Figure 5).

Real-world Parameters—In the same way as ambient intelligence can stimulate the gaming experience by altering physical aspects such as light or sound, these real world properties can also provide an input for the virtual parts of a game. For instance, the background noise level in a room might influence how efficiently digital desk workers in a respective game perform their tasks. Or the light in a room might affect how well digital flowers bloom.

Virtual Attributes of Physical Artefacts—Arbitrary virtual properties that differ from game to game can be assigned to physical artefacts. In one game, an artefact might be associated with attributes such as intelligence or dexterity, in another game, certain behaviours or alignments might be put into the artefact's digital representation providing for context aware enrichments. Even dedicated GUI artefacts might be used to peek into the physical artefact and to modify its virtual state (see Figure 6).

Conclusions. In this contribution, we presented different examples of how we designed experiences by making use of selected parameters and indicators for processes and other characteristics for situations and objects. The application domains range from office environments to interactive hybrid games.

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EXPLORING FEEDBACK AND PERSUASIVE TECHNIQUES AT THE SINK

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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 affect our safety and hygiene.

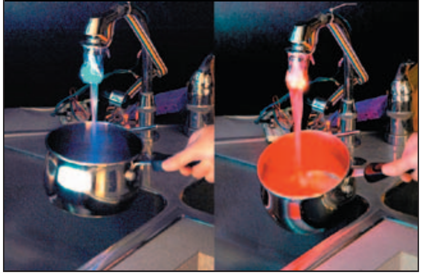

Figure 1: HeatSink illuminates the stream of water according to its temperature, becoming red when hot and blue when cold.

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

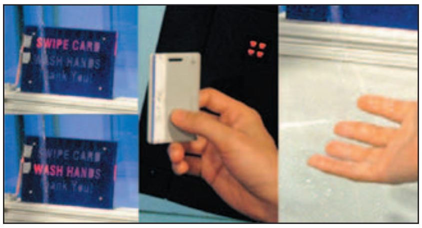

Figure 3: Clean Sink's indicator (left) RFID reader (middle) and sink (right)

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. It is hard to think of a more electronic- and computer-adverse place for computers than a wet sink. 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. Having identified the sink as a site for improving safety, hygiene, conservation, and behavior change we prototyped four functional interfaces directed at demonstrating interaction possibilities at the sink: HeatSink, SeeSink, CleanSink, and Waterbot. These prototypes take advantage of the richness of interaction and behaviors associated with water. They are conceived as devices that could be attached to existing fixtures to provide added benefits, especially in homes, hospitals, and restaurants. 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, while a parallel design process produced a board of solutions all informed by each other.

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 phenomenon is the tendency to leave water running for minutes at a time—something inconceivable in the days when water was carried to its destination. One reason for running the tap is 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; to provide useful information about the temperature of the water without altering the function of the sink. Colored LEDs mounted around the faucet aerator illuminate the stream of water, making it 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.

SeeSink. One impediment to automatic faucets in bathroom and kitchen sinks is the lack of control over temperature and flow. Nevertheless, automation conserves water and promotes hygiene by allowing for "hands-free" operation, including 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 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, conditions exist 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.

Unfortunately these systems do not directly prevent non-compliance (which is estimated at 50 percent in hospitals, for example) [12]. Dirty hands are the primary cause for infection, and are certainly very easy to prevent [6].

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 water stream 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 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 a broad impact on health and safety.

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. 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.

Conclusion. The designs presented 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. As computers pervade our built

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

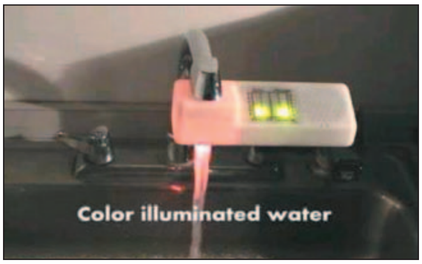

Figure 5: Random patterns in color illuminated water act as reinforcers to reward consistent water-saving behavior. Reinforcers also help to keep users interested.

environments, it will become crucial to consider the details of interaction to make them pleasing and useful to improve our daily life.

There are opportunities 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.

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LIVING IN METAMORPHOSIS: PROACTIVE COMPUTING IN THE HOME ENVIRONMENT

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THE FINNISH ACADEMY of Sciences is funding a three-year research program on proactive computing [1]. The program integrates technological innovations in hardware and software with psychological and social-science research. The 14 funded projects span the wide field of proactive computing ranging from modelling the user's behavior to proactive healthcare sys-