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# Applying Smart Objects for Persuading Users to Change Their Behavior

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***Abstract***

*This paper introduces a novel application area of smart objects, changing users' behavior. By analyzing user contexts acquired by smart objects, applications provide users with appropriate feedbacks to change their behavior. This study demonstrates a concept called ambient lifestyle feedback systems to be used to motivate people to change their undesirable habits to improve their lifestyle. We present three case studies of ambient lifestyle feedback systems, and discuss some findings to design persuasive applications using smart objects. We also discuss future directions of the study.*

***Keywords:*** *Smart Object, Persuasive Application, Ambient Lifestyle Feedback Systems*

## 1. Introduction

One of the successes of ubiquitous computing technologies is that everyday objects that embed sensors have become more common. Gellersen et al. introduced the MediaCup 0, which is one of the first prototypes of augmenting everyday objects with sensors. The cup detects where it is, how it is handled, and so on. SenSay 0 is a context-aware mobile phone that detects whether the phone can interrupt the owner by a phone call depending on environmental noise level, value of acceleration sensors, and so on. A common characteristic of both devices is that they are augmented with no infringement on original functions they have. An owner simply uses such devices as usual – such as drinking coffee –, and the devices extract user contexts by using embedded sensors. The extracted contexts are usually used as helpful hints for providing additional or personalized services.

However, such contexts are also useful to make users realize their own conditions. Often people do not know their own physical and mental conditions. For example, people cannot realize how high their blood pressure without sphygmomanometer. After a patient realizes his blood pressure value, he may try to do exercise in order to lower his blood pressure. In other words, such contexts have power to change their own behavior.

Meanwhile people have a desire to change their behavior to break themselves of bad habits, such as smoking and overeat. Although we know that it is important to keep desirable habits with a great effort, we are apt to being lazy, and having an easy life. Many kinds of persuasion techniques have been developed to change people's behavior from ancient times and specialized interactive systems such as serious games 0 have been developed for the purpose recently. However, these approaches have been not able to provide detailed persuasion for each user because these approaches have not utilized the individual behavior.

Therefore, we have designed a solution to change users daily habits to motivate a better lifestyle by using their own contexts acquired by everyday objects. The solution, called

*ambient lifestyle feedback systems*, is presented as a set of three design principles 0. We have used some basic tenets from operant conditioning as a basic principle for changing users habits. The most obvious issue is that the system should include a feedback loop between the users behavior and the expression shown on an ambient display.

In this paper, we present three case studies using the ambient lifestyle feedback systems, which overcome the problem of existing persuasion techniques to expand the possibility to enrich our experience in our daily lives, and discuss the role of smart objects for persuasion. The rest of this paper is organized as follows. In Section 2, we present Ambient Lifestyle Feedback Systems. In Section 3, we present three case studies, Persuasive Art, Virtual Aquarium, and Mona Lisa Bookshelf. Section 4 discusses the evaluation of the case studies. Section 5 cites the related work, and finally Section 6 concludes the paper.

## 2. Ambient Lifestyle Feedback Systems

Ambient lifestyle feedback systems as shown in Figure 1are intended to be implemented using ubiquitous computing techniques, including everyday objects that embed physical sensors and ambient display devices. Nevertheless most implementation details are determined by the needs of a particular application and what behavior it targets to satisfy the following principles. In order to lend a solid framework for feedback design, we referred to elementary behavioral psychology. Behavioral psychology is a discipline dealing with the relationship between behavior and consequences. It posits that the form and frequency of behavior can be affected by controlling the consequences.

Ambient lifestyle feedback systems could be compared to a mirror. When a person looks at his image in a mirror, he could understand his own psychological state from his facial expression. If the expression is unexpectedly displeased for him, the mirror generates *"self-reflection*". This means that mirror does not only show the usual outward appearance, but also reflects personal facts that may otherwise go unnoticed. As we mentioned in Section 1, smart objects are able to acquire various types of user contexts nowadays. Ambient lifestyle feedback systems produce a graphical visualization from the contexts on an ambient display, and that makes users change their behavior.

### 2.1. Principles

In order to design persuasive applications using smart objects, the system adopts following three principles.

