SINAIS from Fanal – design and evaluation of an art-inspired eco-feedback system

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ABSTRACT
In this paper we present the challenges exposed during the designing, implementing and assessment of a novel eco-feedback system resulting from the intersection of human-computer interaction (HCI), and Digital Art. We explore how a digital art mode of inquiry can contribute to expose existing challenges in eco-feedback technology. Our new art inspired eco-feedback visualization, maps electricity consumption to effects on natural elements of the local natural landscape. The feedback was piloted with eight local families for four weeks. Reactions of the users were assessed through interviews and quantitative measures. Our findings showed that users found the mapping of the eco-feedback to artistic representations of elements of the natural environment somehow compelling, despite lacking of clear quantitative information. In conclusion, the conducted study provide useful findings and insights into future deployment of eco-feedback using artistic visualizations, information visualization and motivating behavior change.

Author Keywords
Sustainability, eco-feedback, digital art, emotional attachment.

ACM Classification Keywords
H5.2. Information interfaces and presentation: Miscellaneous.

INTRODUCTION
This paper describes the design and assessment of an eco-feedback system inspired by a digital art mode of inquiry. We used this approach to push the technical challenges emerging from a non-intrusive sensor-infrastructure developed under the framework of an interdisciplinary HCI research project. By implementing several artistic visualizations of the endemic laurel forest, we propose to investigate the effect of coupling information about energy consumption with natural elements of the local landscapes. Our goal is to leverage on the emotional effect of changes in the natural landscape visualization as a way to foster awareness about energy consumption and the resulting long-term effects such as climate change.

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Motivation
According to Dewey [1] art is fundamentally a non-linear process resulting in an experience that connects author and audience emotions (through aesthetic values) and critical points of view (concepts). The artist explores reality in an emotional way, though aesthetic and conceptual values and reaches its audience beyond what is rational - connecting directly with core life values of the public. This approach is hard to document, measure or replicate in a scientific setting. Our approach, in agreement with Gromala and Bolter [2], sees the main task of Digital Art as one to stimulate, inspire and move people, connecting to their moral, ethic as well as aesthetic and social values. In a way we envision the artistic approach as a complementary way of motivating people from the inside (intrinsic motivation) rather than from the outside (extrinsic motivation).

There is a substantial body of experimental and field evidence supporting the conflict between extrinsic motivation (contingent rewards) and intrinsic motivation (the individual's desire to perform the task for its own sake) [3]. Bénabou and Tirole reconcile the economic and the sociological views of intrinsic vs. extrinsic motivation showing how performance incentives can aversively impact the individual perception of a task, they conclude: "incentives are then only weak reinforcers in the short run, and negative reinforcers in the long run" [3]. Our approach builds on this evidence leveraging emotional attachment and mappings between the daily actions affecting energy consumption and the long-term effects like climate change.

Recent scientific as well as artistic explorations of trees and their energetic fields [1] [2] have created interest regarding the

[1] http://www.brighthub.com/environment/renewable-energy/articles/14779.aspx

[2] http://www.alternative-energy-news.info/power-from-trees/

themes of sustainability and raised people's awareness about the effect of careless energy consumption on natural landscapes, forests and trees in particular.

Figure 1. Laurisilva Forest Landscape in Fanal, Florestal site of Madeira Island - Portugal

RELATED WORK

Most people are concerned about the consequences of the modern unsustainable lifestyle but are also unaware of the impact of their daily activities and more importantly how they can change their behavior to reduce resource consumption. With the advent of new sensing technologies eco-feedback is considered one of the most effective strategies in reducing electricity usage in the home [4]. The advancement and availability of sensing systems for environmentally related activities (e.g., human activity inference [5]) and interactive displays to feedback this data (e.g., mobile phones) provides a rich space of prospects for new types of eco-feedback solutions [6].

Eco-feedback technology is defined as technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact [5]. The technology is based on the working hypothesis that most people lack awareness and understanding about how their everyday activities (energy and water usage, transportation and waste disposal) impact the environment.

HCI researchers have sought to bring the unconscious aspects of energy consumption to conscious awareness, thus making them available for sensible choice. On a seminal paper defining sustainable interaction design Blevis argues that sustainability should be a central focus for interaction design. Starting from the perspective that "design is defined as an act of choosing among or informing choices of future ways of being" [7] he discusses the role of interaction design in terms of design values, methods, and reasoning. Blevis extracts several design principles that should guide sustainable interaction and move the effects of design on the environment and sustainable behaviors [7]. Since then the literature from design, pervasive and HCI fields increasingly describes the various eco-visualization devices that have been constructed in order to make visible the flow of electrical energy and to highlight the amount of electricity consumed by a household (refer to [5] for an extensive survey). Others describe the ways in which social networking systems and computer-mediated communication have been used as means of supporting and motivating energy conservation and sustainable consumption [6].

