Waterbot: Exploring Feedback and Persuasive Techniques at the Sink

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ABSTRACT

This paper presents an exploration of user interfaces, persuasive interfaces and feedback techniques in the domain of the sink. Waterbot is a system to inform and motivate behavior at the sink for the purpose of increasing safety and functionality and ultimately motivating behavior change. Waterbot can be adapted to many current sink scenarios and demonstrates the breadth of interaction possible at the point of use of water. It functions as a platform for experimenting with safety, hygiene and water conservation in a sink. This paper presents the feedback and persuasion techniques of augmented physical interfaces with value-added design, automation, just-in-time prompts, positive and negative reinforcement, social validation and adaptive interfaces. Four design iterations are presented to affect behavior at the increasing cognitive levels of safety, functionality and behavior change.

Author Keywords

Context-Aware Computing, Persuasive Environments, Captology, Ubiquitous Computing, Water Conservation, Behavior Change, Product Design.

ACM Classification Keywords

H5.m. Information interfaces and presentation: Miscellaneous. H.5.2.i Information Technology and Systems: Interaction styles. C.3.h Computer Systems Organization: Ubiquitous computing.

INTRODUCTION

The physical world is full of interactions that at first don't seem to need or be able to benefit from a computer interface; what scenarios should we expect for computers in physical world? How can we sense what is needed and what are appropriate ways to communicate to a person? The sink for example is an important site for interaction in our daily lives. The way we use the sink can directly affects our safety and hygiene. Our behavior at the faucet has an impact on the consumption of clean water and energy. Sinks pose a challenge to HCI because they are traditionally hostile environments for both people and machines. By effecting behavior change at the sink, we can improve safety and performance as well as motivating water conservation.

Simple feedback and persuasion techniques have been applied to sinks in order to motivate basic behavior change. These devices are relatively dumb and affect behavior change at the cost of control and function. Studies in captology suggest that behavior change regarding water use can be achieved through persuasive techniques more complex than those employed in existing faucet devices.

We identify seven design principles for feedback and persuasion techniques that affect behavior change at increasing cognitive levels: value-added design, automation, just-in-time prompts, positive and negative reinforcement, adaptive interfaces and social validation. These techniques are employed in four design iterations directed at motivating safety, functionality and behavior change: HeatSink, SeeSink, CleanSink and Waterbot. HeatSink expresses the value and status of water by illuminating the stream with colored light to communicate its temperature. SeeSink expands water-saving automation by automatically providing the right temperature and flow of water based on what the user presents to the sink. CleanSink enforces hand-washing compliance at the point of use through ubiquitous reinforcement. Waterbot uses audiovisual feedback to motivate sustained behavior change regarding water conservation.

RELATED WORK

Energy conservation and governmental agencies have tried to make people conscious about the implications of wasteful behavior and hygiene. Their efforts have had little or no effect upon behavior [7] [9] [12] [13]. Most of these programs are designed to foster behavior change by relying upon large-scale information campaigns. Media campaigns have concentrated on pointing out the financial advantages of technical modifications to houses such as installing lowflow shower heads or adding faucet aerators. While these modifications can significantly reduce residential water use, the information campaigns used to promote them have been largely unsuccessful at creating new patterns in consumer behavior [13] [15] [33].

Several approaches have been proposed to change user behavior at the sink for water conservation and hygiene. Efficiency improvements and automatic systems constrict behavior at the sink by putting water outside the control of users. Value-added products increase the perceived value of water. Persuasive techniques such as reminders have been shown to be effective in reducing water consumption and promoting hand-washing [23]. Finally, the field of captology proposes the combination of persuasive techniques and digital media as a means of affecting sustained behavior change [11].

Faucet efficiency improvements are mandated by the Federal Energy Policy Act of 1993, which requires new homes built in the U.S. to be equipped with water-conserving toilets, showerheads, and faucets [1] [9]. These reduce water consumption at the expense of performance and without interaction from users. Prior research demonstrates that residents of new homes use less water indoors per capita than residents of older housing [8, 20, 24]. Flow-restricting fixtures, automatic faucets and momentary floor buttons and levers improve hygiene and reduce water consumption at the sink by restricting the user's control over the faucet. These water-conserving devices are relatively dumb and can severely limit the functionality of existing sinks. They rarely allow users to decide the temperature or pressure of water, and for this reason are limited to public bathroom sinks.

