in commercial design (Zimmerman et al. 2007). Rather than emphasizing factors for commercial success, research prototypes focus on doing the right thing. Their value therefore comes from the way they demonstrate significant innovation by integrating theory, technology, and user needs (ibid).

A review of our research problem

In this thesis we explore how we can use persuasive and ubiquitous computing to redesign domestic interaction with energy in order to promote more sustainable behaviors and create awareness around energy use.

By providing a number of design proposals we will explore how this influence by technology can be changed towards a conceived preferred state, which among other things involves an increased interest in energy use in our homes. In this regard we are not purely concerned with changing people's behavior but also how the devised solutions can act as enriching experiences for the users.

The investigated problem space clearly fits the definition of a "wicked problem" in the way that, for example, pedagogical motivations, esthetic concerns, and social interaction are tied together or even conflict. As we saw earlier, we need to design for both complexity and simplicity. In addition we find opposing interests among stakeholders. People both want to save energy and at the same time use technology for different purposes in their homes. Consequently this problem benefits from being addressed in its entirety and thus justifies a design-oriented research approach.

In terms of the suggested concepts we have a particular interest in how our design fits into its use context. For this reason we have, as far as possible, also tried to evaluate prototypes in people's homes in a natural everyday settings. There are, however, a number of practical problems that arise when researching a domestic setting that have limited this ambition.

These problems involve ordinary privacy issues that restrict physical access by researchers, as well as methods of performing studies. But other very practical problems, such as, for example, safety issues that limit the use of experimental non-certified electrical prototypes in a home environment, have also had to be considered in this work. For this reason we have in some cases also been forced to employ more controlled forms of tests.

From a theoretical perceptive, problems like how to study experience and engagement arise. While consumption can be quantitatively measured, things like experience, knowledge gained, and quality of design can be hard to define or depend on personal preferences. This often calls for a qualitative approach in terms of methods.

But even the measurable things like energy consumption are in this case not entirely straightforward to analyze, in terms of what can be derived from normal behavior and what would be the result of an intervention? Parameters affecting this can be outdoor temperature or special events out of the ordinary, such as people going away on trips, etc. Comparing households to each other can also be problematic since the size of living areas, number of inhabitants, and heating systems vary, which makes each household unique.

Referring to consumption figures from previous years, or even a period prior to an intervention, is not straightforward either, since new electrical appliances enter our homes all the time and change conditions and behavioral patterns. To capture all the elements of the problems being investigated, we have here used a combination of quantitative and qualitative methods to analyze the outcomes of our design proposals.

Method outline

In this thesis we have employed a user-centered design approach. Input to the design processes has been collected from both secondary and primary sources (Silverman 2008). The primary sources involve interviews in people's homes, cultural probes, and participatory design workshops. All concepts have in addition been evaluated in simple user tests during the design phase. The design process can be described as an iterative process where we have sought to find a suitable match between concepts and materials (Löfgren & Stolterman 2004).

When technically possible, the prototypes have later also been evaluated in a home setting. The evaluations in these cases have focused on qualitative methods, but also involve quantitative methods in determining consumption change. Data in the form of energy consumption before during, and after the use of the prototypes has for example been collected both from participating households and reference households in the same area. We have also logged usage of the prototypes. Semi-structured interviews have been conducted with all or a set of the participants.

The semi-structured interviews have been transcribed, analyzed, and classified. Consumption change has been calculated with reference to a period prior to the trial. Changes in outdoor temperatures as well as the heating systems in the households have also been taken into account.

Method implementation

The results of this study are based on the results of two different approaches to exploring the design space. First we look into how redesigning existing objects and interfaces in our homes can promote energy awareness. This design approach involves a very close relationship to the materials involved, similar to what Redström has described in his notion of IT as a design material (2001). The prototypes from this approach (The Awarecord and the Element) constitute long terms interventions incorporating what could be seen as unstructured and casual forms of play.

In the other approach we instead look at how temporary interventions incorporating more structured play, i.e., games, could be developed based on data from central metering and existing hardware platforms in the homes (i.e., the electric utility company's existing system for automatic meter reading and mobile phones). This approach adopts a more traditional method of game design, building on associations and existing genres as described by, for example, Hagen (2009). The two prototypes from this approach (the Power Agent and the Power Explorer) were, in other words, developed within a more technology-driven perspective.

In each of the two approaches, we use slightly different methods for the design and evaluation of the constructed artifacts. In the example of the Awarecord and Element prototypes, a lot of research was initially done into people's relationships to energy and electrical artifacts in their homes. This research consisted of both primary sources, such as interviews and cultural probes, and secondary sources, such as existing surveys. This data was then used as input in a number of internal workshops and brainstorming sessions where different concept proposals were created. These concepts were further explored and filtered through visualizations in the form of renderings.

During the implementation phase, the concepts were then continuously reevaluated and updated to match the capabilities of the components, the medium, or the technology used until a satisfactory solution was found. This involved a close relationship to the material (Redström 2001) and the ongoing evaluation of both the overall concept and the technical possibilities (Löfgren & Stolterman 2004).

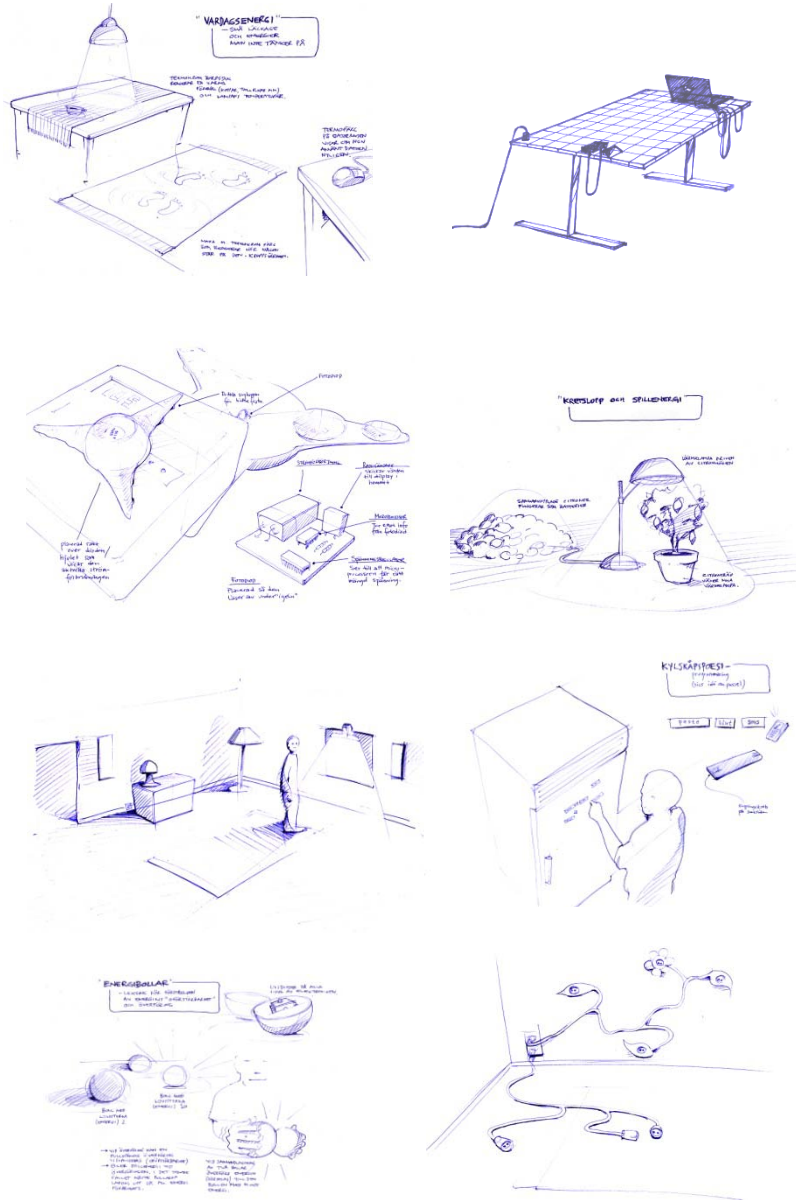


Figure 4. Working sketches from a design workshop. Artist: Magnus Gyllenswärd.

The Awarecord

The various steps of this iterative process are very easy to follow in the designing of the Awarecord. The initial idea to use light intensity in a cord to show electrical current proved to be difficult to implement as the light was occluded in certain directions by the other electric wires in the cord. It also proved very difficult to distinguish between different levels of consumption with the range of intensities provided by the light-emitting wire used, although recognizing consumption changes, on the other hand, was quite easy.

The issues of occlusion and intensity were solved by adding two more light-emitting wires which meant that we ended up with three light-emitting wires alongside the three ordinary wires. This in turn led to other problems such as the cord becoming very stiff. At the same time it was also concluded that the current construction would make it very hard to produce a visualization that would be perceived in the same way in all different situations, since the intensity of light is often judged in relation to the surrounding lighting conditions.

By twisting the internal wires of the cord we attained a more flexible cord construction. This also led to the possibility of animating a flow through the cord, since the three light-emitting wires were now only seen in segments along the cord. From here on, the design work became a task of exploring this new medium we had created and producing the appropriate visualization algorithms.

Figure 5. The twisted core of EL-wires and well as electrical conductors.

While experimenting with this we were intrigued by observing the dynamics of how different appliances consumed electricity. One of the power tools in the workshop, for example, consumed a lot of energy while speeding up, but almost no energy when spinning freely. When the tool was applied to some object, for example to polish it, its use of energy would again increase in proportion to the friction. This property of the visualization was incorporated into the concept during the implementation phase.

Figure 6. Early prototyping of the Power Awarecord.

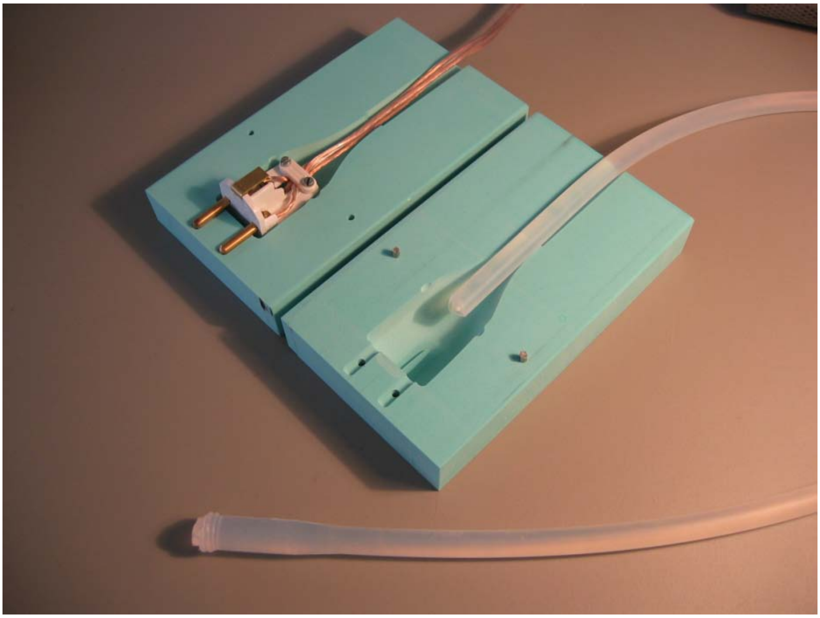


Figure 7. The mould for the Awarecord plug with a material sample as well as one of the initial prototypes for the cord core.

Our design process for developing the Awarecord could be identified as an iterative design process (Zimmerman 2003). This process has also been described by Löfgren and Stolterman (2004) as a process of moving between the abstract and concrete, progressing step by step between ideas and hardware until a match is found. The overall approach in this case was, however, to a large extent inspired by the notion of *IT as a design material* (Redström 2001), that is, how temporal structures and expressions from computational processes can be manifested through a material using the unique properties of that material (Hallnäs et al. 2002 p. 1–2).

Towards the end of the implementation phase of the prototypes, we employed initial user evaluations, where people from a neighboring building were invited to be shown or allowed to interact with the concepts in our office space. The people in these tests were asked to think aloud while exploring the prototypes and were also interviewed in a semi-structured format. The purpose of these evaluations was primarily to get an idea of how well the concept or arguments embedded in the prototypes were understood, how the product was interpreted in terms of esthetics, and the engaging features of these objects. During this phase we also worked intensively with fine-tuning the software in the artifact to achieve the proper mapping.

Not covered by these workshops were things like how the design would fit into a home, how the use of these objects would change over time (i.e., the domestication process, Löfström 2008), and what effects these prototypes would have on energy consumption, attitudes, and behavior. Due to electrical safety regulations the device was not tested in a home environment within the scope of this project. A later version of the Awarecord, however, has been evaluated in an actual home setting (Löfström 2008). In the discussion we will therefore refer to and expand on these results as well. In this later version of the Awarecord, however, some of its esthetic features had to be changed in order to more easily comply with electrical safety standards.

The Element

The Element prototype was designed and implemented in a similar fashion as the Awarecord. This idea was derived from a combination of interview materials as well as concepts from earlier workshops dealing with energy recycling (Figure 8 left). In one of the interviews we were, for example, inspired by a woman who explained her attachment to a particular lamp in her home that she thought produced a very beautiful light (Figure 8 right)

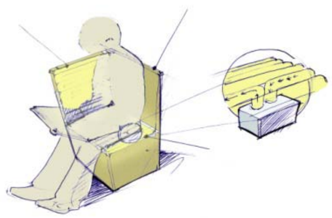



Figure 8. Left, a concept for energy recycling of heat from light (Drawing by Magnus Gyllenswärd). Right, one of the interviewee's favorite lamps.

As the Element concept drew upon earlier project work, it was perhaps more developed at the beginning of the implementation phase than the Awarecord. Consequently it did not undergo refinements along the way in terms of its core concept to the same extent as the Awarecord. Significant effort was however put into fine-tuning the visual expression in terms of the algorithms for mapping output based on input from temperature sensors. The prototype was frequently shown to colleagues and neighbouring office workers in order to gain feedback.

A user test was later also conducted with ten participants. These tests were structured so that the participants, in pairs, first explored the device in a very open-ended way and then were interviewed using a semi-structured interview guide. No testing in actual homes has been done with the Element prototype due to electrical safety regulations.

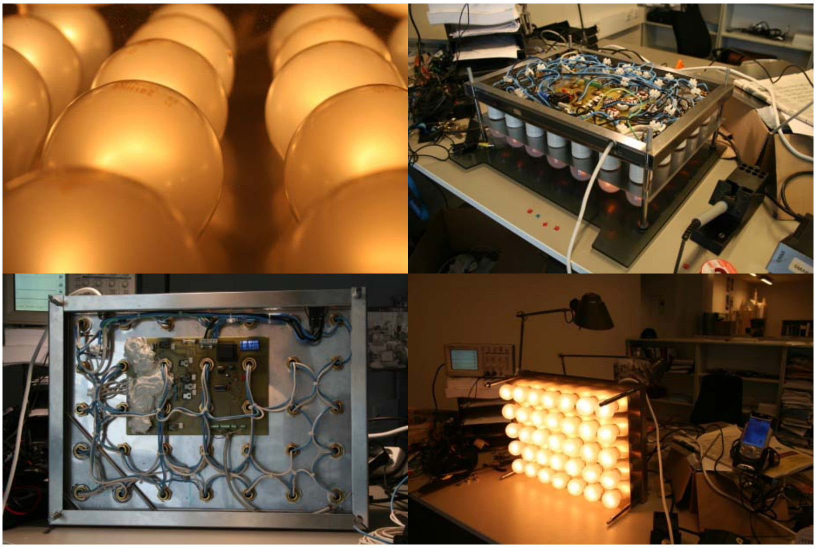


Figure 9. Construction of the Element.

Figure 10. Initial user test. Behind the participants, a normal radiator; in front of them, the Element.

Power Agent

The Power Agent concept was generated though a series of workshops involving game researchers, designers, behavioral researchers, energy consultants, professional game designers, and the presumed target group: teenagers – who came from a gaming community and an environmental organization.

Figure 11. Pictures from one of the initial workshops.

The implementation phase of this project differs in its approach from the one used in the Awarecord and the Element. Since this project had a quite set framing in terms of the technology to be used, the task here became more a problem of adapting the concept to the limitations of the technology. One of the most severe limitations in that regard was the delay of the energy feedback data, which limited the use of direct manipulation. For this reason the design process relied on a more traditional game-development approach, one in which the game concept is developed by combining innovative ideas with recycled ideas from the game domain or a particular game genre (Hagen 2009).

During the implementation phase, the prototype was tested on participants matching the target group in the same manner as the Awarecord and Element prototypes. These tests were a way to verify the basic usability aspects of the prototype as well as to gain initial feedback on some of the features of the game.

The final evaluation of the Power Agent was carried out in six households in two different cities in Sweden (three in each city). In this setup the participating teenagers, aged between thirteen and seventeen, played the game for ten days. As the automatic meter reading system in this one of the areas was still under construction at the time, the participants had to be selected from the electric utility companies' customer registers. In this way we could ensure that the participants had the AMR system installed. If the contacted households showed an interest in taking part in the future consumption test, data collection was initiated in order to gain a reference consumption rate prior to the test. During this process those with bad reception, and technical problems with their automatic meter readings, were as far as possible eliminated. In the cases where these problems consisted of only extended delays in data transfer the households were instead used to form a reference group.

Energy consumption was also logged during, and after the test. In four of the six households, this included electricity use as well as district heating while in the rest of the cases, only electricity usage was measured. After the evaluation all players were interviewed together with their families.

The semi-structured interviews were then transcribed and coded into categories. The consumption data was in addition normalized towards the period prior to the game to show the relative change in consumption. The relative change was here used as a rough estimate of the effort made by the families. In the case where heating was included in the electricity measurement, the families were also compared to a reference group in the same area to remove effects of changing weather conditions.

Power Explorer

In the Power Explorer project, the input to the design process largely consisted of the findings and experiences from the previous Power Agent prototype. The initial design phases therefore mainly consisted of internal brainstorming sessions. But we also tested game features or graphics on a reference group of intended users.

In this project a hardware platform in the form of a wireless real-time energy sensor was also developed in parallel with the game concept. This allowed for a process more in line with the one performed in the two physical prototypes, where both overall concepts and technology design were shaped together to find a satisfactory match. Apart from this, however, the game design approach in Power Explorer was on the whole very similar to that of the Power Agent prototype.

In this project we also employed a number of live pre-tests involving all the project participants. This was a method for tackling the difficulties of exploring this very novel game medium. It was also a method to maintain coherent experience and finding inconsistencies in the prototype with a large number of designers involved.

The final evaluation of the game was performed over a period of seven days. Fifteen households played together with five researchers acting incognito. All of the participants, as well as the 20 households in the reference group, were recruited through class lists from the same school. Both groups were asked to fill in a survey with questions on attitudes toward and knowledge about energy. This survey was done both before and after the game trial.

Electricity consumption data was also collected, in this case before, during, and after the user trial. This collection was made both through the energy company's automatic metering system (which performs very accurate measurements but with a low time resolution) and through our own system (which allows for a high time resolution with inaccurate measurements). This allowed us to make good predictions of consumption change, as well as to monitor specific actions at the level of electrical equipment in the home being switched on or off.

Six of the players were also interviewed after the game. These interviewees were selected on the basis of their having distinguished themselves in some way during the game trial. They could be, for example, the most active players as well at the least active player (according to the game log), the most successful player in terms of saving energy as well as the least successful player, and so on.

The semi-structured interviews were transcribed and coded into categories of energy-saving strategies, attitude changes, learning, and game design. The data collected in the trial was compiled into both qualitative and quantitative analyses. While the quantitative analysis here provided indications of the overall consumption and attitude changes of all participants, the qualitative analysis focused on the six interviewees. These two analyses combined provided both an overall understanding as well as in-depth insights into the problem space.

Chapter 7

Experimental prototypes

The findings in this thesis are based on the implementation and analysis of the four prototypes previously discussed. Two of these prototypes explore the redesigning of everyday objects in the home, and therefore take the form of physical artifacts. The other two explore the utilization of aggregated electric consumption data from the home in the form of services (i.e., mobile pervasive games). Each prototype contributes to the understanding of the design space in its own specific way. In the table below, we provide an overview of how the different research questions are addressed by the prototypes. In this section we will explore the concepts behind our four prototypes in more depth to gain an understanding of how these concerns are addressed in more detail.

	Reveal	**Visualize**	**Engage**	**Socialize**
Awarecord	Tool Real time Situated	Metaphoric Iconic Indexical Ambient	Spontaneous Exploration Discovery	Language for mutual understanding, identity.
The Element	Interface redesign Real time Situated	Metaphoric Iconic Ambient	Spontaneous Captivation	Language for mutual understanding, identity.
Power Agent	Service Delayed Disconnected Aggregated	Symbolic	Rule bound Competition Escape Subversion	Social comparison
Power Explorer	Service Real time Disconnected	Symbolic Metaphorical Indexical	Rule bound Competition Exploration Empathy	Social comparison,

Table 1. An overview of how the different prototypes address the research questions.

The Power Awarecord

The Power Awarecord is an electric power strip where one can see the electricity flowing through the cord as an animated blue light (Figure 12). This concept was inspired by the notion of ambient displays as well as the use of water as a metaphor to explain the functionality of electricity.

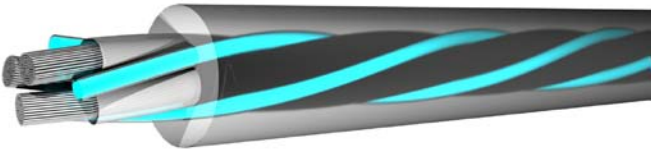
The prototype consists of a transparent electric cord with three electro-luminescent wires molded inside the cord alongside the regular electrical wires (Figure 13). It also consists of a socket box with a small power meter and a microprocessor controlling the illumination of the electro-luminescent wires (EL-wires). As in any regular cord, the core of the cord is rotated in a spiraling fashion making the EL-wires visible in ordered segments. This setup enables us to animate a flow by lighting one of the EL-wires at a time. The Power Awarecord can, in other words, express consumption both through intensity as well as flow of light within the cable.

While intensity is used to show small rapid changes of consumption and small amounts of consumption (below 60W), flow is used to show the overall consumption on a larger scale (0-2000W). The Power Awarecord is in this way able to visualize both small and large changes spanning over a large scale.

The idea behind the Power Awarecord is that it will enable you to intuitively explore your home in terms of energy consumption. Unlike regular energy meters, the Power Aware Cord not only lets the users know how much electricity a particular appliance consumes but also how it consumes electricity. With the Awarecord users can make discoveries such as, for example, that a stereo consumes more energy if the volume is turned up and that base tones in a song can cause a surge of consumption to occur in pace with the music. Users will be able to tell that a plasma TV uses more energy when the image on the screen is bright or discover that an electric drill consumes more energy when drilling through a dense material. This provides a new dimension to the understanding of power consumption, one which exposes the rich and diverse individual properties of electric appliances in your home.

Figure 12. The first Power Awarecord prototype (photo by Magnus Gyllenswärd).

a)



b)

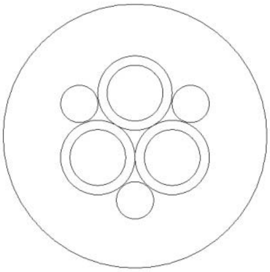


Figure 13. Schematic view of construction of Power Awarecord.

After being used to explored the home, the idea is that the Power Awarecord will find its place in a central and visible location in the home. It is here assumed that its esthetic qualities will make people want to display rather than conceal it, as with regular power strips and cords. In this way the artifact itself also becomes a statement which communicates the intellectual responsibility and awareness of the user. Through its ambient properties it will work as a subtle and ever-present reminder for everyone in the home of the impact of everyday actions or as an indicator of hidden standby use.

This prototype works in many regards as a *tool* (Fogg 2003) to address one's energy use, a tool that provides feedback as to where and when the energy is used. Revealing energy use is done by simulating what electricity might look like if it could be seen in a metaphorical or iconic way. But rather than providing an abstraction of our electricity use – as kilowatt measurements are, for example – we here try to deepen our understanding of this phenomenon by providing a detailed account of its flow. In this way it also supports playfulness by providing a space for exploration and discovery.

The Element

If the Power Awarecord was inspired by water, the Element can be said to be inspired by fire. This prototype explores what in many countries is the most energy-demanding activity of all, namely heating our homes. The Element is an electric radiator constructed out of 20 incandescent light bulbs. These light bulbs together generate about 2200W of heat and light, which is equivalent to the consumption of a normal radiator.

An incandescent light bulb typically emits about 95% of the energy put into it as heat, and only 5% in the form of visible light. But since light also becomes heat once it is absorbed, the amount of heat gained from a incandescent light bulb is the same as the heat from a heating filament in a radiator using the same amount of electricity. The only difference between the filaments in an incandescent light bulb versus those in a normal radiator is that the latter are larger in size. It therefore also becomes less hot, and consequently emits light in a lower part of the spectrum, toward the red or invisible infrared spectrum. Light bulbs, in other words, are just as efficient as radiators in term of generating heat.

The light bulbs in the Element are controlled by electronic dimmers that in turn are controlled by a temperature sensor. A display on top of the radiator, together with a knob on the side, lets the user control the temperature setting. If the room needs to be heated the light bulbs of the Element will start glowing. The intensity of the light bulbs will increase until, if necessary, the maximum effect of the radiator is reached. As the desired temperature is established, the light bulbs will gently fade and the Element will stop producing heat.

An adaptive algorithm in the Element will establish a balance where the light bulbs have just the right amount of current to maintain the temperature in the room. When this delicate balance is reached, the light bulbs will typically be glowing faintly. The smallest disturbance in the climate of the room, like a draft from opening a window, for example, will make the light bulbs flare up again.

Since the temperature of the light bulbs also affects the color of the light produced by the bulbs, a cold or badly insulated room will cause a cold-looking bright white light to be produced. A warm and well-insulated room will, on the other hand, produce a warm yellow or red light from the Element. In this way the ambience of the entire room is affected by its climate.

With this prototype we first of all explore aspects of the use of energy as being or becoming an engaging task. As Borgmann (1984) points out, heating one's house used to be a focal activity that required a lot of attention, with tasks such as finding wood, preparing it, and making and maintaining the fire. The introduction of electric or central heating removed this engagement and replaced it with mindless and transparent consumption.

With this prototype we aim to reengage people in the task of heating their homes by creating something visually closer to the traditional fire. The engaging aspects can here be derived from its very strong visual presence, its dynamic properties, as well as its esthetics. The Element mixes the esthetics of the product categories of lamps and electric radiators. Its 2200 watts of light bulbs, is sure to make an impression that not only can be seen but also physically felt on your skin. Its fluctuating and changing intensity makes it intriguing and alive.

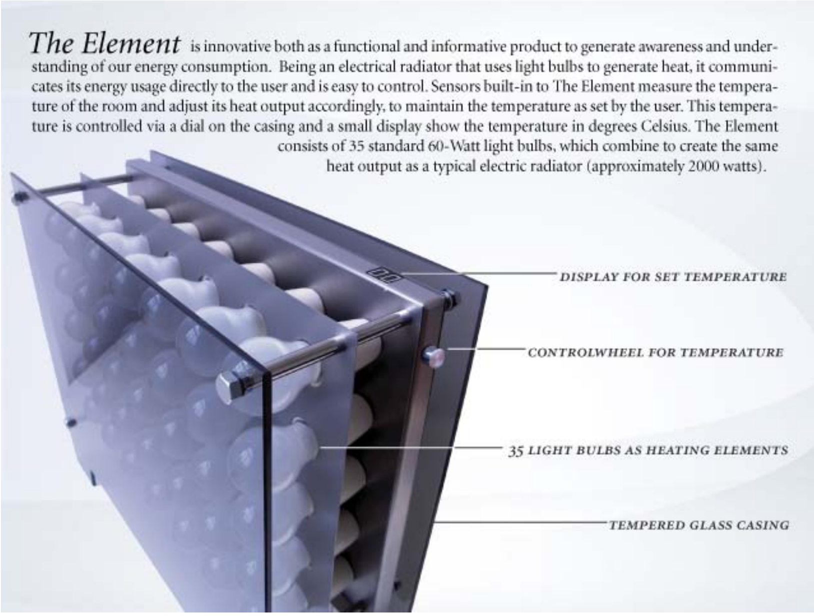


Figure 14. The image shows a page from a brochure about the Element.

Figure 15. Warm versus cold light from the Element (photo to the right by Magnus Gyllenswärd). The camera exposure has been adjusted to the light conditions making the image to the right look darker than it is.

The Element also becomes a pedagogical tool in that it, like the Power Awarecord, performs the function of an ambient display (REFF). The intensity and color of the light becomes a reflection of climate in the room, which aids in conveying to the user the intimate relation between the consumption in a radiator and its surroundings. It also lets you closely experience the amount of power involved in heating a room.

In the case of the Element the energy used to achieve its additional properties does not cause additional energy use. Part of the energy only momentarily serves as ambient light before becoming heat, while another part of the energy performs the function of logical processing in the microcontroller before also becoming heat. In this way it provides an example of how energy use can be revealed in interface design and add to the esthetic experience without requiring additional use of energy.

Power Agent

Power Agent is a mobile pervasive game where two teams of teenagers compete together with their families at saving energy in their homes. The two teams are located in two different Swedish cities. The game is played in a java-enabled 3G phone which through a game server connects to the power meter in the players' homes.

In order to be scalable, *Power Agent* was from the beginning designed on top of existing infrastructure such as the automatic meter-reading system[1] (AMR, also referred to as smart metering). An AMR system is basically a set of networked power meters that are utilized by power companies to automatically measure their customers' consumption of electricity, district heating, or gas. The currently used AMR systems typically report on customers' consumption on an hourly basis, however for reasons of cost, data is often only transmitted and updated to a central server once every 24 hours (during the early morning hours).