**2.1.1. Passive Observation:** One key factor limiting the applicability of the earlier solutions to our intended purpose is the various burdens they place on a user, either in the form of time use or effort. To avoid the burdens of self-reporting, the system should be able to passively observe the user's behavior. To eliminate the need to set aside time or go to a special place, the system should be integrated with normal daily activities. Thus, our first design principle is to use observations of the users' behavior as the system's input, as opposed to using keystrokes or some other proxy behavior. This also facilitates the delivery immediate feedback, a key factor in the effectiveness of operant conditioning.

Although some non-contact monitoring systems including motion capture systems and computer vision techniques can observe many kinds of users motion, it is difficult to extract users behavior only from them. In order to raise the precision of the extraction without installing large-scale monitoring systems, making users give clue to the system through smart

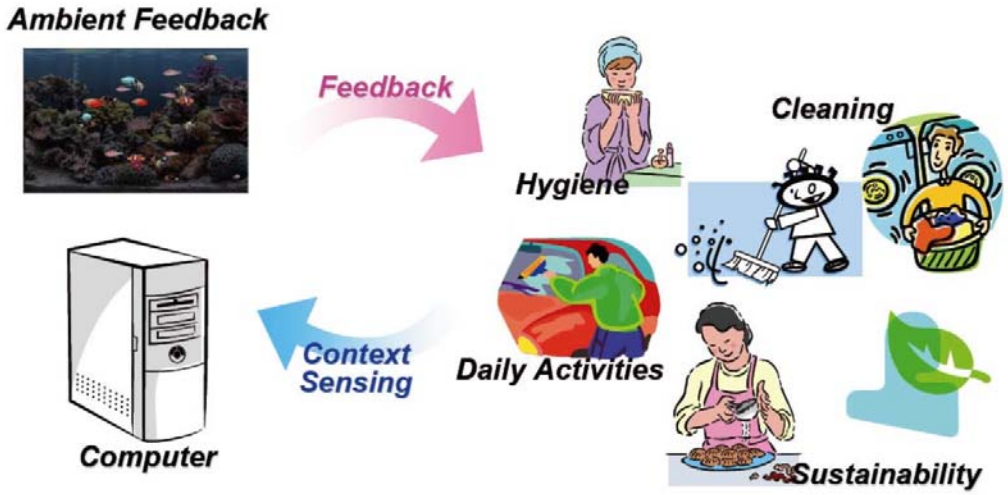


Figure 1. Ambient Lifestyle Feedback Systems

objects is effective. For example, it is difficult to understand how users straighten out their rooms from non-contact monitoring systems, but “smart vacuum cleaner” may acquire how, when, where, and how long users clean their room with extreme precision.

**2.1.2. Choosing Appropriate Incentives to Change Behavior:** To effect a change in behavior in operant conditioning, we must be able to administer some sort of meaningful consequences to the user. Systems monitor the user and reward desirable behavior by using techniques familiar especially from video games. Many existing persuasive applications have given rewards when users reach the goals for boosting and maintaining their motivations. Such rewards do not have to be real value. Just to show “Congratulations!” in a display is valuable, which is a kind of *individual psychological incentives*. Usually these kinds of incentives are given to the users just after users reach the goals.

Another important approach is the use of *social psychological incentives* such as social facilitation and conforming behavior. Social facilitation is the phenomenon where a person performs better at a task when someone else is watching such as a colleague or a supervisor 0. Conforming behavior is the desire not to act against group consensus 0, colloquially known as peer pressure. Unlike former incentive, users can be added these kinds of incentives even they do not reach the goals yet. Thus the incentives are effective particularly for distant goals. In ambient lifestyle feedback systems, broadcasting a user’s status to others is able to produce these social psychological incentives.

*Economic incentives* are also strong incentives to change behavior. For example, the deposit-refund system for PET bottles motivates users to return bottles for recycling. Another example is the emissions trading system which is used as an administrative approach to control pollution for achieving the reductions in the emissions of pollutants. It could be said that in these examples monetary value acts as a comparable reference for the behavior. If users think the monetary value is not equal to the efforts to behave, the incentives do not work well.

**2.1.3. Ambient Feedback:** To complete the integration of the system into the user's daily living environment, we must also make sure that the output produced by the system is appropriate. We refer to Mark Weiser's concept of calm technology: technology that is able to

leverage our peripheral perception to deliver information, as opposed to constantly demanding direct attention 0. Ambient lifestyle feedback systems should be designed to blend into their environment and to be able to deliver information in the periphery. A loud or disruptive feedback system might even find itself thrown out of the house or workplace.

