Designing for Persuasion: Toward Ambient Eco-Visualization for Awareness

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Abstract. When people are aware of their lifestyle's ecological consequences, they are more likely to adjust their behavior to reduce their impact. Persuasive design that provides feedback to users without interfering with their primary tasks can increases the awareness of neighboring problems. As a case study of design for persuasion, we designed two ambient displays as desktop widgets. Both represent a users' computer usage time, but in different visual styles. In this paper, we present the results of a comparative study of two ambient displays. We discuss the gradual progress of persuasion supported by the ambient displays and the differences in users' perception affected by the different visualization styles. Finally, Our empirical findings lead to a series of design implications for persuasive media.

Keywords: Persuasive Technology, Eco-visualization, Sustainable Design, Ambient Display

1 Introduction

In designing persuasive systems [7], particularly for sustainability-related issues, human-computer interaction researchers often draw theories from behavioral psychology [3]. Such behavioral psychologists have studied the stages of persuasion in which an individual gradually modifies bad habits to desired status [5, 11, 13]. For example, Prochaska et al. suggested that at the first stage, *precontemplation*, individuals are unaware or "underaware" of the problems, so they have no intention to change behavior [13]. Moser et al. addressed that the internal (psychological and cognitive) barriers prevent a person from understanding the issue (causes) or seeing the relevance of climate change impacts or solutions to one's daily life [11]. For the initiation of internal motivation, De Young empathized direct experience, personal insights, and self-monitored feedback [5]. However, previous design research has not been typically concerned what would be the appropriate media, strategy, and user interaction according to the stage at which the system is targeting. In contrast to the existing design suggestions that do not specifically concern the graduate steps of persuasion, we present persuasive systems that provide unobtrusive feedback on micro-activities, thereby allowing self-monitoring of energy-use behaviors for those who need to raise awareness in the pre-action stages.

Ambient display is defined as an information system that *displays information that is important but not critical, can move from the periphery to the focus of attention and back again, provides subtle changes in the environment*, and *is aesthetically pleasing* [12]. As an example of ambient display, Mac widgets provide information from a focused domain within its small size and appear with low distraction for checking by user poll. In this sense, we chose Mac widgets as the application of ambient display, which has a potential to be a pervasive and amiable system that makes users become aware that their ordinary actions are related to environment issues.

Our system also intersects with the field of eco-visualization [10] because the ambient display of the system visually represents energy use in order to promote positive and sustainable behaviors. However, they have not yet proven what are the better ways of eco-visualization of sensed data even though there are various forms of representation methods such as text, pictures and diagrams in the field of information visualization. The empirical evaluations of the effectiveness of persuasion, especially comparative studies of different visualization techniques, are not much published.

In this study, we designed a comparative experiment to understand the effect of different visualization styles in persuasive media. In particular, we contrast an iconic representation with a numerical approach. We created two ambient displays using Mac OS dashboard widgets [4]: *Coralog* (Figure 1) and *Timelog* (Figure 2). We then deployed them for a two-week user study with 52 participants. Our study explores, in the specific domain of sustainable design, how persuasive media can create change in user attitudes. Both qualitatively and quantitatively, we examine how the different visualization techniques used in each widget affect the users' perceptions and awareness of their own activities, creating the potential for behavior change.