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[1] In 2006 there were approximately 235 million AMR meters installed in the European Union. The AMR system in Sweden, where this project was carried out, since 2009 covers all households in the entire country.

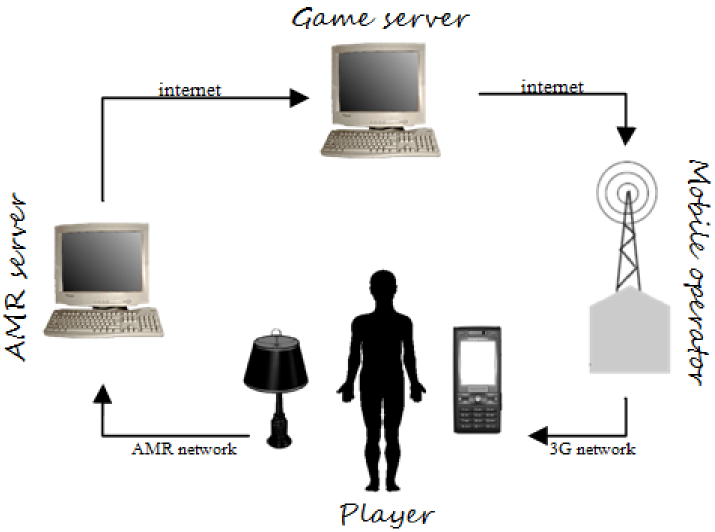

Figure 16. System overview Power Agent.

Gameplay

In Power Agent, the player takes on the role of a special agent assigned the task of saving energy in the home. To be able to achieve this goal, he or she must cooperate with family members and also combine forces with other peers on a team. In this way Power Agent facilitates social interaction in regard to energy use on multiple layers both between and inside homes. The team competes with another team of agents located in another town. A successful player persuades everyone in the household to conserve as much electricity as they can during the mission, which, on most days, takes place between 5:00 and 10:00 p.m. Throughout the mission, the game monitors electricity consumption in the participants' homes. The winning team is the one that achieves the largest combined relative decrease in energy consumption (in our case, electricity and district heating, when present).

Mr. Q – the agents' boss – appears on the phone just before a mission starts and informs the player about the new assignment (voice and animation (Figure 17b). At this point, a warm-up track for the mission – in the form of a small platform game – is unlocked in the phone (Figure

17d). Here, players can collect batteries. Each battery is associated with a clue (Figure 17e) on how to better succeed with the assignment during the evening's mission. A clue could, for example, be "unplug the DVD or stereo from the wall socket to prevent it from using electricity when not in use."

All the first six missions in the game have an energy-saving theme. The themes are (1) lamps; (2) activities in the kitchen; (3) entertainment equipment; (4) heating the house; (5) washing and cleaning; and finally (6) showering and bathing. In the final mission, players take on the task of lowering the *total energy consumption* of the household for a longer period of time, as this mission extends over the entire weekend.

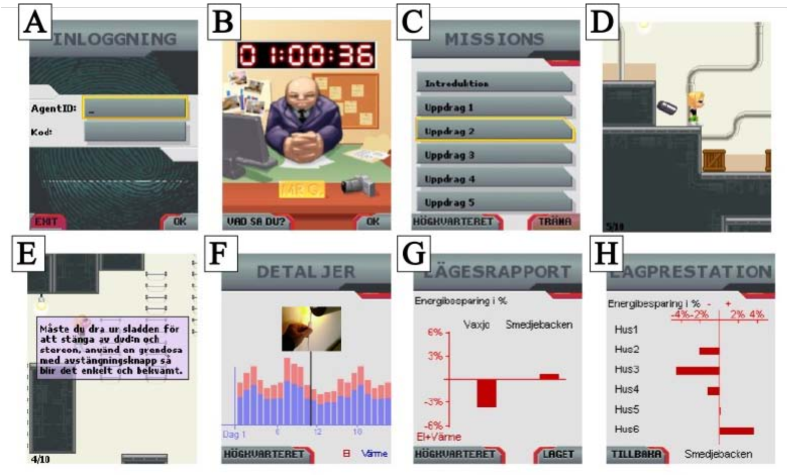

Figure 17. Screen shots of game interface.

The morning after a completed mission, feedback is given by Mr. Q (Figure 17b). Through voice and animation he delivers the outcome of the mission and at the same time encourages the unsuccessful players to try harder next time and praises the successful ones. In addition to the voice responses from Q, a set of screens and bars visualize the result in more detail. These bars consist of (Figure 17f) a scrollable vertical chart with the players' personal home consumption; (Figure 17h) horizontal bars indicating the individual efforts within the team; and (Figure 17g) bars indicating the results during the latest mission for the two teams. In addition to this, a high-score list showing the winning team for all of the previously completed missions is also available. In this way energy use in the home is exposed and gains new meanings through the gameplay.

At the end of the game (after the weekend final), all players receive a summarizing text message from Mr. Q on their phones. This message concludes the game by announcing the winners. In addition, it also provides feedback on how much the reduction in consumption achieved by the player during the final adds up to when translated into money and carbon emissions if the reduction were maintained over an entire year.

The feedback in this case is obviously very different from that employed in the previous two prototypes. Instead of using an iconic or metaphorical approach, a more traditional form of symbolic presentation was employed framed by the fiction in the game.

Interface

To strengthen the role of a secret agent, we encouraged players to employ the mobile phone camera and take pictures of what they did to reduce energy consumption in their homes. When available, these pictures are superimposed on the personal energy consumption feedback chart (Figure 17f), which enables players to map actions to results. A message board was also included in the game to allow participants to send messages to each other.

All functions in the game are accessed by selecting the items behind Mr. Q on the main screen (Figure 17b). This is done by using the phone's navigation key. Selectable items include the camera (the agent camera function); the message board (message function to the other players); the computer (the warm-up tracks); the card index (brief information about the other players); the papers in front of Mr. Q (the missions); and the pictures and graphs (feedback and results).

Power Explorer

The Power Explorer game is a continuation of the Power Agent project. It is also similar to the previous game in terms of being a pervasive mobile phone game connected to the energy consumption of the players' homes. With regard to the gameplay, however, Power Explorer is quite different. With this prototype we explore the use of a real-time feedback system instead of the previously used AMR system. This system more directly converts electricity use in the home into affordances, or mechanics, in the gameplay. Players also compete in real time against each other. Power Explorer, in other words, constitutes a real-time multiplayer game where the game controller consists of the player's entire home.

Platform

Power Explorer is played on a HSDPA and Java-enabled handset (a SonyEricsson K660i). The game client lies dormant in the background when not in use and can in this way *push* messages to the player about exceedingly high consumption and received challenges. It can also act as an ambient interface by making electric sounds as consumption rises to pull the player back into the game when something interesting happens. The client is connected to a game server, which in this case is connected to custom-made Wi-Fi equipped power sensors installed in the central electric distribution box of each player's home.

Gameplay and interface

Players in this game are represented by a game avatar, a "monster blob," that is individual to all players. The monster blob can visit four different environments that each have a different mode of interaction: the pile, the habitat, and two duels. The game is designed to balance the two opposing goals of saving energy (habitat and pile) versus engaging players in using and learning about appliances (the duels). The two existing duels in the current version of the game are the rainforest duel and the polar dual. Playing the duels offers an engaging real-time player-to-player competition, while playing in the habitat is a quite low key explorative task.

The habitat: In the habitat, the avatar lives within a virtual climate environment. The objective here is to keep the monster blob healthy. The data for controlling the climate comes directly from energy usage in the player's home. The present electrical power level is visualized by the bar on the left of the screen. Power events, such as turning something on, are visualized by weeds growing up around the monster blob, while turning something off results in flowers growing. The size of a power event translates proportionally into the size of the plant that appears. These plants serve as food for the monster blob and will therefore be eaten one by one. While flowers will have positive effects on the monster blob's health, too much weeds or thistles will make it sick.

Fig. 1. The main view of Power Explorer (the habitat).

A grey cloud in the sky represents the levels of CO_2. At the beginning, players will by default have a cloud the size of 500 units (on a scale from 0 to 1000). CO_2 will over time slowly evaporate from this cloud causing it to shrink. If you use electricity in your home however, your “monster blob” will start emitting small clouds of CO_2 gas in response to eating too much weeds. Each of these small gas clouds represents a fixed amount of energy having been used in the household. The gas emitted by the avatar will rise and join the big cloud causing it to grow.

This means that using a small amount of electricity will make the cloud shrink, while excessive use will cause it to grow until it eventually fills the entire screen. At this point there will be further negative consequences for the avatar’s health. Hence, in order to keep your monster happy and healthy the player must keep electricity consumption down. The equation is set so that the level where the cloud goes from increasing to decreasing is 85% of the participant’s normal household consumption with reference to the weeks prior to the game.

The pile: In the second view, all of the participating players’ monsters are stacked in a pile. The position of your avatar in the pile corresponds to your current ranking in the game in a King-of-the-Hill fashion (Figure 18 left). The red ring indicates the player’s own blob. The sleeping green monster with a golden scarf is the one who won the last duel. The monsters with closed eyes are players currently offline.

Figure 18. The pile (l), the rainforest- (m) and the polar- duel (r).

By pointing at one of the other players' monsters you can see its current CO_2 level. Game rankings are based on the size of the CO_2 cloud. To reach the top you will therefore need to keep the consumption down as long as possible to clear off all the CO_2. Since some daily activities will inevitably use a lot of electricity, it is important to perform them quickly and efficiently to avoid buildups of CO_2.

The Rainforest duel: This duel sets the two competing players' avatars side by side on a racetrack in the middle of a rain forest (Figure 18 middle). To win, the player has to get to the end of the track before the competing player, and avoid various tricky and dangerous obstacles along the way. These obstacles move or appear periodically throughout the duel. Some obstacles can be avoided by pressing the "jump" button. However, most obstacles must be avoided by timing their periodical movements. That means setting your monster to run at the right speed. The speed is adjusted by manipulating the electricity consumption of your home.

Hence, to win this duel, the player needs to have an understanding of the amount of electricity consumed by different domestic appliances to be able to quickly set the right speed. Increasing the electricity consumption, in order to increase running speed, also increases the precipitation in the rain forest, which will lead to a build-up of rainwater making both players drown (Figure 18 middle). Consequently, the task of the players is to carefully maintain a balance between gaining enough speed to make it through the obstacle and not flooding the forest. Running into an obstacle will make you bounce back and lose health. If the water level is high, this might mean bouncing back into the water and losing even more health.

The polar duel: The other duel is a fighting match on an iceberg at the North Pole (Figure 18 right). In this part of the game, the aim is to knock the opponent off the ice and into the water by throwing various objects.

Small objects like snowballs, fish, and seals have little impact on the opponent. But on the other hand, they do have a much longer reach. Polar bears and whales have a major impact on the rival, but can only be used if the opponent is close. Some objects, like seals, will also slide on the surface of the ice while others, like the whale will go through the ice on impact and leave a hole that must be avoided. The opponent has to reposition his or her monster to avoid objects thrown as well as jump to avoid sliding seals.

The player gets access to the objects by changing the electricity consumption in the home. For example, to get a powerful whale the player has to understand that the task is to turn on a major electricity-consuming device such as an electric radiator, for a second or two. For a smaller snowball, a lamp might be sufficient. Once an object is retrieved the player has to make sure his monster is facing the opponent's monster before pressing the throw button. The players' combined consumption rate will affect the sun over the polar landscape. A hot sun corresponds to a high consumption and will melt the ice cap more quickly.

Chapter 8

Discussion

Each of the prototypes described in this thesis constitutes a working synergy between a number of design parameters. In this section we will provide some of the insights gained from creating these synergies with particular emphasis on the issues framed by the specific questions posed in chapter five. These include how to visualize energy, reveal energy use, as well as how to engage people in energy conservation through playful and social means. They also include the overall question of how to account for the use context of these persuasive arguments in order to create an argument that has something to offer receivers and senders in its use context. In this chapter we will therefore begin by identifying the parameters involved in these different questions and their impact on the design. We will then provide a number of examples from the user evaluation to show when these designs were successful as well as when they failed. At the end of the chapter we will reconnect to our notion of positive persuasion.

Intuitively visualizing and conceptualizing energy usage

One of the aims of this investigation has been to study how these visualizations can be made to fit in and offer something in the context of the home. Another aim has been to learn how we can create new languages for intuitively understanding energy that might appeal to people who are normally less prone to engage with energy related problems in the home.

Esthetics is an important factor in the home. We design and decorate our homes to feel comfortable or to express our identity. So how can energy feedback be made to fit into this context? As we saw previously, the concept of ambient displays provides a very interesting way to embody digital information as highly esthetical experiences in the home. This can enable new modes of interaction and potentially fit better in a home decoration context.

In the domestic setting, consumption is typically communicated in numerical measures such as kilowatt hours (kWh) and, for the flow of energy in the unit, Watts (W). We find this information on our monthly electric bills, on markings on devices, and as feedback in commercially available devices for monitoring consumption. This information, however, is rarely framed as a conspicuous and esthetic experience.

A problem with these units of energy is that many people first of all have a hard time relating to and making sense of them (chapter 10). In addition, they are discouraged from even trying to understand them by the perceived complexity of these unfamiliar concepts. In other words, feedback encompasses both esthetic as well as pedagogical aspects (i.e., how to make sense of it) that are of importance to its understanding.

A numerical value is only meaningful to us if we can see how it relates to our own situation. Developing these notions in relation to, for example, a currency, a temperature scale, or, as in this case, energy consumption requires training and takes time. It should also be apparent that even digits and units have esthetics and semantics that affect the way we interpret and view information. By using or not using numbers or certain expressions we set the context for the interpretation of the feedback. We have therefore purposely avoided using numerical displays in several of the suggested prototypes to allow exploration of information esthetics different from the existing solutions (as shown in chapter 3 p. 38).

In the proposed design concepts, we instead largely explore the use of visual metaphors as a means to provide intuitive understanding, as well as for creating novel and rich forms of esthetic expression. These approaches include the use of notions about everyday things such as, for example, water, fire, or gas, with properties of flow, intensity, or size being mapped onto the amount of energy used. In this way we also use esthetics that reframe our use of electric devices by creating associations to the energy consumption.

The Power Awarecord has, for example, been constructed around a metaphor of water, producing an iconic representation. Electricity is here visualized as a blue light flowing through the cord. Esthetically, the expression of the Awarecord, with its flowing and flickering light, is intended to resemble the way the surface of flowing water will ripple and reflect light. This aims to provide the user with, to some extent, a both familiar but also plausible experience of how electric current might behave. Like water running through a transparent hose, the flow will also be faster the more energy that is consumed.

By means of a number of lab tests with participants as well as though our own reflection we have sought to use this metaphor to find something that provides a consistent experience in regard the amount of electricity used. In other words, we are looking for a form of feedback that for a certain energy usage will be interpreted in the same manner every time it is viewed and possibly also the same way when viewed by different persons.

High consumption has here been defined as being around 2200W for the simple reason that this corresponds to the maximum consumption for most high consuming household appliances running on a single phase (the amount corresponding to the maximum load on a 10A fuse on the European 230V grid). This has visually been mapped onto the situation where the animated flow is so rapid that we perceptually start having problems seeing it as a flow. What constitutes low consumption has here been set to the lower limit of what the sensor can detect, that is, close to no consumption at all. It has correspondingly been mapped onto a slow animation, where we start to have problems perceiving the light to be moving at all.

In the low range of consumption (<60W) we have also made use of the intensity of the light to convey a diminishing level of consumption. At the point where the consumption of electricity goes below that which can be measured by the sensor, the light will be turned off entirely. This helps to put emphasis on whether or not there is standby electricity consumption. Intensity is also used to emphasize a rapid increase or decrease in consumption by temporarily increasing or decreasing the intensity to capture additional details of energy consumption.

In terms of the visual experience, high energy consumption is represented by an aggressive, flickering flow of light, while low consumption is portrayed by a slow graceful movement. This approach creates a visualization where our existing understanding of the movement of water, and the visual expression provide the observer with an intuitive understanding of the real-time use of electricity. In this metaphor we exploits the limits of our ability to perceive animated motion as a means to achieve consistency in terms of the mapping between emotional response and the quantity of consumption being communicated.

Through the selected limits we also provide a context for the energy use communicated. What in this visualization is perceived as large amounts of consumption maps onto what in the context of a power strip can be seen as high consumption. The result is, as some of the participants in the user test who were using it in combination with an ordinary energymeter also expressed, a surprisingly accurate account of the consumption (Löfgren 2008).

In the second design example, the Element, we similarly use a metaphor of fire. In this case a bright light will represent the consumption of large amounts of electricity, while a faint glow represents little use of energy. Unlike the previous example, in this prototype we have not designed the explicit details of the mapping between energy use and visual expression. We have instead, compared to a conventional radiator, moved the heat radiation from the invisible infrared spectrum up to the visible spectrum thought the use of light bulbs. In this way we can as users perceive a portion of the actual heat energy generated being emitted as light. The representation can in this way be seen as being indexical rather than iconic, as in the Awarecord example (for semiotic definitions see Chandler 2002).

The design effort has in this case instead been directed towards making the radiator more responsive to its surroundings than a regular radiator. A typical thermostat turns a radiator on if the temperature drops below a certain range and leaves it on until the upper limit of the range is reached. The radiator is therefore either fully on or fully off. In our case, the control circuit tries to find a balance by dimming the light to provide just the right amount of energy to maintain the temperature in the room.

The balance created is fragile and the smallest draft will therefore make the light bulbs flare up in intensity. In its attempts to maintain the heat balance the Element will also always be shifting slightly up and down in terms of intensity. In this way the Element prototype possesses an expressivity resembling that of an open fire and functions as an interactive mapping between conditions in the room, the setting of the dial, and the visual feedback.

While the two examples discussed so far have explored visualization of energy directly in the interfaces of the devices, in the remaining two examples we have explored visualization through a mobile phone game. These examples largely focus on integrating energy consumption data into a game context to perform the dual role of both conveying energy use and at the same time functioning as part of the logic of the game. While the situation in the previous examples allowed us to produce very believable and realistic forms of feedback, the situation in these examples called for another approach. Here the feedback has instead aimed to provide interpretations and representations of the energy that fit into the contextual framing of a game's storyline or rules.

In Power Agent, the feedback is therefore conveyed as "agent reports" with graphs, as well as spoken comments by Mr. Q, showing relative consumption changes by players and teams as a way to integrate them into the game's storyline. To fit the visualization to its game genre, the feedback on energy use here takes on a very traditional form of communication but with the twist of being fictively conveyed inside a game.

In Power Explorer, the cartoon-like and even somewhat ironic representations of different types of endangered species or different-sized objects are used together with equally cartoony environmental simulations. In these simulations, real-world consumption is translated into a fictive scenario that, in a symbolic way, points out the threat that energy use in the home poses to the environment. In this way, real energy use in the home will also change conditions and possibilities in the game.

These changes include the rate at with the ice cap melts in the polar challenge. This determines how the game avatars can move. The pace at which the water level rises in the jungle challenge which determines how fast the player needs to progress past obstacles in order to avoid drowning. The amount of thistles and CO_2 gas in your habitat which also determines the health of your avatar and your score in the game.

As the feedback on energy use in these cases has to merge with the feedback or reward mechanisms of the game, it cannot always be consistent in terms of energy use. Since it is important in a game that all the participants play on relatively equal terms, we have here instead aimed for consistency in terms of the effort invested by the players. In a game where one competes by lowering one's energy consumption, the means for measuring success must be adapted to the households' differing preconditions. The feedback is therefore largely based on the relative consumption change for each home as compared to a reference period immediately before the game.

Recreating engagement in regard to energy consumption by means of playfulness

As we have previously argued, many activities in the home are undertaken for the purpose of leisure. People amuse themselves by engaging in different forms of playful and experience-centered activities such as playing computer games, watching movies, taking care of their garden, and so on. Technology supports these activities by either making necessary chores easier to perform, or by providing the technical means for these activities, as for instance in the case of computer games.

In this context we have argued that energy feedback systems make more sense if they are framed as an engaging leisure activity. We have also argued that persuasive technology in the home needs to be able to compete with these other activities in order to be effective. In the prototypes presented in this thesis we have consequently aimed to make them both playful and engaging. But in so doing, we also have had to employ a different strategy than the more common functional approach in design.

While functional design, by attempting to make tasks efficient and easy, often simplifies reality and makes it more abstract, here we have needed do precisely the opposite. Instead of simplifying, we have needed to elaborate on the engaging complexities surrounding this topic, or when we have been unable to do this, as with computer games, invent artificial ones in order to make the use of energy more interesting. Playfulness can in this way be facilitated, by providing intricate rule systems, rich visual expressions, esthetic tensions, means for creation, and so on, as we discussed in chapter 4.

In our prototypes we provide an example of how such engaging complexity can be created by building gameplay and esthetics on top of metering data. We also provide examples of how indexical or iconic representations of the flow of energy can be used to utilize the already-existing complexities involved in the electricity consumption for this purpose. Through both the Awarecord and the Element we expose the inherent richness of our use of electricity as a way to make it more interesting.

While the reference to the theories from games research and playful interaction is quite obvious when it comes to the two game prototypes presented in this thesis, it might not be as apparent in the case of the two physical prototypes presented here, as they are not games as such. They do, however, exhibit a number of playful properties as we will illustrate here. The Awarecord and the Element could, in this sense, be said to be loosely structured and spontaneous forms of play, what in Caillois 's model would be referred to as *padia,* while the Power Explorer and Power Agent games, like most computer games, would be regarded as highly structured and rule bound, *ludic* forms of play (Caillois 1962). All the prototypes can in this way be interpreted through, for example, the PLEX model (Korhonen et al. 2009)

We will here show how our four prototypes can be understood through the principles of this model as described in chapter 4. We start by discussing these more spontaneous forms of play provided by the Awarecord and the Element and the way they pose *challenges* to their users, provide means for *exploration* and *discovery,* and in other ways encompass playful features.

Both the Element and the Awarecord pose *challenges* through their esthetic expression as well as their function. This can be very clearly seen in the evaluation of the Element, for instance (chapter 11). The Element is a mixture of two product categories in the sense that it can be regarded as both a radiator and a lamp, but fits into neither of these categories entirely. In a similar fashion, the Awarecord successfully combines the esthetics of an ordinary power strip with Christmas lighting decorations. The first challenge that this ambivalence poses to users is to figure out what the objects are and incorporate them into their existing notions of electrical appliances (Löfgren 2008). This becomes an ongoing evaluation task during the entire use of the prototype, and will, of course, be most active at the beginning or when the object is shown to visiting friends. Through this esthetic tension the object also becomes conspicuous and identity building. It becomes something that needs to be explained and that creates stories in other words it becomes engaging.

The second *challenge* that these prototypes pose is in regard to where they should be placed in the home. While radiators as well as electric power strips, as discussed earlier, are often designed as functional and sterile objects that are placed out of sight, lamps and decorative lighting, on the other hand, are often designed products meant to be placed where they can be easily seen. In this way these prototypes have no obvious prescribed place in the home, and thus explicit reflection is needed before placing them somewhere. This challenge could, for example, be seen in the evaluation of the Awarecord by Löfström (2008) as people became engaged in its placement.

The third *challenge* posed to the user by these objects is how to interpret the visual feedback presented by the devices. Although they have been designed to be intuitive, some exploration is of course needed before one understands how the varying consumption of energy is communicated. After this understanding is gained, it might also need reconfirmation though further use of the devices.

The Power Awarecord and the Element also supports *exploration* (Korhonen et al. 2009). Just as with challenges, *exploration* is offered on several levels. The Awarecord and the Element offer opportunities for *exploration* both in the way their ranges of visual expression in themselves can be experienced but also in the way, for example, that the Awarecord can be used to explore electric devices in the home. The Element similarly provides a means for *exploration* both in terms of its different esthetic modes (intense or tranquil, nervous or calm) as well as in the way it can be used to explore energy consumption in relation to the climate conditions in a room.

Another playful aspect of the prototypes, which follows from *exploration,* is *discovery* (PLEX TODO). *Discovery* can be seen as the reward of the *exploration*. The task of making discoveries could, for example, involve the satisfaction of making the visualization go crazy by running a lot of electricity through the Awarecord. It could also, as in the case of the Element, be the masochistic or subversive pleasure of finding out just how bright 2200W of light bulbs can be. It can, of course also be the experience of finding standby consumption where you least expected it, or observing the effect on the Element's energy consumption of opening a window. The devices discussed here, however, also offer *discovery* without active *exploration* in the way that these prototypes work as ambient displays. As such they can potentially put emphasis on changing or extreme conditions in terms of energy use.

Due to the strong visual expression in the prototypes we could argue that the prototypes also facilitate the playful pleasures of *captivation* and *sensation* as defined in the PLEX model (Korhonen et al. 2009). We will not, however, elaborate further on these here.

If we return to the other two prototypes, Power Agent and Power Explorer, we can see that in these concepts challenge, exploration, discovery, and captivation also play a crucial part. Creation and sensation, on the other hand, are perhaps less relevant. Both games frame the task of saving energy as a competition. In order to win the game, one needs to discover potential savings that can be made and carry them out.

But while Power Agent chooses a role-playing team-based scheme for this, its counterpart, Power Explorer, uses a gameplay based more on intense manipulation as well as the survival of a game avatar. In this way the unique properties ascribed to Power Agent could be said be *simulation*, *fantasy*, *camaraderie,* and *subversion,* while in Power Explorer, *difficulty* and *empathy* are in focus.

Subversion stands out in the Power Agent trial as one of the really enjoyable features of this game. By playing this game in a very focused manner, and also getting their families deeply involved, the teenagers playing the game could get away with many things that they normally would not be able to do. This includes things such as turning off the computer in front of their older siblings, turning off all the lights in the entire house, or ordering pizza for dinner.

Despite the differences between the prototypes in this thesis, and especially the difference between the games and the more physical prototypes, there are clear similarities in how they address the problem of revealing energy use through playfulness. For example, by posing challenges these devices and services all serve to reframe energy use and become identity-building items. The oddness that surrounds Awarecord and the Element will, for example, prevent them from becoming transparent in their use, as well as enable them to be discussed by both the users and their visiting friends. Through the challenges posed by our two games, the meanings of objects and their use in the home will be altered. By facilitating exploration and discovery, these prototypes furthermore all provide means for gaining an understanding of one's energy use.

Revealing the transparent and hidden use of energy

As pointed out earlier, in order to address our energy use we need to both be given the means as well as the opportunity to reflect on our actions. Revealing energy use is, in other words, a problem involving both our knowledge and our attention, although we have in this thesis mainly emphasized the importance of the latter. Feedback has here been proposed as the combined solution to both of these aspects. It is, however, important to point out that it is not just any kind of feedback that counts in this regard. Our homes are already full of devices that provide feedback on our consumption. An ordinary lamp, for example, provides you with feedback in the form of light every time you switch it on.

What is needed here is instead the kind of feedback that reframes the use of energy in our everyday lives and creates new associations with the use of electric devices. In the examples provided in this thesis we have shown how this can be achieved with designed cues that highlight both real as well as constructed effects of one's energy use. This could, for instance, be done by highlighting the flow of energy through a cord or framing a task as a means to win or lose a game.

Revealing energy use, as we can see in these examples, is highly dependent on esthetic properties of the visualization, for instance, how the visual elements create associations that enable us to think in terms of consumption, or how these prototypes can capture the user's attention by being challenging. But it also involves very technical aspects such as temporal, spatial, and qualitative properties of the energy feedback and the data we design this feedback around. It is, in other words, also about where, when, and how we receive the data. These factors determine how we can access the feedback, as well as map it onto different events and activities in the home. As the more esthetic aspects in this regard have been covered in previous sections, we will in this section primarily focus on the more technical aspects of the feedback.

We will here discuss how these aspects affect our understanding and use of the feedback, for instance in terms of how they determine what kind of activities the feedback is mapped onto, but also how they affect the amount of attention required to utilize the feedback. Before we do this, however, we need to identify the parameters involved.

These properties involve:

- The delay of the feedback – That is, the time it takes for a measured consumption variation to be displayed to the user.
- The level of aggregation – That is, how many individual devices that are covered by measurement.

- The accumulation time – Referring to the period of time the measurement covers.
- The locality – i.e., how the feedback is spatially represented in relation to the things measured.
- The interface accessibility – That is, the effort involved in accessing the interface *per se* in terms of logging in to services, etc.

The degree of locality and aggregation in the data can here be identified as *spatial factors* while the length of the delay and period of accumulation constitute *temporal factors*. Accessibility of the interface will here be referred to as a *procedural factor*.

The first three of the above properties of an energy feedback system (delay, level of aggregation, and accumulation of measurement) are often determined by technical limitations of the sensors or the data network involved. But we can, of course, also purposely induce delay aggregation and accumulation in our design to change properties of our feedback. In other words, there is a design aspect even in this, as what we choose to combine in a measurement determines what kinds of activities the feedback corresponds to.

When and where we choose to deliver the feedback also sets the framing of how we reflect on these kinds of feedback. Delayed feedback can, for example, be used to provide references to past behavior, while aggregated consumption can create understanding of larger concepts such as the use of energy in an entire building.

From a design perspective, however, getting real time, non-aggregated, and non-accumulated data from all appliances in a home is of course the optimal condition for data capture, as representations which are aggregated and delayed can always be constructed in an interactive system. Due to obvious technical constraints in the home, this kind of ideal case is of course not often practically possible.