Value-added sink modifications alter consumer perception by creating a psychological sense of importance of the faucet and water. The best examples of these are water filters that attach to the faucet and provide limited feedback on their status [16]. The main role of these devices is to increase the perceived value of the faucet and the water itself, which does not directly affect water consumption or hygiene. Nevertheless, they reveal the consumer acceptance of electric faucet attachments and a direction for new human-computer interaction at the sink.

Persuasive techniques can be defined as those attempting to "shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object or topic" [11]. While efficiency improvements to the sink increase hygiene and reduce water consumption, they do so only at the sink they are mounted to. Persuasive techniques can be employed to effect sustained behavior change that users take with them beyond the point of interaction. Researchers from a wide range of fields have demonstrated the value of using "just-in-time" prompts and feedback to engage sustainable behavior change regarding energy conservation [2, 18]. Successful examples of these prompts include signs reading "Turn off tap when not in use" or "Employees must wash hands before work" mounted near the sink [21]. One study reveals that such signs mounted in a shower reduce water consumption [2]. This study also shows that the more obtrusive these signs are the more effective, but also the more annoying they are perceived to be. Another study reveals that feedback can effect sustained behavior change. In this study, water conservation lessons were taught to students in a class and had a measured impact on their consumption at home [32].

The emerging field of captology suggests that the combination of persuasive techniques with digital technology can have successful applications in the domains of health and safety [10]. Examples of captology are hand-washing compliance systems used to promote hygiene in health care and food preparation environments [19]. These work by recording the user on video or requiring them to "log in" to the sink to record their compliance. These systems are bulky, require a second person to monitor their results, and only act retroactively to punish non-compliance rather than preventing it [6].

DESIGN PRINCIPLES

This paper suggests the rich opportunities for computer-human interaction in everyday physical interactions, such as in the sink. Our designs exploit a number of principles derived from related work in context-aware computing, product design and persuasive techniques to motivate behavior change at the sink. The value of context-aware computing comes from interpreting the sensors relative to safety, hygiene and conservation in relation to task, user and system models [27][28]. We organize the remaining principles according to their cognitive level from lowest (added value) to highest (social validation).

Value-Added Design

One of the most basic means of persuasion employed in product design is to create the impression of added value by subtle enhancements. These strategies are used to differentiate products that are otherwise very similar. By adding perceived value to a product, one can effect basic behavior change that makes the product seem more valuable and attractive to consumers. One basic problem in water conservation is that modern plumbing makes clean water seem plentiful and inexpensive. By applying the principle of "value-added design" to water we can seek to enhance the apparent value of this precious commodity.

Automation

The automatic faucets ubiquitous in our public realm reveal the power of automation to directly affect behavior change to promote hygiene and water conservation. The application of more sophisticated sensing and actuation can further the realm of automation design to become ubiquitous in new realms where water conservation and hygiene are important factors, such as in homes, hospitals and restaurants.

Just-in-Time Prompts

Prompts are an effective technique to encourage sustainable behavior change. Prompts are visual or auditory aids which remind people of actions that they are predisposed to [21]. Computer technologies now make possible to deliver prompts right at the point of behavior in response to user activities, aiding in their effectiveness [10]. Prompts should be clear and explicit and presented at the appropriate place and time in a non-annoying form [14, 17]. Researchers from a wide range of fields have demonstrated the effectiveness of using "just-in-time" prompts to engage sustainable behavior change [1, 2, 18, 26]. One of the best ways to effect behavior change with regard to water is to provide just-in-time prompts at the point of use, the sink.

Positive Reinforcement

A positive reinforcer is anything that a user desires and that occurs in conjunction with an activity. If presented at the time of an action, a positive reinforcer tends to increase the likelihood that the action will be repeated [25]. Jackpots are a type of positive reinforcer that is bigger than normal and that comes as a surprise to the user. They are used to reward and mark a breakthrough in behavior change, and can be extremely useful for training [25]. To effect behavior change at the sink, positive reinforcements could be employed to reward behavior that leads to better hygiene and conservation, i.e. to encourage hand-washing or to encourage turning the tap off.

