

# Extracting Key Factors to Design Applications in Ambient Intelligence Environment

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## Abstract

*In an ambient intelligence environment, the design of applications influences the users behavior heavily. The purpose of this paper is to provide key factors considered necessary in developing those applications. We developed four applications applied Ambient Lifestyle Feedback Systems and evaluated those user studies. From those four user studies, we verified key factors to develop applications in an ambient intelligence environment.*

## 1. Introduction

One of the big differences from a general user's point of view between traditional business application software and others such as casual software is its indispensability. Often office workers cannot avoid using business application software because they could not get anything done without it though the design of the software is slightly poor. In the contrast, each user possesses a right to quit using the other software. When those software displease a user, she stops using them easily even if those are valuable ideally. In case of services in an ambient intelligence environment to support people in their everyday life activities, it must be more serious problem. Main features of the services in the environment are that the services are aware of users contexts and deduce appropriate responses to the users automatically. Therefore if the responses are unpleasant for the users, they may not only quit using such services, but also change their everyday behavior involuntarily to avoid the unpleasant experiences because it is quite hard for them to quit the services which are embedded or hidden in the environment. This phenomenon is explained by an example of positive punishment in the field of operant conditioning [4].

Meanwhile, people have a desire to change their behavior to break themselves of bad habits. 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. Several previous approaches [6, 8] have tried to change users daily habits to motivate a better lifestyle. We have designed our own solution to motivate the desired changes of our behavior. The solution, called *ambient lifestyle feedback systems*, is presented as a set of three design principles [7]. We 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. Thus applications in an ambient intelligence environment must influence users behavior appropriately. In this paper, we discuss how ambient lifestyle feedback systems based applications affect users to change their habits from our four case studies.

## 2. Case Studies

In this section, we present four case studies: 1) Persuasive Art; 2) Virtual Aquarium; 3) Mona Lisa Bookshelf; and 4) Ecoland. Each case study is designed to use different persuasion techniques in order to confirm whether those techniques are effective or not. More details of the first two case studies are described in [7].

### 2.1 Persuasive Art

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

#### 2.1.1 Design

Decorating walls with pictures is 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 current status of the user's exercise in order to motivate him to maintain desirable habits.

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 himself 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 Figure 1: 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, 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.

### 2.1.2 Experiments and key results

To understand the effects of each painting, firstly we conducted a simple experiment. We hired 6 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 ex-

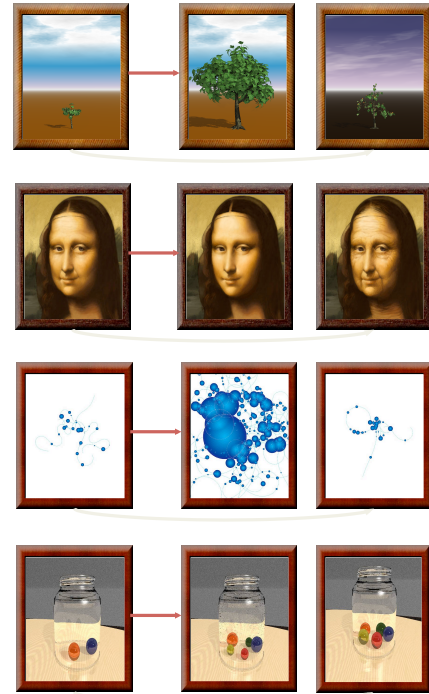


Figure 1. Four alternative virtual paintings

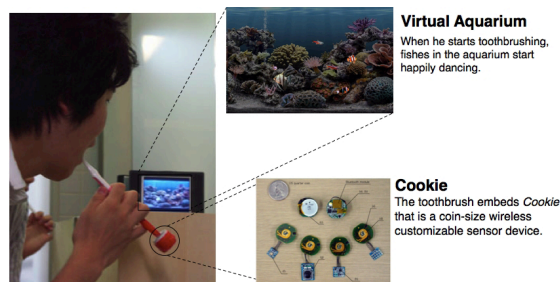
periment, any paintings did not increase users steps significantly though the participants became more conscious of their exercises. It was striking that all participants claimed that they felt close to the tree expression. Most of them said this was because 1)they were connected emotionally to the tree 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, 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 neg-

ative 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. As we mentioned in Section 1, negative feeling and discomfort likely stop target behavior itself. Thus it is extremely important to choose proper expression carefully.