In this study we have consequently explored prototypes ranging all the way from local and real-time feedback to aggregated, accumulated, and delayed feedback. In this sense the Element, whose feedback is directly integrated into an electric device, provides an example of non-aggregated, non-accumulated, real-time, and local feedback. The Awarecord, on the other hand, provides an example of a tool providing feedback in close connection to a task with aggregated feedback on one or few connected devices; i.e., it is partly aggregated. The Power Explorer prototype provides yet another example of energy feedback encompassing a measurement of the entire household's consumption, making it aggregated but delivered in real time. At the far end on this scale we find Power Agent, which is based on the electric utility companies' existing AMR systems and thus only delivers aggregated feedback on hourly accumulated consumption with up to a 24-hour delay.

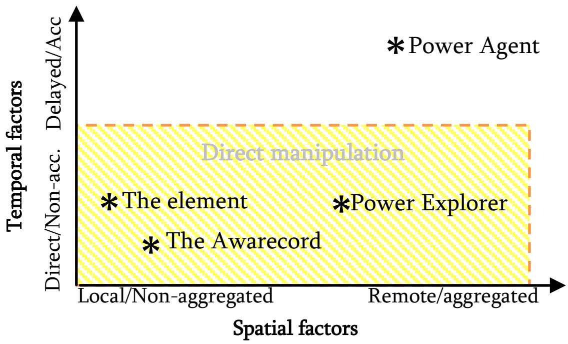

Figure 19. Our design space mapped by spatial and temporal factors.

In figure 19 we present this design space mapped by spatial and temporal properties. In terms of the procedural factors (the possible third dimension not covered by this map) Power Agent and Power Explorer constitute examples of feedback accessed through a service, while the Element and the Awarecord are examples of artifacts directly integrated into the home as ambient displays. We have here also indicated how the temporal factors affect the possibility to design around direct manipulation in terms of energy use, to which we will later return.

Strategies for motivating use

As previously discussed, an important question with regard to energy feedback is how to motivate its use. And as we have also previously argued, attention is a limited resource in the home. The reward gained by utilizing energy feedback information must, in other words, be in proportion to the attention it requires. How the feedback is presented in terms of delay and mapping of what is being measured can be seen as factors determining the amount of attention required in order to utilize the information. Obviously if a greater degree of attention is required to use the energy feedback, the user also needs to be more motivated to do so.

The closer in both time and space the feedback is to the concrete action one performs the easier it is to relate to it. But, as we have pointed out, there is also another important difference between the prototypes with regard to the level of attention required to engage with the energy feedback. The physical prototypes in this example (the Element and the Awarecord) provide us with feedback capable of involving us in the right contexts in respect to both time and place. In the case of Power Agent and Power Explorer, however, the feedback is instead accessed as a service through the interface of a mobile phone.

Unlike an ambient interface, a mobile phone service usually requires active and focused interaction. A phone requires actions such as taking it out, unlocking the interface, and possibly also starting and logging on to the service before information can be retrieved. In this sense, we also need to consider if the feedback can be accessed casually, or if extended manipulation is required.

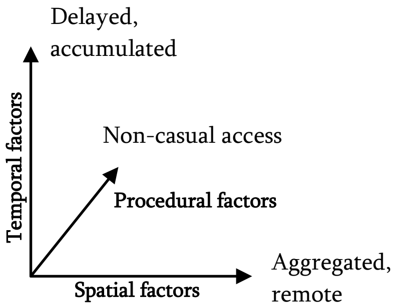

Figure 20. The design space mapped in terms of spatial, temporal, and procedural factors.

The total level of attention required to utilize energy feedback can therefore be seen as a combined function of the distance in time and space, as well as the effort in terms of manipulation, as seen in figure 20. In other words, it is a combination of *spatial*, *temporal,* and *procedural* properties, as discussed earlier.

Because one could typically expect a very high level of motivation and enthusiasm in the beginning when users buy or try out new forms of feedback systems, it could be predicted that even systems requiring a lot of attention will work initially. But as these products or services become domesticated (Löfström 2008), and fade into the background in our everyday lives, their immediate effects are likely to diminish because their use will become less rewarding, i.e., less motivating.

In our design we have had to address this issue by balancing the attention required by the different prototypes against the time they are used. By designing for a limited period of use, a higher level of motivation can obviously be maintained. When designing for extended use of energy feedback, on the other hand, we need to consider how to design for a more economical use of attention.

Our design approaches can in this regard be divided into an event based versus a continuous approach in terms of use. The two games can then be said to constitute a more focused form of interaction requiring a high level of motivation and attention from the user. They can, as a consequence, only be used for a limited period of time. The two ambient forms of interaction here constitute a less focused approach requiring little attention, but in return they allow for continuous use.

Within these categories there are, of course, also differences between the prototypes. The Awarecord, for example, allows for a more focused mode of interaction when actively used to explore the home. The Power Agent also constitutes a far more motivating and focused approach than the Power Explorer prototype. In Power Agent most of the missions are even limited to a specific time each evening.

Of course each of these approaches has its benefits, as we will further discuss later on. While a temporary event-based intervention seems to be able to motivate a quite significant reduction of energy use (chapter 13) during its use, its effects could, of course, be expected to be limited in a long term perspective compared to ambient solutions.

Strategies for delayed feedback

One of the problems with delayed feedback and mapping it onto specific tasks is that it obviously becomes harder to remember specific details of one's actions the more time that has passed. To solve this we can, through game or interaction design, frame actions preformed as particular events in order to make them more memorable.

As a strategy to strengthen the mapping between particular actions and the delayed feedback, we created a function in Power Agent that employs the mobile phone camera in order to log actions. Pictures taken of energy saving measures performed by the participants were, by means of this function, later superimposed on the consumption charts based on the time they were taken. In the evaluation, however, it proved to be difficult to justify the use of such a function. Mapping was also still problematic, as the feedback data, apart from being delayed, also had limited temporal resolution.

In Power Agent, we also used specific periods during the day when the players competed. In this way the energy saving measures were framed by each game session. By holding these game sessions late in the evening we also minimized the time until the feedback was received as well as the number of activities performed in the interim (the AMR system in this case was updated during the night). Participants were expected to end the day playing, and get the feedback upon waking up.

Another interesting way to deal with this in future projects would be to limit the feedback to times when known activities take place, such as, for example, making dinner, sleeping, or being away from home. Feedback on energy use at night could in this regard easily be mapped onto, for example, stand-by equipment in the house or heating.

Alongside the problem of mapping, another serious problem of delayed feedback was the loss of possibilities for direct manipulation. This has implications not only for the pedagogical value of the game, but also for the engaging and playful aspects of the interaction. The warm-up track in the Power Agent prototype can be said to be a strategy to remedy this. A conclusion that can be drawn about this is that the more abstract the energy readings are made, i.e., the more accumulated or aggregated they are, the more the solution has to resort to inventing fictive and artificial forms of interaction. As a consequence, integrating the message and other properties of the persuasive-technology argument becomes harder. As a result we also see more examples of unsuccessful integration of message and medium in this prototype as we will provide more examples of later on.

Strategies for aggregated and direct feedback

In Power Explorer, mapping feedback to behavior was much easier than in Power Agent. This can be seen, for example, by how stories were formed around the use of certain objects (chapter 15 p. 223). Our strategy to support mapping in this case was to focus the feedback on consumption change. In this regard the user received feedback every time something was turned on or off, and could then make the connection to what had caused it based on the activity currently being performed in the home. These so-called power events were then, as we have explained earlier, represented in the game as objects corresponding in size to the consumption change.

This form of feedback obviously requires active use and a significantly more focused form of interaction than the ambient interaction in the Awarecord and Element prototypes. A problem that arose with this approach, however, was that only a limited number of electrical devices were explored by the participants (chapter 15 p. 230). These were in many cases devices of particular interest to the participants, i.e., objects that they often used or to which they were especially attached, which perhaps made these observations particularly valuable. But there may also be a design factor here that limits the extent of the exploration.

As the game builds on aggregated data, it does not distinguish between objects being used other than through the amount they consume. In this regard a 60W lamp will serve the same function in the game as a 60W stereo. Hence, beyond a certain point further exploration becomes pointless, as all the other "buttons" in the game interface (i.e., the home) perform the same functions in the game and are therefore redundant. In this way we can once again see how abstractions of energy use in the feedback limit our possibility to motivate through playfulness as well as achieve integration between the different parts of the argument.

A way to tackle this problem, in term of feedback measuring the entire household, could be for future versions of this concept to make use of more properties than just the power consumption of a device in order to provide more options for manipulation in the game. This could, for example, include electrical parameters such as the amount of phase shift between voltage and current that different devices induce on the electric grid, or the power surge that the device initially induces. It could also include what electrical phase (in a three-phase wiring system) or fuse the energy consumption is connected to. In this way two electric appliances consuming the same amount of electricity could still provide different affordances in the game.

Stimulating social interaction in regard to energy usage

In the discussion so far we have seen numerous examples of how the social interaction surrounding energy use has been utilized as a resource in the design. By materializing energy, as the Awarecord and the Element prototypes do, we make it socially interesting. By making these artifacts that display the energy feedback challenging, we can also make energy use even more conspicuous and identity building in the context of the home.

We have also provided examples of how we can facilitate interaction about energy. This can, for example, be done by framing the use of energy as a competition or by providing a mutual language to discuss it. In the case of the two games, the social interaction relating to energy use in the homes becomes an essential part of the game. A lot of the enjoyment of playing these games obviously originates from the discussions and negotiations surrounding them. In their roles as energy-saving agents, the players clearly acquired some sort of authority over parents and siblings that was frequently employed for subversive purposes.

The social interaction surrounding these prototypes also proves essential to learning. While learning from the delayed feedback in Power Agent proved limited, the participants still learned a great deal through the actively discussed energy measures performed (chapter 13). While the Power Explorer game only succeeded in motivating exploration of a limited number of devices, through the stories they shared, participants still learned about many others (chapter 15). The pervasive game approach in this respect offers a very interesting solution to the problem of integrating learning into games.

Insights from evaluations

In this section we discuss in more detail how our different concepts were interpreted and understood by test users, how they worked in terms of a persuasive argument, and which of their properties that were appreciated or not appreciated. We also account for how the user tests provide support for our design approaches, and furthermore include a substantial part of the findings from the Power Awarecord evaluation by Löfström (2008), as this is not available in the individual papers and in its original form was published in Swedish.

Interpretation and understanding of the concepts

The four prototypes have been tested by a number of participants in a total of six studies altogether (of which four are covered by the articles in this thesis). Some of these studies took place in a lab setting, while other took place in the participants' homes. In the case of the physical prototypes, the concepts were in many cases shown or given to the participants without any previous information regarding their use in order to determine how the concept or esthetics were interpreted and understood.

The Power Awarecord was at an early stage shown to 15 randomly selected individuals in a laboratory setting to test its pedagogical properties (see chapter 10). In this test, three different visualization programs were tested on five persons each. One of these was a static program just showing different intensities of light, while the other two were closer to the final version in showing flowing and pulsating light.

Of the 15 participants, 13 correctly guessed the light to be representing an electric current flowing through the cord. The two participants who did not guess correctly had both been shown the static program. One participant expressed that it felt more like something was being transported when the light was pulsating or flowing. This gives us reason to suspect that the dynamics of the animation, or what could be referred to as the water metaphor, are of importance to the understanding of the concept. It consequently also shows that the dynamic quality of the visualization is important to its being able to act in a reframing manner, i.e., to provide associations to energy consumption.

In later user evaluations done by Löfström (2008), and involving eight households, participants were given the Awarecord for testing in the home. After testing the prototypes for the first time, many of the participants, according to Löfström, expressed that they were quite astonished when seeing it light up. The Awarecord seems to have provided an aha-experience, and none of the participants had any problems interpreting its function as a visualization of electricity. This suggests that there is indeed a strong pedagogical element in this concept.

According to Löfström, the participants interpret the Awarecord as a kind of power strip with a different or fun function. One participant likens it to a hose filled with colored water. Another of the participants compares it to a snake, or something alive that reminds you of electric use. No one associated it directly to economic factors. To some degree it was seen as a technical object, but most often it was seen as design object. It also, according to Löfström, challenges the notion that cables should be hidden away. Its natural place in the home often seems to become a heap of cables that the inhabitants have been unable to hide away.

Löfström further divides the different households into categories according to their stated interests in regard to energy and energy conservation. Of the eight households, four are labeled as being environmentally interested, three as being technologically interested, and one as being economically interested. This, she later shows, has some implications for how the knowledge gained from the Awarecord is employed.

While most participants seemed to be quite positive towards the concept, its lack of a numerical display did cause some skepticism among people with a technical interest in energy. This involved both participants in one household, as well as the man in one of the other of the technically labeled households. The woman in the latter of these households, on the contrary, appeared to be positive towards the concept.

Findings from both these studies suggest that the concept of the Awarecord is quite self-explanatory. Because prior to being used it looks like, and is perceived as an ordinary power strip, by the time it lights up it will already have been interpreted as such. The reevaluation of this interpretation will therefore take as its starting point this first interpretation. This is definitely not the case, however, with the Element.

In a test similar to the lab test performed with the Awarecord, none of the ten participants managed to associate the function of the Element with that of a radiator. This was despite the fact that half of the group was first given the task of exploring an ordinary electric radiator before exploring the Element prototype. Some of the participants did suggest that the primary function of the Element was probably not lighting due to its placement on the floor, but were still unable to arrive at the correct conclusion as to its function.

After later having been given the context of the prototype, however, the participants had no problem relating to it. Consequently discussions arose on how the prototype would fit in their homes and how the light could be helpful as a reminder of open windows or if it were on or off, etc. Most of the participants also found it esthetically pleasing, and appeared to be intrigued and fascinated by it.

In the case of the games, the concept had to some extent been explained to the participants before they could volunteer. In this way the context had already been established when the game started. When asked what they had expected of the experience prior to the test, most explained that they thought it would be a fun thing to try. Most perceived themselves as playing the game by turning off lamps in the home. The use of electricity, in other words, seems to be closely associated with the use of lamps where energy is naturally very visible. Saving energy in the context of the games also seems to have primarily been seen as a task of saving money rather than lowering CO_2 emissions, despite the fact that, for example, Power Explorer graphically communicated the environmental aspects of the game, which was also recognized by some of the players.

After playing the games (Power Agent for ten days and Power Explorer for seven days) reactions in both cases were overall very positive from both players and their families. Only one girl out of the six participants selected for interviewing in the Power Explorer evaluation reported that she would not want to consider playing a similar game in the future. This was also the girl who had been least active in the game.

In terms of understanding, there was, however, a big difference between the two games. While Power Agent seems to have provided a large amount of context-specific knowledge such as how to adjust room or refrigerator temperatures, its main contribution was perhaps the understanding of the impact of the energy saving measures on the participants' daily lives. It was the experience of dramatic measures such as turning off all the lamps in the home and spending the evening in darkness that created the stories. Power-saving strategies were rarely shared outside families or updated in response to the game feedback

In Power Explorer it was instead experiences of specific devices that caused stories to be formed. The participants seemed to have gained a very detailed knowledge of when electricity was used in the home, and in several examples also specific knowledge in terms of devices.

The integration and reception of the persuasive message

After having used the Awarecord for some time, the participants in Löfström's evaluation (Löfström 2008) reported on how the prototype had been incorporated into their lives. According to Löfström, the Awarecord successfully stimulated reflection on and awareness of energy consumption in all test cases, but apparently in rather different ways. We here find examples of how the Awarecord was used as intended both as a tool to explore the home and, after having found its particular place in the home, as an ambient display. The Awarecord in this sense exhibits two modes of interaction, one of which is obviously more focused.

In one home, for example, the participants explained that the Awarecord wound up being placed in a clearly visible space beneath the office desk. This was the only visible heap of cables in the home and they had been unable to hide it, the family explained. It was therefore, as they saw it, the only natural place for it in their home. After buying and installing a new office computer they had noticed that the expression of the Awarecord changed and from this drew the conclusion that the new computer used a lot more energy than the old one.

In another home the Awarecord was used in a more active explorative fashion. When not in use it was placed by the TV. However the participants in this home, although they greatly enjoyed the pedagogical aspects of the prototype, did not like its visual appearance. For this reason it was treated more like a functional object. If they had owned a product like the Awarecord they expected that it would probably only be taken out when needed and be stowed away the rest of the time. Both message and argument are in this example accepted, even though the esthetics are not approved of.

We can also see clear examples of the duality and complexity in people's attitudes. In one case the Awarecord was installed and tested in the living room upon delivery. The participant in this house reflected that this was not a place where he would keep the prototype, as his living room was the sanctuary where he usually relaxed. The Awarecord, he explained, gave him a bad conscience, despite his previously having said that he was not interested in saving electricity. Nevertheless, during a follow-up interview the Awarecord was still found exactly where he had said he did not want it. Although he had considered moving it from time to time, he gradually found himself accepting his bad conscience. In this case the argument was clearly accepted based on its ethics, while the message perhaps was not.

The Awarecord can also provide motivation through provocation as seen in this example. In one of the skeptical homes that had labeled itself as having a technical interest in energy, the Awarecord had been rejected due to its lack of a numerical display. In this home the participants had instead bought another measuring device that showed consumption in digits and that was now used to explore their energy consumption. The Awarecord in this context still served a function in as much as it caused reflection on and engagement with the use of energy. It also seems to have triggered exploration in the way its function was compared to the new energy display they bought.

In this case one could say that the language of the Awarecord here collided with the language with which these people had already learned to understand electricity. At the same time it awakened their technical interest in devices and their use of electricity by visualizing it as well as by pointing out a lack of understanding and knowledge on their part. For these people the inability of the Awarecord to display consumption levels in what for them was the correct language was very provocative and consequently motivated them to get involved in the subject by other means.

In this example the argument but not the message was rejected. That is, while they obviously saw the need for addressing and exploring their energy use they still did not approve of the way the Awarecord enabled this to be done. The persuasion in this situation clearly still worked, but in reality it can be questioned if these people would really buy a product like Awarecord. Here, one could of course again argue that seeing it or, for example, using it at a friend's place or at an exhibition could provide a similar context as the one described in this user test. This involves a social component prior to the engagement with the artifact itself.

We can also see how the Awarecord could be used more in its capacity of a visual effect. In the household labeling itself as having an economic interest in energy, this was particularly obvious, as the prototype did not really find a place where it belonged. Instead it was mostly brought out by the husband to impress visitors. A couple of times he even brought it to work. The husband works in construction and planning of electrical systems and obviously normally deals a lot with electricity.

He explained that he thought it fit best connected to his coffee machine in the kitchen where it made a nice impression. But since he did not want power strips in the kitchen he did not use it there. He would in this case have preferred a cord integrated into the coffee machine. He also explained that he would prefer it if he could manually set the flow of the cable or even be able to change the color. In this way he thinks it would make a nice Christmas decoration or disco light.

From the interview it is obvious that he did understand the concept behind the Awarecord quite well. He also seemed to appreciate its visual effect as he showed it both to friends and colleagues at work. The way he presented it, however, was more in the form of a prank to surprise people. But at the same time he also talked about how the Awarecord reminded him of the spinning electricity meter and how expensive the bill would be. It is clear that he felt uncomfortable with this conservation message. Since this participant it can be had a quite good knowledge of electricity based on his profession the prototype might have offered less in terms of its function to create understanding. Consequently he tried to find other uses for the artifact.

Even so, the thorough integration of the message in the product here seems to have caused him some trouble since it would be hard to use it for pranks or decoration without still being reminded of his appliances' energy consumption. A manual override of the visualization, as he suggested, would of course in this case destroy this integration. In this case, it would seem that the message was rejected but perhaps not the argument, as he continued to show it to people even though he did not normally use it. In this case the person's feelings towards the Awarecord were obviously quite ambiguous.

One can also observe a polarizing effect on the social interplay surrounding the concept of the Awarecord. In one of the households, which labeled itself as technically interested in energy, the husband, as mentioned earlier, remained critical. At the same time his wife embraced the function of the Awarecord and thoroughly explored the home with it. The husband, just like in one of the previous examples, felt that the prototype needed to have a numerical display in order to be useful. But unlike the previous example, he did not doubt that it measured electricity accurately. While his wife went around the house to explore the home with the Awarecord he was observing from a distance. But even if the prototype were to have a numerical display, he doubted that he would want it in his house. “Well you just end up with something like – the TV uses a lot of electricity so I should probably not watch this program.” (Löfström 2008)

In this case both the message and the argument were rejected by the husband. His wife, however, after using the Awarecord extensively still had ideas for what she would have wanted to test if it was returned. She explained that she would have loved to test it on the car engine block heater but that she was not able to, since the agreement was that it could not be used outside. Also, she would have wanted to test it on the stove, but since she could not access the plug she was unable to. For this participant, seeing is knowing.

The social interaction between the two attitudes in this home was very interesting. One can suspect that the enthusiasm for the Awarecord was here boosted a bit by the partner’s negative attitude. This could be seen as the wife using it to signal an identity or as a playful means to annoy her husband (i.e. a case of *subversion* (Korhonen 2009)). Combined with the social interplay in this situation, despite the husband’s overwhelmingly negative experience, the Awarecord could obviously have an effect on him. In that case this example would then argue against our previous assumptions in terms of a positive persuasion needing to appeal to the user. In this case, it could however be argued that our persuasive-technology argument played a secondary role towards the social persuasion going on here. The effect on the husband in this situation was also relatively small compared to that on the wife.

In the power games trials one can say that the medium was to a lesser extent questioned, and we can only find two examples of this. Some of the older participants in the Power Agent trial remarked that the game might be for someone a bit younger than them, although they still enjoyed it. One of the participants in the Power Explorer trial, whose sister had also played the Power Agent, game remarked that the graphics in Power Agent were quite “crappy” compared with the other game.

One reason for this lack of questioning may perhaps be traced to the recruitment of the participants. In the game trials, volunteers signed up to participate in playing a game. In Löfström’s evaluation, the participants were instead persuaded to participate in testing a prototype without much prior knowledge. So while in the game trial people signed up to play a game, the participants in Löfström’s study instead signed up to participate in a research experiment. In this way the communicated notion of what they were volunteering for might have filtered out certain participants as the notion of a prototype is obviously much more general than the notion of a game.

This can perhaps also be related to the fact that this was a temporary event-based intervention in the form of a service, as previously discussed. The participants, in other words, did not need to take a stand in regard to whether it fit into their homes. In Power Agent it was rather a task of taking a position on whether or not the energy saving measures undertaken were something they could live with. The father of one of the participants, for example, reflected that the most effective measure that they performed, switching from electrical heating of hot water to using the wood boiler in the basement, was probably something they could live with (chapter 13 p. 193). At the same time he also mentioned several other measures that had been interesting to try out, but that he didn't believe to be possible to implement in their normal everyday life.

There also seemed to be a high level of acceptance of the message in the Power Agent and Power Explorer games. This was particularly the case in Power Agent, where all the six participants achieved a quite significant decrease in energy consumption (in the range of 10–30%) during the 10 days of the trial. Since Power Agent was team-based game involving the entire family we can here see how the social context of the game worked to enhance the persuasion in the form of, for example, peer pressure. In some cases, however, the players found themselves in conflict with older sisters or brothers over the task of saving energy.

In Power Explorer, twelve out of the fifteen players showed a decrease in energy consumption during the trial compared to the four weeks before the trial, while the rest showed no decrease, or in one case even an increase in their use of energy. In the single case where consumption increased, the player was of the opinion that she did save a lot of energy but still ended up coming last. In other words she did make an effort, but most likely overlooked something.

In one other case a strategy of playing a lot of duals was chosen and consequently a lot of the saved energy was used on dueling. In this case, however, the household still showed a quite dramatic decrease in its use of electricity after the game trial. Only in one case did the persuasion seem to have resulted in a negative experience, as the player did not engage that much with the game, and did not want to play similar games in the future.

Failures of integrating the conservation message with the application

In the study by Löfström on the Awarecord we do not find many examples of the message and the medium failing to integrate, that is to say, cases where participants engage with the experience but fail to recognize the message. The closest example we can find of this is the case where the participant wished that the visualization could be manually controlled.

In the Power Agent trial, however, we can find a few cases which could potentially be regarded as integration failures. These examples include cases where the participants, instead of trying to cook energy-efficient food (the topic of one of the missions), ordered pizza; where participants turned off lights and instead used flashlights or candles; or where a family saved energy and solved a mission by visiting a friend and staying away from the home. In all of these cases, however, even though the saved energy might have been used up elsewhere or in some other form, the events still caused reflection and greater awareness in terms of what the different tasks of using lamps, making dinner, or staying home mean for energy usage.

Mapping of feedback onto activities

Feedback that is delayed, aggregated, or accumulated can provide a different form of understanding than feedback that is not. In our design examples this could be noticed in that, for example, during the Power Agent trial, due to the delayed and aggregated feedback, mappings were often made onto very general things and larger concepts. Successful mapping were, for example, made onto what time of the day electricity was used or if a family was home or not (chapter 13).

In our particular case it seems that these forms of insights, mapping onto very abstract concepts, were not enough to make informed choices about the strategies to be used. As the evaluation revealed, the participants in this trial often continued employing an energy conserving measure regardless of whether or not it was successful in terms of lowering the energy use (See chapter 13). In this case it seems that the feedback provided was of little use, apart from the role it played as a reward mechanism for the effort put into the game. In this regard, a quicker feedback loop, such as in Awarecord or Power Explorer, seems to have provided the appropriate means to map energy onto more concrete actions in the homes (Löfgren 2008, chapter 15). In this way it also appears to be easier to adapt the measures taken in response to the effect they provide.

The more the feedback maps onto concrete actions the more effective it obviously becomes in terms of finding the most effective strategies. This does not, however, mean that this strategy becomes the most effective in terms of saving energy. In the Power Agent trial, where the mapping feedback was clearly more difficult to understand, participants still showed energy savings of on average 21%. During a single game session these savings could even be as high as 74%. This can be compared to the Power Explorer trial where participants using real-time feedback easily mapped onto concrete actions, only saved about 16% in term of electricity usage.

While the feedback in the Power Agent prototype failed in its function to educate, it evidently did not fail to motivate the players to save energy. Nor did it, through its function as a measure of success, fail in reframing the use of devices as energy use. Some participants, for example, expressed how they, as a result of the game, felt uneasy about seeing things using electricity. These finding, we argue, support our previous argument that addressing energy use in the home is more a problem of directing attention towards the energy use as such than one of providing information about exactly where the kilowatts are being used.

The informative part of the feedback, as these results also show, still plays an important role. But this is not so much through its function of providing information about the amount of energy used, but more in its role as a motivator by making the feedback interesting. This interest, we argue, resides in the message through the information becoming dynamic and also provides means for goal setting; i.e., it in this way supports *exploration* and *challenge*.

We can also see here that despite the fact that the feedback failed to educate the participants in the Power Agent trial about energy use, they still learned a lot of things. Instead of learning from the feedback, however, they learned from the experiences that the game created. This included what kinds of energy saving measures they could and could not possibly live with (Chapter 13).

Nevertheless, there are of course limitations to the approach in the Power Agent game. Since this game was deliberately designed to be highly motivating with regard to the task of saving energy, it also quickly consumes the players' enthusiasm. As a conscious choice, the game was for this reason designed to be played only for a short period of time. The effects remaining after this intervention also appear to have been limited, as energy use quickly returned to normal afterwards (chapter 13, p. 188).

Strategies for long term effects

With regard to reframing energy use in a long term perspective, a highly focused event-based strategy can be said to rely more on secondary effects of the intervention, while a low-intensity durable strategy relies more on the immediate effects of the intervention. The secondary effects in this situation can be said to be the reframing of electricity use caused by a change in attitudes or knowledge acquired during the intervention.

We suggest that associative learning (Skinner 1971) is especially important in event-based strategies like the Power Explorer and Power Agent examples. This is because associations made with devices can continue to reframe the use of devices even after the intervention. As the user evaluations show (chapters 13 and 15), both games seemed to have had quite a good effect on attitudes. The participants are also able to successfully map consumption changes shown in their phones onto tasks performed in the home. But since these mappings to a larger extent were mapped onto abstract things in Power Agent and more concrete things in Power Explorer, there is a large difference between the prototypes in this regard.

As concrete objects such as electric devices have a greater visual presence in our homes, post-game associations are likely to be more effective in the case of Power Explorer. In Power Explorer's results we can also see a stronger tendency toward post-game effects (Chapter 15 p. 227) in terms of decreased consumption, while Power Agent, with its limited measurement, shows no such tendency (Chapter 13, p. 188). Another difference between the two prototypes is that in Power Explorer there was a rich discussion between participating homes in terms of how much electricity something consumed. In Power Agent we found no such discussion; here, the conversations among participants from different households instead revolved around declaring one's ambition to win the game.

But there is yet another difference that emerges between these prototypes that is perhaps of even more importance for the long-term effect. That is the type of measures these prototypes promote. While Power Agent, through its design, can be seen as exerting the highest level of motivation on the user, this prototype also motivates extreme measures in terms of energy conservation. These measures include turning off all the lights in the house or skipping dinner in order to save energy. Power Explorer, through its somewhat more casual game style, instead promotes more moderate measures that could be sustained over time. These include, for example, turning off the computer at night or other as they many times put it unnecessary things.

A conclusion that we can draw from this is that in terms of energy feedback interventions, we must not only motivate energy conservation but also the right type of energy conservation. In order words, we need to address those measures that are most likely to also function in an everyday context.

Positive Persuasion

In the discussion above we have seen examples of both the message (conserving energy or becoming energy aware) and the argument (framing the message in terms of esthetics, experience, etc.) have been rejected or accepted independently of each other. We have seen how the argument can be rejected or accepted based on its persuasive, esthetic, pedagogical, or ethical properties. In some of these examples the prototypes are used despite either the message (but in this case not its ethics) or some part of its argument being rejected. These findings support our earlier argumentation concerning persuasive technology and its usefulness. We have argued that in order for persuasive technology to be useful one needs to better address the receiver's context. In order to motivate use, the argument must be able to provide an incentive for use in the context where it is to be deployed. In a domestic context it accordingly needs to be able to compete with other activities present in this setting. Furthermore, the perceived benefits of what is offered by a persuasive-technology argument must outweigh the drawbacks. This needs to be true regardless of whether or not someone is positive to the message, or what the person's final attitude will be towards the persuasive message conveyed. What is important is instead that the argument in itself be found interesting, meaningful, or justified.

