Eco Planner: A Tabletop System for Scheduling Sustainable Routines

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Abstract
This paper presents Eco Planner, a tangible system that aims to encourage users to behave more sustainably. It is based on a tabletop system showing a tabular view on which users can manipulate tokens to express and observe information about their daily routines and associated consumption levels and environmental affects. It is designed to support long-term engagement through a prolonged behavior change process and support high-level group activities such as achieving sustainability goals at the level of an entire household. It argues that these qualities are valuable but poorly supported by current eco-feedback systems. This paper covers the design and implementation of Eco Planner and concludes by discussing the evaluations required to validate these claims.

Keywords
Tangible interaction, sustainability, eco-feedback.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Energy consumption is an integral part of "the routine accomplishment of what people take to be the 'normal'

ways of life” [6]. Such mundane, domestic activities are directly responsible for 28% of the U.S. energy consumption [8]. Although people are increasingly concerned with the consequences of living in an unsustainable society [2], most remain unaware of the impact of their activities on the environment and of the frequency in which they engage in high-consumption behaviors [8]. One reason why everyday behavior is rarely energy-sensitive is because most users lack a sense of the amount of energy and the specific appliances they operate (apart from heating/AC). Users are typically also unaware of the nature and impact of the default configurations preset on their appliances [6]. Prior research has also indicated that habit plays a leading role in guiding energy-consumption behavior. It also suggests that altering habitual consumption practices is a key task as even slight modifications in seemingly arbitrarily but well-developed routines can substantially reduce consumption [6]. Taken together this literature suggests that users are unaware of the relationship between their behaviors/routines and their energy consumption, and that small changes to these patterns can have significant impact.

Figure 1. Two examples of ambient displays for real-time feedback on water consumption – UpStream [8] (top) and Waterbot [1] (bottom).

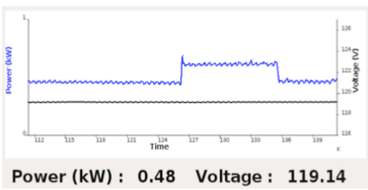
There are diverse efforts in the HCI community to leverage this situation and prompt behavior change. In particular, research on eco-feedback technology ranges widely from ambient displays ([e.g. 1, 9]) to traditional graphical interfaces ([e.g. 2, 7]). Within this space, many authors have proposed systems that sense consumption via custom electronics or smart metering systems and then promote awareness of energy and water use (e.g. see Figures 1 and 2). While it has been shown that such systems are effective in reducing consumption in the short-term [4], few are in widespread use. This paper asserts that one key reason for this is that such devices lack the ability to keep users interested in energy-saving activities in the long term; that after an initial phase of becoming accustomed and acclimatized to the devices and feedback, users’ interest will drop and dampen and the systems will become ineffective and eventually ignored. Moreover, this paper points out that while these systems effectively and intentionally support micro-level actions, they do not deal with more meaningful higher-level goals, such as coordinated group efforts aimed towards realizing a sustainable household. These assertions are explored in the subsequent section that reviews current eco-feedback applications from the perspective of motivational theory.

The paper then moves on to present the design and implementation of Eco Planner, a tangible user interface (TUI) designed to address these issues. The motivations for this are two-fold. Firstly, this paper suggests that a tangible, physical interface may keep users’ attention and interest for longer than traditional eco-feedback systems [10]. Secondly, it argues that the persistence, accessibility and visibility of a tangible interface installed in a shared home space will be ideally suited for the coordination of sustainable activities within a household. Supporting such high level activities provides rich, diverse and relatively unexplored opportunities for realizing energy savings. This paper closes with a description of the issues that need further work prior to evaluating the Eco Planner concept in the lab and field.

Related work

Ambient displays

The WaterBot [1] and UpStream [9] systems provide users with ambient feedback regarding their water



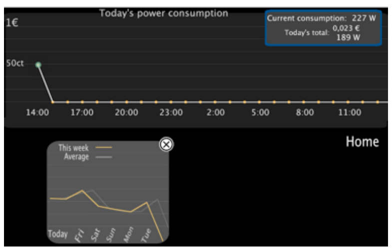


Figure 2. Graphical interfaces for two systems using *smart meters* to measure energy consumptions [2, 7].

consumption. Installed on faucets, taps and showers in users' homes they provide clear, immediate, simple and calm information relating to consumption – for example by displaying different colors (green to red) for consumptions from slight to extravagant. However, they are typically examples of ambient eco-feedback in their limited scope. For example, they do not support meaningful behavior change activities such as: (1) goal creation, commitment, and tracking; (2) comparing current performance against past performance, or the performance of others; (3) publicly committing to sustainable actions. These displays also offer no incentives or rewards for green behavior.