## 3. Case Studies

In this section, we present three case studies: 1) Persuasive Art; 2) Virtual Aquarium; and 3) Mona Lisa Bookshelf. Each case study is designed to use different persuasion techniques and different user contexts in order to confirm whether each technique is effective or not.

### 3.1. Persuasive Art

This study was designed to investigate how aesthetic expressions of ambient feedbacks encourage users to do more exercise. By introducing four different types of expression, we tried to recognize each characteristic.

**3.1.1. Design:** Decorating walls with pictures are common at home. Pictures are a very important way to increase aesthetic feeling in our daily lives. Persuasive Art uses a painting to motivate a user to walk at least 8000 steps every day to keep his/her fit. The number of steps are monitored automatically and stored into a computer. The painting shows the feedback of the status of the user's exercise in order to motivate him to maintain desirable habits. In this case study, an individual psychological incentive – changing picture – was used.

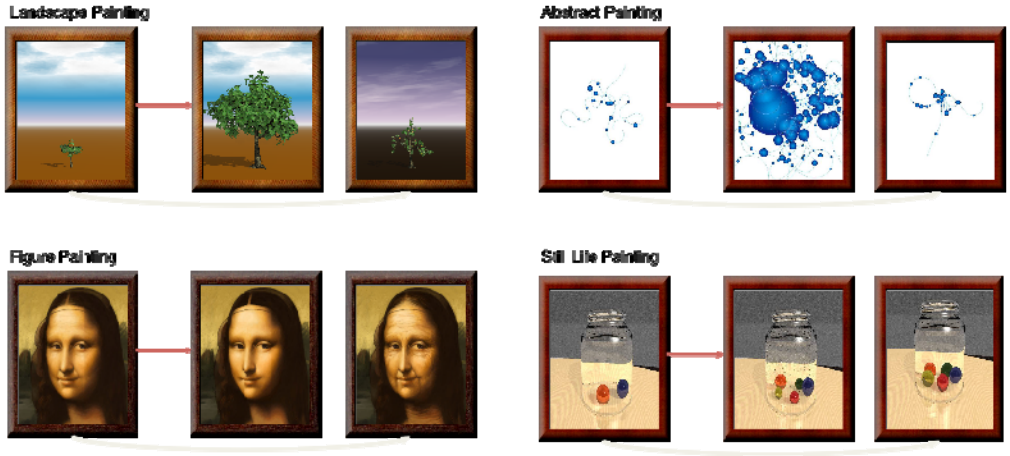


Figure 2. Four alternative virtual paintings

Motivating humans can be classified into two approaches. One is to make users aware of their current situation and the other is to enhance the user's willingness to change his habits. Motivating a change of habits can also be classified into two types. The positive expression style increases a user's positive emotion to motivate a change in the user's undesirable habits. The user feels happy when changing his/her undesirable habits even if the change is challenging and hard. Another type is the negative expression style. This promotes negative emotion to feel a sense of crisis that motivates to change the user's undesirable habits. For instance, if a user looks at him in a mirror and finds that he is significantly overweight, this may motivate him to do more exercise. Persuasive Art currently offers the following four

types of paintings as shown in Error! Reference source not found.: 1) the landscape painting includes a tree that grows and withers, 2) the figure painting is the portrait of Mona Lisa, 3)the abstract painting has objects that change in size and complexity, and 4)the still life painting contains a changing number and size of orbs in a bottle. When using the landscape painting, the tree's growth is varied according to the users' behavior. When the user maintains desirable habits, the tree will grow, but if he stops the desirable habits, the tree will get sick. The painting adopts the following metaphor. The increase of healthy activities makes the tree healthier, but the neglect of the exercise makes the tree sick. When using the figure painting, Mona Lisa gets older and younger according to the users behavior. The increase of healthy activities makes Mona Lisa younger, and oppositely the neglect of the exercise makes Mona Lisa older. When using the abstract painting, the blue objects change in size and complexity according to users' behavior. If the user maintains desirable habits, the objects "grow" significantly. When using the still life painting, the number and size of orbs in the bottle changes according to users' behavior. Even if users do not maintain desirable habits enough, one orb is added into the bottle, but the size is small. If users do maintain desirable habits enough, one big orb is added. If users do not maintain at all, the bottle is cracked.

