Exploring the Dimensions of Eco-feedback in the Wild

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***Abstract*— This paper presents our efforts in understanding the long-term effects of eco-feedback devices. Our work argues that lack of long term in the wild studies is a missed opportunity to understand how these devices are used after the novelty wears off. We build on previous work that showed a significant decrease in user awareness after a short period with a relapse in consumption, with the presented studies we aimed to investigate if new forms of feedback could overcome this issue, maintaining the users awareness for longer periods of time.**

Keywords—Eco-feedback; Sustainability; User Interfaces; Prototyping

I. INTRODUCTION

The effects of human energy consumption on the environment and carbon emissions started to be studied in the 60's and by the end of the 80's scientist drew a first sketch of how human activities were affecting the earth's temperature [1]. This issue quickly promoted a lot of discussion in the mainstream public as well as in world leaders, with initiatives as the European 20 20 20 energy strategy [2] or the Kyoto agreement aiming at worldwide commitment to sustainability causes. Residential energy use is responsible for 36% of the worldwide usage and 26% of the energy consumed in Europe. While is true that appliances are becoming more efficient, households own more appliances than in the past, and currently small appliances are responsible for more than 50% of the household consumption [3], [4].

If we consider that humans can control up to 50% of the electricity consumption in a building [1] the potential for savings if end-consumers reduce their electricity consumption is noticeable. Furthermore these figures mean that savings in this sector are significant in the worldwide energy consumption scenario. Therefore governments are pushing the deployment of smart meters which provide consumers feedback about their energy consumption [5]. Furthermore, studies have shown that consumers are in fact concerned about the consequences of their actions for environmental sustainability. However, they are also unaware of the impact of their daily activities and more importantly how they can change their behaviour to reduce energy consumption. This gap between users concerns and their actual knowledge of energy consumption habits, motivated companies and researchers to develop technologies that present users with information about their consumption. This type of technology is commonly called eco-feedback and is defined as technology that provides feedback on individual or group behaviours with a goal of reducing environmental impact.

In the scope of this document we define eco-feedback as an hardware or software system or any technology-aided intervention that informs or educates individuals about their resource consumption with the goal of reducing it. This includes not only systems that aim at reducing the energy consumption (e.g. the monthly bill), but also systems that try to move the consumption to different time periods, by educating consumers or automating activities in the house to reduce the impact on the environment. Generally eco-feedback devices promote savings between five and twelve percent [6], [7], and work better when displayed frequently and close to the moment of decision.

Currently eco-feedback is an already establish field which encompasses a significant amount of work from academia and industry. However changing individuals' habits is an altogether different and complex research topic with contributions from as diverse fields of psychology, engineering or economics. Eco-feedback researchers have built on the work from the abovementioned fields, and used different techniques to motivate consumers, techniques such using social pressure/incentive (e.g. [8]), displaying the effects of over consumption in nature (e.g [9]) or showing the source of electricity (e.g. [10]).

II. PROBLEM STATEMENT

Besides the positive developments, the effectiveness of eco-feedback is known to have problems. Peschiera reports that that after a certain period of usage of the feedback devices, user consumption relapses to values in existence prior to the study [11]. Holmes also reported this phenomenon in [12] where it was possible to see users gradually returning to their previous behaviours if feedback was less frequent or absent. We argue that the relapse effect holds great importance for the success (in terms of savings) of eco-feedback. It is however important to mention that this usage pattern has been reported in other fields (for example in consumer electronics), but we believe it holds greater importance in the eco-feedback and sustainability fields, since the 5% to 15% reported savings are only going to make a wide impact if this level of saving is maintained by a large number of people over long periods of time.

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Fig. 1. Interface of the systems used in our first two studies. Left: Home view of the Sinais Power Meter I. Right: Home View of the Sinais Power Meter II.

Surprisingly this relapse effect has not really been explored in eco-feedback research, nor is it acknowledged in the majority of studies reviewed in our research. A possible explanation is that most Human Computer Interaction studies with in-home feedback have been restricted to shorter periods (e.g [13]) to test single concepts, or used methods (diary studies or reports/interviews) that have required people to engage in or accomplish some tasks with the eco-feedback system, that has inadvertently, or not, resulted in people having to interact with the system with greater frequency that they might be willing to do in other situations (e.g. [14]). We argue that there are few studies that evaluate feedback systems "*in the wild*" within real homes with normal families, this necessity has been identified HCI researchers, not necessarily working on eco-feedback e.g. the research into the Wild workshop as part of ACM's Designing Interactive Systems conference (e.g. [15]).

Throughout the rest of this paper we briefly present the results of a series of real world deployments, which explored several strategies to motivate consumers to reduce consumption, in which we aimed at better understanding the long-term effect between real consumers and eco-feedback devices *in the wild*. We finalize this document by pointing out future work and opportunities for research.

III. RESEARCH STUDIES

A. *Sinais Power Meter I*

This was our first attempt at developing and deploying eco-feedback device. The device was designed based on an evaluation of commercial feedback system, Fig. 1 shows the home view interface of the *Sinais Power Meter I*. A 10'' notebook was used as the sensing and feedback device, it was placed next to entrance of the house and monitored the whole house consumption. Twenty-one families tested the system for nine weeks, overall the system promoted a 9% reduction in consumption. We also observed a steep decrease in the amount interactions with the system. After four weeks users started to pay less attention to the device. It is however noteworthy to mention that families with bigger consumption interacted more with the system and were also able to save more energy.