Graphical User Interfaces

Another prominent *eco*-feedback technology combines smart meters and interactive graphical displays ([e.g. 2, 7]). These systems normally consist of either a single sensor in the house's circuit breaker box (sometimes requiring professional installation), or several sensors distributed around the house (e.g. electric outlets, appliances). Interactive displays typically present users with complex, data heavy graphs regarding their household's consumption. Although offering more flexibility than ambient displays, these systems are similar in some ways: they typically offer little interactivity, lack incentive systems and do not attempt to support goal management or comparisons within a household. However, unlike ambient displays, such systems also fail to provide real time feedback – the displays are distant from the point of consumption. Moreover, it has been reported that when users become aware of the relatively low costs of appliance use (even with cumulative data), they can lose interest in conserving [6].

Transtheoretical model

Most eco-feedback applications rely on a "one-size-fits-all" solution, providing the same feedback to different individuals, with different motivations, beliefs, and attitudes towards sustainability. The transtheoretical model, however, argues that behavior change is something that occurs through five sequential stages: pre-contemplation; contemplation; preparation; action; maintenance; and relapse [3]. It suggests that the motivational cues required to support users at each stage are different. Therefore, an eco-feedback system intending to leverage this model needs be rich and flexible enough to offer a range of feedback as a user progresses through the stages. Few current systems attempt to achieve this level of sophistication.

Eco Planner

Eco Planner is a tangible system intended to address some of the weaknesses of current *eco-feedback* systems. Primarily, it aims to keep users motivated in sustainable actions in the long term via an engaging physical interface. Furthermore, due to the physicality and visibility of the tangible elements it aims to facilitate understanding and coordination of activity between users in a household.

Eco Planner is composed of a set of tokens and an interactive tabletop interface. Each token physically represents an activity (e.g. watching TV, doing the laundry), and users can collaboratively create their household's routine by laying the tokens on the tabletop. The 2D space of the tabletop represents a day of the week (from 7am to 11pm), so tokens placed closer to the left will represent activities completed in the morning, while tokens placed closer to the right will represent activities performed at night. Likewise,

Figure 3. The Eco Planner prototype.

tokens that are vertically aligned on the tabletop represent concurrent activities. Additionally, small objects (*pyfos*) representing 30 minutes can be aggregated in front of the tokens. These are not recognized by the system, and serve only to help users create a more complete and understandable routine. Also, by placing a token on a specific area of the interface, users can access different options for the activity (e.g. with the laundry token, users can choose to commit to always do the laundry with a full tank). Users are also able to choose between ecological or financial motivational cues, changing how the system interprets their routine and the recommendations it offers. Ultimately, Eco Planner directly captures and is able to understand users' routines. It can compare them to previous routines, and display advice on alterations that would be more sustainable (or cost less). Users are also awarded green points every time they commit to a more sustainable (or cheaper) routine. These points accrue over time, serving as both a metric for comparison and as a simple reward.

Eco Planner aims to successfully motivate users in a household to be more sustainable. It was designed to:

- Avoid user inconvenience and discomfort by supported self-paced routine changes.
- Support self-comparison, as new routines can be interactively compared to previous ones.
- Allow users to set and commit to household goals during the process of producing and adjusting routines.
- Make users accountable for routines, as they are continually in view in the configuration of tabletop tokens.
- Provide nominal rewards (green points), which can be used as comparison to other households. It has been shown that users positively respond to rewards, even if they are nominal in nature [4].
- Support discussion about and eventual agreement on appliances performance, usage patterns and their impact on overall consumption. By offering detailed information and a coherent baseline, Eco Planner develops group efforts toward energy conservation [7].
- Increase awareness of energy-conserving options in products. Users often ignore visible options, instead relying on habit and split-second decisions [6]. Eco Planner informs users of specific greener options on the appliances that are part of their routine, highlighting opportunities for meaningful changes.