In this way the attitude towards the message will always affect the way an argument is perceived and, as we have argued, limit the usefulness of persuasive technology. In some cases, however, participants in the trials, despite having a quite negative attitude towards the message of saving energy, still found the argument of interest. We also saw examples of the persuasive-technology argument being used for persuasive purposes among family members. In such situations a message might be effective even though a person is very negative towards the message or argument *per se*. In both the Power Awarecord trial (Löfström 2008) and the Power Agent and Power Explorer trials, a tension could be seen between family members of different opinions that indicated social persuasion processes emerging in parallel to the interaction with the persuasive technology itself. Nevertheless we have to recognize that there are limitations to what can be achieved with persuasive technologies in a home context. In these user tests, the persuasive-technology arguments were to a large extent put into these homes after an agreement with the inhabitants, and not bought or downloaded by the users themselves. This indicates that they had a much easier task of finding their way in to the homes than would be the case in a real situation. Although these interventions in most cases were used we have no way of knowing if they would have actually been bought by the participants.

Integrating the persuasive message into its medium

As discussed earlier, a strategy of reframing a persuasive message within a game context, as is done in serious games, can be problematic. The players might only learn the details of the medium and not the message, the message might ruin the experience, or the experience might cast the message in a bad light (Bruckman 1999, Linderoth & Bennerstedt 2007). In order to solve these problems, message and medium need to be integrated. This requirement, we argue, is also transferable to persuasive technology outside the game domain. We will here discuss the strategies used in the prototypes presented in this thesis with regard to how the issue of integration has been solved.

The traditional view of playing games is that it is a task of identifying and making sense of objects within a rule-based system in order to manipulate these objects towards a goal. Linderoth & Bennerstedt (2007), on the other hand, says that it is more often a task of discerning affordances and thereby gaining the ability to manipulate objects towards the goal. This is more connected to the actual technical aspects of the medium than what is represented in the game. The level of detail of the graphics of an object can, as an example, provide a clue as to whether the object is an active part of the gameplay or just a passive prop. Although the rules of a game are learned, the parallels between this rule system and real-world phenomena might be lost on the players. Performing so-called transfer between the game context and the real world becomes problematic.

This might also be understood, as Svahn (2009) points out, using the dual process theories, although he seems to be applying these at a more general level rather than to the individual elements of the game. The elements of the game may be processed through a systematic/central route, i.e., examined logically; or a heuristic/peripheral route, i.e., dealt with more casually and automatically, which one might characterize as a more shallow way of processing information. Systematic processing is mostly used when we have a need to fully understand a situation which is very unfamiliar. For experienced players, the basic mechanics of the game may be handled through the fast and automated processing that the heuristic route enables. In this way they might also miss out on the deeper implications offered by the game. There might, however, still be systematic processing in regard to the overall process of attaining the goal of the game in the case of what Svahn refers to as complex games (Svahn 2009).

If the message and the real-world references are made more explicit or if they intrusively demand systematic processing, this might on the other hand throw the player out of the context and ruin the playful loop. Another solution to the problem has been to create so-called debriefing sessions during or after the game (Henriksen 2006). In these sessions, the players are encouraged to reflect on the game experience to bring about systematic post-experience processing of objects and relations in the game. In Power Agent and Power Explorer we instead employed a strategy of combining the goal of the game with the message, as well as designing for the social dimension of the home to generate reflection on the experience. In practical terms this has been achieved through the use of a so-called pervasive game concept.

As explained earlier, a pervasive game is a game that expands out into reality in some way. In this way part of the game's medium is also moved out into reality. In our case, the entire home becomes a game interface. As a result the problem of transfer becomes less of an issue since the manipulations done in Power Agent and Power Explorer are to a large extent performed in the home on real electric devices. The goal of the game and the message, saving electricity, are in this way also combined. However as we have seen in the Power Agent example, the particular framing of conditions in the home that a game brings can sometimes also make it difficult to transfer measures taken in the gaming situation to situations arising afterwards. Therefore, in order to achieve long term effects on behavior a concern can in this case be said to involve how to not changing the situation too much.

The expansion of pervasive games into reality can be understood as consisting of a spatial, temporal, as well as social expansion (Montola et al. 2009). The social expansion in this case consists of players needing to negotiate and discuss while performing energy-saving tasks in the home. This will then generate more in-depth systematic processing of the events experienced. These experiences and reflections will also be shared as stories.

In the case of our physical prototypes, we do not, of course, have an explicit goal as in the example of the games. Even so, all play could be said to have the goal of mastering something, that is, understanding the rules of a context and/or perfecting skills for manipulating entities or factors within this context in accordance with these rules. Hence we can say that in this situation the goal of the play is to understand the objects. It then follows that the message of gaining awareness and understanding of energy use needs to be combined with the process of understanding the artifact in its context.

This is done partly through the metaphor employed, which links the visual expression and the message, and partly through how the message is integrated into fully functional electric appliances. Because of this, understanding these devices also means understanding ordinary radiators and power strips. Just as with the games, part of the rule-set will reside in our implementation, while the other part will be formed by the circumstances surrounding the home and its use of electricity.

Chapter 9

Conclusions

In this thesis we have investigated how we can use persuasive, ubiquitous, and playful energy feedback solutions to create fun, interesting, and in other ways rewarding experiences that promote more sustainable behaviors in the home with respect to energy use. In our approach we depart from current notions within the field of persuasive technology, which see it as a generic tool for changing peoples' attitudes and behaviors, and instead argue for its limited, but still powerful use as a tool for self persuasion.

We have argued that in order for a persuasive-technology argument presented in the form of an artifact or service to be understood and accepted, it first of all needs to appeal its intended users, but furthermore also needs to promote continued use. Since the adoption of the argument in most cases, and in particular in one's home, is done on a voluntary basis, a central issue here is to look at what a persuasive technology argument has to offer the intended users and how it fits together with, as well as competes with other activities in its use context. We consequently argue for a *positive persuasion strategy* in terms of persuasive technology, i.e., a context- and experience-focused design approach that asks precisely that question.

We have shown how such an offering can be created through playful, esthetical, social, as well as functional properties of a persuasive-technology argument. We have argued that in designing for positive persuasion, integration of the different properties of the argument is of particular importance. We have also shown how such integration can be achieved in the home through concepts from ubiquitous computing such as ambient displays or pervasive games.

Using the understanding gained in this exploration, we have argued that the inability to address personal energy use through feedback (Matsukawa 2004, Ersson & Pyrko 2009ab, Pyrko 2009) is due to the problem having been misunderstood as largely being one of communicating information. Current means for energy feedback often focus on providing accurate and objective measurements of kilowatts used (Pierce 2008). But energy feedback, through its ability to motivate awareness of energy use, seems to cause energy savings regardless of whether or not the information is understood and mapped onto the actions causing it (chapter 13). Therefore, we have instead argued that it mainly is a question of attention; in other words, the problem is how to get people to recognize that their use of electrical devices involves energy.

In addressing the transparency surrounding energy use as a problem of attention, we have pointed out a number of parameters that are important to take into account. These include the timing of the feedback and how to balance the demands placed on our attention with the degree of motivation available in a particular situation. We have shown that one way to address the latter of these parameters can be to adjust the length of time that an intervention runs.

In terms of the esthetic properties of the energy feedback we have argued for esthetically rich and playful forms of visualization, rather than accurate measurements in terms of kilowatts or kilowatt-hours. In this way feedback can attract attention and engage users by supporting playful aspects such as *exploration* and *challenge*. Rather than providing abstract and inconspicuous accounts of energy use, we argue, energy feedback should try to exploit the rich details of appliances' use of electricity, as well as the surrounding social context as a means to create engagement.

Through this approach we have in this thesis shown how energy conservation can be made an intrinsically fun and enjoyable experience. We have also shown how these forms of interventions can have a dramatic effect on energy use and how they can appeal to other people than those already engaged with the issue of energy use in the home. In addition to arguing for the importance of interface design as a means to address energy use in the home, we have also provided examples of how this can be done. Through the examples provided in this thesis and the obvious benefits that visualizing energy use can bring to design, our hope is that we can inspire to future exploration of this matter in terms of both research and product design.

Summary of papers and contributions

Chapter 10: Designing for Energy Awareness - The Power-Aware Cord

Ilstedt Hjelm, S., Gustafsson A., and Gyllenswärd M. (2005) Designing for Energy Awareness - The Power-Aware Cord. In *Proceedings of Pride and Predesign* E. Corte-Real, C. A. M. Duarte & F. Carvalho Rodrigues (Eds.), (Lisbon, Portugal, 2005) IADE/UNIDCOM.

This paper deals with the construction and initial user feedback of the Power Awarecord prototype. It is an expanded version of a previous short paper published on CHI 2004.

This author was responsible for conceptualizing, designing, and implementing the prototype, and performing an initial evaluation, together with one of the co-authors. In this study, both parties contributed in the same manner, however the author's work was focused more on the construction of the cord and the visualization algorithm and to a lesser extent the form and choice of material. The initial work of conducting interviews with people to gain insight into their energy use was shared equally by all three authors. The author and the two co-authors have all contributed equally to the writing of the paper.

Chapter 11: Visualizing Energy Consumption of Radiators

Gyllenswärd, M., Gustafsson, A. and Bång, M.. Visualizing Energy Consumption of Radiators. In *Proceedings of First International Conference on Persuasive Technology for Human Well-being, Persuasive 2006*, (Eindhoven, the Netherlands, May 18-19, 2006), http://www.springerlink.com/content/f55x762654301552/

This paper deals with the construction and initial user test of the Element prototype.

This author was responsible for conceptualizing, designing, and implementing the prototype, and performing an initial evaluation, together with one of the co-authors. In this study, both parties contributed in the same manner. The author and the two co-authors have all contributed equally to the writing of the paper.

Chapter 12: Promoting New Patterns in Household Energy Consumption with Pervasive Learning Games

Bång, M., Gustafsson, A., and Katzeff, C. Promoting renewed domestic energy consumption patterns with pervasive learning games. In *proceedings of Second International Conference on Persuasive Technology, PERSUASIVE 2007*, (Palo Alto, CA, USA, April 26-27, 2007), Springer Verlag, 55-63.

This paper deals with the design and implementation of the Power Agent prototype.

As the originator of the basic idea of connecting a persuasive game to the electric use in the home, this author played a central role in conceptualizing, designing, and implementing the prototype, together with a larger project team. The author's contribution to the writing of the paper basically consisted of formulating the description of the design.

Chapter 13: Evaluation of a Pervasive Game for Domestic Energy Engagement Among Teenagers

Gustafsson, A., Katzeff, C., and Bång, M. 2009. Evaluation of a pervasive game for domestic energy engagement among teenagers. *Computers in Entertainment (CiE). 7, 4* (Dec. 2009), ACM New York, NY, 1-19.

This paper deals with the evaluation of the Power Agent prototype. It was originally published at the ACE 2008 conference and was there awarded silver in category the best paper. As part of the reward it was republished in Computers In Entertainment in 2009.

As the originator of the basic idea of connecting a persuasive game to the electric use in the home, this author played a central role in conceptualizing, designing, and implementing the prototype, together with a larger project team. With regard to the evaluation, this author and the two co-authors contributed equally to the design and implementation of the study. This author was solely responsible for interpreting and analyzing the data for this specific paper. The paper was mainly written by this author alone, but with some help from the two co-authors in the final phase.

Chapter 14: Persuasive Design of a Mobile Energy Conservation Game with Direct Feedback and Social Cues

Bång, M., Svahn, M., and Gustafsson, A. (2009). Persuasive design of a mobile energy conservation game with direct feedback and social cues. In *Proceedings of the 3rd International Conference of the Digital Games Research Association* (DiGRA 2009) (London, UK, 2009) http://www.digra.org/dl.

This paper deals with the design of the Power Explorer prototype.

As the originator of the basic idea of connecting a persuasive game to the electric use in the home, this author played a central role in conceptualizing, designing, and implementing the prototype, together with a larger project team. This author's contribution to the writing of the paper was considerably less than that of the two co-authors.

Chapter 15: Power Explorer – A Casual Game Style for Encouraging Long Term Behavior Change among Teenagers

Gustafsson, A., Bång, M., and Svahn, M. 2009. Power explorer: a casual game style for encouraging long term behavior change among teenagers. In *Proceedings of the international Conference on Advances in Computer Enterntainment Technology* (Athens, Greece, October 29 - 31, 2009). ACE '09, vol. 422. ACM, New York, NY, 182-189.

This paper deals with the user evaluation of the Power Explorer prototype. It also relates the results in this paper to the previous evaluation of the Power Agent prototype.

As the originator of the basic idea of connecting a persuasive game to the electric use in the home, this author played a central role in conceptualizing, designing, and implementing the prototype, together with a larger project team. With regard to the evaluation, the author and the two co-authors contributed equally to the design and implementation of the study. This author was solely responsible for interpreting and analyzing the data for this specific paper. The paper was mainly written by the author alone, but with some help from the two co-authors in the final phase.

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Part 2

The papers

Chapter 10

Designing for Energy Awareness - The Power-Aware Cord[2]

Abstract

Design shapes our everyday material world, thereby inhibiting some actions and affording others. During the 20th century, design has been used successfully to increase our energy consumption through the creation of electrical appliances. The paper argues that designers should now use their powerful ability to transform everyday life and behaviour in order to better support awareness of energy use and efficiency. As an example, we present the 'Power Awarecord' a re-designed power strip that visualises the amount of electricity that flows through to the appliances that are connected at any given time.

Introduction

Use of energy is increasing all over the world and particularly in Western countries. In Sweden, households have doubled their energy consumption in the last 30 years. While industry, to some extent, has been successful at efforts to optimize their usage, no such advances have taken place within the domestic sphere. We are instead, at a rapidly growing pace, buying more products for our homes, items such as entertainment and household appliances, personal information and communication products, computers and accessories. Product design has had a crucial role to play in this trend ever since the days when the German electrical firm AEG began designing household appliances to

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[2] Ilstedt Hjelm, S., Gustafsson A., and Gyllenswärd M. (2005) Designing for Energy Awareness - The Power-Aware Cord. In Proceedings of Pride and Predesign E. Corte-Real, C. A. M. Duarte & F. Carvalho Rodrigues (Eds.), (Lisbon, Portugal, 2005) IADE/UNIDCOM.

increase their customers' use of electricity. The design of home appliances not only encourages us to buy items, it also tends to keep the energy use in products explicitly hidden. There is little to reveal if a stereo or freezer is active or not, nor how much energy it consumes. Not everyone realises that the mobile phone charger uses electricity even if the phone is disconnected. In itself, electricity is both invisible and intangible. We can see, feel, hear and even smell its effects, but we can not really grasp it. As the effects of electricity in our everyday life (light, heat and so on) are taken for granted, electricity becomes even more invisible.

This paper argues that design should be used as an integrated tool to raise awareness of energy consumption in everyday products. We propose a design agenda that investigates interaction and product design as a way of visualising energy consumption and to stimulate changes in behaviour. Critical design prototypes may be used as a basis for discussions, as well as to support awareness of design issues related to energy use. As an example of how to design for energy awareness, we will present the 'Power Awarecord', an augmented (Mackay 1998), electrical power strip, in which the electricity running through the cord is made visible.

Figure 1. The modern home; littered with electrical appliances while electric meters and fuses, from a design viewpoint, still are at a very immature stage of representation. Images from the interviews.

Design and energy – a background

The success story of the 20th century is intimately connected to technological development and artefacts associated with this 'progress'. In the beginning of the century, the archetypical designer Peter Behrens started working for AEG, or Allgemeine Elektrische Gesellschaft. AEG was a company that primarily produced electricity and had just begun to enter the consumer market. The problem for many electricity companies at that time was that amounts of usage were spread unevenly during the course of the day. There were peaks during the morning and evening hours, but during the day consumption fell to almost zero. In order to meet demand, the companies had to sustain the same high capacity at all hours. This was obviously not profitable, and many shrewd men were wondering how to increase the demand for electricity during the daytime. One of the most successful ventures turned out to be kitchen appliances. Just to name a few, the electric stove, mixer, toaster, washing machine, kettle, heater, and iron were all developed in quick succession. A hundred years later we can see that AEG and Peter Behrens were highly successful. Electrical artefacts seem to have marched into homes in ever increasing numbers. During the last 30 years, Swedish households have doubled their energy usage and there is no sign of the trend slowing down. One important factor in this development is industrial design. Design is what forms these products to new, attractive and desirable objects that we fill our homes with. Besides being a useful tool in product development and marketing, design is literally what shapes the material environment of our everyday life thus enabling or disabling human activity and behaviour (Illstedt Hjälm 2004).

What people think about energy

We conducted a series of semi-structured interviews with 10 people of various ages, background and housing to gain rich materials and insights concerning people's understanding and use of energy and as inspiration for future work. As expected, electricity in many cases seemed to be taken for granted, for example most people had no clue as to how much electricity they use, on the other hand they usually had a quite good idea of how much they paid. Questioned on how much electricity they consumed, some answered:

> I have no idea, but the bill from Fortum (The local energy provider) is usually 200 kronas each month.
>
> Not a clue, I have higher bill now than before…I payed about 1 200 a year before, but now they raised it so last bill was 700 but that was one of those….you pay more the last time, so it might be about 2 000 kronas per year…well maybe not quite….

In addition, none of the people living in flats knew where the electric meters were situated nor how to access information on their energy consumption. The only way to get feedback on their use was via the electricity bill, which many felt was very difficult to interpret. The 'watts and volts' on bills or labels seemed hard to relate to the actual use of a lamp or a washing machine. Electricity was described mainly through its various effects. Informants answered that they knew that the power was there because there was "sound and light", or "you could see it on the bill". One woman said.

> You see if the house is electrified…well if there are electric lights in a cottage in the countryside you see the telephone cables so to say…

Modern life is highly dependent on electricity and we were constantly reminded about this from the respondents. A middle-aged woman reported on the cause of a power failure:

> Well, it's catastrophe. The radio is quiet, you can't cook, the radio clock needs to be reset…one gets totally…you can't do anything…

To summarize, the interviews showed us how abstract the phenomena of electricity is to people and the difficulty they have to understand and relate to it. It is hard to describe what energy is, merely how it is displayed and were it is situated. Understanding is further obscured by incomprehensible bills and hidden electricity meters.

Energy as design material

Making or not making technology visible is a long debated issue in industrial design and architecture. One of the main criticisms by the modernists in the beginning of the 20th century was the inconsistent use of material, styles and ornaments during the preceding century. Honesty in form, function and material became one of the new mottos. Redström argues (2001) that in order to create a meaningful presence for technologies in domestic environments, we need to consider them as design materials. What then are the design properties of electricity? How could design methods be used to explore the aesthetic values of energy?

Product design and aesthetics is what literally expresses the product. A product may be read as a text that conveys a number of semantic messages. In his book Mythologies (1967), Roland Barthes explains the way myths work and the power they have on the way we think. Taking a lot of examples, Barthes shows how seemingly familiar things signify all kinds of ideas about the world. As Forty remarks: “Unlike the more or less ephemeral media, design has the capacity to cast myths into enduring, solid and tangible form, so that they seem to be reality itself.” (1986) One such myth is that the power fuelling these household appliances seems to appear out of nowhere. All we have to do is to pay the bill the energy company sends us. Electricity is invisible, abstract and the amount that flows through our cables is not for us ordinary users to see or control. And yet – we can not manage our modern lives without it.

Product designer and researcher Anthony Dunne (1999) argues that mainstream industrial design uses its powerful visualisation capabilities to propagandise desires and needs designed by others, thereby maintaining a culture of passive consumers. He suggests that design research in the aesthetic and cultural realm should draw attention to the ways products limit our experiences and expose to criticism their hidden social and technical mechanisms. Central to the work of Dunnes and his partner Fiona Raby is a consideration of the imperceptible electromagnetism that surrounds us and attempts to visualise this invisible radiation.

The Power Awarecord

If product design is one reason for our high consumption of electric appliances and thus of power usage, could design also take part in helping to break this trend? Could design be used consciously to make people aware of energy use and offer alternatives? Redström offers one approach when he suggests that technologies such as computation and electricity should be explored as design materials, thus raising our awareness of its presence. To inform users of power, how much and when it is used, is certainly one of the first steps in such a quest.

The ‘Power-Aware Cord’ is a working electronic prototype and an example of how to design for energy awareness. It is basically a re-designed electrical power strip, developed as a working electronic prototype, in which the cord is designed to visualize the amount of electricity used. Thus, the user interface of the Power-Aware Cord is the same as for any ordinary electrical power strip, with the addition of a dynamic visualization along the cord where the current use of electricity is represented through glowing pulses, flow, and intensity of light. The entire cord acts as an ambient display to inform users of electrical current passing through en route to electrical appliances plugged into the extension sockets. The interface of the Power-Aware Cord invites users to plug in different appliances and experiment with how these relate to each other in terms of energy. With the Power-Aware Cord, users' actions, such as plugging or unplugging electrical devices into sockets, immediately result in a response from the cord, giving the user direct feedback and the feeling of both seeing and interacting with electricity. This approach might inspire users of the Power-Aware Cord to explore and reflect upon the energy consumption of other electrical devices in their home. Since this design has no added interaction or functionality, it does not become 'yet another gadget for the home' but a product people already buy.

Representing the amount of electricity with light, rather than a numerical display, creates a display where information can be accessed at a glance. This enables the interface to be accessed from anywhere in the room in which it is situated, and thus provides constantly available, subtle information on energy usage, something often referred to as ambient displays (Ishii 1998) in human-computer interaction. This could be useful in order to change awareness and thus usage behaviours over time, or to detect unnecessary stand-by consumption.

The prototype

The lighting effects in the Power-Aware Cord are achieved through the use of electroluminescent wire. This wire contains a semiconductor layer that glows with an intense blue-green light when an alternating current is introduced. Due to the colour of this layer, the wire appears to be white when unpowered and adds to the surprise when the device is powered and starts to glow. Since the cable will shift in colour when going from unlit to lit mode it will also make it easier to detect low intensity levels. Three electroluminescent wires are bound together with ordinary copper wires for electric conduction. The wires are twisted together to improve the flexibility of the resulting cable. Twisting the wires also gives the possibility to create an effect of motion through the cable by powering each of the three luminescent wires in turn. The whole structure is coated with a layer of transparent silicone.

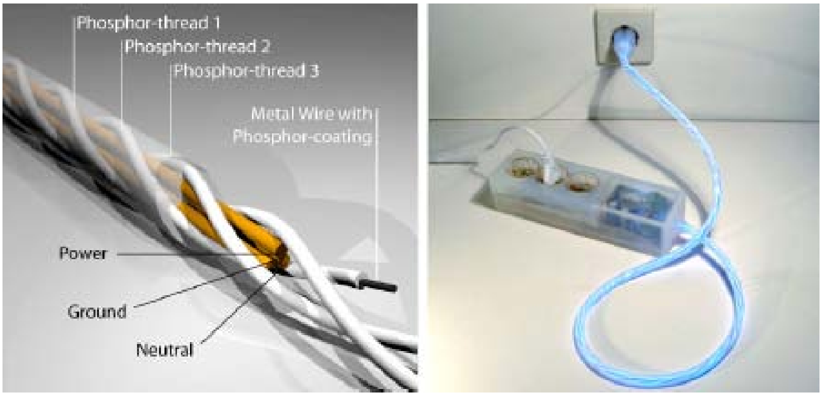

Figure 2. To make the light inside the cord simulate a flowing motion, the three threads are lit one at a time. Silicone protects all the wires .To the left is the working prototype.

In the Power-Aware Cord, we wanted to display a wide range of information values, from (0 – 2000 Watts). Ideally a user should be able to recognize small differences like that between a 40W and a 60W light bulb (20W) and also be able to distinguish among effects observed on one day compared to those observed another day.

User feedback

Fifteen people (4 women, 11 men) between the ages of 15 to 55 took part in an initial user test of the implemented prototype. Three different forms of light feedback (static intensity, pulsating intensity and moving intensity) were each tested on groups of 5 people. The following results were obtained. All 15 people reported seeing the blue light in the cord. 13 of these perceived the blue light as a representation of the electrical current.

The test persons were then asked to explain what they experienced. The two people that did not connect the light to the electrical current were both shown the static intensity program. The flow or moving intensity was, as expected, easier to interpret than the static intensity. Something that was not predicted, however, was that pulsing intensity was also easier to interpret than the static intensity. One person remarked he felt something being transported when the cord was pulsating compared to when it was shining in a constant level of intensity. The overall response to the Power-Aware Cord was very positive. Most test participants seemed to easily grasp its functionality and immediately came up with examples of how they would use it. One woman explained how she would use it to teach her children about electricity. Others reflected on how it could be used to test stand-by products. Our test participants clearly saw the need for a device like the Power-Aware Cord. They also seemed to appreciate its pedagogical properties.

Figure 3. Different appliances, such as lamps, were plugged in during a user test scenario.

Whether the users could perceive the light as actual electricity is more difficult to tell. One woman clearly did, as she explained: “I think this is what power cords look like on the inside. You have just made it transparent!” Most people, however, thought there was something more to it. This notion often seemed to derive from the fact of the socket box being bigger than usual. One person thought the light looked too harmless in order to be electricity. Another person compared the Power-Aware Cord to a bicycle dynamo – “the faster it goes, the more it glows” – while someone else compared it to a heart – “it pumps the electricity at different speeds”. All except one of the participants were positive about having a Power-Aware Cord at home. Some saw themselves having several Power-Aware Cords in their homes, while others expressed that they might not use it as an everyday product but rather as a reference from time to time.

Discussion

During the last century, design has been a used as an innovative tool to create household appliances and thereby raise consumption of electricity in the home. But the actual use of energy has been hidden both in products and in the domestic surroundings. With increasing use of energy in Western countries, it is important that we create awareness of how much electricity we use and how this could be reduced. We propose design to be both a useful tool and an approach to this issue.

The Power Awarecord is an experimental prototype and a tool for learning about people's perceptions about electricity. Initial user testing has proven the Power Awarecord to be an intuitive and intriguing object with an overall positive response from the test subjects. The actual usage of the cord remains to be seen. Which devices will people choose to power with the cord and when? In depth user studies in domestic environments would therefore be the next step to take. At a more developed stage, our hope is that the Power Awarecord can be introduced as a home application to visualise electricity use. A critique of the Power Awarecord might be that the prototype in itself consumes electricity. We argue that if a user increases his or her awareness of energy consumption and understanding of relations between electrical devices, it is worth the small amounts of extra electricity used by the cord. In the long run, our hope is that the information given by the cord and the increased awareness will result in a more optimized consumption of domestic energy (Matsukawa 2004). If so, the cord's own consumption can be justified.

Design is a powerful tool that allows values and cultural codes to be materialised into actual objects, thereby making them a 'natural' part of the world. Design can also be used to criticise and deconstruct such values, but because design finds itself operating within a commercial framework this rarely occurs. In the design of household appliances, there is usually very little time for explorative design research and critical aesthetics. In the light of the discussion in this text, it seems a dubious approach to continue to make electrical usage invisible. Our increasing energy consumption is too problematic to be hidden objects and buildings. Something hidden or invisible will not only exercise power, it will also be impossible to understand and interact with. Instead of hiding technology, we should use the power of design to visualise and express these issues.

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Chapter 11

Visualizing Energy Consumption of Radiators[3]

Abstract

Heating is a significant expenditure of many households today but the actual power consumption of the heating devices are seldom recognized. To help people understand and reflect upon their domestic energy consumption, we have designed an electrical radiator that emits heat entirely from light bulbs. This appliance responds to temperature changes in the room via sensors. The idea was to combine the product semantics of lamps and radiators and direct focus on the latter neglected product category. We argue that by re-designing domestic appliances adding means to visualize energy consumption in engaging and interesting ways it is possible to make energy utilization less abstract and easier to comprehend.

Introduction

In domestic environments, we seldom recognize that appliances are consuming electrical energy. Since the home appliances do not communicate their consumption behaviour it becomes difficult to understand and make rational decisions about energy-related issues.

We believe that by visualising the energy consumption of various devices, consumers can learn when and how the devices consume electricity and be encouraged to save energy (Jensen 2003, Matsukawa 2004). Direct feedback, for example, could help consumers build

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[3] Gyllenswärd, M., Gustafsson, A. And Bång, M.. Visualizing Energy Consumption of Radiators. In *Proceedings of First International Conference on Persuasive Technology for Human Well-being, Persuasive 2006*, (Eindhoven, the Netherlands, May 18-19, 2006), http://www.springerlink.com/content/f55x76265430l552/

conceptual models of how energy-consuming devices behave in different situations making the perception of electricity less abstract (Jensen 2003).

Researchers and artists have created artefacts that visualise and draw attention to energy and heating in various ways (Laarman 2004). Our work is – in its form – related to the art of Höller (2001) and Veilhan (2004). Both these artists are using light bulbs as building blocks in their pieces. For example, Veilhan created the Big Light Machine, a screen by acting pixels that merge visuals with heat experiences (ibid.). However, their work are not intended to direct the viewers' attention to the energy consumption of the object per se.

The overall aim of our research is to explore new designs for energy awareness and clarify the abstract phenomenon of electricity. In this paper, we present an alternative radiator and information display, designed to raise awareness, visualise and make a statement on the invisible energy consumption in the home. We discuss the design concept and the results from a user study.

