“show-me”: Water Consumption at a glance to promote Water Conservation in the Shower

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ABSTRACT

Water is a scarce resource worldwide. Yet, we have many opportunities to conserve it. One particular opportunity for water conservation is the shower, because depending on the shower head and shower habits, an individual can save many liters of fresh water each day. Feedback proved to be an effective method to promote sustainable behavior. Therefore, in this paper we suggest to promote water conservation by providing feedback in form of an ambient display that can easily be integrated in current shower types. We built a prototype to study the potential of such a feedback device. These shower water meter (show-me) display the amount of water, that is used during one shower in form of LEDs assembled on a stick. Thus, an increasing water level is visualized. The user study revealed two groups. The subjects who considered themselves as ecologically conscious changed their behavior and turned the water down or off while soaping. Also, they are willing to pursue this behavior. Other subjects who did not have the goal to act more sustainable, were surprised about their water consumption and tried to reduce it. However, after the removal of the show-me device they did not maintain their behavior and fell back into their previous habit.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**] (D.2.2, H.1.2, I.3.6): Prototyping, Evaluation/methodology; J.4 [**Social and Behavioral Sciences**]: Psychology

General Terms

Measurement, Design, Experimentation, Human Factors.

Keywords

Ambient display, awareness, water consumption

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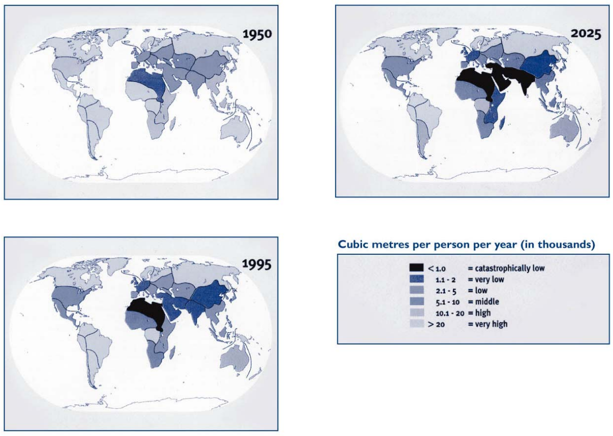

Figure 1. Global water availability [20]

1. INTRODUCTION

People usually consider water as an infinite resource. Whenever they turn on the water tap, there is fresh and clean water. However, this is not true all over the world. In Zimbabwe, for example, the degradation of the already scarce water supply has caused a cholera outbreak of epidemic proportion. Considering the fact that the world population is growing and that businesses are expanding constantly, the need of fresh water is increasing drastically.

According to the UN, water usage has grown twice the rate of population during the past century. Today, already 1.1 billion people lack access to safe water. At the same time, one flush of a Western toilet uses as much water as the average person in the developing world uses for a whole day’s washing, drinking, cleaning and cooking [20]. Clearly, these facts should make everybody start thinking about water and its consumption. However, water does not get much attention, unlike crude oil. In the latter case, prices vary heavily and thus the effects on our daily life are much more tangibly and media report every change in detail. Water scarcity does not affect us and our daily lives yet, which leaves it a distant problem that only is located in African countries.

Still, industries have already started to promote water conservation and underline their sustainability concern by producing water saving appliances. Washing machines and dishwashers are prominent examples of this trend. Also water saving faucets are on the rise. Different types of faucets can have a large effect on water consumption. A conventional shower head uses 11 to 27 liters per minute, while a water saving shower head uses only 3.8 to 9.5 liters per minute. [6]. According to a study from Mayer [13] the average shower takes 8 minutes 30 seconds with a "Low Flow" shower head and 6 minutes 48 seconds with a regular shower head. This means that one shower uses from 32.3 liters up to 183.6 liters of fresh water. Considering the fact that there is a high variability in shower length and that 16.8% of all water used for indoor purposes are used for the shower, there is a need of making people more aware of their water consumption in the shower. At the same time, the potential to save water in this area is clearly given.

The way to provide feedback on the water consumption in the shower should be easy to understand and should blend in with the environment. Ambient displays are unobtrusive and convey non-critical information in a subtle way, which makes them suitable for displaying the water consumption. The cognitive load is kept low when reading the information and also children can understand the relation between the feedback display and their action.

2. RELATED WORK

As water conservation is closely related to energy conservation in general, this chapter will address the latter one. Energy conservation is a major topic in different research areas. Especially behavioral science is interested in energy consumption habits and how to change them into a more sustainable behavior.