However studies have shown that the financial incentives associated with eco-feedback devices are often too small to motivate behavioral change – between 5 and 15% reduction on average [8]. Dunlap [8] and Bostrom, et al [9] conducted a series of studies aimed at finding what people know and understand about global warming. They found that although respondents showed concern over the problem their knowledge and understanding was highly limited. Subjects participating in the surveys tended to confuse the processes involved (often having difficulty in differentiating between causes and actions) or offer highly literal interpretations. In particular Dunlap [8] found that these perceptions did not consistently vary across social levels and that most people were willing to admit their lack of knowledge and understanding.

More specifically in what concerns residential energy feedback, Pierce et al. [10] identified some inefficiencies. One of them was the baseline consumption that most users used as a reference not to make changes in their household but to rather maintain their behaviors. A second was the awareness and engagement that would not provide alone, the adoption of lasting sustainable behaviors. A third inefficiency was that actual and anticipated behavioral changes were not reasons for the adoption of new behaviors even though the users were aware of its high level of consumption. And finally, a fourth inefficiency consisted in the difficulty of fine-tuning consumption for conservation. These inefficiencies seem to gather a number of general obstacles that eco-feedback technologies seem to face in the initial phase when they are first introduced in the households.

Petersen et al [11] argue that pragmatist aesthetics is a promising approach for designing interactive systems as it promotes aesthetics of use, rather than aesthetics of appearance. Aesthetics play an increasingly important role in interaction design, in particular when designing for homes and everyday lives rather than for the workplace.

Also in the digital art domain efforts have been made in making people more aware regarding their behaviors in relationship to sustainability. DiSalvo [12] discusses how HCI researchers can understand the discourses and practices of ecologically engaged art as a means of enriching their own activities. He argues that an understanding of ecologically engaged art and the critical discourses surrounding it provides a new perspective for rethinking sustainable HCI [12].

In the artistic domain, digital artist Tiffany Holmes reports on her project "7000 oaks and counting", geared towards using eco-feedback in the form of energy consumption visualization situated in a building hall public space [13]. In

Holmes case, digital art is used to display hidden data of real time usage of key resources such as electric appliances in order to offer new strategies to visualize energy in the home and workplace.

Finally, Pierce and Paulos investigate the need to improve people's engagement with energy consumption. Coming from the fact that "energy has been designed not to matter to us" [14] they defend on time feedback technologies that raise cognitive awareness and motivate energy conservation behaviors.

EXISTING INFRASTRUCTURE: TECHNICAL POSSIBILITIES AND LIMITATIONS

The work described here generated from a sustainable HCI project called SINAIS (Sustainable Interaction with Social Networks, context Awareness and Innovative Services) In which a low-cost non-intrusive load monitoring (NILM) sensing system was deployed to study residential energy consumption.

The SINAIS sensor system is a simple low-cost netbook that reads voltage and current signals from the main power feed to detect and classify events at the appliance level. The netbook performs all the data acquisition and processing and is also capable of recording user events (movement and attention) through the built-in camera and providing local feedback by means of the built-in display (see Figure 2).

Figure 2. SINAIS low-cost non-intrusive energy monitoring system installed in the house setting

The netbook also communicates with a server sending data over the Internet to a data warehouse enabling statistical analysis of the aggregated data. This infrastructure was deployed in 30 houses for a long-term study of residential energy consumption. The preliminary results during a period of 9 weeks shows an overall reduction of about 9% of consumption [15]. When looking in more detail to the level of interaction with the eco-feedback system we found out that the group with higher interaction reduced their consumption in 6,4% while the other group only reduced 3,4%.