**3.1.2 Smart object and lifestyle tracking:** Persuasive Art counts a user's steps by using an Omron's HJ-710IT pedometer. By connecting the pedometer to a Persuasive Art system, the measurement is transferred to the system and analyzed. The Persuasive Art system generates graphical visualizations. However, users have to wear the pedometers and connect them to the system. This could be said that this design partly violates the principle mentioned above.

**3.1.3. Experiments and key results:** To understand the effects of each painting, firstly we conducted a simple experiment. We hired six participants from our laboratory (age: 22 – 24) in 10 days. Participant's steps were counted by the system and they appraised those four types of paintings installed in the laboratory. In this experiment, any paintings did not increase users steps significantly though the participants became more conscious of their exercises. It was striking that all participants claimed that they felt close to the tree expression. They said this was because 1) they were connected emotionally to the tree and wanted to mature it, and 2) they were wracked by guilt when the tree died. Of course, the Mona Lisa also represented empathetically, that lacked "unexpected" expression like growth of tree. From these impressions, we found important factor is applying empathetic expressions such as animate things.

Secondly, we conducted another experiment to investigate the effects of positive and negative expressions. We hired 8 participants (M: 4, F: 4, all are our university students not belonging to our laboratory) in 3 weeks. Just like the former experiment, each participant's steps were counted by the system. In this experiment, one half of the participants appraised positive expression without any negative expression, other half of the participants appraised positive and negative expressions. In the former case, the tree just grew when participants did well. In the latter case, the tree grew when participants did walk well and got morbid when participants did not walk well. In this experiment, there were no significant differences in numbers of steps. When we interviewed the latter participants how they felt the negative expression, 5 out of 6 participants commented they felt that they must walk more. However the negative expression did not translate into the actual acts. The other 1 participant emphasized that the painted tree looked revolting and she failed to continue the experiment.

Negative feeling and discomfort likely stop target behavior itself. Thus it is extremely important to choose proper expression carefully. Besides, several participants often forgot to wear the pedometers and to connect them. We confirmed from interview that the participants felt that wearing pedometers and connecting them to the system were bothersome.

### 3.2. Virtual Aquarium

Virtual Aquarium shown in **Error! Reference source not found.**has the objective of improving users' dental hygiene by promoting correct tooth brushing practices. This prototype uses 2 types of feedbacks: 1) dancing fish and a moving scrub as immediate feedbacks, and 2) death of fish and hatch of fish as accumulated feedbacks. This study was designed to investigate whether these 2 types of feedbacks were effective.

**3.2.1 Design:** This system is set up in the lavatory where it turns a mirror into a simulated aquarium. Fish living in the aquarium are affected by the users tooth brushing activities. If users brush their teeth properly, the fish prosper and procreate. If not, they are weakened and may even perish. In this prototype of the system, the ideal behavior was defined as follows: 1) users should brush their teeth at least twice per day; 2) one session should involve at least three minutes of brushing; and 3) brushing should involve patterns that ensure the teeth are properly cleaned. User behavior is compared to this ideal and translated to feedback as described below.

When a user begins to brush her teeth, a scrub inside the aquarium starts cleaning algae off the aquarium wall. At the same time, a set of fish associated with the user starts moving in the aquarium in a playful manner. When the user has brushed for a sufficient time, the scrub finishes cleaning and the fish-dance turns to a more elegant pattern. When the user finishes brushing, the fish end their dance and resume their normal activities. Both the activity of the fish and the movement of the scrub are designed in such a way as to give the user hints regarding the correct method of tooth brushing. The right picture in Figure **3**shows a scene from the aquarium during brushing. However, if a user does not brush his/her teeth sufficiently, the aquarium becomes dirty, and the fish in the aquarium become sick. The health of the fish is visibly affected by how clean the aquarium is. If a user neglects to brush her teeth, some fish fall ill and may even die. In contrast, faithful brushing may result in the fish laying eggs (The right picture in Figure). At first the eggs are not very likely to hatch. If the user continues to brush consistently for a number of days in a row, the incubation ratio increases. This way, the accumulated feedback gives clues to the correct behavior and attempts to maintain motivation over a period of time. In short, individual psychological incentives – cleaning aquarium, dancing fish, and growing fish – were used in this case study.