2.1 Behavioral Sciences

Studies are divided into two groups of intervention studies. On the one hand, antecedent strategies include commitment, goal setting, information, and modeling as methods. On the other hand, consequence strategies make use of feedback and rewards as methods to promote energy conservation [1] . The interventions are not necessarily applied separately, they can also be combined. For example, goal setting is intrinsically tied to motivation. It gives people a reference point which they can head for, e.g. to save 5% energy every month. This goal can be set by either the subject or the experimenter. Becker [4] carried out a study to compare goal setting with and without feedback. 40 families were given a difficult goal of reducing their electricity consumption by 20% and further 40 families were asked to set a goal of saving 2% of electricity. Half of the families of each group received feedback three times a week in addition to the goal setting. The result showed that the 20% feedback group conserved the most. The improved performance can be derived from the joint effect of feedback and goal setting. Direct feedback alone results in average savings of about 10% [8]. Indirect feedback, which is usually given in form of an electricity bill is too distant in time to be as effective as direct feedback and therefore not further considered in this paper. Interactive Feedback offers the user more information and helps to establish relevant conservation measures. Benders, Kok, Moll, Wiersma, and Noorman [5] examined the effectiveness of an interactive web page in 137 Dutch households. The result was an 8.5% cut in energy consumption.

2.2 Ambient Feedback Systems

Feedback can be given in various forms. Also ambient displays have already been implemented as feedback systems in order to create awareness in different areas. Plaue, Miller, and Stasko [17] evaluated the effectiveness of ambient displays for presenting awareness information. Results showed that participants recalled more information from the ambient displays than from other displays.

Nakajima, Lehdonvirta, Tokunaga, and Kimura [16] developed two prototypes of ambient lifestyle feedback systems to motivate desired changes in lifestyle. The first, called Mona Lisa bookshelf, is aimed at keeping a bookshelf organized, by showing the image of Leonardo da Vinci's Mona Lisa, where each missing book leads to a missing piece on the image. If the book is lying on the shelf instead of being aligned with the other books, the corresponding piece of the digital image gets distorted. Another desired effect is to motivate users to read a book once in a while. If no book is removed from the shelf for over a week Mona Lisa grows old. As soon as someone takes a book Mona Lisa becomes young again. The second prototype is a virtual aquarium with the aim to promote good tooth brushing practices. If the users get lazy brushing their teeth the fish inside the aquarium will get sick and may even perish.

Today, only few projects use ambient displays for promoting energy awareness. A product that is commercially available is Wattson from DIY Kyoto [9]. It shows the overall electricity use in numbers and colors. It glows from cold blue for no electricity usage to bright red for high usage. Another interesting project is called Kuckuck [18], where a cuckoo clock would cuckoo every time one kilogram of carbon dioxide was emitted to the atmosphere because of electricity usage. The Power-Aware Cord [12] is an electrical power strip in which the cord visualizes the electricity by a flow of light. The velocity of the light flow is directly related to the electrical current flowing through the cable. Heat as another form of energy that is picked up by Element [3] a radiator built from light bulbs. The heat radiation from the array of light bulbs can be regulated using a dimmer, which affects also the brightness, thus showing the actual status of the radiator. The Disappearing Pattern Tiles [3] visualize the heat in the bathroom, by fading away the patterns from the tiles. Thus, they react to a long hot shower in the same way as to a hot bath.

3. SUSTAINABLE BEHAVIOR

Individuals generally show more self-interest than collective interest, meaning that conserving water for the greater good is not motivation enough even though all individuals and also oneself will feel the effect of water scarcity. The conflict between self-interest and collective interest is most visible when society is threatened by an immediate resource crisis, as this stresses the need for widespread conservation. This social dilemma can be addressed by a structural approach, which aims at eliminating the conflict by combining the collective interest with the self-interest, thus making conservation a more attractive behavioral option [21]. Financial incentives or the installation of water meters are examples for a structural approach, as these reveal the personal financial impact of water consumption. Householders that are aware of the overall consumption are supported in keeping the general water consumption at a constant level. However, they do not obtain any information on the areas of water dissipation. The