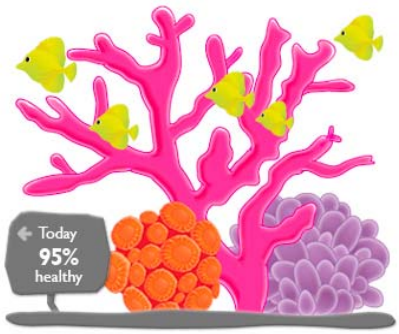

Fig. 1. Coralog: An example of iconic representation

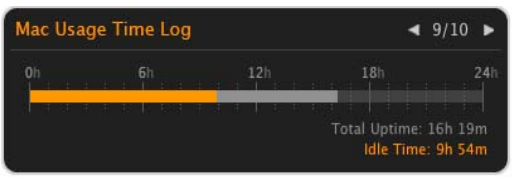

Fig. 2. Timelog: An example of indexical representation

2 Experiment Design

We created two Mac OSX widgets called *Coralog* (Figure 1) and *Timelog* (Figure 2) for a comparative study with 52 users for two weeks. The users are divided into three groups–Coralog, Timelog, and now no widget as a control group. In this section, we describe the design of the two systems and the methods of the comparative experiment.

2.1 System Description of Coralog and Timelog

2.1.1 Data: Computer Usage Time

Both widgets bring the same data, allowing users to see how much time their computers are not in use when the power is on, but represent them in different graphical styles through a different recalculation. They show a user's two kinds of computer usage time–*total uptime* and *idle time*. We define total uptime as the entire time during which the computer is turned on. It does not include the time while the machine is in sleep modes. Idle time is considered the amount of time that the computer is turned on but a user is not actively using it. In our research, idle time was defined as the accumulated inactive time that is detected if no keyboard or mouse inputs occur for more than five minutes.

Mac widgets are designed to work only when the dashboard is called by the user to avoid spending CPU cycles on all of the widgets that run in it [4]. Therefore we had to implement a stand-alone application that detects computer usage time. The logging software does not require a user's active involvement. It accumulates both total uptime and idle time and saves them in external files on a daily basis. When a user runs Dashboard, the widget loads the external data and represents them.

2.1.2 Design 1: Coralog

For a metaphor of iconic representation, we attempted to discover objects or creatures that are scientifically related to real environmental changes but typically hidden from our everyday lives. While searching ecological changes impacted by pollution, we found out that coral reefs are currently being destroyed by the rapid increase in the amount of CO_2 dissolved in the ocean and the elevated sea surface temperatures. Those phenomena are partially caused excessive fossil fuel use, which is the biggest source of electricity in the United States [6].

The effect of environmental change (e.g., an increase in carbon dioxide levels and/or water temperature) will yield the following negative results on reef ecosystems. First, coral reefs turn white, which is called being 'bleached'. Second, coral skeletons are weakened by higher temperature and subsequent chemical reactions [9]. Finally, reef fish also can be exposed to danger because of the lack of suitable reef shelter. However, coral reefs and fish are likely to recover if the

environment anomalies persist for less than a month. We employed the feature of recovery as well as the three major aspects of coral reef damage in visualizing the real-time data into the instantaneously changing coral's health status (Figure 3). Here we list the logic of coral reefs and fish change that we considered in recalculating the raw data:

- The ratio of idle time to total uptime decides the condition of coral reefs.
- The coral reef change reflects the performance of the past: if the ratio of idle time to total computer usage time is smaller than the previous day, the coral reef will become healthier despite the increased accumulated idle time.

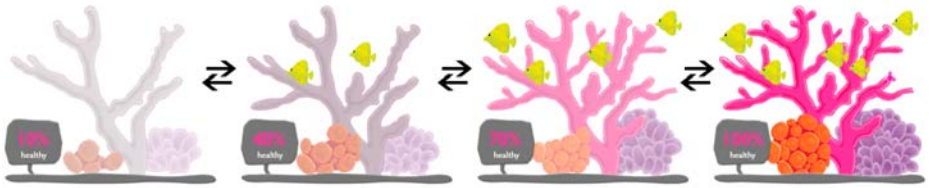

Fig. 3. Gradual change of coral reefs and fish according to the health condition

2.1.3 Design 2: Timelog

In contrast to Coralog, what a user sees on Timelog is the original log data without any recalculation or manipulation and the interference with the past days. For an *indexical* representation we used bar graphs, through which Timelog directly shows daily idle time and total uptime (Figure 2). On the rectangular-shaped widget, total uptime is shown in a grey bar, above which a green bar standing for idle time is overlaid. Finally, we added text labels to the bars to deliver the accurate value of the two detected times as the format of hh/mm.