**3.2.2 Smart object and lifestyle tracking:** Virtual Aquarium uses a *Cookie*, which is a wireless customizable sensor device 0. Cookie has a 3-axis acceleration sensor that is attached to each toothbrush in a household. Since toothbrushes are usually not shared and each Cookie has a unique identification number, we are able to infer which user is using the system at a given time. The system recognizes tooth brushing patterns by analyzing the acceleration data. **Error! Reference source not found.** shows a user brushing his teeth in front of the Virtual Aquarium using a brush with a Cookie. The system is able to observe how a user brushes his/her teeth passively without requesting extra actions.

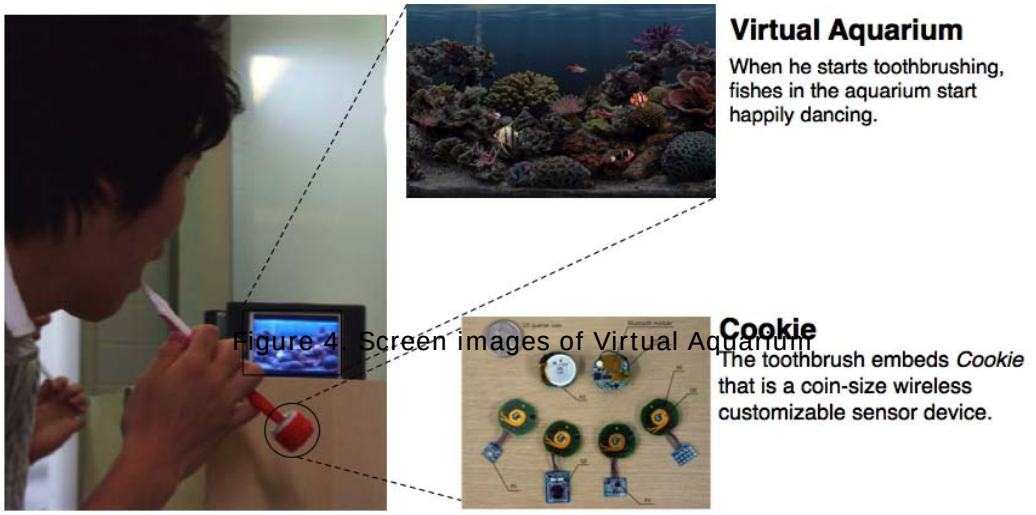


Figure 1. A user toothbrushing in front of a Virtual Aquarium system

Figure 3. Screen images of Virtual Aquarium

**3.2.3 Experiment and key results:** In this experiment, we hired seven adults (M: 4, F: 3, age: 22 – 50) in 3 weeks. In the first week, we measured usual brushing time of each participant using sensors without aquarium visualization. In the second week, aquarium visualization was introduced. In the last week, the visualization was removed and only brushing time was measured again.

While all participants did not brush well in the first week, after the visualization introduced we made sure that all participants did brushing at least 3 minutes. Noticeable point is that all participants still brushed longer than the initial level even in the third week. Besides, they did not neglect brushing any time in the second week. This means that moving scrub and dancing fish were totally effective to make users have habits of brushing in sufficient amount of times. From interviews after this experiment, more than half participants were enthralled by the unexpected behavior of fish, blowing eggs and so on. This means that accumulated feedbacks are effective for remaining interesting in the system.

### 3.3. Mona Lisa Bookshelf

This study was designed to examine whether our approach could be applied for shared resources unlike users' own resources or themselves.

Figure 5. Two example visualizations of the Mona Lisa Bookshelf

**3.3.1. Design:** Resources shared by a number of people, such as a public toilet or a bookshelf in a research laboratory, tend to deteriorate quickly in a process called the tragedy of the commons. This happens because each individual derives a personal benefit from using the resource, while any costs are shared between all the users, leading to reckless use. Mona Lisa Bookshelf is aimed at keeping a bookshelf organized. It tries to encourage users to keep books in order and to return missing books, but also to take books out every now and then for reading. Each book in the shelf is linked with a piece of a digital image of the Mona Lisa. Like a picture puzzle, the image changes according to how the books are positioned. A high-quality flat display placed near the bookshelf shows the image to the users.

In this system, its feedback logic aims to encourage the following ideal behavior: 1) books should be arranged correctly and aligned neatly; and 2) at least one of the books should be read at least once per a week. The correct arrangement of the books is pre-programmed, and could be e.g. alphabetical. User behavior is compared to this ideal, and translated to feedback as described below.