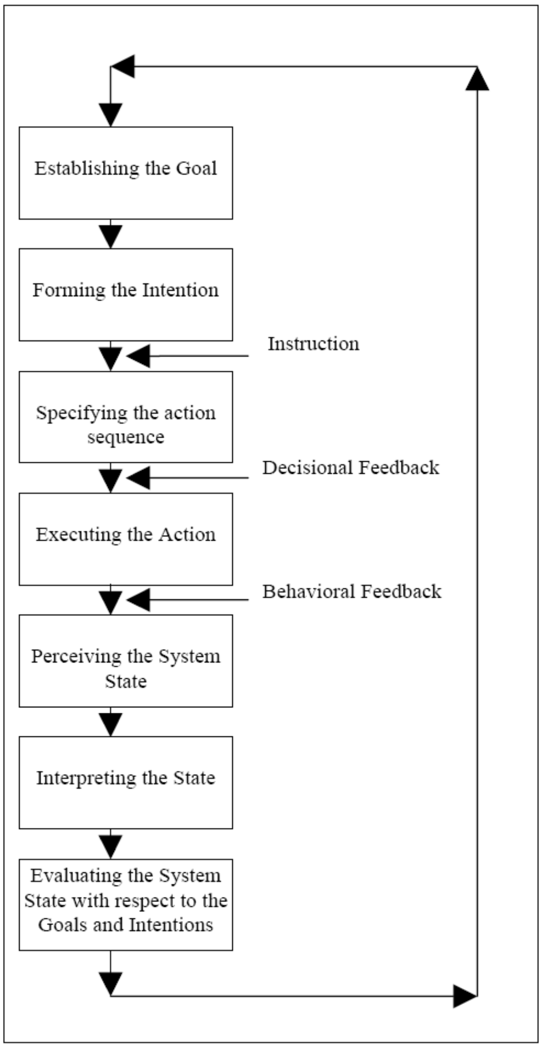

Figure 2. Adapted task-action protocol [14].

overall consumption supports householders to keep the general water consumption at a constant level, but does not show areas of water dissipation.

However, before people will start using water more consciously, they need to be more aware of their water consumption. This awareness can be created by using feedback. Studies show that feedback plays a significant role in raising energy awareness [1], [7] and direct feedback results in average savings of 10% [Darby 2006]. Among the different forms of feedback (direct, indirect), direct feedback is the most effective one with respect to energy savings [7]. This feedback can be delivered by an electricity meter, orally from an energy advisor, or in any other form that provides immediate information on current energy consumption. A study of McCally and Midden [14] showed that also product-integrated feedback can have a large effect on energy consumption. Feedback is more effective when it is located close to the source of consumption, as the householder can relate his actions to the feedback, thus realizing what action causes how much consumption.

In contrast to electricity a conventional household gets no information about its water consumption. There are no water meters installed, so that not even the overall consumption is shown. Because water expenses are usually included in the operating costs and are not based on the individual consumption, the householder does not serve his self-interest when saving water. The lack of information about water consumption results in ignorance of the amount of water that is used for different household activities.

We conducted a study to find out about the energy literacy and the behavior of householders. The results of a questionnaire among 120 respondents (49 female) show that even though 20.83% take a bath once a week, 62.5% try not to waste water when taking a shower and turn the water off while washing their hair and body. Only 10.8% state that they do not care at all about their water consumption. These respondents also do not consider themselves as being energy-conscious. Overall 65,8% think of themselves as being energy-conscious and take actions in different areas of their life to conserve electricity, gas and/or water.

According to Festinger [10] each individual strives towards consistency among his cognitions. Whenever there is an inconsistency between attitudes and behavior a cognitive dissonance exists, that needs to be eliminated. This can be reached either by changing one's attitudes and beliefs or by changing one's behavior. One can also add more consonant beliefs that outweigh the dissonant beliefs, however, when it comes to environmental responsible behavior (ERB), it is hard to find plausible consonant beliefs. The desirable way of reaching consistency is to change ones behavior into a more environmental responsible behavior. The questionnaire showed that many people are environmentally conscious and already conserve energy. This makes a spillover of ERBs more likely [19], i.e. saving electricity can facilitate a change in behavior towards a more water conscious behavior.

The goal and the appropriate feedback interventions are closely related, as the goal to save energy can be reached more easily with appropriate feedback [14]. McCalley and Midden [14] adapted Normans task-action protocol to identify useful sites of feedback (cf. Figure 2). Instructions are given before the user chooses an operational action. This may affect the initial decision. Decisional feedback is feedback in response to this decision. After the execution of the action the user can be given behavioral feedback, reflecting the consequence of his decision and the executed action. Instructions alone are not very effective and do not show long-lasting effects. Behavioral feedback is more powerful, however, it is only effective when the time gap between action and feedback is kept to a minimum. According to McMakin, Malone and Lundgren people are more likely to adopt sustainable behaviors under the following conditions [15]:

- People view energy efficiency in terms of benefits to themselves rather than curtailment, especially in terms of increased thermal comfort and health.
- Energy use and savings are made visible, thus providing goals and motives where they did not previously exist.

- Information is conveyed in a vivid, salient, and personal format, including visual modeling of specific actions to be taken.