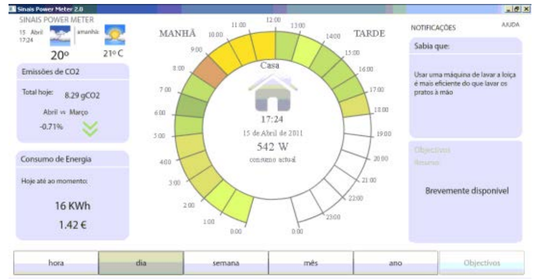

Figure 3. Previous eco-feedback visualizations tested in the SINAIS project

However, through previous eco feedback studies that we carried out (15, 18), we found out that current eco-feedback solutions based on simple qualitative and quantitative representations of consumption are not particularly effective in retaining people attention over time and motivating a long term behavior change based on intrinsic motivations. To overcome this limitation highlighted from the preliminary research we are exploring with different eco-feedback strategies like the one described in this paper.

SINAIS FROM FANAL – A DIGITAL ART INSPIRED ECO-FEEDBACK SYSTEM

Bolter and Gromala claim that any digital artifact is meant to change something in the user's relationship to their physical and cultural environment - otherwise there would be no reason to produce an artifact at all [2]. Starting form this premise we brainstormed and refined several artistic concepts that lead to the final system we named "SINAIS from Fanal"[3] after one of the well-known laurel forest sites in Madeira Island (Figures 1 and 4 are images of Fanal landscape and trees). A series of formal and informal brainstorming sessions between the artists and the researchers worked as the springboard for ideas. The research team presented to the artists several of the technical challenges with the eco-feedback. These span from simple visualization challenges – how to depict energy consumption from house aggregated to single appliance; to more complex research challenges – how social networking and goal setting affect behavior. The selected focus stemmed from the combination of work-in-progress projects related to digital art and sustainability [16, 17] and the existing SINAIS research and prototypes [15, 18].

The central concept exploited for "Sinais from Fanal" regards developing an eco-feedback visualization [16] centered on the local endemic forest landscape. Data from the energy consumption gathered from the SINAIS deployment is used to influence visualizations of specific laurel forest (or "Laurisilva") trees and landscapes. Those visualizations are displayed on private screens (in the selected homes) leveraging on the extraordinary beauty of the natural patrimony of the local landscape. The Island

[3] Sinais translates from the Portuguese to "signs" emphasizing that signs are sent from the Fanal Laurisilva site to the families through the eco-feedback visualization.

conserves the largest surviving area of primary Laurisilva, a vegetation type that is confined to the Azores, Madeira and the Canary Islands, now UNESCO world heritage patrimony (see Figures 1 and 4). This unique patrimony has been recently put at risk by natural calamities (Winter 2010 mudslides and Summer 2010 forest fires). These disastrous occurrences have raised awareness in the local population about the relationship between disastrous effects of climate change mostly related to carbon emissions from energy consumption.

Figure 4. Laurel trees in Fanal Madeira Laurisilva

Furthermore the connection between conservative consumption and natural landscapes is made even more effective by the sheer beauty of the laurel forest. This beauty inspires both artists, in creating powerful aesthetic visual experiences by using such a setting as material for the eco-visualization (see Figures 1 and 4) and the public who would engage with such visualizations crafted as esthetically powerful experience.

Interaction with the SINAIS platform

The SINAIS eco feedback platform [18], has three different levels of interaction with its users: it detect users passing by the computer through its inbuilt webcam. Passing by the screen, stopping and looking at it, will be detected by the camera of the netbook and signaled as a first possible level of interaction. Passing by the screen, stopping for some time, will be determined as interest in the visualization and in the consumption data and the system will record it as an interaction of second level. By touching the keyboard, the touchpad or moving the mouse the system will record an interaction of the third level and respond accordingly. In order to reflect on these different modes of interacting with the SINIS platform (see Figure 5) that correspond to different behaviors and intentions of the users we have re-designed the SINAIS eco-feedback as described in the following subsections.

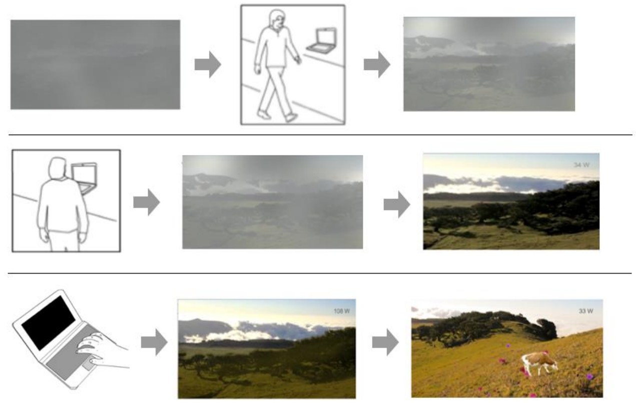

Figure 5. Different levels of engagement of users with the SINAIS eco-feedback system and corresponding response

Mapping eco-feedback visualizations to natural elements

The real challenge in the domain of eco-visualization is how to express the energy consumption to the users. In eco-visualization the typical strategy is to couple the data regarding energy consumption to different artistically driven media pieces. Hence, through multiple rounds of brainstorming we explored ideas about mappings that match and emphasize the aesthetics of the produced media and relating to the theme of natural elements of local landscapes.