Mona Lisa Bookshelf also offers two expression styles to return feedback to a user to encourage cleaning his/her bookshelf or reading books in the following ways. When a book is removed from the shelf, the corresponding piece of the Mona Lisa image also disappears. If books are lying on their face or otherwise misaligned, the pieces of the image also become misaligned, distorting the picture. When the books are arranged neatly, Mona Lisa smiles contently. The assumption is that users are aware of how da Vinci's Mona Lisa is supposed to look like, and as when completing a picture puzzle, inherently prefer the correct solution to a distorted image. The feedback thus provides clues and motivation for keeping the bookshelf organized. The left picture in Figure 5 shows an example of a distorted image.

In addition to the accumulated effect of the pieces of the image being moved around, there is an accumulated feedback mechanism that attempts to encourage users to read the books once in a while; if none of the books are removed from the shelf for over a week, Mona Lisa starts getting visibly older. The right picture in Figure 5 shows an example of an aged portrait. As soon as one of the books is removed from the shelf (hopefully to be read), she regains her youth.

Figure 6. Mona Lisa Bookshelf installation

**3.3.2. Smart objects and lifestyle tracking:** In this system, visual tags are attached to the spines of the books to facilitate their detection and identification. Visual tags are also attached to the corners of the shelf to determine its dimensions (Figure 6 Left). The detection part (Figure 6 Middle) comprises the following hardware: a digital video camera (iSight by Apple), a high-resolution digital camera (D50 by Nikon) and two infrared distance detectors (GP2D12 by SHARP). The distance sensors and the digital video camera are used to detect whether a user is manipulating books in the shelf. OpenCV, a real-time computer vision software library, is used to analyze the video signal. As soon as a user is seen leaving the shelf, the high-resolution still camera takes a picture of it and all the books contained within it. Images captured by the still camera are analyzed by the Visual Codes 0 software library, which recognizes the visual tags attached to the books. The system is shown installed in (Figure 6 Right). Each visual code yields data regarding its position, alignment and identity. This is the translated into context information that describes the bookshelf's width and height, which books are currently contained in the shelf, and how they are aligned and ordered. This approach is able to observe how a user uses her bookshelf passively without requesting extra actions.

**3.3.3. Experiment and key results:** We conducted a simple experiment in our laboratory whether users could change their behavior to deal with shared resources. One 61-inch plasma display showed the Mona Lisa related to one big bookshelf in the lab in 2 weeks. Unfortunately, this was not effective at all. Firstly someone who noticed the relationship between the picture and books kept book organized. However, after few days, many of those researchers and students lost interest in the picture and the Mona Lisa was left apart. Besides, some participants commented that the apartness and missing were fun to see, so they changed the order of books intentionally.

This failure is because the presentation could not solve the tragedy of the commons. Even if the Mona Lisa was distorted, anyone could not find out who did not keep the bookshelf organized. Besides, the participants commented that they assumed somebody else read books when the Mona Lisa got older. In short, the presentation could not encourage a sense of ownership.

## 4. Discussions

### 4.1. Sensing Accuracy and Auxiliary Interaction

As we mentioned in Section 2.1.1, ambient lifestyle feedback systems request no explicit interaction from users. Virtual Aquarium could observe a user's brushing behavior by reading the movement of the toothbrush that embeds a 3-axis accelerometer. Similarly, Mona Lisa Bookshelf used computer vision techniques to detect the tilt of books in a shelf.

However, our experiences show that there are some limitations to recognize users behavior with no explicit interaction from a reliability point of view. Although we could analyze reliable contexts in the Virtual Aquarium and the Mona Lisa Bookshelf, it is generally difficult to analyze users behavior precisely without heavy-weighted algorithms. We need some auxiliary interaction from users to support behavior analysis.

One of the most important points to introduce auxiliary interaction from users is that the auxiliary interaction itself must have a role to persuade users and to give incentives. In Persuasive Art, we had no alternative but to make users wear pedometers and connect them to the system. Because these bothersome actions were mere distractions, participants preferred to forget about wearing their pedometers and to neglect to connect them. Oppositely another case study EcoIsland 0 adopted a self-reporting method to input what kind of actions a user takes in order to avoid complex behavior analysis, and we found a user learned many kinds of good behaviors from the interaction.