2.1.4 History Review Function

We originally intended that users simply glance at the real-time status of the widgets, when they run dashboard. However, in our preliminary study composed of seven-day testing and a survey regarding the usage experience, users required a function for the review of past activity. They commented as following: "if there is something that shows the historic logs then ... maybe I can see the pattern of my usage" and "I'd like to see my usage everyday, not just 'yesterday,' 'three days' and 'a week ago'." To respond to the feedback from preliminary research, we added a function for history review up to seven days to the widgets. This feature of the review on the past activities is suggested as a persuasive design strategy, "Trending/Historical" by Consolvo et al. [3].

2.2 Participants

We recruited participants, who are active Mac OS X users (more than 2 hour use per day) through emails, social network sites, and word of mouth based. A total of 52 participants (52% male, 48% female) completed the 2-week study in August 2009. Participants represented a wide range of age from 18 years old to 47 years old and occupations including a graduate student, engineer, web designer, biologist, economist, and housewife. Many of participants (71%) were heavy computer users who had spent up to five hours a day. Most of them except 10 people had actively utilized and downloaded widgets for fun or practical uses. We distributed subjects to retain the range of age, gender and computer usage time even in all groups.

More importantly, we assigned active widget users who had been using dashboard at least 1 to 3 times a week to Group 1 and 2, since these two groups rely on the use of dashboard; 21 participants in Group 1 were provided with Coralog; Timelog was given to 20 participants in Group 2. We assigned the rest of the participants to a control group, Group 3, who installed only the logging software so that their usage time would be tracked but they do not have any visible clues of their compute usage time opposed to the other groups. The third group enabled us to compare ordinary computer usage patterns without any presence of ambient display with the one affected by the usage of the ambient display.

2.3 Methods and Process

We combined both quantitative and qualitative methods, which range from online surveys (one prior to the two-week experiment and the other at the end) to analysis of 2-week usage logs, and to semi-structured interviews. We expected the surveys and log data from each participant to derive descriptive statistics of the system usage. We also complemented these quantitative data with qualitative analysis to understand the underneath nature of each person's experience. The primary method used for the qualitative data analysis was a grounded theory [14] that allowed us to draw bottom-up findings based on the direct quotations from the two surveys and interviews, and to establish hierarchies and connections among the remarkable findings.

1. Pre-experiment Survey: Before they proceeded to install the applications, all participants completed the survey on a given online survey URL. The goal is not a description of the context of computer usage per se as seen in a previous research project [1]. Instead, we aimed to know their everyday computing habits that may influenced the experience and perception toward the tested ambient display.

2. 2-Week Field Experiment: At the beginning of the 2-week study, we provided participants with the logging software to all groups and either widget to Group 1 and 2. All participants were not informed where the log files were recorded on their machines until they were asked to send the files to the researchers at the end of the study. During the study, we did not force the participants to complete specific tasks. Instead, we merely informed how the widget works. The chronologically recorded idle time for the two weeks may provide the evidence of the possible behavior change on the individual level in semi-longitudinal manner. We hypothesized the decrease of

idle time while experiencing widgets would reflect the participant's attempt to change her or his habit of energy waste.

3. Post-Completion Survey: At the end of the 2-week use period, we sent participants notification emails of study completion. We requested them to send the recorded 2-week log files and complete the final survey. Our goal is to evaluate and compare the following concerns through the self-report based survey:

- Quality of visual design of widgets in terms of aesthetics
- User experience with the widget, specifically the frequency of usage, explicit usage and the attractive aspects
- Communication and visibility of the design intention by asking their impression and reaction to the widget

In addition, we asked about their current awareness of energy consumption. We did not include these questions in the pre-experiment survey because we intended to hide the research goal in order to keep the situation untampered with.