On the effectiveness of eco-feedback an important design challenge emerged from the related and previous work. The challenge relates to the fact that negative feedback fosters a more immediate reaction from users that will consume less for the immediate but short time following the feedback, while positive feedback is known to be more effective over time as a means to achieve behavior change and sustained reduction in energy consumption [3, 19].

Keeping this in mind we have designed an eco-visualization feedback for the family members to stimulate them to check the system screens and gain an aesthetic pleasure, by being aware of the depicted energetic consumption, building of positive feedback rather than negative, and building intrinsic motivations to consume less based on the emotional connection to their local natural landscape.

Figure 6. Fog suddenly wrapping up a tree in Fanal

Fostering curiosity Through Fog Effect

Due to the specific weather conditions in Madeira it is very common for clouds in the high mountain to appear and generate a sudden fog that completely hides the surrounding for sometime (see Figure 6). This is a very specific weather phenomena of Madeira that residents clearly identify and connect to. The sudden fog can wrap the trees and animals in the surrounding landscape, to the point of not being able to see more than a few centimeters of distance. The thick white soft blanket can disappear as rapidly when the wind blows it out. We decided to use this phenomenon in the idle mode of the application of the eco-feedback to increase awareness (this is the default mode that is triggered after a some time with no interaction), therefore in the default mode of the visualization the Laurisilva landscape is fogged. Once the camera detects movement in front of the screen the fog starts to rarify. When a person stands in front of the screen for more than a few seconds the system detects that the user is looking at it, hence is interested in the content. The fog then starts disappearing and leaves space to a landscape (see Figure 7) that maps the current state of the energy consumption described in the following section. In this way, we aimed at encouraging people curiosity in finding out what lies behind the thick white layer of fog, and check the eco-feedback more frequently, by avoiding having the data exposed all the time.

Expressing Consumption with Moving Clouds

The artist produced a series of time lapses of moving clouds and shadows of the trees that capture the beauty of the landscape and add movement to the visualization. In this way the eco-feedback maps the energy consumption to a faster or slower frame-rate of the time-lapse, generating a mesmerizing visualization of a sea of clouds continuously moving in the sky just below the mountains where the Laurisilva thrives (see Figure 7).

The resulting hypnotic landscape media visualization can attract attention to both high and low consumption mapping, fostering awareness without inferring judgment. With this kind of mapping awareness about nature and its beauty is the message itself, in this way avoiding to convey negative feedback.

Figure 7. Frame from the video time-lapse with the moving clouds. The energy consumption is expressed as cloud movement

Mapping Appliances to Flowers and Animals

The SINAIS NILM sensor infrastructure enables a low-cost detection and classification of energy events. The system is capable of detecting power on/off events and also classifies those events at the appliance level (e.g. when the microwave was turned on and how much energy was consumed by that particular appliance). All of this information enables various possibilities in terms of the detail that can be provided via the eco-feedback visualization and feedback per appliance or group of appliances (kitchen, living room, etc.). The artists proposed to map the energy events and activities to the already complex, but yet very natural, elements of the forest and trees (see Figure 8).

In the final deployed prototype we chose to map the power events of different power levels to: i) flowers blooming in the landscape for low consumption events and ii) animals for medium to high consumption events. Figure 8 represents this mapping in action on the SINAIS platform.

DEPLOYMENT AND PILOT ASSESMENT

The SINAIS framework allowed the research team to perform two previous studies of eco-feedback [15,18]

Figure 8. Expressing power events as animals in the landscape. From top to bottom left to right, an increasing number of appliances are turned on and more elements appear in the eco-feedback

In order to evaluate SINAIS from Fanal system we deployed a prototype in a subset of the houses used of the previous studies. The selected sample for this study consists of 8 houses that were selected using the following method: The households were organized among 50% percentiles for energy consumption (low consumption / high consumption) and 33% percentiles for interaction with the system (low, medium and high interaction). To select a significant sub sample, the goal was to choose 2 houses from each group (totaling 12 houses). However issues such network coverage, and other technical problems limited the number of participants. Also some families opted not to participate in this last study. Therefore the low consumption/high interaction and high consumption/low interaction group had to be excluded, thus the final sample is composed of 8 families.