Rationale

Verbeek and Kockelkoren discuss engaging objects (1998). These are attractive artefacts in terms of form and interaction and the appealing properties are designed so that users become involved and learn from them. Following Heidegger, the idea is to move underlying operations of objects to a visible level and make users part of the functional processes. These authors discuss typical engaging object such as a heating device developed at the Cranbrook Academy of Arts. This device can direct its output spatially and allow people to interact with heat. This means that users can actively and playfully reflect on its function and the environment that it aims to control.

Our work is also inspired by augmented reality designs where the aim is to superimpose information directly onto the physical world such as the Heatsink (2005). The Heatsink was developed at the MIT Media Lab and it incorporates red or blue colour information (light) in ordinary tap water depending on its temperature. We believe that engaging objects generally have good persuasive powers – due to the reflective learning process that they support – and this has been one of the starting points in our work with radiators.

Lights and lamps have a very central and personal role in the Swedish home. Radiators, on the other hand, are seen as solely functional objects and they are placed out of the way in the home. Typically, people buy the most inexpensive and efficient ones. In other words, lamps are more in the centre of attention in the Swedish home than products like radiators. This is fairly self-evident, but from a use-of-energy point of view it should be the other way around, because radiators consume much more energy than lamps and they should preferably communicate this.

The Element

The Element was constructed from 35 light bulbs that were attached in a metal frame between two panes of tempered glass. 60-watt lamps were chosen to obtain the same heating effect as a conventional electrical radiator (approximately 2000 watts). The casing contains control electronics and a set of internal and external heat sensors – attached via a cord – and they determine the temperature. A dimmer circuit connected to a microprocessor controls the intensity of the lamps. A control wheel is placed on the right side and it is used for temperature settings and this value can be seen on a display on the top of the casing. Figure 1 shows the Element.

Fig. 1. The Element

When the appliance is turned on, it will slowly start to glow increasingly brighter and the temperature in the room will rise to the value of the control wheel. If the temperature in the room suddenly drops or the control wheel is altered to raise the temperature even more, the Element attempts to balance this by emitting more light. The external heat sensor does not only portray the immediate thermal climate near the radiator, but also disclose the climate of the entire room. For example, when the external sensor pick up a small change in temperature the light bulbs signal this information immediately as they try to compensate for this. The climate in the room is in this way portrayed and the users can see the consequences of various activities such as opening the windows.

User Interviews

We presented the prototype to ten individuals to collect user feedback in a semi structured interview approach (Kvale 1996). The aim was to let users explore the prototype and discuss their experiences (Buchenau & Suri 2000). The group consisted of students between ages 20 to 29.

In the first part, each person was shown the prototype and encouraged to explore it. We did not provide explanations letting users create their own interpretations of the object. To investigate the results of the blurred product semantics, we wanted to find out if the participants could understand the relation between the control wheel setting and the light, that is, see it as a radiator. Moreover, we were interested in the emotions the artefact imposed on the subjects to determine if it was seen as an engaging object.

However, very few saw it as a radiator when they turned the control wheel. People usually started with the assumption that it was connected to the intensity of the light like an ordinary dimmer. When proven wrong whilst turning the knob, most participants suggested that it was a temporal light control and that it was a delay. Apparently, the connection between heat and light is not a very clear one, at least not when interacting with light bulbs. In some cases, we also showed an ordinary radiator before we presented the prototype and they still failed to recognize it as a radiator.

This is possibly an indication of how strong the product semantics of light bulbs are. A common remark in our sessions was “I don’t think it’s just a lamp”. In other words; a lamp was their first association. However this was often quickly ruled out probably due to the placement of the bulbs or the form of the casing. Naturally, possible bias situations are difficult to rule out in experimental designs such as these.

During the second part of the evaluation, we were interested in what kind of information the object conveyed. Specifically, how the subjects related it to external factors that influence power consumption, heat, and light. That is, what kind of energy information the test persons would be able to gain from the prototype and their general understanding of the functionality of the radiator. The subjects were asked to rate the Element in relation to other electric devices in terms of its energy consumption. Subsequently, an ordinary radiator was shown to them and we asked questions regarding the relationships between the two. Finally, a brief explanation of the Element was given followed by some concluding questions on how they would use it in their homes and what kind of benefits they saw.

Some participants said it would be useful as an indicator of changes in the domestic climate such as open windows and function as a reminder of it being on or off. The information given by the Element was also seen as something that could provide a more environmentally sustainable way of thinking about energy because it visualizes the actual consumption. Moreover, almost all participants found the Element aesthetically pleasing and were intrigued and fascinated by it.

Conclusion

In this paper, we have presented a concept and prototype for an electrical radiator that visualizes energy and emits heat entirely from light bulbs. The aim was to blur the product semantics of lamps and radiators to create an engaging object that disclose hidden properties of heat and energy. Users found the ambient display to be an intriguing and interesting way to present energy consumption. To conclude, engaging objects such as our Element can influence users to reflect on energy and render such intangible phenomena more understandable.

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Chapter 12

Promoting New Patterns in Household Energy Consumption with Pervasive Learning Games[4]

Abstract

Engaging computer games can be used to change energy consumption patterns in the home. Power Agent is a pervasive game for Java-enabled mobile phones that is designed to influence everyday activities and use of electricity in the domestic setting. Power Agent is connected to the household's automatic electricity meter reading equipment via the cell network, and this setup makes it possible to use actual consumption data in the game. In this paper, we present a two-level model for cognitive and behavior learning, and we discuss the properties of Power Agent in relation to the underlying situated learning, social learning, and persuasive technology components that we have included in the game.

Introduction

Computer games have been used as educational tools for over two decades. However, the efficacy of this learning and behavior-modifying approach has been criticized on several accounts. For example, researchers are questioning whether students can actually use the knowledge they acquire in simulation games and apply it to real-world tasks (e.g., generalization and transfer of knowledge) (Mayer & Wittrock 1996, Gee 2003). Moreover, traditional interactive games seem to result in shallow learning. This problem has to do with difficulties in conveying deeper meaning, as well as the underlying learning models in

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[4] Bång, M., Gustafsson, A., and Katzeff, C. Promoting renewed domestic energy consumption patterns with pervasive learning games. In proceedings of Second International Conference on Persuasive Technology, PERSUASIVE 2007, (Palo Alto, CA, USA, April 26-27, 2007), Springer Verlag, 55-63.

the expeditious interactive games (Ramsden 1985). Modern theories on learning have also criticized the notion of knowledge transfer. Instead, researchers emphasize the importance of relevant and authentic real-world tasks in learning, and they discuss the social aspects of education, including mediation of skills via peer interactions (Brown et al. 1989, Lave & Wenger 1991). Among others, Brown and colleagues (Brown et al. 1989) have stated that learners actively construct knowledge, and that it is built on previous experience of real-world tasks. Studies in the field of persuasive technology have also highlighted the role of social aspects such as peer group pressure (Fogg 2003, de Vires 2006).

Advances in augmented reality and ubiquitous computing show promise, and new computer games in this area have the potential to turn ordinary surroundings into sophisticated learning environments. Pervasive games constitute a relatively new class of computer games that extend the gaming experience to the real world (Magerkurth et al. 2005). In these games, the players are framed by real-life surroundings and interact with computer enhanced objects. This approach has attractive properties from the perspective of learning and behavioral modification: learners do not have to rely on simulation, and tasks can be trained in the real environment, which might reduce problems with knowledge transfer.

According to Thomas (Thomas 2006), pervasive learning games are important primarily because they entail social processes that connect learners with communities of devices, people, and real learning situations. We are exploring this new game approach to target energy-use behaviors in the home. The hypothesis underlying our work is that persuasive games have the potential to strengthen situated learning and promote behavioral changes by reframing familiar activity and social systems.

Few pervasive games have been developed for the purpose of learning (ibid.). Furthermore, to our knowledge, no games in this genre have been described that promote behavioral changes aimed at altering energy usage patterns. In this paper, we present PowerAgent, a pervasive learning game for teenagers designed to encourage more efficient energy use in the home. To strengthen the learning and persuasion components, PowerAgent has been constructed from the perspectives of situated learning (Lave & Wenger 1991) and social learning theory[5] (Bandura 1977, Bandura 2001), and it also makes use of persuasive technology methods (Fogg 2003). We begin by discussing the area of pervasive gaming and summarizing research on pervasive learning games. Thereafter, we present the theoretical foundation on which our game rests. The main part of the text covers the design of the game, or, more correctly, how the micro-social activity system is reshaped by the game. Lastly, we consider aspects of the design of pervasive learning games from the standpoint of behavioral and persuasion technology.

Pervasive Gaming and Learning

Pervasive games belong to a rather heterogeneous category of such entertainment that includes location-based games, urban mobile games, cross-media or hybrid games, immersive games, urban super-hero games, and alternative reality games (Thomas 2006). The main feature that distinguishes pervasive games from traditional simulation games is that they extend the gaming experience to the physical world (Magerkurth et al. 2005). Consequently, there is no need for developers to simulate a game world such as that in the Sims (http://thesims.ea.com/); instead, the approach involves overlay of game scenarios onto real world objects and environments (cf., augmented reality). Typically, the games utilize technologies like ad hoc computer networks and satellite positioning to link and track devices and users in the physical surroundings. Special interfaces such as displays and cameras are frequently used to superimpose the virtual game world and its tasks onto everyday physical artifacts and spaces. BotFighters (http://www.botfighters.com) was an early location-based game on mobile phones, the mission of which was to find and defeat other players' bots out on the streets. By comparison, the goal of the modern pervasive game called Epidemic Menace (Lindt 2006) is to seek out and destroy viruses that invade different physical locations. To enhance the gaming experience, Epidemic Menace includes a set of special interfaces and physical props, such as mobile phones, mobile-augmented reality systems, physical game boards, and special communication stations.

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[5] In 2001, Bandura renamed social learning theory (SLT) social cognitive theory to emphasize the cognitive aspects of learning and behavior modification.

Pervasive games are particularly interesting when considered from the perspective of persuasive technology and learning. Researchers such as Sotamaa (2002) have argued that a fundamental trait of pervasive games is that they alter the social landscape. A possible consequence of blurring the distinction between different social landscapes is that the internal social rules of a game can have an influence on previously established activity rules. That is, activities in the game have the potential to be learned and transferred to related off-game activities. Of interest in this discussion are the four tenets of pervasive learning games suggested by Thomas (2006): community, autonomy, locationality, and relationality:

- **Community:** Pervasive learning is a social process that connects learning to communities of devices, people, and situations that can also include other pervasive learning situations. Learning in such environments are mediated by peers in the game community.
- **Autonomy:** Gamers direct learning experiences themselves and are in control of their learning processes.
- **Locationality:** Learning occurs at places and at times that are relevant for the learner.
- **Relationality:** Learners construct meaningful and relevant learning situations to which they can relate. Learning familiar concepts within their own personal environment allows them to better understand the implications of what they have learned, and this facilitates the construction of meaning.

Before we describe the Power Agent game, it is appropriate to discuss underlying theories of learning that are related to our design.

Modern theories of learning seem to involve a consensus of major standpoints. First, as pointed out above, the learner is regarded as an active constructor of meaning, which is a view of learning emphasized within constructivist theory (Piaget 1977). Second, learning is regarded as a social process; just as the physical world is shared by all of us, we also share an understanding of it (Vygotsky 1978). Learning is a process that is in progress not only in the individual learners, but also in the culture of the learners (Lave & Wenger 1991). For example, according to ideas of situated learning (Brown et al. 1989) and distributed cognition (Hutchins 1995), knowledge exists not only within individuals, but also in the discourse among those persons, their interconnecting social relations, and the physical artefacts they employ, as well as the theories, models, and methods they use to produce supporting tools.

Social learning theory (SLT) is related to the above-mentioned perspectives[6], in particular situated action (Bandura 1977). SLT is especially attractive for the purpose of persuasive game design, because it can provide principles to guide that process. For instance, SLT includes behavioral reinforcers such as positive feedback, which is very common in interactive games, and such notions are outside the scope of the situated learning theories. The power of SLT lies in that it explains human behavior as an interaction process between cognitive, behavioral, and social/environmental components.

The basic tenet of SLT is the importance of observing and modeling: people learn by observing the behavior of others and by watching the outcome of actions (cf., vicarious learning). The outcome of observations can be in the form of cognitive learning alone, and it can also entail changes in behavior. The learnt is subsequently reinforced by several factors. For example, imitating the model can result in being accepted in the social group from which the model originated. Compliments and praise from people that back such behavior also reinforce the modeled behavior. Vicarious reinforcements, that is, when the model is being reinforced and that is observed by the learner, can increase the response and thus be regarded as yet another form of reinforcement.

According to Bandura, there can be two models, one that is symbolic and one that is live. The latter refers to a person who demonstrates behavior in the real world, and the former can be a person portrayed in a medium such as television and computer programs. It should also be noted that the maximum level of observational learning is achieved when the modeled behavior is symbolically rehearsed and the behaviors are subsequently enacted and rehearsed in the real world. Moreover, symbolic coding by use of words, labels, and images can further strengthen retention of behaviors.

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[6] Situated learning, situated action theory, distributed cognition, and social learning theory share several assumptions about how learning is achieved. However, it should also be said that there are significant divergences on some issues, particularly in terms of the feedback components and modelling that are not addressed in the situated theories.

Power Agent

Power Agent is a pervasive game for teenagers designed to have a positive influence on everyday energy consumption behavior in the home. It can be seen as a hybrid pervasive game, because it makes use of several media components—both traditional gaming and pervasive mechanisms—to support both cognitive and behavioural learning. A key design goal was to foster social interactions with peers that are playing the game and also with family members that becomes entangled indirectly in the game due to its pervasive social nature. Power Agent is shown in Figure 1.

Fig. 1. The PowerAgent game

Game scenario

The person playing Power Agent has the role of a secret agent, and the mobile phone is the main agent tool. Via the phone, the boss, the mysterious Mr. Q, gives the player special missions to save the planet from the energy crisis. These are divided into training missions and real-world tasks. The training missions are played on the cell phone and these precede the actual real-world missions in the home. This training element is in the form of a traditional platform game characterized by jumping/climbing to and from suspended platforms (cf., Super Mario Bros.), which is done to catch batteries. Every battery contains a suggestion on how to act in order to be energy efficient in the upcoming real-world task, and it also holds information o n how to influence family members.

For example, the tips for the cooking food mission can be the following: “Use the microwave oven instead of the ordinary oven, use the water boiler to heat water instead of putting the kettle on the stove, and tell everyone that you love food cooked in the microwave.”

All real-world missions are focused on saving electricity in the home, particularly in conjunction with everyday activities. Typical missions include (1) adjusting the heating in the house, (2) washing clothes, (3) cooking food, (4) switching off all standby appliances, and (5) minimizing the total household energy use for a day. Hence, the goal is to figure out how to reduce energy consumption while performing the mission assigned by Mr. Q. The mobile phone is connected to special equipment in the home that measures the use of electricity and heat water during the missions. In this way, it is possible for us to provide feedback on the success of the missions and reinforce behaviors that are appropriate from the standpoint of energy conservation.

PowerAgent is normally played by two teams with five members each. The realworld tasks are done individually at home, but at the end of each mission the results from all team members are summarized and compared with the results of the competing team (see Fig. 3g). We included the competition factor to create engaged coherent social teams that work together to win. A special mobile chat is also available to the agent to share tips on how to carry out the missions with other team members.

System and Infrastructure

To monitor electricity consumption, PowerAgent makes use of existing automatic meter reading (AMR) systems in the players' homes. Basically, the AMR systems are connected to the residential central fuse hubs and provide consumption data automatically to the servers at the power companies via a computer network.

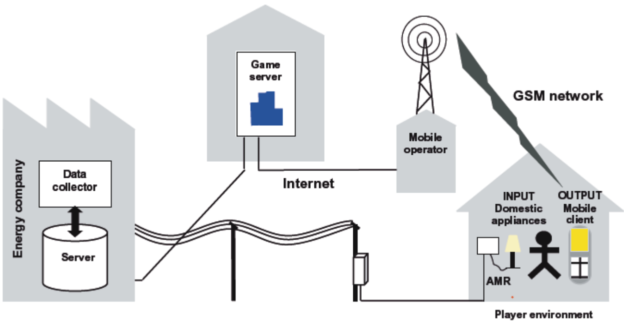

Fig. 2. Infrastructure of PowerAgent

A set of collector daemons relays this information to a central game server that processes and normalizes the data for the game so that all players have the same chance of winning[7]. Figure 2 shows the infrastructure of the game.

Unfortunately, a deficiency in our prototype is that the data can be delayed up to 12 hours in the power grid due to the underlying implementation of the AMR databases. This means that even though we can monitor each player's consumption on an hourly basis in most cases, the full results might not be accessible until next day. It was necessary to design the game based on those limitations.

The mobile game client that accesses the energy statistics is implemented in Java for SonyEricsson K750 mobiles, and the central game server is implemented in Python. An additional Java-based chat server is also provided in the system to support in-game communication among players.

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[7] We had to normalize the energy consumption data, because different households use different means of heating, which could have a negative impact on the outcome for some players.

Playing the Game

Before the beginning of a mission, the game client asks the user to logon to the Agent Network (Fig. 3a). Once logged on, the player is directed to headquarters where Mr. Q is waiting (Fig. 3b). Mr. Q. gives his mission directives verbally, and a countdown clock is started in the background (Fig. 3b). This counter indicates the time remaining until the real-world mission starts at home.

Agent logons are usually requested at 4 PM, so that the players can prepare and practice for the upcoming tasks. An important part of the preparations is the abovementioned platform game in which the player can find clues with important information about how to get the best results during the upcoming real-world mission (Fig. 3, d and e).

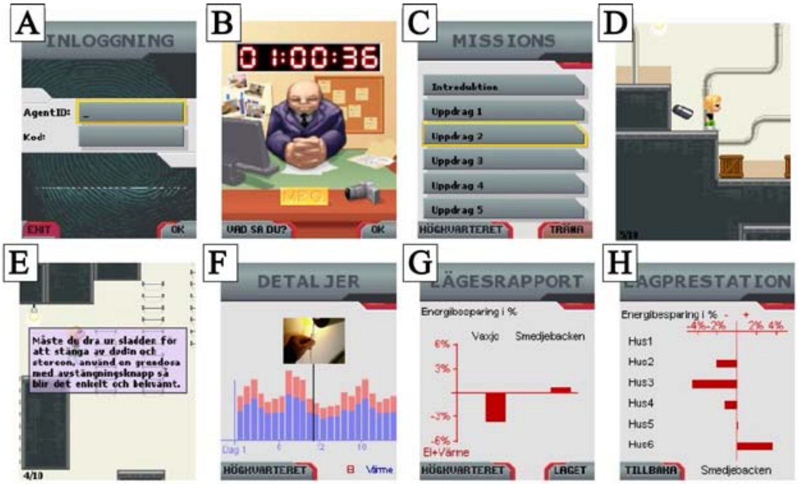

Fig. 3. Screenshots from the Power Agent

Preparations can also include getting the family to participate in the game session and starting to turn off energy-consuming devices in the home. Other measures can be to check the Internet for information on how to be energy efficient in relation to the specific task. In addition, the player can browse Mr. Q's office when he is not there to access crucial information and chat with other team players.

A typical real-world mission will last for 24–48 hours, and during the mission the mobile phone notifies the user if something important happens in the game, such as when a sub-task starts or when there is new information available. If the mission lasts for 24 hours or longer, a partial result is presented halfway through the mission. Once a partial or a final result is available, the user is notified and asked to logon to the agent network. Then the player again meets Mr. Q, who provides feedback on both the individual player's work and on the team results.

The player can also view individual and team performance statistics (Fig. 3, f, g and h).

Every real agent records his or her mission carefully. Hence, an important task for the energy agent is to document the conservation actions made in their homes. They are using the camera in the mobile phone for this purpose. These pictures are time stamped, mapped to the consumption data, and presented on a timeline after the end of the mission (Fig. 3f). In this way, the pictures serve as reminders of the actions and enable players to get feedback as to whether the things they have done had any effect on the electricity consumption.

Discussion

Traditional simulation games for learning have been questioned regarding whether learners are really able to generalize knowledge they acquire in a virtual game world and apply it to real life situations. This is a phenomenon referred to as knowledge transfer, and it is of central interest to researchers in pedagogical psychology.

However, when performing the learning tasks in the real world, such as in the PowerAgent game, the mentioned uncertainty becomes, as we shall demonstrate, at least partially obsolete. The question here is not whether the game provides a sufficiently accurate simulation of the real world, but rather if the game supports both cognitive and behavioral learning, and if the acquired knowledge can be remembered and applied in similar situations.

Bandura has suggested that the highest level of learning can be achieved if the modeled behavior can first be symbolically (i.e., cognitively) organized and rehearsed and then overtly enacted (Bandura 1977; cf., Bandura 1965). We have attempted to make use of a similar twostage model in PowerAgent. Essentially, PowerAgent can be looked upon as a hybrid game, since it has both virtual and pervasive gaming parts. The underlying idea is to let the users first play a simulation (platform) game on the phone to symbolically learn wanted behaviors, and then let them enact and rehearse these behaviors at home in the family context (the real-world tasks). Thus, in the real missions, the gamers can test the behaviors and get both direct and social feedback on their actions.

The first version of the game—the one presented in this paper—is limited in that the platform game does not show people performing the target behaviors (i.e., modelling via observation). Hence, the platform part of the game could probably be improved significantly by also allowing the players to catch “batteries” that contain video snippets of people illustrating proper energy conservation behaviors to support observational learning and cognitive modeling. Nevertheless, after conclusion of the platform game (using the model available in the present version), we deliberately provide time to prepare for and reflect on the upcoming real-world task. Being able to rehearse game scenarios and create strategies to solve problems are crucial factors that strengthen cognitive learning and lead to a positive outcome that reinforces the target behaviors (Bandura 1977).

We have also included a text chat function to support knowledge sharing among team members, which agrees with the situated learning theories that emphasize social collaboration to solve tasks. Further improvement might be achieved by including the means for video chatting or attaching movies clips in which gamers show each other how they deal with their missions, and that could strengthen social learning and peer modeling. We are currently performing a pilot study of the game at two sites in Scandinavia. Our goal is to investigate the concepts and the playability and to determine how we should empirically evaluate the cognitive and behavioral learning components.

Conclusion

In this paper, we present Power Agent, a pervasive game designed to have a positive influence on energy consumption behaviors and activity patterns in the home. The principles underlying the design of the game were derived from situated learning and social learning theory. We believe that the two-stage model for learning, in which gamers observe target behaviors in a simulation game and subsequently enact these behaviors in the real world, is a promising persuasion strategy for future pervasive learning games.

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Chapter 13

Evaluation of a Pervasive Game for Domestic Energy Engagement Among Teenagers[8]

Abstract

In this article, we present Power Agent—a pervasive game designed to encourage teenagers and their families to reduce energy consumption in the home. The ideas behind this mobile phone- based game are twofold; to transform the home environment and its devices into a learning arena for hands-on experience with electricity usage and to promote engagement via a team competition scheme. We report on the game's evaluation with six teenagers and their families who played the game for ten days in two cities in Sweden. Data collection consisted of home energy measurements before, during, and after a game trial, in addition to interviews with participants at the end of the evaluation. The results suggest that the game concept was highly efficient in motivating and engaging the players and their families to change their daily energy consumption patterns during the game trial. Although the evaluation does not permit any conclusions as to whether the game had any postgame effects on behavior, we can conclude that the pervasive persuasive game approach appears to be highly promising in regard to energy conservation and similar fields or issues.

Introduction

Recent reports from the United Nations on the changing climate set new demands on our society (Solomon et al. 2007). It is clear that much needs to be achieved to reach the new targets towards sustainable living.

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[8] Gustafsson, A., Katzeff, C., and Bång, M. 2009. Evaluation of a pervasive game for domestic energy engagement among teenagers. Computers in Entertainment (CiE). 7, 4 (Dec. 2009), ACM New York, NY, 1-19.

Engaging people in making the, often small, behavior changes that are needed is crucial for fulfilling goals of energy reduction in the domestic sector. While most people tend to possess quite positive attitudes towards climate-saving actions, this is rarely enough to have any real impact on their behavior.

Additionally, there is also an educational problem: knowing what consumes a lot of electricity in the home, for example, is very difficult for most of us.

Large-scale information campaigns are frequently used to support learning and to create an awareness of pressing societal problems. Recently, companies and state authorities like the European Union have utilized simulation computer games targeting children in regard to domestic environmental issues like energy consumption (Kidscorner 2009). While children and teenagers tend to respond to different motivating factors than adults —children, for example, rarely pay for their own energy usage— alternative approaches such as computer games make sense.

Hence, in our previous work, we suggested the use of pervasive games as an alternative approach to motivate teenagers towards energy awareness (Bång et al. 2007). Pervasive games are very interesting from a learning perspective (Markovi et al. 2007), since they have the potential to better support what is known as transfer (Gagne´ et al. 1948). In classic leaning theory, transfer refers to the situation when a learner must generalize and use abstract knowledge (i.e., learned from a book) and apply this knowledge to real-world problems and requirements. Pervasive games can minimize this contextual gap because the game can be situated in the real world with real hands-on tasks that require player engagement. Thus, from a research point of view, it is important to investigate what constitutes successful design components of pervasive learning games.

In this article we evaluate and analyze a pervasive game designed to motivate and educate teenagers towards energy conservation in the home, that is, encourage positive behavior change in the home regarding for example electricity usage. We particularly look into the social and motivational aspects of the design as well as the situational and contextual knowledge aspects of our approach.

Power Agent

Power Agent is a pervasive game for mobile phones that connects to the electric power meter in the home. The underlying design idea is to let players compete in teams and learn hands-on how to conserve energy in their homes. This design approach is based on the assumption that a change in behavior requires both motivation to act as well as knowledge of what to do. In Power Agent, motivation is achieved by utilizing the social aspects of a competitive multiplayer game at the same time as the player is educated through the contextual and situational aspects of a pervasive game.

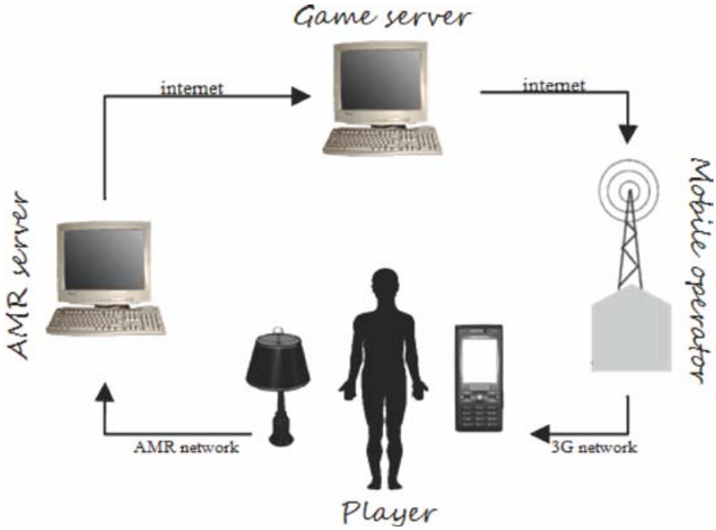

Fig. 1. System overview.

In order to be scalable, Power Agent was from the beginning designed on top of existing infrastructure such as the automatic meter-reading (AMR) system. An AMR system is basically networked power meters that are utilized by power companies to automatically measure their customers' consumption of electricity, remote heating or gas. The currently used AMR systems typically report on customers' consumption on an hourly basis, however due to cost, data is often only transmitted and updated to a central server once every 24 hours (during the early morning hours). In 2006 there were approximately 235 million AMR meters installed within the European Union. The AMR system in Sweden, where this project was carried out, is currently being expanded, and is expected to cover all households in the entire country by the summer of 2009.

Gameplay

In Power Agent, the player takes the role of a special agent assigned the task of saving energy in the home. To be able to achieve this goal, he or she must cooperate with family members and also combine forces with other peer agents in a team. The team competes with another team of agents located in another town. A successful player persuades everyone in the household to conserve as much electricity as they can during the mission, which, on most days, takes place between 17.00 and 22.00. Throughout the mission, the game monitors electricity consumption in the participants' homes. The winning team is the one who made the combined largest relative decrease in energy consumption (in our case, electricity, and the consumption of remote heating, when present).

Mr. Q—the agents' boss—appears on the phone just before a mission starts and informs the player about the new assignment (voice and animation, see Figure 2(b)). At this point, a warm-up track for the mission—in the form of a small platform game—is unlocked in the phone (Figure 2(d)). At the warm-up track, players can collect batteries.

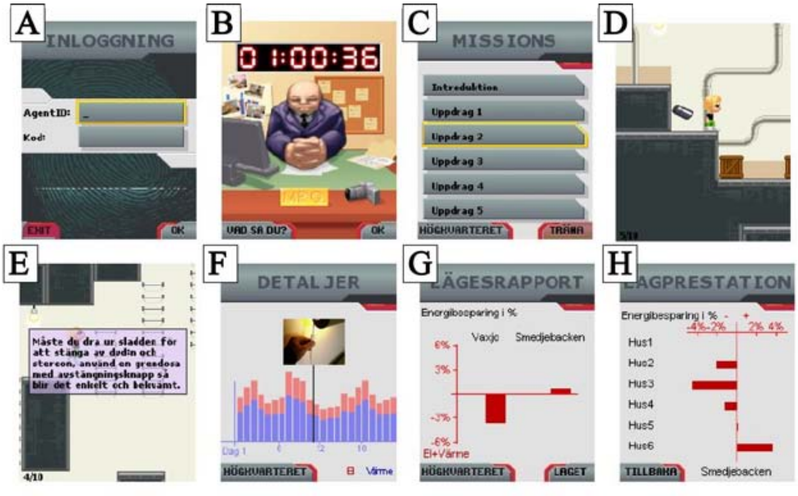

Fig. 2. Screen shots of game interface.