Fig. 2. Visualizations used in the *Sinais From Fanal* System. Left: The real time consumption is mapped in the clouds on the background of the landscape. Right: Animals and plants appear on the forest based on the usage of appliances.

B. *Sinais power Meter II*

A second study was conducted with an updated version with the system. For these study the front end of the system was completely redesigned based on an extensive literature review (see Fig. 1 right). Thirteen families tested this version of the system for one year (a sub-sample of the 21 families that tested the first version). This study further confirmed our observations from the previous one, families stopped to pay attention to the system, and some individuals even closed the lid of the laptop hiding the feedback altogether. The average consumption of these families remained unchanged from the first study.

These first two studies also revealed that system promoted discussion in the family about behaviours that affected the electricity consumption. For example the father in one of the families complained that the kids always forgot to close the fridge door properly: "*I saw high consumption and went around to see that the fridge's door was open ... they always forget to close it properly!*" (Family 7 Father, ref 1).

C. *Sinais from Fanal*

The experience gained from the studies described above disclosed that families stopped using the feedback system after a period of time, indicating that a different approach was required to overcome this decreased interest of users in the energy data. Motivated by the good results gathered from the literature review, when presenting consumption as the impact on the environment (e.g. [12]) we sought inspiration from art and nature, brainstorming ideas to change our strategy and implement a new eco-feedback mechanism. In this system the feedback was mapped to an image of a local landscape, here the real time consumption was displayed as the movement of the clouds in the background, and the electric appliances were depicted as animals in the forest, Fig. 2 displays these two interface views. Eight families tested this version of the system for a month, no change in consumption was observed, however this new version renew the interest in the system of families that used the other two versions. Even though families appreciated the aesthetic value of this version of the system they missed the concrete data presented by the older versions.

D. *WattsBurning* portable eco-feedback device

With the *WattsBurning* eco-feedback device we aimed at combining the concrete data from "traditional" feedback systems with the more abstract information presented at the *Sinais From Fanal* system. The experience from running the *Sinais From Fanal* study, made it clear that users found the feedback interesting, but they still wanted the concrete data about the consumption. In the *WattsBurning* system the real time consumption was mapped as a landscape of a well known local forest, the landscape changed its apparent health based on a comparison between the real time consumption and a baseline for that period (see Fig. 3 left). However users could access more detailed information such as numerical or graphical representation of their consumption (Fig.3 right).

For this study our sensing and feedback platform suffered a major update, the feedback was given via an android tablet and the sensing was made at the basement of the apartment building, covering all the houses from one point.

Fig. 3. Different views from the WattsBurning system. Left: Forest visualization of the electricity consumption. Right: Graphical representation of the weeks consumption.

Six families evaluated the system for 17 weeks, results showed that all of the families had a lot of interaction in the first 4/5 weeks of the study, however the decrease was not equal across all households with some households still using the system at least once a day until the end of the deployment. Overall houses in the study reduced their consumption by 2%, again we verified that houses that interacted more with the device managed to achieve a higher reduction in their consumption.

E. *WattsBurning in my mailbox*

With the *WattsBurning in my mailbox* study we employed the artistic feedback of the *WattsBurning* eco-feedback device as a public household energy consumption visualization. This experiment utilized the same households sample gathered for the *WattsBurning* system. At the time of this study the families were still using the digital *WattsBurning* system described above, while we added the public display component to it. Both studies were finalized at the same time. In this study families shared their electricity consumption by placing a set of magnets in their mailbox. Each day of the week had a particular magnet that when altogether formed a landscape of the island. Depending on the families' consumption the landscape would appear healthier or damaged, Fig. 4 displays the same mailbox at the beginning and at the end of the study. Our results showed that the task of placing magnets reflecting daily energy consumption outside of the houses was not considered too difficult or a burden by the families. When given the opportunity, children become the gatekeepers for the magnet update, and we observed that the magnets function as probes and awareness aids for the adults about their consumption. We believe that this can provide opportunities for children-oriented eco-feedback systems that are more playful and stimulate communication about routines and energy consumption patterns inside and across families.

IV. Conclusions and Future Work

Our work explored several dimensions of eco-feedback systems, form fixed to portable to public. Using concrete representation or metaphors. A common observation in all of our studies is that all of the participants learned something about a particular appliance or consumption pattern, this indicates a rise in the awareness about energy consumption, despite the level of usage or the change in overall consumption.

We argue that our long term *in the wild* approach allowed us to truly understand how families adopt eco-feedback devices after the novelty effect fades.

The next steps in our research aim at building on the emotional connection of users and the impacts on the environment by shifting the feedback focus not so much on

Fig. 4. : Public display used in the WattsBurning in my mailbox study. Left: Mailbox of one family at the beginning of the study. Right Mailbox depicting a landscape at the end of the study.

consumption as much as on production, in particular production of renewable energy. In the proposed study consumers will receive information about the source of their electricity (thermal, wind, solar or hydro), motivated by the literature results (e.g [10]) which report an increase in awareness and consumers knowledge. We believe there is space for research in the area of renewable energy displays as the state of the art in this area is limited to micro-generation scenarios. We plan to take advantage of unique set-up of the island in which no electricity is acquired from the mainland means that the grid operates on a "large-scale micro generation" set-up in which it is possible to know in real-time the exact quotas of each energy source being used.

V. References

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