Negative Reinforcement

A negative reinforcer is an unpleasant stimulus. Behavior change can be elicited by providing negative reinforcement during undesirable behavior and removing it when change occurs. Although negative reinforcement is not a desirable persuasive technique, situations that pose physical danger sometimes require the use of unpleasant stimulus. Behavior change with regard to the sink might require negative reinforcement in the case of hand-washing compliance in health care and food preparation, for example.

Adaptative Interfaces

While constant reinforcers should be presented at the beginning stages of behavioral modification, once a behavior is established, they can become less effective and potentially annoying. In "variable interval reinforcement" the reinforcers occur at intervals that cannot be readily predicted by users in order to be less annoying and more effective. Variable schedules of reinforcement are effective at producing behavior change that remains consistent [31]. Because water is often used in intimate contexts, it is especially important to vary feedback modalities so that interaction does not become annoying or invasive. To effect more complex behavior change, feedback could vary in modality as well as frequency. "Interface fading" is a gradual reduction of feedback that makes the interaction gradually disappear. An adaptive interface can fade from a user's perception by gradually withdrawing and changing the type of feedback presented.

Social Validation

People often base their behavior on the perception of their peers. "Social Validation" states that people determine what is correct based on what other people think is correct. Behavior change may be effected by revealing the actions of others [4]. Guidelines for the design of educational software show that cooperation or competition are useful to motivate users to utilize a system. In the case of water conservation, for example, one can imagine the difference in time spent showering alone or when multiple people are waiting for their turn.

PARALLEL AND ITERATIVE DESIGN

Our industrial design intelligence approach promotes parallel design as a way of having ideas in artifacts rather than people compete with each other. Having identified the sink as a site for improving safety, hygiene and conservation and a series of strategies for best affecting behavior change, we prototyped four functional interfaces that demonstrate the interaction possibilities of the sink. All are conceived as devices that could be attached to existing fixtures to provide added benefits especially in homes, hospitals and restaurants.

HeatSink

Modern plumbing serves up clean water as though it were effortless to produce and distribute. The colorless, odorless liquid does not make its energetic and natural value evident to the user. One example of this phenomena is the tendency to leave water running for minutes at a time - something that would have been inconceivable when water was carried to its destination. One problem is that we often run the tap for an arbitrary time to ensure that we have achieved the right water temperature.

HeatSink is a project that seeks to return a sense of value to water exiting the tap and provide useful information about the temperature of the water without altering the function of the sink. Colored LEDs mounted around the faucet aerator are driven by a PIC microprocessor to illuminate the stream of water red when it is hot and blue when it is cold (See Figure 1). This simple interface eliminates the need to "test" the water and wet one's hands or scald oneself. A more subtle consequence is the added perceived value achieved by layering this high-tech interface on an otherwise mundane plumbing fixture. HeatSink can inform subtle behavior change regarding water use while increasing the functionality of the sink.

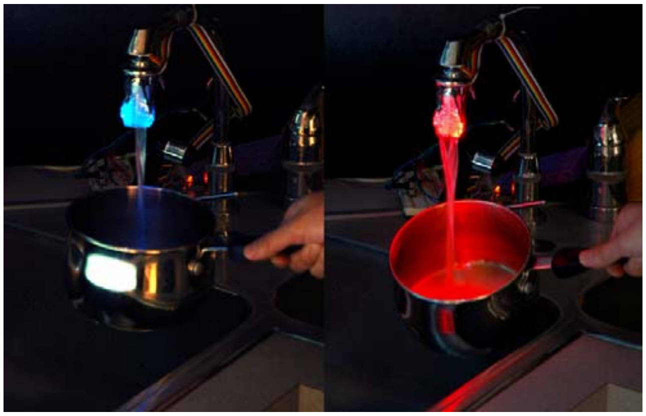

Figure 1. HeatSink illuminates the stream of water according to its temperature, becoming red when hot and blue when cold.