4. Ambient displays as persuasive technology

Ambient displays are suitable for a constant and subtle persuasion by providing continuous and unobtrusive feedback. People do not like to be annoyed by irritating devices. Instead, such devices would be simply turned off and thus have no further effect. Ambient displays have the feature of being unobtrusive, therefore they are also called calm technology [21]. They blend in with the environment and are aesthetically pleasing. Ambient displays are often used as awareness devices, to keep people informed, e.g. the dangling string keeps people aware of the network traffic by twisting a string that hangs from the ceiling a small degree each time a packet passes through the network. It is only a small step from an awareness device to a persuasive device. If the information is perceived as feedback on a certain behavior, and a specific goal exists, the device turns from awareness to persuasive. A display showing the overall carbon dioxide emissions for one house can be seen as an awareness display. However, if the display shows the emissions for only one source, e.g. the washing machine, and the user can relate his actions to the visualization, the device suddenly becomes persuasive, as the user gets persuaded to save energy.

Ambient displays have a number of features that makes them apt to act as persuasion devices. They are aesthetically pleasing objects, which can be located in a prominent place in the living environment, thus, being constantly visible. Fogg states that physical attractiveness has a significant impact on persuasive power. Thus, visually attractive computing products are likely to be more persuasive than unattractive products [11]. The way of presenting information is easy to comprehend. The cognitive load is low, because of the simple representation of information, which can be perceived in the periphery. There is no need to switch the focus of attention to the display for reading the information.

People often cannot see the relationship between their behavior and its effects if those effects are too distant in time or space. Ambient displays deliver information constantly, thus, serving the fact, that timing is a critical factor for persuasion [11]. Ambient displays deliver immediate and direct feedback, while at the same time being unobtrusive. Because they are neither *interrupting* nor *demand action* they do not enforce a behavior change. However, the permanent visualization of energy consumption leads to increased awareness, which in turn can result in energy conservation. Another advantage is the privacy of the data. Information is encoded and not interpretable without prior knowledge of the context (i.e., what is metered) and the encoding scheme (i.e., what the visualization stands for). Even though the data is encoded, the representation is simple and abstracts the technical background.

Finally, ambient display can have another benefit. Depending on the design of the ambient information system, it is possible indeed to stimulate some kind of competition. Trying to use less energy than the day before or less than the sibling in the other room are conceivable scenarios.

Figure 3. show-me prototype

5. SHOW-ME

show-me stands for shower water meter. It is a device that measures the amount of water that is being used during a shower. As it is widely known today, taking a bath almost always uses more water than taking a shower. However, people are unaware of how much water is used for taking a shower or a bath. Therefore, with show-me, we implemented an ambient representation in order to visualize this information. One goal of the design is that the user does not have to read an amount of numbers from a standard LCD display, which he has to remember until next time he gets into the shower. Rather, with an ambient display the user is provided with a visually attractive product that presents information in a way the user can easily remember. The cognitive load for reading it is low which also makes it interesting and fun for children.

show-me gives the user feedback and an impression of the amount of water going down the drain. This impression is achieved by exploiting the metaphor of the drain being closed and the water level increasing within the closed shower. The imaginary water level is visualized in the form of LEDs that are vertically assembled on a stick. During operation, one (additional) LED is lightened up for every five liters of water consumed. This approach guarantees the delivery of direct feedback on the users' actions. Figure 3 shows the prototype that we built and used during our user studies.

A key idea is that show-me delivers immediate feedback, so that the user can immediately relate his actions to the information presented in form of an ambient display. The display lets the user take control of his water consumption and makes setting a goal an easy task.

The goal of saving water is often not very precise and therefore the goal becomes more difficult to reach. Using our prototype, the user is equipped with a tool the helps to form precise goals. For example, a user could set his water conservation goal to reducing the water consumption for his daily morning shower by 2 LEDs. This would equal a total water saving of 10 liters for one shower. The behavioral feedback reflects the executed action, thus, supporting the user in reaching his goals.

Figure 4. Model of show-me

5.1 Prototype

The show-me prototype consists of a flow meter (AMess), a prototype board (Olimex), a microcontroller (Atmel) and 16 LEDs assembled on a stick. The flow meter is installed between the faucet and the flexible tube (Figure 3 left). For each liter of water flowing through the meter one tick is sent to the microcontroller. This information is converted into LEDs lighting up according to a factor that can be set by the user. The prototype board and the microcontroller are placed in a black box that on one end is connected to the flow meter and on the other end to the LED stick with cables (Figure 3 right). The cables are long enough in order to place the box outside of the shower, as it was not built watertight but permit the visualization part to remain in the shower and thus within direct sight of the user.