Applying the transtheoretical model

Eco Planner was developed with the goal of motivating users to pursue sustainable activities across all five stages of the transtheoretical model:

- **Pre-contemplation**: As users describe their normal routine on Eco Planner for the first time, they get tips on what is not sustainable, and the consequences of such behaviors.
- **Contemplation**: Users can plan for very small changes on their routine (e.g. dealing with only one activity token), encouraging them to commit to larger sustainable activities in the future [3].
- **Preparation**: Eco Planner allows users to come up with different plans for their routines, allowing them to set goals and commit to them.
- **Action**: As users engage in their new routines, Eco Planning provides them with positive reinforcement

(through green points). Moreover, by allowing for interactive exploration and on the system's interface, users may develop intrinsic motivation to behave more sustainably [3].

- **Maintenance, Relapse, Recycling**: In order for users to maintain their routines they should be, first and foremost, intrinsically motivated. The natural and engaging experience possible with tangible interaction may encourage this. Users are also able to keep track of their progress (through the accumulation of green points), which may help them reinforce and reflect on their sustainable activities and behaviors [3].

Implementation

Eco Planner was developed under the Processing environment, using the reacTIVision marker tracking technology. It's composed of tokens representing activities constructed from Lego blocks and tagged with fiducial markers, and a multi-touch interactive tabletop (which uses rear diffused illumination to track the tokens and touch controls). Currently the system works without sensing and smart-metering systems, instead relying on a knowledge base of sustainable practices to generate content. This is used to generate text-based tips on how to create more sustainable routines, as the system compares when and how the user performs certain activities to optimal versions stored in the database (e.g. comparing when users drive their cars to known traffic patterns and impact data). Eco Planner is currently a functional prototype and is undergoing user interface design iterations.

Future work

This paper argues that due to the visibility, corresponding accountability, support for collaboration and ease of physical manipulation, an application using tangible interaction will be more likely than traditional eco-feedback technologies to motivate individuals to pursue sustainable practices. This claim is unproven and much further design, technical, and evaluation work will be required in order to validate it. This future work is discussed in the following section.

Design Issues

- The system relies on the easy manipulation of the physical tokens and on the unambiguous correspondence between them and the appliances and activities they represent. Design iterations could improve these aspects.
- The system models household routines. An important design improvement would be to support the mapping of particular activities to particular users.

Technical Issues

- Eco Planner currently offers day-by-day routine creation and visualization. Recent systems that can actuate token positions on a tabletop offer the potential of storing different routines for different week-days [5].
- Increase and validate the data on sustainable practices in the knowledge database.
- Incorporate sensing devices and smart metering systems so that discrepancies between the users' routines on the system and the reality of consumption can be compared.

Evaluation Issues

Eco Planner will need to be evaluated in both the lab and the field. Due to the size, cost and complexity of the system, lab studies are much simpler to execute

5than field deployments. Lab studies will also allow many of the basic system features to be tested and refined in a rapid cycle, but will lack the ecological validity of field evaluations. In contrast, deployments will take the form of 2-3 month case studies of individual families [e.g. 10]. Metrics will include quantitative measures of consumption and frequency of system interaction, subjective measures of attitudes and perceived performance and qualitative measures of how the system is used. This last category will explore the suitability of the application to coordinate sustainable actions within a household and the ability to keep users invested in sustainable activities for long periods of time. It will also consider how people use the tokens outside of the tabletop interface (e.g. handing tokens to members of the household to attribute responsibility over a specific task, leaving tokens around appliances to serve as reminders of commitments or goals) – such unexpected interactions are one of advantages of tangible interaction over other approaches to eco-feedback.

Conclusion

Eco Planner allows users to visualize and compare the impact of their daily routines on the environment, ultimately aiming to encourage more sustainable practices. This paper argues that, compared to other eco-feedback systems, a TUI might better maintain users' motivation over long time periods. Tangible interaction may also effectively coordinate sustainable activities within a household. In order to validate these claims a series of users studies and evaluations is planned. We anticipate that the results of these studies will be a valuable addition to HCI research in the domain of sustainability and serves as a meaningful new domain in which to investigate tangible interaction.

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