Each battery is associated with a clue (Figure 2(e)) on how to better succeed with the assignment during the evening's mission. A clue could for example be "Unplug wall sockets to prevent the DVD or the stereo from using electricity when not in use".

All the first six missions in the game have an energy-saving theme. The themes are (1) lamps; (2) activities in the kitchen; (3) entertainment equipment; (4) heating the house; (5) washing and cleaning; and finally (6) showering and bathing. In the final mission, players took on the task of lowering the total energy consumption of the household for a longer period of time, as this mission extended over the entire weekend.

The feedback after a mission is given by Mr. Q in the morning after it was preformed (Figure 2(b)). Mr. Q encourages the unsuccessful players to try harder and praises the successful ones. In addition to the voice responses from Q, a set of screens and bars visualize the result in more detail. These bars consist of (Figure 2(f)) a scrollable vertical chart with the players' personal home consumption; (Figure 2(h)) horizontal bars indicating the individual efforts within the team; and (Figure 2(g)) bars indicating the results during the latest mission for the two teams. In addition to this, a high-score list showing the winning team for all of the previously completed missions is also available.

At the end of the game (after the weekend final), all players receive a summarizing text message from Mr. Q on their phones. This message concludes the game by announcing the winners. In addition, it also provides feedback on how much the reduction in consumption achieved by the player during the final adds up to when translated into money and carbon emissions if the reduction were maintained over an entire year.

Interface

To strengthen the role of secret agent, we employed the mobile phone camera and encouraged players to take pictures of what they did to reduce energy consumption in their homes. When available, these pictures are superimposed on the personal energy consumption feedback chart (Figure 2(f)), which enables players to map actions to results. A message board was also included in the game to allow participants to send messages to each other.

All functions in the game are accessed by selecting the items behind Mr. Q on the main screen (Figure 2(b)). This is done by using the phone's navigation key. Selectable items include the camera (the agent camera function); the message board (message function to the other players); the computer (the warm-up tracks); the card index (brief information about the other players); the papers in front of Mr. Q (the missions); and the pictures and graphs (feedback and results).

Platform

Power Agent is played on standard Java-enabled mobile phones. Consumption data from the players' homes is collected via the ordinary and existing metering equipment used by the energy company to monitor the household consumption. This data is then relayed to our game server during the early morning hours. On the game server, data is processed and results calculated. The results are then sent to the Java client on the mobile phone where the information is transformed into feedback in the form of graphics and announcements from Mr. Q (see Figure 1).

Related work

The Power House is a traditional simulation-type computer game designed to stimulate teenagers towards energy awareness (Bång et al. 2006). This conventional desktop game shares a lot of common ground with Power Agent, in that it aims to educate and motivate teenagers to conserve energy. Power House, however, does not incorporate the pervasive component of Power Agent.

The area of pervasive learning games is still quite unexplored. In "The ambient wood journals" (Weal et al. 2003), an educational system based on ubiquitous technology that is placed in a forest is described. The system delivers location-based experiences and simulation capabilities regarding biological functions in the forest. In this way knowledge is put in a context. Other than that, as far as we can judge, it lacks many of the basic qualities of a game.

In the article "Living on the edge" (Benford et al. 2005), a pervasive learning game called Savannah is described. It is a location-based pervasive game designed around the GPS system. It is played on a predefined open field where the participants take the role of a pack of lions hunting virtual animals. In doing this the teenagers are intended to learn about the life in the savannah. The work focuses primarily on the technical aspects of the implementation of the game prototype and the use of the GPS. Since the location of the players is about the only thing of the real world this game utilizes (everything else is fictive), this game does not in our view fully utilize the learning potential of a pervasive learning game. Although these kinds of games can still be successful in a school environment where reflection and debriefing can be provided, it is possibly only as efficient as the traditional type of educational program in terms of facilitating transfer between the game context and the real world.

Method

Two teams (Team Smedjebacken and Team Växjö) each consisting of three players and their families played the game for ten consequent days in two small cities in Sweden during the spring of 2008. Energy consumption data for the participating households was collected before, during, and after the game trial. By means of the existing AMR system and the local energy company database, we acquired the hourly consumption rates for both electricity and, when present, remote heating. The total period monitored after the gaming sessions extended to a total of 57 days for the three players on Team Smedjebacken. During the entire trial the participants had the ability to contact evaluators by means of instant messaging (MSN, Skype, etc.). All IM conversations were logged. The game trial was followed by semi-structured interviews with the players and their families. These conversations were transcribed, analyzed, and categorized into the following classes:

- player actions taken to reduce energy;
- motivating factors;
- situated learning; and
- user feedback on the game design.

Pictures taken by the agent camera provided yet another source of information on the actions users took to reduce energy consumption.

To estimate the efforts taken by each household regardless of preconditions for the families—we primarily investigated the relative change in consumption. This measurement was calculated by comparing consumption during the game with a period of normal consumption preceding gameplay (i.e., a reference period). Due to cyclic behavior in the consumption pattern of most households, we compared consumption during a certain hour during the game to the average consumption during the same hours in the reference period.

A source of error in the players' consumption data could be attributed to changing outdoor temperatures. Lower outside temperatures meant significantly higher energy consumption for the households (in warmer countries this might of course be the opposite when using air-conditioning). For test participants with remote heating, this effect will be isolated to the readings of remote heating. For participants not having remote heating, a reference group of six households not participating in the game test was employed.

Results

In this section we present the outcome of the game play sessions in terms of renewed energy conservation patterns, behavior changes, and participant learning. Moreover, we report on how social interactions were shaped between the players in the teams and between the players and their families. Finally, we summarize a set of comments from the players on the game and its design.

Behavior Change—Player Actions

Individual Efforts. The first four agents presented below had remote heating installed in their households (and outdoor temperature changes could therefore be ignored regarding the electricity data). Since we chose to focus on electricity, efforts made by lowering temperature for these participants will not be visible here. For the remaining two participants, results from electric metering in terms of relative change were subtracted by the savings of the reference group, to remove the outdoor temperature bias. Original values for these agents are found inside brackets below the corrected number. The summary of measures taken by the agents is based on the interviews as well as the pictures taken by the agent's camera.

Table I. Relative electric consumption agent 101

Mission	1	2	3	4	5	6	Final
Change	0.1%	-14.1%	-60.9%	-	-42.7%	-42.7%	-36.0%

Agent 101's house was heated by remote heating. During the game, the agent and his family tried to use only one of the TV sets as much as possible, started washing with a full machine, and turned the lights off more frequently. They also lowered room temperature with 3°C down to

19˚C. During the mission that involved lamps, this agent approached the problem by turning all lamps off and used candles for illumination.

Table II. Relative electric consumption agent 102

Mission	1	2	3	4	5	6	Final
Change	-72.6%	-27.6%	-14.3%	-16.6%	-51.2%	-30.6%	-30.5%

Agent 102's house was also heated by remote heating. During the first mission, the family attended a party and was away during most of the evening. The family reports that they kept turning lights off during the entire game, and the agent said he adjusted the refrigerator temperature. The family felt, that they achieved great results, even though their efforts were perceived as small.

Table III. Relative electric consumption agent 103

Mission	1	2	3	4	5	6	Final
Change	+17.5%	-7.3%	-34.0%	-62.5%	-48.3%	-7.3%	-35.6%

Agent 103's house was heated by remote heating. Actions taken to reduce energy consumption included turning lights and appliances off, unplugging standby equipment, as well as lowering temperature for a couple of days. The father in the family estimated that he—during the light mission—replaced standard light bulbs with low-energy ones for about €80.

Table IV. Relative electric consumption agent 204

Mission	1	2	3	4	5	6	Final
Change	+55.3%	-44.6%	-49.9%	-23.6%	-31.5%	+34.3%	-17.3%

Agent 204's house was heated by remote heating. Based on the interview and pictures taken by the agent camera, we identified several energy conservation measures that had been taken by the family. The agent had for instance turned down the room thermostat, adjusted the refrigerator temperature, tuned lamps off, disconnected the TV from standby mode, and avoided using the tumble dryer, the computer, and hot water. The agent explained that the family was already quite good at saving energy.

From the start, the temperature in the house was set low and the fridge was already set to the temperature suggested by one of the clues in the game.

This agent seems to have followed the clues from the instructional part of the game quite exactly, however, the agent admits that she—during the first mission that involved cooking food efficiently, skipped dinner altogether because she was home alone. During the final session she said that she "let things be"; didn't use the computer as often, didn't watch TV much, turned off almost all the lights and avoided using the shower.

Table V. Relative electric consumption agent 205

Mission	**1**	**2**	**3**	**4**	**5**	**6**	**Final**
Change	-17.4%	-15.3%	-29.6%	-28.8%	-12.9%	-4.6%	-11.4%
	(-20.7%)	(-35.0%)	(-50.2%)	(-41.3%)	(-30.9%)	(-27.8%)	(-32.4%)

Agent 205's house was heated by electricity. Just as agent 204, she (205) also couldn't lower the room temperatures that much since it was already set low. The fridge was also already set to the values suggested by the game.

Other measures taken by 205 involved turning off the electric lights. She said that the family kept the whole house in the dark and lit only one lamp or used candles if they absolutely had to have some light. She also disconnected all standby equipment and ensured that the washing machine was filled more than it usually was. The family also tried to use the microwave oven instead of the stove for certain meals. On the initial assignment, the agent went and bought pizza instead of cooking at home. Moreover, the mother of the family expressed concerns that she ruined the results for her daughter by performing some slow cooking during the weekend of the final.

Table VI. Relative electric consumption agent 206

Mission	**1**	**2**	**3**	**4**	**5**	**6**	**Final**
Change	-72.4%	-45.2%	-52.5%	-55.6%	-41.5%	-46.9%	-32.3%
	(-75.7%)	(-64.9%)	(-73.1%)	(-68.1%)	(-59.5%)	(-70.1%)	(-53.3%)

Agent 206's house had a flexible heating system; it could be heated by electricity or wood either by a boiler in the basement or two old tile stoves and a huge baking oven in the kitchen. Normally, the family primarily used electricity to support the tile stove heating system. The tile stove on the second floor was only used when it was extremely cold (–30˚C or so), since it would otherwise became too hot. Before the game, hot water in the building had been produced by an electric heater.

The clues for energy-saving from the batteries in the platform game were followed partially, even though they were not always applicable. One example is the clue to put the dishwasher in eco-mode. The washing machine in this particular home was too old and lacked such a mode. At one point the family began to turn all the lights off. A picture of a burning candle can be found in 206's agent camera. This ascetic strategy was abandoned after about two days.

The father in 206 put a lot of effort into the task of lowering heat consumption. The first measure was to use a lot more wood for heating. This resulted in a warmer indoor temperature than the family normally had. He also partially reconnected the water piping in the house so that hot water could be obtained from the boiler in the basement instead of the electrical boiler.

Table VII. Relative changes in consumption for the teams

	Smedjebacken		Växjö	
Mission	Electricity	Heat	Electricity	Heat
1	-13.6%	-7.0%	**-18.3%**	**-15.1%**
2	**-48.2%**	**-12.6%**	-16.4%	-10.3%
3	**-57.7%**	**-11.2%**	4.1%	-11.4%
4	-44.3%	-15.3%	**-39.5%**	**-21.2%**
5	-40.6%	-11.2%	**-47.4%**	**-32.8%**
6	-21.2%	-11.2%	**-26.9%**	**-26.8%**
Final	-34.3%	-12.1%	**-34.0%**	**-35.3%**

Team Effort. The results after each accomplished mission were normalized and augmented to include heat consumption from houses with remote heating. The results presented to the players were based on the calculated outcomes in Table 7.

The gray cells in the table indicate the winning team. The numbers denote averages of the players' relative change in energy consumption. Each player's relative consumption was calculated by comparing his or her energy consumption during the mission to the average consumption during the same hours during the five weeks prior to the test. In other words, this table does not take outdoor temperature biases into account. It merely serves to show the kind of feedback (positive or negative) each team got from the game after each mission.

Overall Results. Most game missions took place between 17:00 and 22:00. It is during these hours that our homes consume the most electricity. This short five-hour period, in which the missions must be carried out, makes it possible for players to move energy consuming activities outside the missions (displacement). To not affect gameplay, the washing machine, for example, must be done after 22:00. Hence, even though everything looks good in the game score, due to displacement the family may have the same rate of energy consumption total as before. In this section we will therefore take a closer look at displacement effects and overall consumption change during the entire game period.

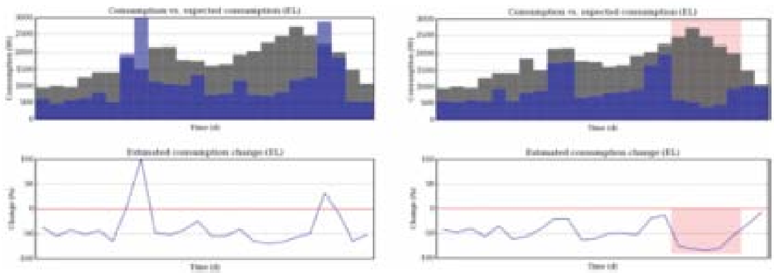

Fig. 3. Illustration of displacement occurring during mission one for agent 206.

To the right in Figure 3 (blue bars), we can see a detailed plot of the electricity consumption one week before the gameplay for one of our players. To the left in the same figure, we provided the gamers with a plot for the first mission during the game evaluation. The gray bars indicate average consumption for the specific hour during a normal day. The pink area in the right plot indicates the mission time. It is clear that consumption is a lot lower during mission time; but we can also see a clear case of displacement, since the bars prior to the mission are a lot higher than at the same time the previous week. This kind of behavior by the participants was anticipated. To get an idea of the magnitude of the displacement, we present the overall savings for the entire game week for both mission and nonmission times in Tables 8 and 9.

Table VIII. Team Smedjebacken: Electricity consumption entire game period

ID	Expected	Measured	Change
204	110 kWh	99 kWh	–12,1%
205	570 kWh	398 kWh	–11,1%
206	345 kWh	164 kWh	–24,0%
Med			–15,7%

Table IX. Team Växjö: Electricity Consumption Entire game period

ID	Expected	Measured	Change
101	104 kWh	—	—
102	310 kWh	240 kWh	–26,1%
103	256 kWh	169 kWh	–31,5%
Med			–28,8%

For Agents 205 and 206, the savings were adjusted in relation to the reference group (which had a reduction of 22 percent in electricity usage for the entire week). The table has an incomplete entry for Agent 101 since a faulty AMR meter caused an incomplete data set for this participant at some instances during the week. The tables show that the net effect on the entire week was clearly positive in terms of savings for all of the participants.

Postgame Observations. Postgame observations include the Smedjebacken team and the reference persons only. Here we present the average consumption change relative to consumption before the game, where the consumption changes for players 205 and 206 have been subtracted from the results of the reference group.

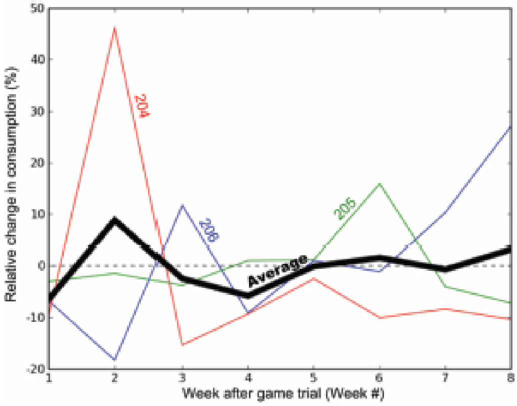

Fig. 4. Postgame consumption.

The postgame consumption is illustrated in Figure 4. The line in boldface shows the average for all players. The players' individual consumption is shown by colored lines (blue 206, green 205, and red 204). Player 204 shows a significant peak in consumption the second week after the game, reaching a 46.2% increase in consumption compared to the period prior to the game. This increase can be located as occurring at two specific times during the week, namely on Friday between 11.00 and 22.00 and on Sunday between 06.00 and 21.00, when a peak in consumption of 2 to 6 times higher than normal can be found (about 3000W more than normal). Average consumption for all players during the entire eight weeks after the game test was –0.2%.

Social Motivation

The level of involvement by family members in the game varied a great deal. In all families, except agent 204's, the parents appear to have been involved in saving energy. Agent 204 lives with her older sister and father, and said she mostly carried out the missions herself. The sister and father appeared to have been away quite often during the period when the agent 204 was playing. Where the agent had younger sisters or brothers, as in the case for agents 101, 103, and 206, the siblings, in addition to the parents, were often also involved in game tasks.

The form of involvement also varied among the families. In some cases, as in that of agent 206, the family members (in this example the younger brother) interacted just as actively with the game as the player herself, playing the "warm-up tracks" (see game play). In most cases, however, family members (especially the parents) only occasionally interacted directly with the game console, and for the majority of the time participated in the game using their teenagers as mediators.

Table X. Involvement by Family Members

	People in the family	**Involved in the game**	**Kind of involvement**
101	Parents and a sister	Everyone	Player read clues out loud so that everyone could participate.
102	Parents brother, sister	Parents	Turning off lamps. Tacking part of the feedback. The father also used the actual application once.
103	Parents, several smaller brothers and sisters	Everyone (but mostly parents)	Tacking part of the feedback. Buying and replacing lights with low-energy ones.
204	Father and older sister	No one except player	-
205	Parents and two older brothers	Parents	Guarding and turning lights off after one another.
206	Father, stepmother, and little brother	Father and brother	The brother played both warm-up tracks and final mission. The Father took extensive energy-saving measures.

Regardless, the content of the game (clues, missions, and feedback) seem to have been effectively conveyed among the members of the family. The joint mission of reducing energy usage in many families became a task of guarding and reminding each other to turn off lights and other appliances. In some cases, we saw parents taking quite extensive and ambitious measures to lower energy consumption in the home. Examples can be found in the families of agents 103 and 206. The father in agent 206's house, for example, rerouted heating pipes to make the heating system more effective, and the father in family 103 replaced most of the incandescent light bulbs with low-energy ones.

Most players reported that getting cooperation from the family was quite easy.

Interviewer: "How did you do to get the family to cooperate? Did you use any special kind of tricks?"

102: “No it was more like ... Now I’m going to do this, we can win this and they understood.”

Interviewer: “They wanted to be in on it?”

102: “Yes, yes. They thought it was interesting as well. How it worked and so on, that it was a game where you save electricity. They also thought it was interesting.”

Although in most cases the players were wholeheartedly supported by their families, some conflicts did occur from time to time. Players 204 and 205, for example, reported arguments with older sisters and brothers, who, at times, found it difficult to adjust to not using computers (204) or TVs (205). Turning off all the lights could also lead to complaints from family members. According to agent 206, her stepmother complained about the darkness. Agent 205’s mother worried that she might have ruined the results for her daughter by doing some slow cooking during the weekend final.

Team member interaction was greatest among those who already knew each other. Two of the players in the Växjö team (101 and 102) were in the same class in school, and in team Smedjebacken one of the girls, agent 205, knew both of the other players on her team. The other two girls in team Smedjebacken, however, were not familiar with each other.

Agents 101 and 102 in the Växjö team reported that they discussed the game when meeting at school as well as using the game’s built-in chat board. In the Smedjebacken team, agents 205 and 206 reported having discussed the game frequently at school. Agents 205 and 204, said they discussed the game occasionally when they met.

Communication in the Växjö team seems not to have covered specific details about game strategy. On the question whether they exchanged any clues, 102 said: “No, we just said that just to try to turn off things and keep the electricity down and so we did. That’s about it.”

The only communication with the third member of the team was initiated because agent 103 got a really bad result in one mission. Agent 102 then sent him a message on the discussion board, telling him to “pull himself together”.

For Agents 205 and 204 on team Smedjebacken, the conversations seem to have been about “How it was to play the game” (204). Agent 204 appears to have been unclear about certain things in the game, and consequently asked for agent 205's help in understanding the game.

Agents 205 and 206 seem to be the only ones who exchanged specific strategies.

206: "Then later when I got back to school we talked about it all the time".

Interviewer: "You did!"

206: "Yes, and gave each other clues and talked about it and so".

In the Växjö team the participants clearly felt obligated to contribute to the team effort and said that, to a degree, they also competed against each other, even though they belonged to the same team.

Interviewer: "Do you feel that you did more than the others for your team in order to save energy? "

101: "No ... David (agent 102) did very much, he saved a lot, you could really tell, you could see it on those bars. Each time it was David that was best almost all the time. So ... ".

Interviewer: "What did you think then?"

101: "Well, I guess I thought that then we have to work some more so that we become ... ".

No instances of communication seem to have occurred during the game between the two teams.

Interviewer: "Did you talk about the other team at all? You, girls, did you talk about them?"

206: "No"

Interviewer: "Or was it just of what you did?"

206: "Yes, that we were going to win over them."

Interviewer: "Ok!"

206: "He he"

Interviewer: "So you where very motivated to win then at least?"

206: "Yes"

Learning

To structure learning analysis, we categorized the knowledge gained by the participants who we identified in the interviews according to (1) aspects of knowledge suggested by the game; (2) situational knowledge gained from applying measures; (3) information the players were forced to acquire consciously or unconsciously to solve the mission at hand; (4) aspects of knowledge learned from discussing strategy with parents and teammates; and finally (5) aspects learned from the feedback mechanism in the game. Here we will give examples from all of these categories.

In the first category, we can put the clues provided by the game's warm-up track (see Section 2.1 Gameplay) where the players collect batteries. Some of the players commented that these clues were often quite obvious, implying that they had acquired the knowledge previously. Nevertheless, it seems that it was these particular clues that they applied the most during the missions, or at least remembered using. The clues with some degree of humor appear to have been the easiest to remember.

In some player contexts the very explicit nature of the game clues sometimes made them useless, for instance in adjusting the temperature for the refrigerator if it was already adjusted correctly. In other cases, lack of knowledge prohibited the players from applying the clues from the game, as in the example below on applying the eco program to the dishwashing machine.

206: "Yes, but we couldn't, or Marion (the stepmother) didn't know any functions on it so it was the same old usual".

The most prominent example of situational knowledge gained from this evaluation was regarding the experience of turning off lights. When prior to the game question what they envisioned themselves doing to save energy, all players answered turning of lamps. This was also probably the most common measure taken during the game sessions. Many families took this to the absolute extreme by turning off all the lights in the house for a long period of time. In the interviews, many informants reflected with amusement on this dramatic experience:

101: "We had everything turned off until it was dark outside. Then we started lighting some candles ... . But it was actually really dark here, hehe".

Or with insight:

Father of 206: “I don’t think you could stand it having that dark all the time”.

In another case of situational knowledge, the father of agent 206 also reflected on other measures taken by the family:

“But the kind of larger change, the thing with the hot water and so on, that I kind of think that we could ... live with”.

He explained that they were all surprised at how long the hot water lasted after a fire in the basement boiler was lit, which had not been used until then.

We often found very practical discoveries for category 3, such as locating the temperature control for the fridge, the location of a room and working out how it functions, or identifying and locating standby equipment in the home.

Category 4 often also involved tasks in resolving practical issues in the home. Parents, when available, were frequently made use of, as can be seen in the example with the dishwasher from earlier on. As for information exchange between team members, this appears to have been very limited, with agents 205 and 206 as the only examples.

When looking at the personal feedback mechanism of the game (category 5), we asked what the player and his family thought about the consumption bars.

Father of 102: “You put it in relation to what has happened during the day. What was it that made such an effect ... . Perhaps you are away one evening... which we perhaps are normally as well, but it becomes special now when you are thinking that, aha that made that big difference ... and that perhaps doesn’t make much overall difference”.

In this case, the anticipated outcome was of being away from the house was expected but obviously became a bit more dramatic than initially predicted by the father. This provided new insights for the father as well as the rest of the family causing reflection and discussion. When on the other hand the feedback from the game, from the player’s perspective, was contradictory to what was expected, a degree of speculation as to the cause could be anticipated. In these cases, however, as far as we could tell from our investigation, discussion went only as far as to conclude that it was strange.

101: “Then one other time when we were away from half past two until midnight. Still there where red bars there and then we thought, well that’s strange”.

We conclude that players did not learn much from this negative feedback, since the energy-saving measures taken were often maintained and enforced, regardless whether they registered well on the bars or not.

The Game

One of the most critical bugs in the game prototype used in the trial was the game’s inability to handle delayed data transfer from the AMR system. At one point this caused a lot of confusion among the players, due to a mission first presented by Mr. Q and later changed during the same day. To avoid all delays in data transfer, measures were taken prior to the game to eliminate players with bad reception on their AMR equipment. Nevertheless, one of the players experienced a delay during one of the missions. Regarding the overall game experience, reactions were generally very positive from both players and their families, and all of the participants were very positive about trying similar games in the future.

Interviewer: “If you got the opportunity would you want to play something like this again in the future?”

205: “Yes ... I would. I thought it was quite OK. I am a quite competitive person so it’s fun when you compete against others and things like that”. Interviewer: “Did it feel like a true competition would you say?”

205: “Yes, it became just like a competition. Sure it didn’t feel exactly like regular competitions I compete in otherwise, but still ... . I thought it was fun. It was quite alright”.

However, the two oldest boys among the participants (101 and 102)—both 17 years old—remarked that the game might be more suitable for someone a bit younger than them. Most participants also agreed that, in order for the game to last longer, the missions needed a greater degree of variation.

101: “Yes but you learnt quite much ... kind of about how you save and so on... Having gotten clues and applying it in practice and seeing what happened and so on ... if you then do this ... perform those tasks right and how much you save and ... So, well I think it is a quite fun way to learn. But ... it might not last for several months or so to play with but ...

Because its still, you still keep a lot of the clues so maybe, one got too see then that it saved thirty percent and ... during one day ... and that becomes quite a lot of money in the long run".

Discussion

Changing energy consumption patterns in the home requires both knowledge and motivation. The approach taken in our game demonstrates a significant decrease in energy usage by the participants. This indicates a change in behavior, which in turn implies the presence of both knowledge and motivation. The actions taken to reduce energy consumption by the participants involved several measures that clearly infringed on their normal level of comfort. This fact gives us reason to believe that the degree of motivation was very high in this game.

Based on an analysis of the interviews, it is clear that the number one factor behind the motivation was the competitive aspect of the game. The outspoken ambition to win the competition was stated explicitly by team as well as family members on several occasions during the game. It seems that in this game design the competitive factor was twofold: players competed both against the opposing team as well as with and against their own team mates.

The second most important motivational factors were social demand and peer pressure between team and player. It is clear that players in the trial felt obliged to increase their efforts if their results were not as good as those of the other team members. Players who did not go along with this social dynamic received verbal and written reprimands from fellow team members. The effects of peer pressure in the game was—just like the competitive aspect—present in several layers, since each participating family constituted a team within the team. Peer pressure within the family was manifested as a kind of "meta-game," that of watching closely and reminding each other to turn off appliances.

Given that the teams have such an important role in motivating play, it is important to identify factors that are consequential to team performance. The first of these factors seems to be how well the team members knew each other before the game. We also identified that age difference could be a factor that might affect the teams' dynamics. This factor could be seen when older sisters and brothers did not cooperate with younger players (although this could also be interpreted in several other ways). Expanding on this issue, we believe that when designing this type of game it is important to let users form their own teams and natural social groups to maximize motivation and to support communication within the game.

From the start, the current game prototype was developed to support one team in Smedjebacken and one team in Växjö. By coincidence, all members in the Växjö team were boys, while all members of the Smedjebacken team were girls. Moreover, some of the team members in each group already knew each other from school. These circumstances may have contributed in strengthening the teams' identities as well as the motivation to win.

Considering learning in the game: it seems that energy-conservation strategies and knowledge of what constitutes energy-conserving behaviors were gained both directly and indirectly through the game sessions. Not only did the participants learn hands-on what they should do via the pervasive game approach, but also how they should do it. Perhaps the most intriguing aspect here was how in this pervasive process they were able to gain unique contextual knowledge and experience in applying a certain energy saving strategy. This led to insights by the participants as to which strategies and behaviors could perhaps be sustainable over time in their everyday lives.

Interestingly, families appear to have employed a joint strategy to reduce the negative effects of extreme energy-saving and a low comfort level by transforming it into a social event (for example, lighting candles, making things cozy, buying pizza or attending a party).

However, one important question about the persuasive pervasive game approach that needs to be answered is: do people that play pervasive learning games retain the behaviors that they had acquired in the game over time? In this study we have not been able to show any conclusive long-term effects of our approach. When interviewed, several of the participants assured us that they still conserved energy and were committed to continue doing so. For the Smedjebacken team, however, energy consumption seems to have returned to normal within a few weeks after the game ended. One of the team members (agent 204) did have a slightly lower consumption level after the game, if we disregard an initial peak during the second week after the game (see Figure 4). Since we were unable to measure the Växjö team's postgame consumption, we don't know if the postgame trend for this team (who won the game) was the same. Some households made permanent changes in lightning and heating, and these measures should naturally have an impact on their long-term energy consumption.

Nevertheless, to reinforce behavior change over time, we suggest three different strategies that are worth exploring. The first could be to prolong the actual gameplay. This could be achieved by providing additional game content, preferably by building on the social aspects of the game. For example, we could set up leagues where the different teams fight against each other for a place in a final, or adding missions that, in line with strategies in this game, encourage energy-saving social activities such as taking the family to cultural events like a movie or a concert.

A second design strategy could be to expand, based on a real-time sensor system, on the pervasive interaction component of the game. In this way— when the player is using different home appliances—the game could provide immediate energy consumption feedback from those particular devices. This strategy would strengthen learning and enable other forms of less event-based forms of games.

A third approach worth considering is to append the current game experience with a low-intensity kind of postgame information service to sustain some of the motivation for energy conservation, as well as provide feedback on the participants' postgame energy saving strategies.

Of these three strategies, the second one (investigating how a game design on top of a real-time sensor system can be done) is currently being investigated in an ongoing project at the Interactive Institute (Bå ng et al. 2009; Gustafsson et al. 2009).