4. Semi-structured Interviews: We invited the five participants who showed distinguishable answers to the surveys from others. During the individual 20-minute interview over the phone, each interviewee discussed how their awareness and habits had been changed through the use of widget. The goal of the interviews was to unpack what we had not been able to find and predict from the other methods.

3 Results

We obtained the 47 complete data sets (G1=17, G2=16, G3=14) at the end of the experiment, and the interview result with five participants. Each set is composed of the daily idle time and total uptime during the fourteen days and the two completed surveys. Our analysis showed the participants' increased awareness in general and each individual's varied and gradual persuasion toward behavior change. Besides the general effectiveness of ambient display for early persuasion, we present the result of the detailed comparison of the two widgets.

3.1 Increased Awareness through Persuasive Medium

The post-completion survey explained that the participants had become more interested in their computer usage habits after the study ($t=5.89$, $p<0.001$). The qualitative analysis also supports the findings and delineates the process of persuasion. The analysis of individual data showed that each participant displayed a different reached level of persuasion. We roughly categorized the widget users into three according to the reached level of persuasion–those who 1) showed the level of awareness, but not action of behavior change, 2) tried to modify their habits, and 3) appeared not to be motivated, who were mainly Timelog users.

3.1.1 Awareness of Micro-activity

While seeing the change of the coral reefs or the bar length, they became curious and tried to find a solution to turn the status back.

"I thought that's a bit sad (…) it reflects back on my behavior using the computer (P37, Coralog)."

A real-time feedback of a single device usage was appeared to be benefit to acknowledge the otherwise ungraspable effects.

"I never gave a thought to how much electricity my Macbook uses, but it isn't that I don't care. So if an easy-to-understand tool like this can help me track it, I would try and conserve energy. (P14)"

"Bringing something that is hidden and not so obvious to the front of our minds helps change behavior. (P42)"

3.1.2 From Awareness to Behavior Change

The more the participants became aware of their micro-activity, i.e., computer usage habits, the more they were motivated to change their habits, and finally some of them start action ($r=0.539$, $p=0.003$). 10 of 33 (30%) widget users answered that they actually had taken action of behavior change beyond the stage of awareness ($t=5.217$, $p<0.001$). They tried to change behavior explicitly by using sleep mode or turning off more often in order to returning to a better condition. The interview with a user who had not been cared about computer idle time at all also strengthened the result.

"My first thought was I wanted to try and reduce my total idle time, or in other words, make use of my computer when it's on and put it to sleep if I'm not with the goal to make the most of the energy I use. (P42, Timelog)"

"I tried very hard not to kill coral logs, I constantly kept checking it, it was even stressful. (P36, Coralog)"

"Just showing my computer is good. I can actually do immediately. (P3, a Coralog user who had no initial interest in her computer usage habit)"

3.2 Emotional and Retrospective Engagement in Eco-Visualization

Two experimental groups exhibited different patterns of engagement as they gained awareness of energy consumption. Quantitative analysis showed the level of engagement through the frequency, purpose, and intentionality of viewing widgets. Among the total 33 widgets users, 26.5% self-reported that they ran Dashboard more often than they had before the study. The trend of checking frequency–or how often they access the widgets–was different according to the group ($\chi^2=13.504$, $p=0.001$). 52.9% of Coralog users reported an increase. By contrast, no Timelog users reported an increase of dashboard usage at all. Both groups' primary reason to see the widgets was to check their computer usage behavior. 58.8% of Coralog and 31.3% of Timelog users accessed the Dashboard explicitly to see the experimental widget; others described their habit "glancing at" it while they used other widgets on the Dashboard. We also explored other factors of engagement such as aesthetic appeal and the perceived functional benefits of each representation style.