SeeSink

One impediment to automatic faucets in bathroom and kitchen sinks is the lack of control over temperature and flow. Nevertheless, their simple application of automation conserves water and promotes hygiene by allowing for 'hands-free' operation and automatically shutting off. The infrared technology used in these systems has limited sensing ability and cannot account for the variety of scenarios possible in a sink. SeeSink is a project that seeks to combine the advantages of faucet automation with context-aware sensing and actuation to be useful in kitchen sinks. A CCD camera mounted to the faucet serves to interpret a variety of tasks and provide the proper flow and temperature of water automatically (See Figure 2). When a user presents his hands, the sink dispenses warm water for washing. When a user presents vegetables, the sink dispenses cold water. A pasta pot calls for filling with cold water, whereas a dish sponge indicates the need for hot water to wash the dishes. A PC interprets the video stream using Microsoft Vision SDK and dispenses the proper temperature and flow of water through an instantaneous heater and pumps. In order to communicate the temperature of the water to a user, a version of HeatSink is installed in the faucet that colors the water according to its temperature. Because of the multitude of possible scenarios for such a system, a provision exists in the software for training new tasks such as setting custom hand-washing temperatures. SeeSink helps to make the sink more functional while improving hygiene and water consumption.

CleanSink

Whereas SeeSink is optimized for situations where water conservation can be effected at the point of use, there exist conditions where conservation of water needs to be discouraged in order to promote thorough hand-washing. Hospitals, restaurants and industrial clean rooms often need to install invasive systems that monitor hand-washing compliance so that non-compliance can be punished.

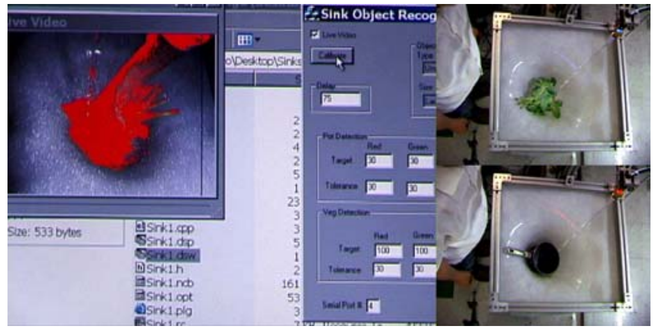

Figure 2. SeeSink can interpret a variety of tasks being performed by the user to provide useful hands-free control of water temperature and flow.

Unfortunately these systems do not directly prevent non-compliance (which is estimated at 50% in hospitals, for example [30]). Dirty hands are the primary cause for infection, and certainly very easy to prevent [3].

CleanSink seeks to motivate critical behavior change by augmenting the role of the sink as part of the larger context in which hand-washing compliance is necessary. Several versions of the system have been prototyped. In its most basic form, the CCD camera used for SeeSink confirms the presence of hands under the stream of water and HeatSink provides a subtle prompt by flashing illumination in the stream of water when sufficient time has passed. In a more typical setting, the same system is combined with an RFID reader that logs the identity and compliance to a central database (See Figure 3). More persuasive techniques allow the sink to connect with automation in the space around the sink. In a medical examination room scenario, CleanSink was connected to a relay that controls the room lights and so that they only brighten once the staff washes their hands. For an industrial clean room, on the other hand, we have prototyped an electric door lock that impedes access until hands are clean. Used in combination, these techniques can directly impact hand-washing compliance at the point of use with broad impact on health and safety.

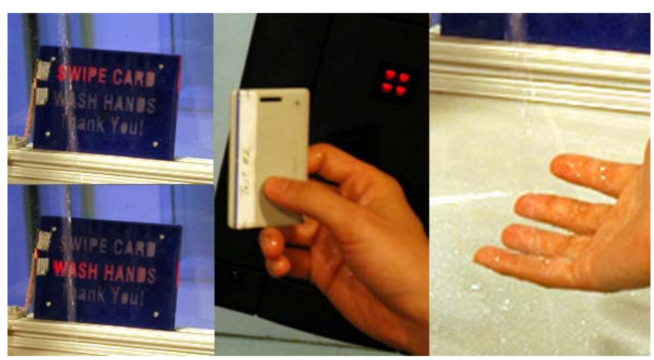

Figure 3. Clean Sink showing indicator (left) RFID reader (middle) and sink (right).

WaterBot

Many of the behaviors that lead to wasting water occur at sinks in the home: people leaving the water running while brushing their teeth, washing dishes, etc. WaterBot is installed on household faucets to motivate people to turn off the tap when the water is not being used. It motivates water conservation by providing "just-in-time" feedback to users (See Figure 4). Positive reinforcement is used to persuade people to save water by giving them positive feedback and reminders while using the sink and when closing the tap. Social Validation is employed to allow sink users to compare their performance to other members of the household. An adaptive interface varies feedback modality so that persuasion is more effective and less annoying. Finally, value-added design is used to increase the perceived value of the water and the device through artful colored illumination.