In this project however the use of existing platforms such as the AMR systems, Java-enabled phones, as well as the HSDPA network was a deliberate choice in order to provide a concept with real-world feasibility, which at a later stage can be implemented and introduced on a larger scale[9]. Hence, in this sense, the technical development and evaluation can also be said to be part of the results of this project. The problems mentioned earlier, with delays in data transfer, are examples of

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[9] During 2010 a commercial project based on Power Agent and these findings will be tested on 150 households.

unexpected difficulties that arise with a novel system such as the AMR. Despite this problem, which could be accounted for in the design, the overall success of the game prototype gives us the confidence to say that it is feasible to build an engaging and scalable mobile pervasive game for energy conservation based on existing AMR infrastructure. A game that, despite the limitations of a slow feedback loop, can both motivate and educate on the topic of energy conservation, through what appears to be an enjoyable and interesting experience for both indirect and direct participants.

Conclusion

This study indicates that mobile pervasive games can be an effective way to motivate teenagers and their families to lower energy consumption in their homes. The participants were highly engaged in the game and accepted levels of comfort in the home way below normal standards. Moreover, the study indicates that pervasive games can also be great tools to educate people about energy consumption in the home. In this trial, however, we were not able to show any indication of long-term reduction in energy consumption, and more research is clearly needed in this regard. Nevertheless, we believe that pervasive learning games that have a pronounced social component like the Power Agent can be a very successful tool for behavioral change and learning in related domains such as lifestyle-induced health problems, and other complex real-world issues close to the domestic and personal domain.

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Chapter 14

Persuasive Design of a Mobile Energy Conservation Game with Direct Feedback and Social Cues[10]

Abstract

Pervasive gaming has the potential of transforming the home into a persuasive environment in which the user can learn about appliances and their electricity consumption. Power Explorer is a mobile game with a special sensing approach that provides real-time electricity measurements and feedback when the user switches on and off devices in the home. The game was developed based on persuasive principles to provide an engaging means to learn about energy with positive and negative feedback and social feedback from peers on real energy actions in the home. We present the design and rationale of this game and discuss how pervasive games can be viewed from a persuasive and learning point of view.

Introduction

The present global environmental crisis requires new approaches for communicating the necessity of saving energy as a mean to the end of reducing emissions of carbon dioxide. Studies have shown that smart use of electricity and saving in the home has a potential of reducing electricity consumption in the home up to 30 percent (Abrahamse et al. 2005). Just small changes in personal habits are needed to accomplish significant energy savings.

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[10] Bång, M., Svahn, M., and Gustafsson, A. (2009). Persuasive design of a mobile energy conservation game with direct feedback and social cues. In Proceedings of the 3rd International Conference of the Digital Games Research Association (DiGRA 2009) (London, UK, 2009) http://www.digra.org/dl.

A problem, however, is that the general public does not know what actions constitute wasteful use of electricity in the home. It is difficult to understand what activities and what devices that consume large amounts of electricity and how small individual actions may impact a homes' electricity consumption. Furthermore, it is known from research in advertising and communication that campaigns and information on urgent social topics, (e.g. quit smoking, don't ´drink and drive, use a condom etc), can be considered "a nag" and are filtered out (Babor et al. 2003, Rosengren 2008, Severin & Tankard 2000, Storch 2008(.

It has been put forth that computer games can be a way to persuade and educate the player into new attitudes and new behaviors (Acar 2008, Glass 2007, Nieuwdorp 2007, Nicovich 2007, Winkler & Buckner 2006, Wise 2008). However, there is still little knowledge of how such games should be designed to enable learning, foster new behaviors and attitudes and break through the filters. For example, some salient questions in the area of learning game design is how to make the game engaging while keeping the message intact. That is, provide just the "right amount" of tips and information for the game not to become boring and get filtered out.

Moreover, researchers are questioning how effective computer games and consoles intrinsically can be in terms of promoting learning and behavior changes since they either often just provide a *simulation* of suitable actions in a virtual world and these may not be transferred to the real world (Schunk 2004), or lead the player to learn the game instead of the message (Linderoth & Bennerstedt 2007).

In this paper, we suggest that pervasive games is a sub- genre of game design that has suitable properties as a home- genre for educational and persuasive purposes because gamers can be immersed in real tasks in the home and can get immediate feedback on those behaviors. Our approach is embodied in Power Explorer - an experimental game designed to promote energy awareness and aid gamers to learn about energy efficient actions in the home. The suggested game design can be said to be information- shallow since it provides no in-game informative content, no in-game tips on how to succeed and no overt topical information and pointers to avoid issues such as the nagging problem.

Instead, the game design relies entirely on shallow cues on own behaviors (in real time) and on basic social cues from peers. The paper is organized as follows: First, we present earlier research on pervasive games, feedback and cues. Second, we present the design components of Power Explorer. In the remainder of the paper, we relate the design components and our approach to theoretical aspects of persuasive design.

Background

Pervasive games

The definition of the concept "pervasive game" is still the subject of some terminological and philosophical discourse (Magerkurth et al. 2005, Montola et al. 2009, Nieuwdorp 2007, Stenros et al. 2009). The term, however, mostly implies some sort of reality expansion of the game. Montola, Stenros & Waern (2009) have suggested that one can view pervasive games in terms of three expansions; *Spatial expansion* is probably the most salient trait of pervasive games and it means that the game "breaks its boundaries" and takes to the streets of the real world (this opposed to assumed "normal" digital games that are played on stationary standard computers and consoles). *Temporal expansion* is when a game expands the time structure of the play. When appropriating real-life objects into the game ordinary real- life objects get a new meaning and history. Temporal expansion can also mean that there is no "on" or "off"-time from the game. *Social expansion* is when the game includes ordinary people who are not actual players of the game, and who may or may not be aware they have become part of a game. A pervasive game can utilize the design of social expansion in controversial or benign ways. For example, the socially expanded research games Hot Potato[11], utilizes mobile phones and Bluetooth transmissions and unwitting passersby as game resource for the players in ways that is intended to raise ethical issues. A game like Insectopia[12] also uses unwitting passersby as game resources, but in ways that may raise less ethical concerns.

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[11] In Hot Potato, the players roam an urban area and pass a "Hot Potato" between themselves via Bluetooth. The players can "park" the potato on the mobile phone of an unwitting passerby via a form of "*blue jacking*". Then the player, who has parked the potato, must take it back, the player is driven to follow the passerby in ways that may resemble stalking.

[12] Insectopia is a collection-game where the player collects "insects". The presence or absence of insects is defined by the presence of blue-tooth enabled devices in range. The passerby whose presence is a resource has no way of realizing that he/she is a resource in the players´ game. See: http://iperg.sics.se/iperg_games7.php

Common for many pervasive games are that they in order to function need to rely on some sort of sensor system. There are two attributes to such a sensor system that are desirable. Firstly the system needs to fairly accurately interpret something in the real world that has meaning for the players. Secondly the system is preferably one that is feasible given the particular situation, i.e. not being to obtrusive, be scalable, offer enough coverage, be affordable etc.

The most popular choice of sensor system in pervasive games has so far been the GPS system. With the players' position a game designer can approximate players' locations towards each other as well as towards fictive or real objects. Examples of pervasive learning games utilizing GPS are Savannah (Benford et al. *2005*), Rexplorer (Waltz et al. 2007) and Frequency 1550 (http://freq1550.waag.org/). Savannah is played on a predefined open field where the participants take the roll of a pack of Lions hunting virtual animals. Rexplorer and Frequency 1550 both aims to teach the player about local history of a particular city. Power Agent (Gustafsson 2008) is a mobile pervasive game that utilizes the existing Automatic Meter Reading system (AMR) to measure the homes electricity consumption and provide feedback in the game.

The AMR approach to sensoring and data collection is clearly feasible since it already exists in place provided by some of the energy utility companies. The system however delays the feedback to a game built on it, since data in most cases is only transferred once every night. As a result Power Agent game design relies on ascendant intervention trough explicit clues and tips on how to save energy and is also very much played in a slow turn based event fashion.

In Power Explorer, the design case presented here, we will instead use a custom made real time sensor system to measure electric consumption in the home. Recent advances in consumer electronics have led us to the conclusion that this is now feasible, since similar solutions are provided by products like Wattson (www.diykyoto.com) and Eco-Eye (http://www.eco-eye.se/).

Behavior, cues and learning

A fundamental part of the learning process is to get feedback on our actions (Piaget 1977, Skinner 1971). More recent research on behavior modification has suggested that behaviors can be controlled by adjusting the antecedents or the consequences of an action. That is controlling the possibilities for a person to take a certain action or controlling the feedback of an action. Examples of the former are physical barriers and designs that disallow certain behaviors. Another example is artifacts that invite and promote actions. Examples of the latter strategy are positive and negative feedback and reinforcements on actions in terms of directs rewards i.e. classical behaviorist approaches. Hence, strategies that can be said to frame the interpretation of an action.

An example relating to the use of electricity would be the Power Aware Cord by Gustafsson et. al (2005). Several studies have emphasized the importance of relating the two strategies and they have also underlined the need to contextualize and frame the feedback in time and place so that the subject can understand what the feedback was about.

Immediate feedback and contextualization has also been suggested as a means to change peoples´ energy consumption patterns in the home. For example, McCalley and colleagues have suggested that persuasive technologies that aim to promote energy conservation should provide informative feedback on the appliance-level, rather than on the aggregated household level because this would make it easier for the consumer to contextualize and understand the impact of an action (McCalley 2006ab).

Power Explorer

Power Explorer is a pervasive action-oriented multiplayer game where the overall goal is to explore the household, learn about its´ electricity consuming devices and develop a positive attitude towards conserving electricity. The gamer can also engage in real time duels with peers, and winning those duels is based on manipulating household electricity consumption. At the onset, all players are assigned a medium sized CO_2 cloud that will expand or disappear depending on the use of electricity in the home. The goal is to keep your cloud smaller than your opponents' clouds.

System overview

In Power Explorer the entire home acts as a game interface through its electric appliances. The flow of electrons into the house is continuously analyzed by a small microcomputer wirelessly connected to the internet. The computer measures the magnetic field around main incoming electric cables trough clip-on sensors.

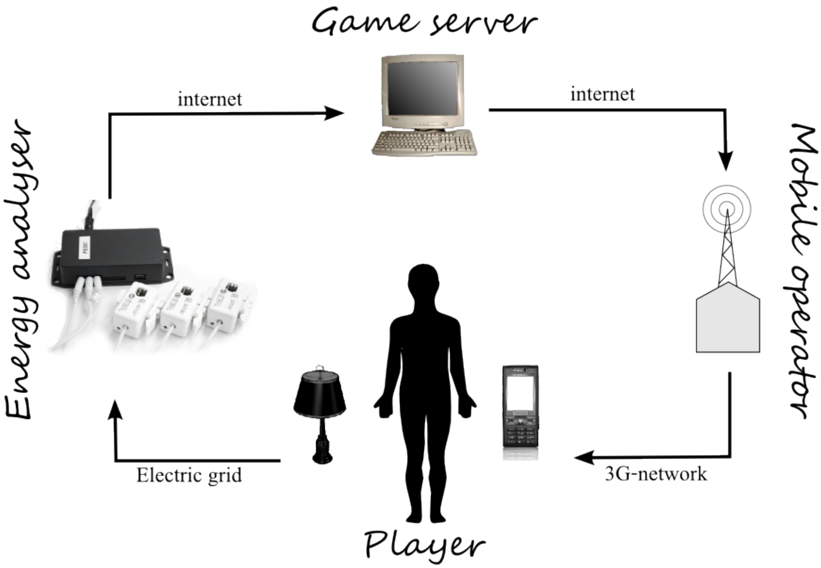

Figure 1. System overview

The results of the measurements are compressed and relayed to a game server. The game server compiles the results of all players and transmits appropriate data to each game client on the mobile phone over the UMTS network.

Game play

In Power Explorer all players and households are represented by their avatars – their own “monster blob”. The Pile shows all players and their position in the game and it also provides means to invite peers to duels (see Figure 2).

A monster’s position in the pile represents how much the household have been saving or consuming lately. Hence, the player at the top of the pile is the player who has made the currently largest decrease of consumption and has the smallest CO_2 cloud in his yard, and the players at the bottom of the pile are the ones who have the biggest CO_2 cloud. This setup also means that when household members are not home such as in the middle of a workday the drop in consumption can automatically result in a more prestigious position in the pile. Conversely, during weekends, when there are a lot of electricity consuming devices running, the player may automatically drop in the pile if the player does nothing about it. The same is simultaneously true for all players; one player may rise or fall in the pile, only due to the rhythms of daily life. This creates a dynamic that enables all players to feel that they have a fair chance in the competition.

Figure 2. The Pile shows all players and their position in the game. The pink monster with a red ring around is the current player's monster. The green sleeping monster with a golden scarf is the one who won the last duel. The monsters with closed eyes are players currently off-line.

To advance in the pile is, basically, a matter of exploring the home, identify the devices that are consuming a lot of electricity and turn them off. The meter on the left side of the pane shows the total consumption of the home in real time and, hence, it shows the consequences of turning on and off devices. To play in this mode is a relatively low- key, requiring little attention from the player as regards to the game console, itself but cognitive attention is required as regards to exploring devices and shaping everyday activities in the home.

Single player view

Power Explorer also provides other means to explore the energy environment of the home. In *the single player view,* the players´ own avatar is situated in its home, in the visual metaphor of a garden (see Figure 2). When the player or someone in the player's home turns a device on or off, a *flower* or a *weed* shoot up from the ground in the monster's home, and the avatar indefatigably consumes that weed. A weed shows up if the player increases the households' electricity consumption and a nice flower appears if the consumption decreases.

The size of the weed and the flowers indicate the amount of electricity variation3. This visualization of power changing events enables the player to map consumption levels to the current tasks performed. Hence, this playing mechanism allows gamers to investigate home appliances by turning them on and off and the game provides a direct feedback mechanism on the real-world actions.

The main problem with the weeds, is that when consumed by the monster blob, they give the avatar indigestion and this gives the avatar an unhappy face and make it puff out *carbon dioxide.* The rate of the CO_2 puffs generated by the monster blob is the rate at which you are using energy (*i.e., power × time). The carbon dioxide accumulates in the grey cloud that overshadows the sky.*

The CO_2 from this cloud will spontaneously evaporate thus the cloud will disappear in time, as long as you don't add to the cloud by using electricity. The balance in this equation has been chosen so that a player needs to lower the consumption of the home with at least 15% in order for the cloud to start shrinking. The calculation is based on an average of the own household's electricity consumption a month before entry into the game4. Thus players compete with their relative consumption. If the players maintain their previous consumption the cloud will grow in size to eventually cover the entire screen. As a result the monster will get a lower position in the monster pile and become visible sick.

The obstacles will appear in cycles so the difficulty lies in timing them correctly. However, the running speed is determined by *manipulating* the household' electricity consumption. To win this duel i.e. to be able to adjust the running speed, the player needs to have an understanding of the *amount* of electricity different domestic appliances consume continuously. For example, turning *on* a microwave oven or a hairdryer – two big short-term electricity-consumers in a household – will result in a speedy avatar.

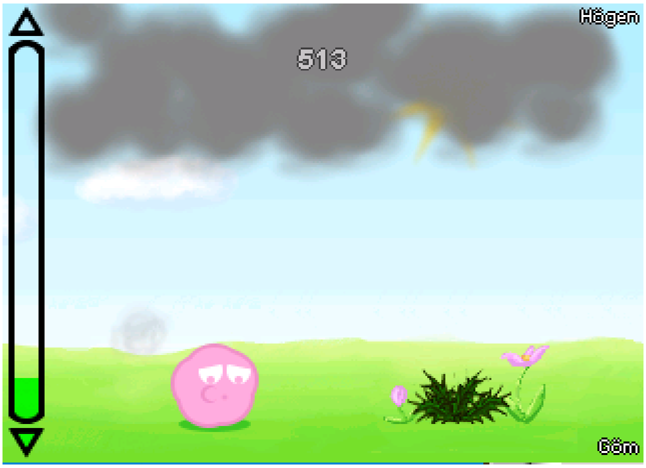

Figure 3. The single player view of Power Explorer. The player is doing rather badly and the avatar is unhappy due to the amount of thistles to consume and because the cloud of noxious carbon dioxide is large.

Duel modes

Power Explorer also offers an engaging real-time duel- mode where players can challenge any other player in the pile. Two duels are presently available in current version of the game.

Duel in the rain forest. The idea when designing the *Duel in the rain forest* was to bring learning about the amount of energy different devices burn when in continuous use. The key is to find the right level of energy.This duel set the players´ two avatars running side by side on a racetrack in the middle of a rain forest. To win, the player has to reach the goal before the other player without running into too many of the obstacles along the way.

Figure 4. The Rainforest duel.

However, turning on appliances in order to increase running speed also has another effect. The added consumption of the two players' electricity consumption is connected to the amount of the precipitation in the rainforest. High consumption will therefore lead to a build-up of rainwater making both players drown (see Figure 4). Consequently, the task of the players' is to carefully maintain a balance between gaining enough speed to win the race, the right speed to time obstacles while not going to excess and drown.

Figure 5. The North Pole duel.

Duel at the North Pole. The other duel is a fighting match on an iceberg at the North Pole (see Figure 5). In this game, the aim is to knock the opponent off the icecap into the water by throwing various objects. Small objects like snowballs, fish and seals have little impact on the opponent but polar bears and blue whales have a major impact on the rival. The player gets access to the objects by controlling the electricity consumption in the home. For example, to get a powerful whale the player has to understand that the task is to turn *on* a major electricity-consuming device such as an electric radiator, for a second or two. Hence, a short “spike” endows a player with an object.

Buttons on the console controls the throw direction while the destructiveness and length of the throw is determined by the “weight” of the object (snowball or blue whale). Light objects like a snowball will smash onto the ice and disappear if you miss the opponent, medium objects like a seal will slide away on the ice after landing while the heavy objects like the blue whale will crash through the ice and leave a big hole in the ice cap.

However once again like in the rainforest duel, there is a price if one goes to excess. Too much increase in consumption will melt the polar cap and drown both players. In the rain forest mode, the winning strategy is to leave the right combination of consuming appliances *on*, (though not too much). In the North Pole duel the winning strategy is to very quickly turn the right appliances on and off. These two challenges were created to illustrate two opposing principles; the rainforest challenge illustrating the concept of continuous electricity consumption, while the North Pole challenge illustrates the concept of the power used of an appliance.

Winning a duel makes the players’ avatar in the pile wear “the golden scarf of victory” until some other player wins it over in a new duel. However, these duels increases home electricity consumption and this will inevitably lead to a corresponding drop in ranking in the pile as well as the home garden being overgrown with thistles and become overcast with the CO2 cloud. However; *winning* a duel lead to a one hour long immunity against weed, which gave the natural system time to clean up the cloud and garden.

Discusson

Reality expanded games like Power Explorer provides a number of unique opportunities in terms of persuasion and learning. First, they can transform ordinary environments into interesting and motivating landscapes by "keying up" everyday tasks into a frame of fun to drive attention to topics otherwise given little or no attention. If a mundane and otherwise filtered task such as conserving household electricity can be "keyed up" then it may be also possible that large amounts of overt messages such as tips can be omitted and still have the persuasive component and message intact.

Moreover, by applying this approach we need not to rely on simulated tasks in the game. We provide a real situated learning experience so problems of transfer becomes a non-issue and we have, in this game, joined the message and the game experience to minimize the effect of just learning the game and not the message (Linderoth & Bennerstedt 2007, cf, Svahn, 2005).

Taking this as a point of departure, the Power Explorer game does not just that; it provides virtually instant individual feedback on appliance-level consumption. Hence, it is setting feedback in a frame of activity that may facilitate understanding of the power consumption of the home appliances.

Most often educational games come with in-game information or a structure for reflection and an educational context that aid users to interpret actions and information. However, our design approach can be said to be information-shallow since it provides no such in-game informative content, no in-game tips on how to succeed and no overt topical information and pointers. For example, many educational games provide tips and information with the game and managerial role-playing games are often followed by *debriefing sessions* where the experience is discussed. This information is used to foster reflection and joint understanding of events. However, our game relied entirely on shallow cues on own behaviors (in real time) and on basic social cues from peers. Hence, it can be seen to promote behavioral learning rather that cognitive learning. In Power Explorer, we intentionally left interpretation of actions and information to the gamer and this can seem to be a too narrow approach from a learning point of view. However, if we regard the *total social system and social expansion* of Power Explorer, we believe that actions and information can be interpreted in discussion with the family and peers outside the game. Let us now discuss how the social expansion of pervasive games can have a persuasive effect and to some extent also support reflection.

Power Explorer supports social expansion by necessitating communication with non-playing family members. The characteristic of the social expansion in Power Explorer is rather open and may not seem to be an obviously intended part of the game design at least when compared to games like Hot Potato or Insectopia. Power Explorer is designed for teenagers all living at home with families and sharing their households with parents and siblings. In previous studies with a similar game, considerable amount of family involvement was reported in the game and its tasks (Gustafsson & Bång 2008). This included ordinary tasks such as players turning off appliances and lamps, reminding each other to conserve electricity, to more extensive measures like buying energy efficient lamps and even rebuilding the entire home heating system to make it more efficient. It seems that the family interactions that Power Explorer stimulates off-line can have a positive role in supporting reflection and debriefing.

To iterate; the debriefing and reflection sessions that Power Explorer may seem to lack, when viewed narrowly as a game system are actually very present when Power Explorer is viewed as a larger social interaction system. Therefore, a hypothesis one can state is that designers of educational pervasive games could omit traditional overt informativedebriefing components of serious and educational games if that information instead is present in a social expansion particularly designed to fill that particular task. Hence, what becomes important is to form the conditions in the game so that it directs social formation and communication, for example, by choosing target groups appropriately and have a back-story that promotes interaction within the target groups. This opens up for pervasive-persuasive games as a means for bridging advergame design, serious game design, and viral marketing.

Power Explorer was field tested during 2008 and the results are undergoing analysis. Should the analysis show that our approach is too shallow in terms of information we may add parts to the game that will promote reflection on how energy and actions are intertwined. Particularly interesting would be to have situated information in the mobile when gamers are using a specific device.

Conclusion

In this paper, we have presented Power Explorer – a pervasive game that transforms the entire home into an engaging environment for learning about electricity. The approach allows gamers to get direct feedback on their own actions and on the electricity consumption of specific devices in the home. We suggest that pervasive games are ideally suited for persuasion and learning since that are able to transform ordinary mundane tasks into a frame of fun and drive attention to topics otherwise given little or no attention.

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Chapter 14

Power Explorer – A Casual Game Style for Encouraging Long Term Behavior Change among Teenagers[13]

Abstract

When it comes to motivating teenagers towards energy awareness, new approaches need to be considered. One such is the use of pervasive games connected to the players own energy consumption. Earlier work has confirmed this to be a highly effective approach. The question however remains if post game effects on behavior can be achieved. In this paper we try to answer this by trying out a slightly different design compared to previous work. The hypothesis is that a more casual game play and a richer learning interaction enabled by building the game on a real time sensor system could stimulate more lasting effects. Electric consumption data after the seven days evaluation on a test group of 15 players shows tentative indications for a persistent post game effect compared to the control group of 20 households. Findings also show a statistically significant positive change in the players' attitude towards saving energy compared to the same group. Findings, at the same time, also indicate a negative effect on the player's attitude toward environmental questions in general.

Introduction

The recent UN reports (Solomon 2007) on climate change set new demands on our society. It is clear that much needs to be achieved on all levels of society in order to reach the new targets towards sustainable

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[13] Gustafsson, A., Bång, M., and Svahn, M. 2009. Power explorer: a casual game style for encouraging long term behavior change among teenagers. In *Proceedings of the international Conference on Advances in Computer Enterntainment Technology* (Athens, Greece, October 29 - 31, 2009). ACE '09, vol. 422. ACM, New York, NY, 182-189.

living. One part of the challenge is the reduction of our energy consumption. Studies of home electricity consumption have shown that people's behavior plays an important role when it comes to excessive energy usage (Socolow 1978). The savings potential – by changing energy usage behaviors in the home – is estimated to lie between 10-30% (Socolow 1978, Abrahamse 2005, Gustafsson & Bång 2008). Engaging people in making these - often small – behavior changes to reduce electricity consumption and emissions of CO_2 is therefore crucial.

Energy in our homes however (in terms of heat or electricity at least) is often visually concealed to us. Underlying electric functionality is for example many times hidden away by product manufacturers for reasons of safety or esthetics. Knowing what constitutes everyday saving behavior and what matters is therefore difficult. When targeting teenagers, this problem description is particularly true since the knowledge level regarding energy conservation in this group is generally low 0. This group is also often less cost-motivated since they rarely pay for their own use of electricity.

In earlier work, we have shown that a mobile pervasive game connected to the players' energy meters can be used as a powerful tool in order to both **motivate** and **educate** teenagers and their families towards energy conservation in the home (Bång et al. 2007,Gustafsson & Bång 2008). This game used consumption data that was updated every 24h from automatic meter systems employed by energy utility companies. Two teams of teenagers competed to save energy in the evenings and received results the following morning. The evaluation (Gustafsson & Bång 2008) of this concept named Power Agent, with teenagers and families playing the game for a period of 10 days showed a remarkable reduction in energy consumption (both heat and electricity were measured). However, the study was not able to show any persistent long-term energy conserving effects on the participants as energy consumption basically returned to normal within a few days after the game trial had ended.

In this paper, we contribute to the discussion on design of pervasive learning games to encompass **long-term sustained learning and behavior changes**. This work applies mainly to pervasive learning games in the area of energy efficiency but results should also be transferable to areas where one aims at developing learning games to change long term behaviors such as lifestyle-induced health problems and psychotherapy.

We report on the evaluation of a newly developed pervasive mobile game called Power Explorer (Bång et al 2009). This prototype builds on the previous research of Power Agent but takes an alternative design approach in order to investigate how to successfully design for long-term effects in regard to electric energy conservation.

This prototype employs a real-time sensing system capable of providing ***instant feedback*** to the player. This means that the player – when turning on and off electrical appliances in the home – can directly receive feedback on their actions. The approach also provides a more ***casual*** and laidback game play. Our hypothesis hypothesis is that this will stimulate a stronger post-game effect on players' behavior by building stronger associations with specific appliances (instant feedback) and encouraging players to adopt long term, rather than radical short term strategies (casual game play).

The article is organized as follows: at the onset we discuss fundamental aspects of pervasive games that make them particularly suitable for learning and behavioral change. Moreover, we report on related work within the field of persuasive technology and computer-supported learning. After presenting our game – Power Explorer – we present the findings from an evaluation study with 15 teenagers and families that played the game one week in the spring of 2008. In the remainder of the article, we discuss how one can design games to prolong learning and reinforce behavior changes over time.

Background

The use of computer games for the tasks of educating and motivating people on various topics is common today. The effectiveness of games as carriers for learning and persuasion has however also been questioned 0 as players tend to learn the medium and not the message and have difficulties in applying knowledge learnt from these games into real life contexts. In the following sections, we will argue that pervasive games, in this regard, are better suited for motivational and educational purposes compared to traditional forms of computer games.

Pervasive games as motivators and educators

Pervasive games are often referred to as games that extend beyond the traditional interface into the real worl (Nieuwdorp 2007). Montola et al (2009) have further more suggested that one can view this reality expansion in terms of a *spatial, temporal and social expansion*. Whilst traditional learning games typically struggle with achieving transfer (Gagné 1948) between game simulation and real world tasks, pervasive games have the potential to directly incorporate reality, providing a **situated learning experience**. In classic learning theory, transfer refers to the situation where the learner must generalize and use abstract knowledge (i.e., learnt from a book) and applies this knowledge to real world problems and requirements. An inclusion of reality will obviously minimize this contextual gap.

In the case of Power Agent and Power Explorer the reality expansion emerges as the game utilizes a sensor network connected to the energy consumption in the home. In this way the entire home and its electrical appliances are transformed into a game interface. We will refer to this method as a *subject-specific reality expansion*. By interacting with the appliances the game provides feedback on actions in relation to the goal of saving energy. The critique regarding, players of learning games, learning the medium and not the message here becomes somewhat obsolete. In the case of Power Agent and Power Explorer being successful in the game also means being successful at saving energy, hence, the **medium and the message are merged** (Svahn 2005). The quality of having a game with a common goal of game and message also lets game designers focus on the concept and content of the game instead of balancing game experience with for example learning goals which often have been seen as a difficulty in many serious or educational games (Waltz et al. 2007, Linderoth & Bennerstedt 2007).

Moreover, interesting from a learning and motivation perspective is also the way pervasive games **include non-players** such as family and friends in the game experience (e.g., social expansion). The *social expansion* of pervasive games arises from the fact that the physical stage (the street, the home etc.) of the game is shared. The social interaction emerging from this – which could be seen in Power Agent (Gustafsson & Bång 2008) – seems to generate a more **natural platform for shared reflections, experiences and interpretations of events**.

Post game effects

Although a *subject-specific reality expansion* of a persuasive learning game brings the player closer to a reality context there still exists a gap between game situation and the post game situation. As the motivation to change behaviors comes from winning the game and not from the benefits from adopting the behavior there is always a risk that the participants will fall back into their old behavior when the game ends. This is true unless some kind of shift of motivation from the game to the task in general occurs (implying a change in attitude among the players). Within the field of psychology there are a number of theories that formulates that such a shift of motivation is likely to occur as the players engage in real-life game-tasks regarding a subject (such as saving energy). One of these is the Self-Perception Theory (Bem 1972) which asserts that we form our attitudes by observing our own behavior; another is the Cognitive Dissonance Theory (Festinger 1957) which deals with the human need of resolving internal conflicts between behavior and belief. Yet another is classical conditioning (Skinner 1971) which can be seen as a form of low-level associative learning.