The SINAIS in Fanal prototype was installed in households during in the first week of Dec. 2011 and the study lasted for four weeks. Families were informed by phone that a new version was available. Only a general description of the new interface was provided. We wanted to infer the unbiased reaction of the users to the visualizations and explore how they would interpret the mapping without any prior explanation. Our system saves to a local database the interactions with the eco-feedback interface by keeping track of every mouse click and navigation between the different visualizations (direct interactions). Additionally the system also uses the webcam to detect and store when a user approaches the computer to check the consumption information (indirect interactions). The older version of the system also saved the interactions data in a similar format. Therefore it was possible to make a comparison in terms of the amount of interactions between the two versions.

Quantitative Assessment

After four weeks of the deployment we aggregated all the databases from all the households in order to check if the frequency or extent of engagement of the families with the system had undergone any variation.

Figure 9 Shows that the new version of the feedback raised users' awareness for the system. However if we look at the long-term effect (after the above mentioned 4 weeks) of this deployment, there is a noticeable drop in the in interaction between weeks 3 and 5 (consistent with our previous findings about the general users relapse [15]). A qualitative interview from the research team with the families explaining the eco feedback mapping in details, triggered renewed interest in the system and the interaction values peaked. Those values decrease in the next 7 weeks with a similar ratio as before the interview, pointing out to the next possible challenge with users and eco feedback, the fact that users stop interacting with the system usually 4 weeks even if any novelty or change has occurred.

Finally we investigated how families that were not in the study behaved in the same period. For this we selected 3 families (one for each percentile of the houses with the new version). In total this houses had 34 interactions with the system over the same period as the SINAIS from Fanal families study (4 weeks period). On average each house had 11.3 interactions. The houses in the study had 7158 accesses, averaging 1202 per house. Which means that in average houses with the SINAIS from Fanal prototype installed had 110 times more interaction than the others. We conclude that even thought the novelty effect was present the SINAIS from Fanal system raised users' awareness to the feedback device.

The installation of the new version of the system triggered in average less interactions when compared with the previous deployment. Despite that, houses with the new system had more interaction than the other ones still engaged with the older system during the same period. Like expected the response-relapse pattern was observed. However it was noticeable that 5 weeks after the installation the interactions increased abruptly. No change in the overall consumption was observed. Even if, it remains clear that the main goal of any eco-feedback system is to reduce energy consumption, nevertheless the focus of this assesment was understand in depth how users interact with the eco-feedback system, and in particular one which is more inspired to aesthetic values and intuitive visualization, instead of a more abstract one, provided with charts and numberred values.

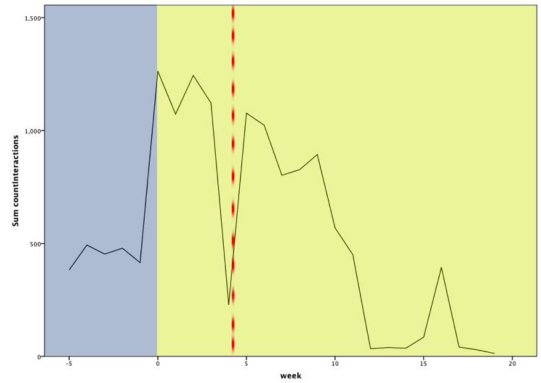

Figure 9: Sum of the weekly interaction with system before (blue) and after the SINAIS from Fanal pilot, the dotted line represents the date of family interviews.

Qualitative Assessment

In order to understand how families interacted and reacted to the new system in depth, we conducted an extensive qualitative study and analysis of the users. We interviewed 4 out of the 8 families exposed to the new eco-feedback. For simplicity we call these families F1 to F4, and specify their role inside the family. They all had children except one (F3). The children were not interviewed but sometimes cited by their parents. We will call husband and wife the couple without children and mother and father the other families. Parent's ages were between 30 and 47 years old (M=41) and children ages were between 8 and 16 years old (M=12,3). The semi-structured interviews lasted around 30 minutes per family. Interviews were transcribed and analyzed extracting recurring and relevant emerging themes and grouping them under three main categories: emotional attachment (EA), information visualization (IV) and attitude or behavioral change (BC). We will describe the collected and analyzed interview data below.