3.2.1 Emotional Attachment to Scientifically Related Images

All 17 Coralog users recognized that the coral reefs were damaged due to the increase of the idle time. At this negative change, 82.3% answered they tried to reduce idle time intentionally to save the coral reefs. The iconic representation helped make a connection between the presented information and the effects on real world. Conversely, when facing the increase of idle time through the lengthened bar on Timelog, 87.5% of Timelog users did not express the desire to change their behavior (χ^2=16.70, p=0.001).

> *"It was an interesting application, but hardly motivating to save more energy. (P28, Timelog)."*

Many Coralog users expressed emotional reactions using subjective words such as *guilty* (P5), *frustrated* (P8), *sad* (P37), *stressed out*, *felt pressure* (P36). In reaction to their attempts to repair or recover the coral state, they used subjective but positive expressions such as *happy* (P8), *encouraging* (P17), *felt good* (22), *glad to see* (P23), and *relief* (P34).

3.2.2 Numerical Data for Informative and Retrospective Purposes

Timelog users did not show considerable awareness or potential behavior change. The major reason for this was that they could not immediately match the reported usage time to an exceeded threshold for electricity consumption. Upon the change in idle time, they did not react emotionally, but impartially. They perceived Timelog as a functional utility for tracking usage time rather than an assistive application for reducing energy consumption.

> *"I had considered the log data more as reflection of my daily behaviors. Maybe I would pay more attention to the application if it displays exact amount of energy I consume (comparing to average use) (P4)"*

> *"It doesn't mean anything to me if I don't know how that uptime and idle time affects either my electrical bill, even Mac battery, or anything. (P25)"*

> *"It means I've been on the computer a lot. I was impressed that I was on the computer 11 hours one day. (P38)"*

35.2% of Coralog users wanted to see numerical data expressed either as electricity used or monetary expenses for a further motivation toward energy conservation. However, their requests did not indicate the dissatisfaction with the iconic representation. Instead, the qualitative analysis explained that numerical data might help users to understand the correlation between the users' unconscious behaviors and the changes in coral reefs imagery, thus resulting in higher awareness. In addition to the higher awareness, the numerical data helped set an explicit goal of energy conservation, so that users were more likely to change their behavior.

4 Discussion

The result of our study answered the two research questions: ambient display can boost the awareness of their everyday and micro-habits, so they are motivated to change them. Iconic representation through scientifically-related metaphors simulates emotions than numerical data do. In addition, the comprehensive analysis delivered a number of implications and benefit in HCI and interaction designers designing ambient display for persuasion. Here we articulate the four design requirements for raising awareness derived from the analysis of result. We also argue the design opportunities for the later stages of persuasion that may encourage further behavior change. We also include the aspects of the systems that need technical enhancement for persuasive empowerment.

4.1 Design Implications for Early Stages of Persuasion

We have come to a set of design requirements for ambient display focused on the early stages of persuasion. These principles are grounded in the theories for persuasion the findings from our comparative study. We hope that a number of implications reported in this section will be the ground of design that promotes behavior change.

1. Minimal domain for focused awareness and immediate trial of modification: We focused on micro-activity as opposed to collective usage, such as in an entire residential building. The results supported our intuition that a focused domain was effective making people become aware of otherwise ungraspable habits. When they check the immediate result of a small range of activity, they find the reasons easily enough to start action immediately. Other research that stressed immediate feedback and depth-based learning [15] support this design requirement.

2. Non-disturbing and subtle indicator for tracking: Mac widgets are designed to be ignored by default and displayed only by bringing the Dashboard to the foreground. While viewing the Dashboard, the users did not feel distracted regardless of whether they checked the tested widgets intentionally or simply glanced at them. We might consider designing a more non-distracting system such as a background image of upper menu bar on the desktop, so that users do not even have to take a specific action to see the feedback. As long as the system does not interfere with primary tasks, a subtle visual notification via color or shape change would be also effective.