WaterBot presents feedback using non-obtrusive interaction modalities in the form of visual and auditory reminders. Continuous visual feedback helps users track their water usage while appealing color patterns in the water entertains them through the lifecycle of the system. Positive auditory messages and chimes sound every time the tap is closed to act as positive reinforces for having closed the tap. WaterBot chooses feedback modalities depending on how long water has been running and on the type of interaction with the sink. A water flow sensor allows the system to track water usage, water savings and open tap duration. Finally, WaterBot allows researchers to evaluate different feedback types, persuasive techniques and how they interact when placed together.

Through the principle of social validation [5], it is possible for WaterBot to imply that other members of the household have saved water while using the faucet to motivate the current user to reduce their water consumption.

Figure 4. WaterBot offers continuous water usage feedback. It does not interfere with tasks performed at a typical sink.

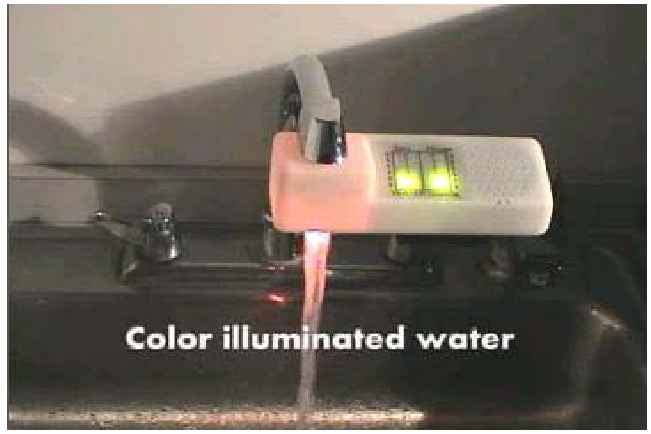

Figure 5. Random patterns in color illuminated water act as reinfocers to reward consistent water-saving behavior. Reinforcers also help to keep users interested.

The system presents continuous visual feedback by means of two illuminated bar graphs that indicate current and average household water usage (See Figure 4). Users can compare their water usage to that of their peers. This feature is intended to encourage users to talk to each other about changes in water use reported by the device. WaterBot is meant to become a topic of conversation to help a household form an attitude about water conservation by creating a social experience among family members.

WaterBot relies on sound and light to motivate water savings. Since the bathroom sink is not a common place for multimedia interaction, we took precautions to ensure that the interaction is not perceived as a game that would otherwise reduce water savings. The faucet should be treated as a utilitarian object while the water should be seen as a valuable resource. To accustom users to their new interactive faucet, we incorporated the HeatSink projection in WaterBot. In addition to simplifying tap usage, it helps to save water: A user who leaves the tap on while waiting for the right temperature will know as soon as it is ready. These features add an aesthetic touch to the tap that adds perceived (and merited) value to the water itself.

WaterBot uses positive reinforcement in the form of audible chimes/sounds in conjunction with changes in the displays. An appealing sound or message plays every time the user closes the tap and the display gradually glows to show its current reading. WaterBot also presents novel patterns of lighting at random time intervals to reward and mark a breakthrough in water savings (See Figure 5). Thus introducing a novelty factor known in persuasive terms as the "scarcity principle" [5]. This jackpot is accompanied by an auditory message used to clarify the reason why it was awarded.

In order to maintain newly established behaviors, WaterBot switches to a variable schedule of reinforcement [25, 31], highlighting the action of closing the tap occasionally and on an unpredictable basis. WaterBot's implements an adaptive interface that fades away by gradually withdrawing feedback based on the stages of behavior change [34].

The adaptive interface takes into account the date of introduction of the device, observed behavior changes, and the permanence of these changes. WaterBot can also be adapted by replacing the labels on the illuminated bar graphs to represent alternate values such as the amount of money saved. Finally, in order to give users a wider sense of control, WaterBot can be disabled at any time.