Out of the 4 families interviewed, two families (F3 and F4) recognized the landscape as local, by naming it: "It's Fanal" (F3, F4). The other two family members (F1 and F2) mentioned not recognizing the landscape because not paying attention to the visualization as shared by the mother in F2: "we didn't pay enough attention to it" (F2 mother). F2 mother also clarifies they were very busy lately and that: "This last month we were not so available to look at the system" (F2, mother). Moreover F1 father mentioned that the details in the visualization were not enough in order to be recognized: "I think we need to see the landscape with more detail" (F1, father).

We also found that families interpreted the visualization in diverse ways. Families F1 and F4, mistook the change to the new visualization for a technical problem: "At some point I thought it was broken" (F1, mother). Others also mentioned technical misconceptions "I thought the program was in stand-by" (F4, father). This made them (F1, F3, F4) keep coming back to the system to check it, as stated by this user "that's what I thought too. I thought you were working on something behind it" (F4, mother). One user thought the visualization was a screensaver (F4 wife).

Some family members (F1, F3, F4) were not affected by the positive feedback given by the visualization and would have liked to see more dramatic changes if consumption was rising beyond acceptable levels, "I assume that if there were more plants and animals, I was doing good things for the environment". On the other hand if the effects were tailored to negative feedback users might have got a better connection with their consumption behavior: as the husband from F3 says: "…and if the consumption increases the landscape will probably show desertification". [20]

All families felt the previous visualization provided them more information, was more clear and precise, and allowed comparisons, but did find value in this one and described it as more simple and aesthetically powerful but more difficult to make sense of, as confirmed by the following statement, "This one is simpler, there's just the image and the consumption on the right. The other one I could see the consumption in terms of the whole day and this was more elucidative. I find this one more interesting but we need some kind of heads up about how can see the consumption" (F3, husband). Only one family definitely preferred the previous version: "I preferred how it was before it presented the information using colors. It was more elucidative than this one. It was more attractive for us to look at it and could easily call our attention. Even for the kids, they would look at the other one more than this one" (F2, mother).

Families (F2, F3, F4) felt this latest visualization was incomplete in terms of the information provided but still somehow perceived the value of a more qualitative feedback, such as the mother from F4 says, "I can see there is a value there. But before this I could see the consumption per hour, per day and now there is nothing like that. I don't have a way to see the highest consumption moments or peaks throughout the day. I miss it, it's like the speedometer, and it's like I have been riding for this amount of time and here's the total so far" (F4, mother). As a result families (F3, F4) felt they reduced their interaction with the system "I would check the other almost everyday day. This one I didn't check it as often. Now that I think about it I didn't do it because there wasn't so much data as the previous one"(F3, husband) or even "I miss the graphs and the information as clear as possible. I checked the other one, almost everyday several times a day. I confess that now I rarely look at it" (F4, mother). But to note is that one family relates their lack of interaction with the new visualization to their decreasing motivation concerning general engagement with the whole eco-feedback trial, as shared by this Mother (F4) "We lost the interest in the device after the summer, and I feel this type of visualization might have made more sense in the first phase when we were motivated to learn about our energy consumption". Nonetheless, family members (F1, F3, F4) found the visualization to be of value and pleasant, therefore, they expressed clearly that they would maintain it if additional information was integrated as suggested "This one is more interesting but I feel there could be more information at the end of the day of the whole day on the lateral side of the landscape. So I could see the historic data of my consumption, see the consumption throughout the whole month, the whole week" (F3, husband). Note of mention is that the tested families had engaged with the system prior to the SINAIS from Fanal visualization for several months before installing this new one. They became used to checking their energy consumption through the previous visualization. The numerical and clear information format contained in the previous visualization was explained to them in details in order to understand their energy consumption. In fact, about this new system the wife shares: "I think its interesting having a landscape that changes according to our consumption and how much we use, however I need to have the data and the numbers" (F4, mother) and "I guess it could look like it is right now but it could be completed with the hour, day information (F1, father).