One problem in the current case studies is that a user may cheat the analysis of the sensors consciously. For example, in Virtual Aquarium, some users imitated the movement of their toothbrushes in order to make the fish dancing. There are two approaches to solve this problem. The first approach is to prohibit cheating by increasing the accuracy of the movement analysis. The second approach is to encourage users to ethically. The both of two approaches are necessary to be studied; especially we are very interested in adopting the second approach in our future case studies. This approach makes users to compare merits and demerits of cheating. For example, social psychological incentives between close friends may give a sense of guilt to cheated users.

### 4.2. Persuasive Expression

The case study on Persuasive Art shows that animate thing is an appropriate expression for motivating users because users are connected emotionally to the thing. While any visual representation can be used to relay information, shapes that come with pre-attached meanings (e.g. “a tree withering has a negative meaning”) are more capable of evoking emotional engagement. Tan and Cheok showed that a real creature is found to arouse more empathy than a virtual creature in 0. However, people feel empathy also to virtual creatures, even abstract symbols 0. We sometimes assign different meanings to a real creature and a virtual creature because we know the differences between them. Apple’s notebook has a lamp that blinks when the notebook goes to sleep, which looks like a breathing of a sleeping person. This design appears to be succeeding in having a special attachment to the computer. We need to investigate the effect of virtual creatures as a persuasive expression in future case studies.

Moreover we need to know how to map appropriately between their behavior and the expressions. Even if we can pick up a virtual creature or another appropriate expression, we have to decide how and when the creature behaves. In the case study of Persuasive Art, participants preferred the tree expression to the Mona Lisa though both expressions are creature expressions. It is important that not only introducing felicitous metaphor, but also designing accumulated feedback and keeping users from being bored.

### 4.3. Unexpected Effects and Privacy Issues

As we introduced in Section 3, Persuasive Art was designed for single use and we assumed that the display was placed at a participant’s personal room. However several participants placed the display at their living room and their family members began to comment on the

visualization and to complain about the lack of sufficiency of exercise to the participants. Such unexpected events could not be measured but could be bad effects. In a ubiquitous computing environment, we have to consider not only about the application itself, but also where the application installed and whether social effect works. When the smart object that indicates the owner's status is there, this may produce similar effects.

Moreover, due to the privacy issues, expressions of both applications and smart objects must be designed with the location in mind. We think one acceptable option is to hide detailed information and to convert them to abstract information, such as Persuasive Art in which counted steps was converted to the growth of a tree. Fujinami et al. showed that people feel empathy for even virtual creatures represented as abstract symbols in 0. By using this idea, a user could disclose the expression to the public, and the user could be affected by social facilitation without any privacy violation. –"*Oh the tree is finally blooming! You did good job!*"– Other people can see the progress or differences between participants, but cannot see the actual data.

When we think about applications for personal use, which do not deal with privacy issues, it is still unclear whether expressions should be abstract or not. There are some close systems to ambient lifestyle feedback systems. Playful toothbrush 0 shows virtual teeth representing the current status of the user's tooth brushing. Calorie-Aware Cooking 0 shows the amount of calorie of meal that the user is currently cooking. These systems explicitly show the goals of the user's behavior. The user continues to use and enjoy the systems until he achieves the goal. However, motivating a user based on a long-term goal is important to maintain desirable lifestyle. We do not investigate yet whether such systems can motivate users long time.

### 4.4. Feedback Control and Personalized Expression

In operant conditioning, feedback content can be divided into reinforcement and punishment depending on whether some behavior is encouraged or discouraged. Reinforcement and punishment are further divided into four types 0:

- **Positive reinforcement:** encouraging the user's behavior by providing a favorable stimulus in response to it.
- **Negative reinforcement:** encouraging the user's behavior by removing an averse stimulus in response it.
- **Positive punishment:** discouraging the user's behavior by providing an averse stimulus in response to it.
- **Negative punishment:** discouraging the user's behavior by removing a favorable stimulus in response to it.

Our case studies used the combination of the above four types of feedback. One of our findings is that the balance between positive reinforcement and positive punishment is important in changing a user's behavior permanently. The user may be bored if the expression offers only positive reinforcement. On the other hand, the user may give up his hope to change undesirable habits when only positive punishment is offered. An appropriate balance is important in order to change the user's behavior permanently.

Moreover, there is a possibility that they may quit persuasive applications to avoid the unpleasant experiences if the expressions are too unpleasant for users. As we described, one participant in Persuasive Art could not continue the experiment due to the tree expression. To

avoid this situation, we think personalized expression should be introduced. Of course some patterns of effective expressions will be extracted in detail, but we will not be able to propose the best expression for every people because many people are particular about the expressions and this can differ according to generation, the area in which people live and the sense of beauty people have 0.