Implementation

Each of HeatSink, SeeSink, ClaeanSink and WaterBot were designed to resemble add-on sink products. The progression from the first Heatsink that required a new faucet to more subtle designs was carried into all projects. The casing of WaterBot was designed to be physically and visually unobtrusive so as to minimally disrupt the user's activity. WaterBot consists of two joined modules: a sensor housing exposed to the flow of water and a waterproof computer module. The sensor module contains a flow sensor and color LEDs to directly illuminate the stream of water. The sensor module screws onto the aerator of a standard faucet in the style of a water filter and can be rotated to be unobtrusive. The computer module is differentiated by a sloped surface oriented to optimally display the illuminated bar graphs. WaterBot can be rotated freely about the spout to allow for the correct viewing angle depending on sink orientation (See Figure 6).

A printed circuit board was developed for the WaterBot. The board uses a PIC16F876 microcontroller [22] running at 4Mhz and provides enough computing power, speed and memory to perform all of the WaterBot functions. A flash memory-based voice chip [35] provides 8 minutes of pre-recorded digital audio amplified over an 8-ohm speaker. A LED display driver controls two LED bar graphs of 10 segments each. Solid-state temperature and flow sensors provide water usage metrics. Low-power components and energy saving algorithms allow the system to run for two weeks on 2 AA-sized batteries. A power supply was carefully hidden and used to power the system in order to prevent it from losing usage data when batteries were replaced. Oxidation of the cables used for measuring water flow yielded the idea to power WaterBot with a small turbine activated by the flow of water and use the same turbine to measure water flow. The firmware in the system is designed so that in can be configured through a serial interface, allowing the system to be tested with all or some of its behaviors enabled.

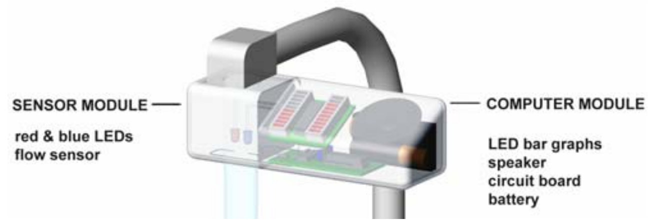

Figure 6. WaterBot modular design. The sensor module has red and blue LED's and flow sensor directly exposed to water flow. The computer module includes a microcontroller, voice circuitry, battery, serial interface and LED bar graph driver.

DESIGN DISCUSSION

Our principal design goal was to make these interfaces context-aware, intuitive and realistic. An iterative design process supported the evaluation and improvement of each device. And a parallel design process produced a board of solutions all informed by each other. Clearly, the visual design that people most react to is HeatSink when it colors the water. The most practical solution is CleanSink that solves a known problem, enforcing medical personnel to wash their hands. WaterBot is the most sophisticated device from a psychometric, integrated engineering and design aesthetic point of view.

HeatSink was found to be immediately intuitive when shown to visitors to our lab. In addition, numerous people expressed their desire to have one and this motivated us to adopt the system in all subsequent devices for added value.

SeeSink was well-received by numerous technologists and kitchen manufacturers. New scenarios such as the dishwashing scenario were added as a result of discussions with experts.

CleanSink was the product of discussion with experts in health care and restaurants. It is the most directly effective of our four iterations because its feedback is direct and it is almost impossible to defy the system.

WaterBot was designed based on observations and two pilot studies. In short interviews, subjects described their faucet usage habits and were observed washing hands and brushing their teeth. They washed their hands on a real sink while being observed and a "Wizard of Oz" tool generated auditory feedback when the tap was closed. As expected, subjects perceived auditory messages as a direct feedback for closing the tap. Messages were perceived as positive, but not really informative. User input was very valuable for the selection of auditory messages and sounds. Users preferred chimes and bells sounds over voice feedback, but liked voice when used for clarifying things because “it makes sense to hear an explanation.” Subjects feedback also helped generate label descriptions, alternate labels, and colorful interactions.

Ten users aged 18-50 from outside the research community volunteered to participate in our first pilot study. Subjects were instructed to wash their hands thoroughly in a normal sink that had WaterBot installed on it. They washed their hands several times while WaterBot cycled through all of its modes. They were told there would a device installed on the faucet, but they were not told what such system would do. Subjects' reactions and comments were registered by an observer.