## 2.2 Virtual Aquarium

Virtual Aquarium shown in Figure 2 has the objective of improving users dental hygiene by promoting correct toothbrushing 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.



**Figure 2. Virtual Aquarium System**

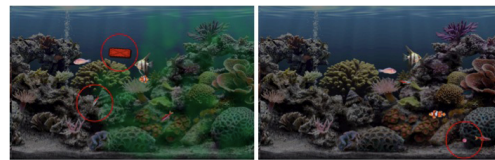
### 2.2.1 Design

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 toothbrushing 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 toothbrushing. 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.



**Figure 3. Images of Virtual Aquarium**

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 3). 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.

### 2.2.2 Experiment and key results

In this experiment, we hired 7 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.

## 2.3 Mona Lisa Bookshelf

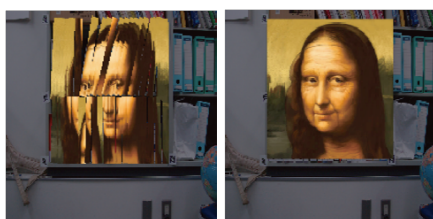
This study was designed to examine whether our approach could be applied for shared resources unlike users' own resources or themselves.

### 2.3.1 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 4 shows an example of a distorted image.



**Figure 4. Screens of Mona Lisa Bookshelf**

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 vis-

ibly older. The right picture in Figure 4 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.

### 2.3.2 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.

## 2.4 EcoIsland

This study was designed to examine whether our approach could be applied for shared resources by introducing social psychology and economical notion.

### 2.4.1 Design

EcoIsland is a game-like application intended to be used as a background activity by an ecologically minded family in the course of their normal daily activities. A display installed in the kitchen or another prominent place in the household presents a virtual island. Each family member is represented on the island by an avatar (Figure 5). The family sets a target CO<sub>2</sub> emission level (e.g. national average minus 20%) and the system tracks their approximate current emissions using sensors and self-reported data. If the emissions exceed the target level, the water around the island begins to rise, eventually sweeping away the avatars' possessions and resulting in a game over.

On their mobile phones, the participants have a list of actions that they may take to reduce the emissions: turning down the air conditioning by one degree, taking the train instead of the car, et cetera. Upon completing an action, a participant reports it using the phone, and the water level reacts accordingly. Reported activities are also shown in speech bubbles above the corresponding avatars. A lack of activity causes the avatars to suggest actions. Participants can also see neighboring islands and their activities in the





**Figure 5. Screens of Ecoland**

display, and can list buy and sell offers for emission rights on a marketplace. Trading is conducted using a virtual currency obtained from a regular allowance. The credits are also used to buy improvements and decorations to the island, so successful sellers can afford to decorate their island more, while heavy emitters have to spend their allowance on emission rights.

The virtual island shown in the display acts as a metaphor and makes the participants conscious of the ecological consequences of their choices and activities. We also tap into social psychology, attempting to exploit *social facilitation* and *conforming behavior* to encourage the desired behavior. Social facilitation is the phenomenon where a person performs better at a task when someone else, e.g. colleague or a supervisor, is watching[10]. Conforming behavior is the desire not to act against group consensus[1]. Ecoland's design facilitates these by involving the whole family, and by presenting the participants' activity reports in the speech bubbles and providing contribution charts and activity histories. On the other hand, the fact that the game is played by a family unit instead of an individual means that participants can also agree to assign tasks to certain members.