3. Visual fun and rewards through iconic and aesthetic representation: Iconic images helped people understand the relationship between their actions and subsequent changes to the population of creatures that are sensitive to pollution. We also found that people responded more emotionally to the recovery of the coral reefs than to their destruction. The feedback for rewarding and encouragement should be 1) visually pleasing but not too abstract because it can provide a correlation between the action and effects. In addition, the feedback should encourage more when people behave well.

4. Accurate data from real users through non-intrusive sensing: To make users aware of the problems caused by their own activities, we should provide them with

data about their own activities rather than general collective information about others. We also suggest that the system should not bother users by creating specific tasks merely for data gathering. The users should be exposed to the same environment while experiencing the persuasive medium, especially when they are not prepared to make changes or even aware of what needs to be changed.

4.2 Targeting the Later Stages of Persuasion

User engagement with a system is connected to the reaction to feedback. and to the level of persuasion. Here we discuss several aspects of persuasive media that encourage stronger engagement that may lead to action. We also propose possible technical enhancement to our designs for persuasive empowerment.

4.2.1 Personalized feedback and suggestion for initiation of action

Some users did not show a considerable behavior change in terms of the decrease of idle time. We suspect that the reason that users did not show a clear behavior change during the 2 weeks was the fact that the system did not give personalized guidance beyond the repeated feedback. A further advice system reflecting personal factors such as the level of self-motivation might lead them to more immediate action. Not only a timely suggestive feedback, but also a reminder of previously recorded habits would be useful for correcting negative behaviors.

4.2.2 Self-monitoring for maintenance of targeting state

Participants who considered themselves already very knowledgeable about environmental issues still thought Coralog was intriguing enough to help with their self-monitoring. Coralog helped them make sure to use sleep mode when away from the computer. This reflects that ambient media could be useful for the latest stage of persuasion, i.e., maintenance through self-monitoring for pursing the desired lifestyle.

4.2.3 Leveraging network or social media

Previous research discussed the role of the social world intersecting personal lives in designing for sustainability [15]. Our participants also suggested that social networking could help. For example, users wanted to share their stats with family members, creating an environment of mutual encouragement. Combining social media and ambient display would benefit goal-oriented tasks in a larger context of community.

4.3 Enhancement Opportunities of Our Design

Although the logging software detects *the data from real users* and the widgets represent the data, our system has limitations. Since idle time in our system is determined as no happening of mouse or keyboard input more than five minutes, it does not distinguish from the net *not-in-use* time. When participants found that their background operations such as running simulation for a long time and playing music

or movie was not accurately reflected, they tended to lose motivation while oppressed against their primary tasks.

Some participants desired to see the real electricity usage. In fact, we tied to show the actual electricity usage on Timelog, because this request was obtained from the preliminary user study. However, the electricity consumption is varied according to the various contextual factors such as the model of computer, power plug/battery and sleep mode/turning off. If a more elaborate technology that can distinguish such context were embedded, we could expect more effects on awareness.

Since our study focused on the early stages of persuasion that needed the increase of awareness, the duration of several weeks was reasonable [2]. However, if a researcher wants to evaluate the actual behavior change and the possible maintenance, a longitudinal field research of around three months will be required [3]. We expect future persuasive ambient display that incorporates our suggestions such as personalized and narrative-based feedback would yield more behavior change, which will be appropriate for a longer user study.

5 Conclusions

We developed two ambient displays with which we performed a critical study with 52 participants. The result supported our arguments that ambient display is suitable for persuasion without obtrusive feedback. Also we found that iconic and metaphorical images triggered more awareness and motivation for future behavior change through emotional attachment, while indexical representation was good for informative and retrospective purposes. We expect the newly created good habits through experience with the widget may extend to cover other usage of appliances. It also may stimulate the interest in environment issues in a macro sense as an informal educational medium. Our research contributes to the intersection of persuasive design and ambient display in HCI research. We also lay out a series of design principles coupling persuasive theories and the findings from our comparative study.

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