Observations and subjects' comments indicate that information represented by the bar graphs was easily understood. The constantly changing bar quickly got subjects' attention and was identified as having a direct relationship of some type with their activity. All subjects intuitively compared the information on one bar graph to the bar graph next to it. Five subjects reported that the visual reminder of how long the tap is open made them more likely to shut the water between tasks. Bar graphs, temperature feedback, and "just-in time" messages were intuitively identified. Other persuasive elements remained unidentified at first glance, as for the case of cooperation and competition. With this mode, WaterBot allows users to see each other's scores by making the last individual score available for a few seconds when the next user opens the tap. Subjects noticed the information, but failed to correlate it with the last reading. Another feature that remained unidentified was the ability to superimpose plastic screens on top of the bar graphs.

Results from user studies suggest that there is a significant learning process necessary to understand some of the WarterBot's persuasive features. A possible approach to this problem is to introduce the user to features that are hard to identify and gradually activate more intuitive features. Another approach could take advantage of the mere fact that the longer the tap is on, the more lights turn on, was enough to make people aware of their water usage. This illustrates the effectiveness of prompts even as simple as LED lights. This fact has been demonstrated by previous work [29]. The use of visual prompts appears to be the most effective in getting people's attention.

A second investigation gathered feedback about how the system's adaptive interface would be perceived by users. The test environment is not a typical setting or the intended destination for WaterBot; nevertheless, it provided with enough traffic to test if the system would be capable of withstanding the dangers of an everyday sink. 15 users of a research laboratory agreed to participate and provide feedback about their interaction with a community sink. WaterBot was installed at a community sink for about two months. This sink was mainly used for drinking water and washing hands on a regular basis. After an introductory period of two weeks, the system was turned on. Subjects were surveyed bi-weekly to track user responsiveness. Users voluntarily reported their experiences and comments by email. Observations and user reports suggest a change in behavior by the presence of the system itself (device off). Users indicated they were simply more careful when using the sink, but quickly became accustomed to it. During a follow up e-mail survey, 12 users indicated they still were engaged using the system after two months of use. They became so accustomed to the device that expected it to turn on every time they used the tap.

Interestingly, users did not report being annoyed by the system, but instead expressed their desire for more meaningful and entertaining feedback, such as a bigger variety of sounds and chimes. The seven pre-set sounds and messages were not enough to provide a fun and interesting experience to last two entire months. The adaptive interface limited the number of prompts presented after a month had elapsed. This behavior probably accounted for the fact that the WaterBot wasn't perceived as annoying.

The system was robust enough to withstand daily use in a hostile environment. The evaluation indicates that with few changes, WaterBot is ready to be installed in a typical residence exposed to real-life situations. WaterBot can be used as a platform for experimentation aimed at, but not limited to, a faucet. The system allows the evaluation of different persuasive techniques and how these techniques interact when combined. The system also allows researchers to evaluate several feedback modalities and the use prompts at a novel location.

CONCLUSION

Computer interfaces can work and be unobtrusive in environmentally challenging places. It is hard to think of a more electronic and computer adverse place for computers than a wet sink. Existing water-saving devices and faucet attachments do not take advantage of the richness of interaction and behavior associated with water. Now that context-awareness, sophisticated sensing and computation can become ubiquitous, computer-human interaction in real-world settings can have positive impact on us and our environment. Feedback can be applied at a variety of levels to aid people in their activities. The designs presented in this paper reveal that digital augmentation of the sink can have tangible results and deserve further exploration. Automation can be replaced by persuasive techniques that operate at increasing cognitive levels instead of taking control away from users. Users can learn to improve their own behavior rather than being left out of the process by technology.

In order to design ubiquitous computers that improve daily life in cooperation with their users, the design of their interaction must be considered at multiple cognitive levels. Any device that seeks to promote behavior change must offer pleasing interaction modalities and aesthetic design. The concern for appearance in this design goes beyond marketing and has direct consequences on the success of the persuasive interface. The design principles detailed in this paper can be broadly applied to solve solutions through the encouragement of behavior modification in ways that can be pleasant or attractive to users. As computers pervade our built environments, it will become crucial to consider the details of interaction to make them pleasing and useful to improve our daily life.

This paper demonstrates the opportunity for using alternative feedback approaches in a natural environment. Even in a constrained environment, such as a sink, a hierarchy of helpful goals for feedback can be considered ranging from safety to captology. Finally, this paper shows that context-aware computing can be used to recognize a variety of behavior even in a natural environment.

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