Most of the problems that the family members encountered with the system and why they failed to relate their energy consumption with the visualization was due to lack of an initial clear explanations about the interface mapping and changes. "I noticed some changes in the image, but I feel there were minor, and unless I was there for some time I would not notice them (…)" (F2, mother). Furthermore she adds: "This last month we were not so available to look at the system to have the amount of time needed to really understand the changes in the landscape" (F2, mother). Due to lack of clear information delivery the feedback visualization could easily be misinterpreted: "I couldn't relate it to my consumption. I assumed if there were greener fields and more plants and animals it was positive thing for me as I was doing good things for the environment" (F3, husband). Some users were focused on finding elements from the previous visualization or even confused: "No I didn't relate it to my consumption levels. I wasn't even near to realize that (laughs). I was looking for data, logical data about it (…) I could see some extra elements, I thought you were decorating the landscape but I didn't understand why were they being placed there" (F4, mother).

Overall, after the interviews we cleared that families exposed to this visualization seem to express a low intuitive understanding of the mapping but still connect to the aesthetic of the visualization portraying a natural landscape. The main issue raised by the users was that this visualization didn't accomplish its task of expressing the monitoring of the consumption as clearly as the previous one. Nevertheless only one family really stopped engaging with it "For me it makes no sense being there anymore. It stopped being useful for me. I was always expecting you would add data to it and not just the landscape" (F4, mother). All the other Families thought this visualization was interesting (visually) and innovative, although it didn't have the clarity of the previous visualization about their consumption, to which they got used to see through the previous deployment. These last families propose to have both eco-feedback systems working, as the landscape was more pleasurable to watch and the other one more informative in the details of their consumption: "I think both are valid. Maybe there could be a symbiosis between the two. This one is more pleasant the other one is just data. What matters to me is to have the data, it's probably the most important for me. However, I like the way this one is presented, I think it's more interactive than the other one"(F3, husband).

Families (F1, F3, F4) suggested the two visualizations could be merged to provide the information they need as well as the aesthetic pleasure of the natural landscape: "I like the landscape, and the place it is. I find it interesting you used it. But I feel like you need to be straight with people, have clear information, you are consuming this much, you need to change this and that. Maybe there is a way of combining these two concepts, data and a landscape. I am not sure how. Maybe the grass could become greener as you consume less or redder as you increase consumption" (F4, mother). Another suggestion would be to divide the information per visualization: "maybe you could use this one to show the day, and the other one to show the week and month information" (F1, father).

The multiple suggestions of how to keep the natural landscape interface and merge it with the quantitative previous one shows clear general interest and engagement with the SINAIS from Fanal eco-feedback and points out clear directions for future work and improvement. We will outline the system refinement based on the users feedback in the next section.

REFLECTIONS AND FUTURE WORK

Art practices have a critical function in our world and can function as inspiration for scientific and technically driven research, such as HCI. Digital Art reminds us that interfaces don't just have to be windows into new perspectives but can also function as mirrors to our actions, and make us reflect on our mundane behaviors[2]. By coupling Art practices and HCI we have stimulated a reflection that goes beyond traditional eco-feedback and tries to tackle important problems with this area of research, in particular the function of aesthesis in motivating people and fostering intrinsic motivations to act according to our ideals and values. This work proposes eco-feedback to go beyond a window for energy consumption into a mirror of our goals to live and act sustainably with an increasing emotional connection between our daily actions and the long-term effects in the natural environment. The pilot described here raised many important findings and critiques on a new form of eco-feedback but also pushes us to reflect on the role of art as inspiring critique of technology, science and the process of research itself.

Lesson learned: insights and refinements to the system

After collecting and analyzing the data from the qualitative interviews we collected a series of findings and insights regarding the design and deployment of art inspired eco feedback visualizations. In order to facilitate the intake and re use of the findings, in the section below we group these findings in terms of three categories emerging from our analysis: emotional attachment, information visualization and attitude or behavioral change.

Emotional attachment

From our study we learned that leveraging on the emotional attachment of the feedback users with elements of the natural environment is a potentially powerful way to raise people's sustained awareness for their energy consumption, The qualitative assessment confirmed that people appreciate this type of mapping and the quantitative data confirms increased interaction with the eco-feedback system. However some major issues have risen regarding the choice of the landscape, not always recognized as local, and the meaning of the mapping of the energy to the visualization. Our findings suggest that additional care should be taken when choosing the natural elements to make the emotional connection more clear. A potential improvement would be to test or work with the users themselves and choose together the natural landscapes or images that could guarantee a more effective emotional connection. Finally the fact that users found the landscape pleasant can be explored further by implementing a similar solution in a tablet device that would resemble a digital portrait or a picture to showcase on the wall or a prominent site of the house. As it stands in fact the system is hidden, usually situated nearby the sensors for the electricity and hence far from being visible in the commonly inhabited spaces of the house, while most of the users found the visualization aesthetically pleasant. Position the visualization in a more prominent place, such as on a tablet, in the living room for example, or in a commonly used space, could expose the families to more frequent feedback, hence leading to more awareness of their consumption habits.