The amount of water that is needed for one LED to light up can be set according to the range needed. This allows adapting the visualization to each individual's needs. In multiple different trials it was found out that an amount of five liters per LED is ideal. This decision helps to keep the water consumption visualization of people that use a lot of water within the 16 LEDs limit while a lower water consumption is still sensibly shown within 4 to 6 LEDs. Any higher setting would show no or only limited effect for people who already use little water.

The assembly on a stick was chosen for two reasons. First, the design shall resemble an increasing water level, with the key idea to use a metaphor for better understanding. Second, the vertical assembly was chosen with regard to a future integration in current shower types. One possibility of such an integration is shown in Figure 4. The LEDs are integrated directly in the slide bar of the shower, thus being within the field of view of the user.

5.2 User Study

For the user study we selected various households in order to show that show-me has an influence on the subjects and to evaluate what kind of effect this is. We installed the prototype in four households with nine occupants (four female) including one child. The results show a great potential for ambient water consumption displays. Even non-tech-savvy people showed great interest in trying out the prototype and get informed about how much water they use.

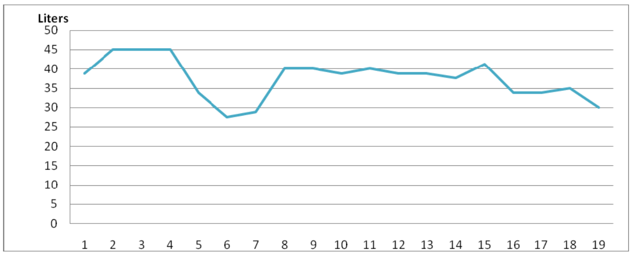

Figure 5. Average water consumption

Before we installed the prototype each subject had to fill out a questionnaire. The questions aimed at getting a self-assessment of the subjects and some information on their shower habits. It turned out that all subjects clearly misestimated their water usage per shower, with the self-estimation being either significantly too high or significantly too low. The subjects' estimation was on average 49 liters for a shower and 92 liters for taking a bath. The estimated average shower length was 10 minutes. Additionally, the questionnaire surfaced that most people did not turn off the shower while soaping.

5.3 Results

In each household, we installed the prototype for a duration of about 3 weeks. Figure 5 shows the average water consumption during the test period. It showed that for the very first shower with show-me installed most people used less water than they did the next couple of days. On the one hand, this can be explained with the installation of a new technology. On the other hand, the subjects feared that they would use much more water than they expected and therefore reduced their consumption. Starting with the second day of the installation, the testpersons wanted to know how much water they usually consumed when they followed their regular shower habits. Therefore the water usage increased for the subsequent days. At the 4th or 5th day, the subjects reduced their water consumption drastically in order to determine how low their consumption could go. They turned the water off while soaping and did not turn the shower on for adjusting the temperature long before they got into the shower. This extreme water saving behavior did not persist, as they perceived it to be a curtailment to their comfort (self-interest). However, after knowing how much water they usually used and how high their personal savings potential was, the subjects tried to strike a balance between these two extremes. This resulted in an overall reduction of their water consumption for the rest of the study duration. The mean water consumption decreased by approximately 10 liters.

The prototype also triggered some interesting side effects. A couple used to argue that one of them always took longer in the shower and consequently used more water. After they installed the display, they learned that the woman used only half as much water, even though she spent more time in the shower. This discovery stimulated the man to further reduce his own water consumption. In another household the child (11 yrs.) triggered discussions about the water consumption, because he used much less water than his parents. This stimulated his mother to begin reducing her own consumption, as she was using the most of the whole family. Her lowest result of 30 liters resulted in compliments of her son “See, Mom, I told you that turning off the water would make the difference”.

6. CONCLUSION

Based on existing studies about energy consumption from behavioral sciences and studies about ambient displays for creating a behavior change, we developed a prototype to promote water conservation in the shower. The prototype consists of a flow meter, a microcontroller, and LEDs. The LEDs visualize an imaginary water level that would rise with the continuous water flow, if the drain was closed. One LED lights up for every five liters. This amount resulted from preliminary tests and proofed to be the ideal value also in the user tests. The results from the tests are promising in terms of water conservation potentials in the shower and with regard to using ambient displays for delivering feedback in this area. The new technology was met with great interest and acceptance also from non tech-savvy people. Further steps include the technical refinement of the prototype and its extension towards a (separate) visualization of warm water consumption as it is the most relevant factor for energy consumption in the shower. Furthermore, a permanent integration of show-me into the faucets is planned.

7. ACKNOWLEDGMENTS

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