### 4.5. Personalization of Persuasive Presentations and Smart Objects

When we developed persuasive applications mentioned in Section 3, those presentations were designed according to the metaphor of target behavior. For example, when a user maintains desirable habits, the tree will grow, oppositely the tree will get sick when s/he stops the desirable habits in Persuasive Art. Though we found that participants preferred animate (live) things for persuasive presentations, it is still unknown what the most appropriate presentation is. Ferscha et al. mentioned in 0 that usually an ambient information system provides only one expression, but they found users were particular about the expressions from their experiment. If the presentations can be personalized, users might get involved in the applications deeper. So we need a software framework for such ambient information systems to acquire and to filter sensor data, to control and to change the presentation.

## 5. Related Work

### 5.1. Smart Objects

As we mentioned in Section 1, usually extracted contexts by smart objects are used as helpful hints for providing additional or personalized services. AwareMirror 0 presents abstract information relevant to a person in front of it by super-imposing his/her image. AwareMirror detects who is in front of the mirror and provides the user with useful information such as weather forecast and traffic information where the user goes.

On the other hand, people have developed many kinds of convenient utensils that attract a fair amount of attention when needed. For example, whistling kettle signals when water is at a boil. This comes to the owner's attention that s/he has to put out the fire. Recently Ambient Devices released Ambient Umbrella 0, which illuminates its handle to suggest an owner to take it with her depending on local weather forecast. Although these utensils make users change their behavior, target behaviors are quite simple. The approach is unidirectional from the utensils, and they do not aware of users behavior.

Users contexts acquired by one particular sensor are often not enough to provide rich services, and smart objects need to equip two or more sensors to extract rich contexts. Besides, smart objects installed in each household must be reconfigured in order to provide personalized services. Kimura et al. pointed that it was hard for end-users to imagine extractable users' contexts just by looking at sensors, and introduced input primitives used in tangible user interfaces 0. Kawsar et al. proposed an infrastructure and a tangible deployment tool for smart objects, which involves end-users in building and enhancing a smart home 0.

### 5.2. Persuasive Applications

Informative art project **Error! Reference source not found.** explored information visualization techniques that use art as inspiration for both their appearance and their role in our surroundings. Its information presentations disappear into the background and enable people to be notified information without too much attention. Though ambient lifestyle

feedback systems are similar to the project in terms of embedding information visualization in daily objects, our systems include changing users behavior rather than just showing information.

Digital Game-Based Learning 0 discussed how learners have changed, how digital media including games teach and why they work. 0 and 0 describe about serious games that are computer and video games that are intended not only entertain users, but have additional purpose such as education and training. As these books shows, the positive effects of games on learning, training, and exercising are being explored in recent years. However, they have not explored how to apply user contexts into the games.

Some latest persuasive applications such as 0 used users' mobile devices for persuasion. The strength of mobile devices for persuasion is that users can see the displays every time and everywhere they want. Unlike ambient display, however, displays on mobile devices cannot be shown until users want to see. In operant conditioning, feedbacks must be provided just after users' behavior. Thus there is no guarantee that the mobile device is suitable device for persuasion at all times.

## 6. Conclusion and Future Directions

In this paper, we introduced a concept of ambient lifestyle feedback systems and three case studies. From the case studies we derived various insights and findings. We observed users could enjoy being encouraged to change their behavior through the persuasive applications in our short-term experiments. However, we also found it was not easy to motivate users to keep desirable behavior for a long time because users will feel bored watching the expression. We also pointed that the expression is a matter of personal taste. If a user changes and customizes the persuasive expressions, there is a possibility that the user can enjoy the applications for a long time 0. Thus we are now interested in developing a customizing tool for persuasive expression.

Moreover, we are interested in smart objects themselves as tangible user interfaces. As Ishii et al. pointed in 0, a tangible user interface itself has to have a physical form of digital information. This means that a tangible user interface has two features, an input device and an output device. In our case studies sensing and expression parts were separated, but we think well-designed tangible user interfaces combine the two parts. We will investigate whether tangible user interfaces can be utilized for persuasion.

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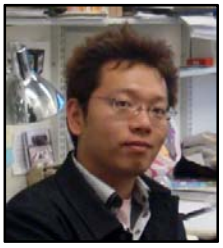

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