Information Visualization

The choice and the mapping of the consumption to the visualization also provides an important challenge. The families did not intuitively perceive some of the visualizations suggested by the artists and implemented by the research team. For instance the mapping of cloud speed of movement to the speed at which energy is consumed instantaneously was not clear to most of the users. Suggestions from the users point out that changes in the landscape and animation should be made clearer and explicit in their meaning regarding consumption of electricity– for instance changing the color of the grass, from greener to dry would mean an increase of energy consumption. The mappings for disaggregating consumption (e.g. appliances, time periods, etc. mapped to the appearance of animals and flowers in the landscape) suffer from the same lack of clarity and should be further tested with end-users before hand in order to improve the mapping and recognition. Furthermore, users themselves often suggested the employment of negative feedback as an effective way of mapping consumption to the landscape (if you consume more, the grass will dry, for example), which was something we wanted to avoid, due to lack of long term results, reported by previous studies.

Behavioral Change

Overall the results from our study show an increased awareness of the users about their consumption, stimulated from the novelty effect but also from the family discussion emerging from the not always clear mappings of consumption to the natural elements. An important limitation of our pilot was the fact that SINAIS from Fanal was installed in families that were already familiar with a quantitative and highly informative eco-feedback system. The previous system already provided detailed information about the consumption, and to substitute the visualization with the artistic based one, without a detailed explanations led to a lot of confusion. The artistic eco-feedback is not an alternative to the detailed information but rather a complement. Our findings support that combining both strategies would be optimal in increasing awareness and promoting behavior change while also giving detailed information that could help users understand their consumption patterns.

Future work

Future work in this area calls for further qualitative research about the emotional coupling of energy consumption with natural environment. In particular in this investigation, although some light was shed, some questions regarding art inspired feedback visualizations became more pressing.

How to evaluate an art-generated visualization compared to other visualizations in terms of effectiveness, retention over time, etc. And what aspects, in particular aesthetical and emotional, play a major role?

The next steps in order to develop such a study would be: a) Recruit new families without prior experience with eco-feedback systems; b) Deploy the system and interview families to perform a qualitative evaluation; c) Record actual behavioral changes and energy consumption and compare with previous deployment and pilot; c) Perform a quantitative evaluation and statistical analysis of the effects in terms of user interaction and energy consumption.

On the technical side there are many possibilities emerging from this study. Porting the eco-feedback interface to tablet and mobile phone versions will enable further studies regarding where and when feedback is useful and sough after. The fact that tablets could be placed in different locations in the house can have a major effect in awareness in particular when combined with the aesthetical appeal of the artistic visualizations. Finally we are exploring the use of computer graphics to enhance the information visualization of historical energy consumption thus bringing the artistic visualization one step further. Examples include using a computer-generated animation of a tree to represent daily, weekly and monthly consumption mapped into braches and even representing appliances as leaves or fruits.

CONCLUSION

With the growing impact of climate change and limited energetic resources sustainability is becoming foundamental research theme in HCI as well in other sciences. In this paper we described how to explore Digital Art as a way to inspire HCI research and promote sustainability awareness. The approach described here combines a previously developed NILM technical infrastructure to monitor and feedback energy consumption in houses with some innovative art exploration and conceptsrevolving around the emotionally connections between families and elements of their local natural ecosystem.

The quantititave and qualitative evalution of SINAIS from Fanal during a period of one month in eight houses provided many insights on how people react to this approach. We aggregate our findings in three categories providing insights for future development of such systems: emotional attachment, information visualization and behaviour change. On average houses with the SINAIS from Fanal system installed showed increased interaction than the houses with traditional systems. Families felt the previous visualization provided them more clear information, although when asked they didn't want to give up the new visualization of the landscape but rather combine it with the previous more informative one. An evident solution to this problem would be to combine both solutions and make the artistic visualization the frontend. Most of the family members failed to relate their energy consumption with the visualization because of the subjective natures of the metaphors. Overall, families exposed to the new visualization seem to express a high aesthetic appreciation for the new system, which showed as they provided many insights on how to improve the visualization and seemed very engaged.

In summary this paper provides evidence that artistic visualizations of energy consumption are well received by users as long as the mapping with the natural element is clear and detailed energy information is conveyed.

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