Lastly, there is a trading system, which is based on the same principle as industry level emissions trading systems: reductions should be carried out in places where it is easiest to do so. A family that finds it easy to make significant reductions can sell emissions rights to households that find it difficult due to e.g. location or job. This should make it possible to attain the same amount of total reductions with a lower total cost (measured in disutility), promoting use of the system.

## 2.4.2 Experiment and key results

We conducted an experiment to investigate whether social factors and economical notion were effective. We recruited 6 families (20 persons, age: 15 – 58) who were interested in environmental issues. The experiment lasted for 4 weeks. In the first week, we equipped participants' air conditioners with a simple electricity usage meter to compare the readings between experiment weeks. In the second week, the system was installed and only one family member from each household used it. In the third week, all family members used the system. Comparing the results of the second and third week provides insights regarding the social psychological effects. In the fourth week, we introduced the emission trading system. After the experiment, we conducted a survey in the form of a questionnaire asking about changes in the participants' attitude and feedback.

From the questionnaires, 17 out of 20 participants said that they were more conscious of environmental issues after the experiment than before. Some families said that the sinking virtual island contributed to a change in their consciousness, suggesting that the metaphor works well. Our system log of the reported emission reduction shows that 5 out of 6 persons reported more actions in the third week than the second week, lending support to the hypothesis that social facilitation and conforming behavior can be used effectively. As for the air heater electricity usage, however, there was no observable correlation with the reported emission reducing activities. While this is an alarming result, it did reflect that the experiment period was short considering ordinary day-to-day variance in electricity use.

Meanwhile, during the fourth week, only 2 out of 6 families used the emissions trading system. 10 participants commented that the target reduction levels were so easy to achieve that there was no need to resort to emissions trading. This points that these kinds of presentation need appropriate "parameters" same as video games (in this case, target levels, effect of actions and currency allowances).

## 3 Discussion

### 3.1 Types of expressions

The case study on Persuasive Art shows that animate(="live") thing is an appropriate expressions 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 is a negative") are more capable of evoking emotional engagement. Tan and Cheok showed that a real creature is found to arouse more empathy than a visual creature in [9]. However, especially in Japan, people feel empathy also to virtual creatures. Fujinami presented that

Japanese users feel empathy for even virtual creatures represented as abstract symbols in [5]. We sometimes assign different meanings to a real creature and a virtual creature because we know the differences between them. We need to investigate the effect of virtual creatures as a persuasive expressions 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.

### 3.2 Social facilitation and expression

In order to produce intended effects of social facilitation, not only is it important that showing current status of other participants, but it is also important where the display is placed. In the EcoIsland, the application installed in each family was used by all family members from the third week. That was why all displays were placed at their living room. This situation helped social facilitation go smoothly because participants could accessed the displays easily and that was conducive to conversation with the family about their playing styles and an environmental issue. Oppositely the Persuasive Art was designed for single use and we assumed that the display was placed at participants personal room. However several participants placed the display at their living room and their family members began to comment on the expression 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 an ambient intelligence environment, we have to consider not only about the application itself, but also where the application installed and whether social facilitation works.

Moreover, due to the privacy issues, expressions of applications 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. As we showed in the Persuasive Art, number of user's steps was converted to growth of a tree. By using this, the user can 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, and cannot see the actual data.

When we think about applications which do not deal with privacy issues, it is still unclear whether expressions should be abstracted or not. There are some very close systems to ambient lifestyle feedback systems. Playful toothbrush [2] shows virtual teeth representing the current sta-

tus of the user's toothbrushing. Calorie-Aware Cooking [3] 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. It is not sure whether the system can motivate users long time.

## 4 Conclusion

In this paper we introduced some key factors for applications in an ambient intelligence environment. We will need not only applications for office productivity but also applications for life enrichment in the near future. We believe that these key factors will be more important at that time.

However the difference of detailed and abstract expressions is still unknown. We will distinguish the difference by conducting additional user studies applying two different expressions. Moreover, we will polish findings from the case studies to develop a concrete guideline or framework for designing applications in an ambient intelligence environment.

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