In the previous Power Agent trial (Gustafsson & Bång 2008) the participants did indeed demonstrate a shift in attitude towards energy conservation. After the game, participants claimed that they were still motivated and committed to continue to save energy. Despite this measured energy consumption levels returned to pregame levels as soon as the game trial ended. We could here also see that many of the extreme measures performed by the participants during the game – such as turning everything off, or skipping dinner – was short term strategies not continued after the game. A key problem with these kinds of interventions is therefore to explore how to successfully design for long-term behavioral change.

In Power Explorer, we suggest the use of a real-time sensor system for measuring electricity consumption which would provide continuous updates on consumption. The use of real-time sensor system implies a richer learning environment. By visualizing changes in consumption, we enable the user to map power events to the current tasks performed and in doing so are able to better provide support for associative learning. The use of real-time sensor system furthermore enables a game that could be played in a more casual game style (i.e. less committing, faster rewarding and also less immersive) which would endorse more long term strategies by players as the extreme measures seem to have been a result of the very focused and committed game style of Power Agent that in turn was a necessity of the slow feedback loop.

Related work

Consumption feedback: Feedback on one's personal energy consumption can play an important role in helping people adopt new energy consumption patterns in their homes. The Twin River Investigation in the seventies (Socolow 1978) is probably the opening work on energy consumption feedback in the domestic environment. In this study, home-owners were given feedback in terms of notes with consumption figures (i.e., trend data) placed outside their kitchen windows. This feedback enabled them to decrease their total consumption about 10-15 percent. Since then, a lot of research has been carried out in a similar vein (Abrahamse et al. 2005) of investigation with varying approaches and means to provide the feedback Lately, these studies focus on using modern communications and digital means to convey the feedback. Most studies however fail to, in depth address the design aspect of the feedback as well as whether the effects could be maintained in a long term perspective (ibid.).

Pervasive learning games and advergames: The prototypes Savannah (Benford et al. 2005), Rexplorer (Waltz et al. 2007) and Frequency 1550 (Raessens 2007) all represents the few examples of pervasive learning games, that currently exists. All of them are location based. Savannah is played on a predefined open field and aims to educate school children about the life of the savannah. The other two examples teach about local history in Regensburg and Amsterdam respectively through a story driven game play. Conqwest (Lantz et al. 2007) is an example of a pervasive location-based advergame. It is a treasure-hunt-game designed to promote a mobile operator (Qwest), where the players collect points by photographing semacodes or capture other teams' bases.

Of these four examples Rexplorer with its aim to get people to move about the city and Conqwest with a goal of among other things display technical features (such as the use of semacodes) supported by the mobile operator, can be said to be closest to Power Explorer (in terms of a *subject-specific reality expansion, and a merging of message and medium*). None of these however addresses the issue of long term effects of the games.

Power Explorer

Power Explorer is a mobile phone game played on a HSDPA and java enabled handset (e.g. SonyEricsson K660i). The game client lies dormant in the background when not in use and can in this way push messages about exceedingly high consumption, received challenges or act as an ambient interface by making electric sounds as consumption rises to regularly pull the player back into the game. The client is connected to a game server which in turn is connected to WiFi equipped current sensors[14] installed in the central electric distribution box of each player's home.

Game play and interface

Power Explorer is played through an avatar – a "monster blob" – that is individual to all players. The monster blob can visit four different environments that have different modes of interaction; the pile, the habitat, and two duels. The game is designed to balancing the two opposing goals of saving energy (habitat and pile) versus engaging players in using and learning about appliances (the duels). The two existing duels in the current version of the game are the rainforest duel and the polar dual. Playing the duels offer an engaging real-time player-to-player competition while playing in the habitat is a quite low key explorative task.

Fig. 2. The main view of Power Explorer (the habitat).

The habitat: In the habitat, the avatar lives within a virtual climate environment. The objective here is to keep the monster blob healthy. The data for controlling the climate comes directly from energy usage in the player's home. The current electrical power level is visualized by the bar on the left of the screen. Power events such as turning something on, is visualized by weed growing up around the monster blob while turning

[14] The sensor module was in this case custom made. Affordable wireless energy sensors are however becoming readily available in different energy monitoring products in the market.

something off results in flowers growing. The size of a power event occurring translates proportionally into the size of the plant appearing. These plants serve as food for the monster blob and will therefore be eaten one by one. While flowers will have positive effects on the monster blobs health too much weed will make it sick.

A grey cloud in the sky represents the levels of CO_2. At the beginning, players will by default have a cloud the size of 500 units (a scale from 0 to 1000). CO_2 will over time slowly evaporate from this cloud causing it to shrink. If you use electricity in your home however, your "monster blob" will start emitting small clouds of CO_2 gas in response to eating too much weed. Each of these small gas clouds represents a fixed amount of energy having been used in the household. The gas emitted by the avatar will rise and join the big cloud causing it so grow.

This means that use of small amounts of electricity will make the cloud shrink while excessive use will cause it to grow until it eventually fills the entire screen with further consequences for you avatars health. Hence, in order to keep your monster happy and healthy you must keep electricity consumption down. The equation is set so that the level where the cloud goes from increasing to decreasing is 85% of the participants' normal household consumption in reference to the weeks prior to the game.

The pile: In the second view, monsters of all of the participating players are stacked in a pile. The position of your avatar in the pile corresponds to your current ranking in the game in a King of the hill fashion (see Figure 2 left). The red ring in indicates the players own blob. The green sleeping monster with a golden scarf is the one who won the last duel. The monsters with closed eyes are players currently offline. By pointing at one of the other players' monster you can see its current CO_2 level. Ranking in the game is based on the size of the CO_2 cloud. To reach the top you will therefore need to keep the consumption down as long as possible to clear off all the CO_2. Since some activities each day inevitably will use a lot of electricity it is important to perform these activities quickly and efficiently to avoid buildups of CO_2.

The Rainforest duel: The idea when designing the Duel in the rainforest was to bring learning about the amount of energy different devices consume when in continuous use i.e. this duel focuses on energy. The duel set the player's two avatars running side by side on a racetrack in the middle of a rain forest (Fig. 2 middle). To win, the player has to get to the end of the track before the competing player and avoid various tricky and dangerous obstacles along the way. The obstacles move or appear periodically throughout the duel. Some obstacles can be avoided by pressing the “jump button” however most obstacles must be avoided by timing their periodical movements. That means setting the right speed on your monster. The speed is adjusted by manipulating the electricity consumption of your home.

Hence, to win this duel, the player needs to have an understanding of the amount of electricity different domestic appliances consumes, to be able to quickly set the right speed. Increasing the electricity consumption, in order to increase running speed, also increases the precipitation in the rainforest that will lead to a build-up of rainwater making both players drown (Fig. 2 middle). Consequently, the task of the players´ is to carefully maintain a balance between gaining enough speed to make it through the obstacle without flooding the forest. Running in to an obstacle will make you bounce back and loose health. If the water level is high this might mean bouncing back into the water loosing even more health.

The polar duel: The other duel is a fighting match on an iceberg at the North Pole (see Figure 2 left). In this game, the aim is to knock the opponent off the icecap into the water by throwing various objects. Small objects like snowballs, fish and seals have little impact on the opponent but can be thrown much longer while polar bears and whales have a major impact on the rival but can only be used if the opponent is close. Some objects like seals will also slide on the surface of the ice while others, like the whale will go through the ice on impact and leave a hole. To avoid objects the opponent has reposition his or her monster and when sliding objects are used the monster has to jump to avoid trouble.

The player gets access to the objects by changing the electricity consumption in the home. For example, to get a powerful whale the player has to understand that the task is to turn on a major electricity-consuming device such as an electric radiator, for a second or two. For a smaller snowball a lamp might be sufficient. In this way the thought is that this duel will forces the player to explorer the power (rather than the energy) aspect of electric appliances in the home. Once an object is retrieved the player has to make sure his monster is facing the opponent’s monster before pressing the throw button. The players combined consumption rate will affect the sun over the polar landscape. A hot sun corresponds to a high consumption and will melt the ice cap more quickly.

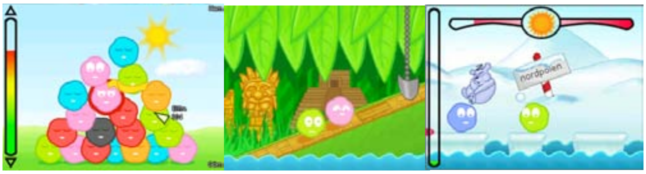

Fig. 3. The pile (l), the rainforest- (m) and the polar- duel (r).

Method

Both quantitative and qualitative methods were employed in this study. Quantitative data consists of game server logs, electric consumption data, temperature logs for the area and forms filled out by the participants before and after the game. Qualitative data consists of interviews with the participants after the evaluation was completed and in-game observations made by the participating researchers.

The trial was carried out during one week's time during the late spring of 2008. The game was played by 15 test participants in the age of 12 to 14 years old together with five researchers acting incognito as players. Moreover, a reference group of teenagers living in the same area was used. Both the reference and the test participants participated on a voluntary basis (permit from parents was required). Special care was taken to make sure the composition of types of heating systems concurred in the two groups to eliminate effects by weather.

A questionnaire with general questions about energy and electricity was filled in by test participants and reference persons alike, once before the game and once after. Another form with specific questions regarding the game was only submitted to the test participants after the game trial. Six of the participants were also interviewed after the game. The semi-structured interviews were recorded, transcribed and categorized.

Electric consumption data was logged for all households before, during and after the game test. Data from each house was normalized in relation to a reference period four weeks prior to the game trial. An average of the relative change in consumption was calculated for the game period as well as the following weeks for each house. These two values were then compared to estimate the savings made. In addition a T-test was carried out on the two groups to establish the statistical significance of the readings. The estimated savings were also tested for correlation to temperature readings as a second precaution to verify that the reference group and the test group were similarly affected by temperature shifts.

Results

The observations in this study have been sorted into the categories; energy saving strategies, attitude changes, learning and a more general game design category. In this section, examples from each of these categories will be presented. First, however, we will present the overall consumption figures followed by a short presentation of the six interviewees and their individual achievements.

Overall consumption change

The observations based on the AMR data shows that consumption for both groups follow the temperature synchronized during the weeks prior to the game (Fig. 3). The black line (Fig 3) is the average of the relative energy consumption for the players and the grey line corresponding data for the reference group, also plotted as a dotted line is the outside temperature. The red dashed line shows the results of T-tests (the P-value) between the two groups. The blue area indicates the week of the game trial.

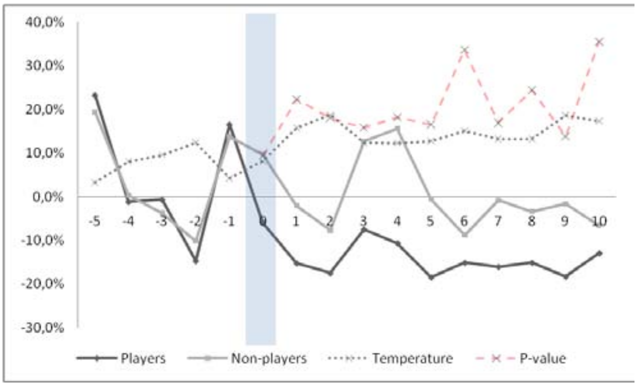

Fig. 4. The relative consumption change (x-axis in weeks).

As expected, at the point of the game trial (week 0), the two groups diverge. This diversion persists during the entire post game period measured. Significance of difference between the two groups however decreased shortly after the game trial ends (P-value increases), indicating a greater overlap between the two groups. Consumption during the 10 weeks following the game trial was on average 14% lower in the player group compared to the reference group (P-value=0.16 for the same weeks). Of the 15 participants 12 showed some level of decrease in the use of electricity. Only three of the participants increased or showed no changes in their consumption during the game trial.

Background interviewees

The following section aims to provide us with an understanding of the range in preconditions as well as the difference in how the game was embraced and played by different players. The players interviewed have therefore actively been selected to represent extremes within the player group.

Willem is a 13 year old boy he lives in an apartment heated by remote heating (i.e. not effecting electric consumption). During the game trial he played 85 duels and was actively interacting with the game about 7h and 26 min each day. This makes him the **most engaged player.** Despite this he only ended up on a 9th place among the 15 participants. Willem had a malfunctioning meter during the first couple of days which might have affected his game results. The energy log from Willem's apartment (not affected by this fault), shows that he still managed a reduction in electricity consumption by 18% during the game trial and a 14% reduction in the weeks following the game.

Maja is a 12 year old girl living in a house with remote heating. During the game trial she only played 11 duels and was only actively interacting with the game for about 2½ minutes each day. This makes her **the least involved player** in this game trial. Maja finished 2nd last in the game. Energy logs from Maja's house shows an increase in consumption by 8% during the game trial but surprisingly a decrease in consumption the 10 weeks following the game by 27%.

Sara is a 13 year old girl who lives in a house heated by wood pellets. During the game trial she played 26 duels and was on average active 17 minutes a day. In terms of savings, Sara was **the worst example** among all players. Energy logs from Sara's house show an increase in electric consumption during the game trial by 71% and an increase by 65% the weeks after the game.

Vincent is a 12 year old boy who lives in an old house which is heated partly by electricity and partly by two tile stoves and a wood boiler in the basement. He describes himself as somewhat of a game fanatic and explains that he really enjoyed the game. After having held the top position for more than half the time during the trial, Vincent **finished first** in the game. During the game trial however he only played a moderate 25 duels. He spent about 2h 11min each day actively interacting with the game. Energy logs from his house show a reduction in use of electricity by 51% during the game and 23% after the game. Vincent's older sister had earlier been participating in the Power Agent trial. He was therefore well acquainted with the earlier game concept which gave him an advantage.

Adam is a 13 year old boy who lives in a house that is heated by an air-source heat pump. During the game trial he played 23 challenges of which he won 17. With a success rate of 74% this makes him **the most skilled player** in the trial when it comes to the duels. Adam spent about 2h and 43min each day actively interacting with the game. In terms of savings however, Adam did not do so well. Out of the 15 players he only ended up as number 13 and was never able to gain the top position on the pile, even for a short time. Energy log from his house shows an unchanged consumption level during the game. The ten weeks after the game however the log shows a reduction of electric use by 22%.

Maria is a 14 year old girl living in a house that is heated by remote heating as well as an open fireplace. During the game Maria engaged in 71 duels and actively played for about 2h and 2 min each day. Maria **finished 2nd** of the 15 participants and held the top position for 21% of the game time. In terms of energy savings, the log in her case indicates a reduction by 20% during the game week but only a reduction by 7% during the following 10 weeks.

Energy saving strategies

On the question of what they did differently during the game most participants mentions turning off lamps, TVs and computers. Many express it as turning of things that were unnecessary or that you didn't use indicating rather non-extreme measures being performed.

Table 2. Change before vs. after.

Q13: Do you usually check out how much appliances consume?			
	Players	**Non-players**	**P-value**
Change	12,1%	0,7%	0.1

In Marias case the whole family seams to continuously have discussed which devices they could turn off. Marias mom: "*We turned off the computer during nights, before we were a bit sloppy in that regard. But now it was like that... the computer was turned off and in fact it still is now as well, even though it's over (the game)"* (ex. 1). This is a clear example of a non-extreme, sustainable, long term strategy.

In a few cases the participants talk about energy saving measures that would directly infringe on comfort levels. In Marias case they express it as that they wanted to make a commitment for the game, but that particular evening there was a big TV event that they had planned watching. Unable to turn the TV off and be - as they express it - cheated on the evenings TV festival, they made a compromise by turning off the surround sound system connected to the TV set. In the game they could see that this actually made a whole lot of difference which made them satisfied with their decision. This measure was however, as they expressed it, *"done for the game"* and would fit as a typical example of a short term strategy not likely to be continued after the game.

Maja (the seemingly least involved player) tells us she: *"… kind of told mom that she should turn off the radio and other unnecessary things… and not to do too much laundry"* (ex. 2). She however later added that she also tried to remember to turn off the TV after she was done with it (something she had not always done in the past). Vincent (the winner) on the other hand employed a strategy that he learned from his sister playing the earlier Power Agent game. That is, he employed a – not more than two devices at the time – principle and made fires in the tile stoves to save on electric heating. In this case classifying measures as long-term or short-term is not entirely straightforward. Vincent however reflects that they to a larger extent – as he expresses it – *"kept it up"* after the game this time than they did after previously playing the Power Agent game. He attributes this to the fact that Power Explorer in his opinion was more fun to play.

Attitude changes

In Table 3 (Q1), we can see an attitude change toward saving energy before versus after the game.

Table 3. Change of rating before vs. after the game trial.

Players	Non-players	P-VALUE
Q1: How important is it to save energy?		
6.1%	-5.3%	0.04
Q2: I usually encourage my friends to save energy!		
8,8%	-4,3%	0.08
Q3: How important do you feel, questions about the environment are?		
-7,1%	0,8%	0.16

On average the player group felt more positive about saving energy after the game while the reference group became slightly more negative (a statistically significant difference). We can also see that participants also saw themselves as more prone to promote energy conservation to their surroundings, indicating a change in self perception.

Players also perceived appliances to consume more electricity after the game compared to before. A learning test in the questionnaire, showed that devices were on average rated 4.6% higher in term of experienced electricity consumption by the player group when asked after the game compared to before (1.4% by the reference group, p-value = 0.25). In Table 3, Question 3, we can also see that the game did not appear to have any positive effect on the players' attitude towards the environment in general. In fact, results rather indicated a more negative attitude in this regard.

Of our interviewees, Sara (our "worst example", who increased the consumption both during the and after the game) also displayed the least enthusiastic attitude. On the question of what she thought about the subject of saving energy, she answered that she didn't have an opinion. On the question if she thinks about the subject often (after the game) she answered that she didn't. She then however reflected that she probably thought of it a bit more often than before.

While Willem (our "most engaged" player) shows a more split opinion on the subject. ***Willem:*** " *Well… you don't have to use it unnecessary. I don't feel that it is that important but… You can't just use… nothing. You have to use some"* (ex. 3). Adam (our "most skilled" player) on the other hand clearly felt that not using too much electricity was rather important. **Interviewer:** *"Is this something you have always thought?"* **Adam:** *"Well…It was probably when I started playing this game that I started getting an opinion of it".* ***Interviewer:*** *"Opinion of what?"* ***Adam:*** *"Of that it is good to save electricity because it costs very much and so… it is not good"* (ex. 4). In this example, for Adam, the private economy seems to be the primary reason for saving energy.

Adam furthermore explains that it felt good to turn things off. Another of the interviewees, Maria, similarly explains that she now after the game reacts more and gets annoyed by things "*just being on for no god reason".* Our top contender, Vincent also talks (and at the same time laughs) about the fact that he now (after the game) feels "huge pressure" from seeing for example the washing machine being on which he knows consumes a lot of electricity.

Learning

Two of the questions in the 2 x 2 questionnaire aimed at finding out if the participants gained explicit knowledge about electrical appliances from the real-time feedback mechanisms in the game. These two questions were constructed so that the respondents had to rate a number of tasks or appliances in regard to electrical consumption. The first question focused on power (i.e., the rate of consumption) for different appliances while the other focused on energy used for different tasks. The results from these questions were transformed into points by comparing how the rated the different tasks or amongst each other. The points before and after was then compared.

Table 4. The change in scores after versus before the trial.

PLAYERS	NON-PLAYERS	P-VALUE
	Power test	
0.6%	-0.9%	0.4
	Energy test	
-3,5%	2,4%	0.17

The results from the power test are weak in terms of statistical significance. The indication is that the increase in explicit knowledge in regard to power rating on appliances is marginal. The results from the energy test, is on the other hand somewhat stronger. This test indicated that the players were actually worse at determining the amount energy used for different tasks after the game.

The results are in some regard contradictive to findings from the interviews as we here could find a lot of examples where the participants had gained detailed knowledge regarding specific appliances from playing the game (in terms of power). One example of this could for example be the use of the surround sound system by Maria and her family (ex.1). Many of the players also mention the washing machine or the dishwasher as large consumers.

The question of what appliances that consume much electricity, we can however also see a tendency to include things that are not big consumers in terms of power but that waste energy as well.
Interviewer: *"What consumes much electricity then?"* ***Willem:*** *"The vacuum cleaner, the stand-by mode on the TV and things like that… the computer and…"* (ex. 5). Several participants also used the visualizations in the game to refer to the consumption of devices. Moa refers to lamps as making small flowers and the TV as making larger ones while Vincent refers to the objects in the duel as to how much things consumed (snowballs etc.).

On the question of what time of the day the player's house used most as well as the least amount of energy, 10 out of the 15 players gave a very accurate and seemingly correct answer in both questionnaire and interviews. ***Maria:*** *"Well it changes. Like in the evenings for example it was pretty high and then in the mornings it was lower since not everything was on as much and then it wasn't as much lamps and so, since it was much lighter then."* (ex. 6).

Finally, it seems the knowledge regarding different appliances was also widely shared and discussed among players in story like fashion. ***Vincent:*** *"I played against my second cousin and he put on his coffee machine and then… an ice block can disappear in an instant. Washing also consumes a lot of electricity I've noticed and well coffee is… well you probably get that to"* (ex. 7).

Game design

During the seven day game trial, the average participant engaged in about 14 hours of play and 35 duels. The reviews from most interviewees were positive. ***Moa:*** *"It was between average and good."* ***Interviewer:*** *"Between average and good?"* ***Moa:*** *"Yes… It was quite fun!"* (ex. 8). The most appreciated feature of the game was the polar duel. Many also explained that it was fun to find out how much electricity you used although not everyone appreciated learning about appliances. ***Maria:*** *"It wasn't that fun to check the appliances at home but..."* ***Interviewee:*** *"But it was fun? What was it that was fun?"* ***Maria:*** *"Well to see how much electricity you use!"* (ex. 9). When offered to play again in a future test all interviewees except Moa were positive. Moa explained that she had, had little time to play the game and were unsure of whether to participate again.

Understanding: The players were also asked to explain 8 different features of the game both in the questionnaires and in during the interviews. The features asked about were, the CO_2 cloud, the CO_2 level counter, the "monster blob" (The avatar), the power bar, the weed, the flowers, the control of the avatar in the rainforest challenge and the controls of the polare challenge. Findings show that most features were very accuratly understood by players. Most uncertainties were however, found around the exact interpretation of the CO_2 level counter and the controls of the two duels.

Feedback: A few technical issus were encountered during the trial. Williems meter showed a constant high consumption during the first day of the game. There were also multiple instances where duels were interupted due to problems with mobile network coverage. During the real time duels there could also sometimes arise problems with delays in data transmissions. The same applied to the power bar and the plants, where the feedback sometimes got delayed a second or two causing confusion among players. The interviewees however report that feedback most of the time was percieved as accurate and that they felt a clear connection between their actions and the feedback. ***Adam:*** *"I was moved up and down sometimes... the more electricity I used."* ***Interviewer:*** *"Did you feel that it was correct then?"* ***Adam:*** *"Yes it corresponded quite good i think!"* ***Interviewer:*** *"It was like that... when you did something at home then..."* ***Adam:*** *"Yes when I put on the computer then maybe... you would start losing... and get more on the* *this meter.”* **Interviewer:** *“And did something happen in the pile then?”* **Adam:** *“Yes... someone else perhaps saved some energy and then it changed place with me.”* (ex. 10).

Game strategies: In terms of strategy some of the players claimed to occasionally having used a second phone in parallel with the game in order to talk to their opponent while playing in duels. Players in the top region of the pile also seem to have avoided challenges from those in the bottom of the pile since these players often had nothing to lose in terms of ranking and therefore could use as much energy as needed to knock down the opponent. On the question on how many devices they used in combination with the game most answered between 1-5, two persons answered “many” and 7 players answered that they didn’t know. In the questionnaire most players, 10 of the 15, noted that they sometimes did and sometimes did not look at the visualizations at the same time as they maneuvered electric appliances when exploring the home. Three of the players did often use the application in this synchronized fashion, one player claimed to rarely having used the device in a synchronized way and one other player that he/she never employed synchronized usage

Discussion

A persistent effect of 14% reduction can be measured during the whole period monitored after the game had ended (Fig 3). Although these findings are not statistically significant, it gives a tentative indication that a post game behavior change was achieved. We can also see that in this trial the participants do not report on extreme measures as in the Power Agent trial. They rather defend the necessary everyday use (ex. 3) at the same time as new habits regarding wasteful use of electricity is formed (ex. 1). These findings together support the idea that a casual game play would promote more long term sustainable energy conservation strategies thus achieving post game behavior change. We can also see how stories and reflections regarding particular appliances are shared between players (ex. 7) indicating how the immediate feedback aided in creating associative experiences. The two top contenders (Vincent and Maria) also express how they were emotionally affected by seeing appliances being on that they knew consumed a lot of energy which could be interpreted as cases of classical conditioning.

As expected, savings during the game are on average lower in Power Explorer compared to Power Agent (an effect of less extreme measures, and the duels). Savings in Power Agent are on average 22% for the game period with peaks of up to 75% savings during certain game sessions, savings with Power Explorer averaged on 16% during the game period. This should be put in relation to that the goal of the game can be said to be set to 15% of savings since this is the point where players were starting to get positive feedback from the game. The conflicting design of on one hand wasting energy during duels and on the other hand saving energy in between seems to have contributed positively to the dynamics of the game (se game strategies previous section). While some players like for example Adam choose a strategy of focusing on the dueling, others like Vincent choose a strategy of focusing on saving energy. As we can see by the segregation of players in regard to dueling these choices were also recognized among the players. Interestingly Adams's and Vincent's post game results despite the different strategies are both very similar.

In terms of game experience we can from extensive engagement by the participants and positive reviews from interviewees conclude that interacting with electricity in this way was a fun and rewarding experience. Although the concept seems to have appealed more to some than others, a genuine (perhaps underestimated) interest in *"how much you used"* (ex. 9), could be seen. The context of this statement, implying a rating on a social scale, rather than in kilowatts.

We can in this user test also see a significant positive attitude change towards energy savings among the player group (table 2). Participants also seem to be more positive about promoting topic of energy conservation to others. But even though the esthetics in Power Explorer conveys the environmental aspects of saving energy (the CO_2 cloud for example), some players still seem to have interpreted the task of saving energy first of all as an economical task (ex. 4). A quite peculiar result is also that the players, at the same time as having become more positive towards energy saving, appear to have become more negative towards questions about the environment in general. This could possibly be interpreted as a case of cognitive dissonance 0. Since the esthetics of the game, would have communicated the bad impact on environment, from daily use of electricity that many times were inevitable, the players might instead of changing behavior, resorted to changing their attitude to match their behavior.

When it comes to learning similar conflicting results can also be found. The results show that players gained a specific understanding of what time of the day they consumed electricity they also claim to have seen a connection between for example their computer and the position in the pile (ex. 10) and also showed specific knowledge regarding devices (ex. 1). The power test on appliance level taken by the respondents on the other hand implied only a very weak indication of learning and the test aimed at energy consumption of tasks even show a decrease in points among the players. One explanation to this is that the participants learned only about devices relevant to them i.e. things that they frequently used, such as lamps, the TV, computer, stereo and so on.

As we could see in excerpt 5 there is also a tendency to include things that constitutes wasteful use energy on the question of "What consumes much electricity?" There is however also a problem of keeping the two concepts of energy and power apart. Although Power Explorer had the ambition to address this issue we can see that it in this regard is not entirely successful. While a microwave oven for example consumes quite a lot of power, it still is very energy efficient since it typically heats food very quickly. Including wasteful use of energy, as in excerpt 5 would imply a one-dimensional view of electric appliances, by the participant. In other words, an appliance is either good or bad on a scale. A power consuming device as the microwave oven might therefore mistakenly be labeled as bad in terms of energy consumption.

Conclusions

Findings from Power Explorer show tentative indications for a persistent post game effect on consumption, a significantly positive attitude change towards energy savings, the forming of what appears as long term energy saving strategies in forms of new habits as well as a lower degree of extreme energy saving measures being performed by players compared to the previous work of Power Agent. This supports the notion that, in order to achieve long term effects, a casual game play, with small investments by players and fast and frequent rewards in terms of feedback is preferable compared to a highly immersive game with extensive investments by players and a slow reward mechanism. Findings furthermore show, examples of device specific learning, and detailed experience sharing among players. This indicates that the direct feedback of the game also works towards enriching the learning environment as well as enabling appliance level associative learning.

In the Power Explorer trial we can also see indications for a more negative attitude change regarding environmental questions in general, an effect that we attribute to the occurrence of cognitive dissonance induced by the esthetic message of the game. Nevertheless based on the findings so far we conclude that pervasive games, with a *subject related reality expansion*, employing a casual game play and a real time feedback loop appears to be an effective tool in order to encourage teenagers towards both short term as well a long term behavior changes.

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Watch the amazing complexities of energy use in your own home, or save a monster blob and become king of the castle using your electric appliances.

This thesis investigates how interaction design can be used to address the increasing use of electricity in our homes. In the form of mobile phone games or using different forms of visualization we try to get both children and adults to reflect on their everyday use of energy by making this concern both fun and interesting.

In one of our design examples, a modified power strip called the Awarecord, you can see every little change in the power consumption of your different electric devices in the form of pulsating and flowing blue light inside the cord. In the mobile phone game Power Explorer, the habitat of your own "monster blob" is connected in real time to your home's electricity usage. This means that practically everything you do in your home will create an echo in the game world, and by manipulating your energy use you can compete with other players.

We believe that if feedback on domestic energy use is to be effective at increasing awareness, it must be designed to be able to compete with other activities in the home. We have shown how this can be done by visualizing the rich and complex properties of electricity or by supporting social interaction centering around energy use.

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