Eco-feedback performance exploration for Eco-feedback design

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Abstract

Motivation for an ecologically friendly use has frequently focused on feedback between the product to the user. Yet, product use issues are more complex since the former involve human cognition and subjectivity. The study of this in relation to the ecologically driven use is usually so extensive, it is difficult to understand how it can be used to define a technical solution. In this work, an exploratory experimentation as well as theoretical reviews have been done to understand these challenges. A framework (EcoFF) to caracterise the eco-feedback and a method (EcoDeM) to aid in its design are proposed. The first considers 3 eco-feedback aspects (Shape, Quality, Quantity), and five analysis categories (1-user relationship to the product, 2- product type, 3-context of product use, 4-type and level of ecological impact of product use, 5-feasability of follow-up). The EcoDeM uses the EcoFF and contributes to the simplification of ecofeedback design.

Keywords: Eco-design, eco-feedback design, environmental impact in product use, sustainable behaviour.

1. Introduction

The efforts towards the motivation of an ecologically friendly use have been directed in several applications towards some type of feedback between product and user (Lilley (2007), Kirman et al. (2010),Wever et al. (2008)). This can be understood as a result of the phase of product use being more and more regarded as central in terms of environmental impact in certain types of products. The efforts to design a product as ecollogically friendly as possible go beyond the choice of low-impact materials, the elimination (or at least reduction) of polluting manufacturing processes, or the implementation of recycle/reuse strategies at the end of the product life. On the other hand, addressing product use issues is more complex than focusing on the rest of the product life, since they involve human cognition and behavioural aspects. This has lead, as we will see in section 2.2, to the development of a resarch area devoted to understading people's motivations in terms of the environment and their relationships to it. The drawbacks of this approach will be argued.

The particularities of eco-feedback will be further explained in the next section. They include the different approaches the messages can have in order to motivate users, as well as the media through which they are conveyed. These are determinant for the performance of the eco-feedback, as will be seen in section 2.1, where a general review of the literature is presented. From it and empirical results from an experimentation developed by the authors, the eco-feedback and the considerations for its design will be defined . A framework to caracterise the eco-feedback and a method to aid in the eco-feedback design of a product are proposed. The framework relies on 3 eco-feedback attributes defining the eco-feedback: a) Shape (message in a written form, in oral form, by way of symbols, etc-?), b) Quality (is it positive encouragement, emotional blackmail, goal-seeker, determined by individual vs. social tendencies, etc.?), and c)Quantity (frequency of communication, length of duration of each message, etc.). Also, five ecofeedback analysis categories of the eco-feedback are proposed: 1)user relationship to the product, 2) product type, 3)context of product use, 4)type and level of ecological impact of product use, 5)feasability of follow-up. This work's main contribution lies in proposing and clarifying categories that have been overlooked or not considered essential before, such as the feasability of follow-up. Also, it reconsiders the approach used to caracterise context of use. It is argued that while the thorough analysis of the different use situations is interesting, technology relationship to them must also be taken

in account. The framework and method are explained in section 3. The limits and scope of our proposal are further discussed in section 4.

2. Eco-feedback: product and user

Thanks to the advance in technology, products have increasingly acquired communicating capabilities. In the past, products had to rely on static symbols and product semantics to convey information about use. The products that could reconfigure its functionalities were rare, closer to machines than to objects. Nowadays, products are more and more like machines and less like static unchanging objects. Users can now expect a product to adapt to changes in their needs and preferences. These results in the need for the product to update the information it conveys to the user about the ways it should be operated. Feedback has been incorporated to products in order to fulfil this need.

The focus of this work is a type of feedback aimed at communicating the user how to have an impact on the environment as low as possible when using the product. Termed eco-feedback, it has been used mostly as a technique to change the way a person uses the product, when the use is at the origin of negative environmental impact.

The eco-feedback is nothing more than an information exchange. Several works have focused on the justifications behind eco-feedback, and the different strategies the feedback can take. Yet, as it will be argued, there are more pragmatic considerations to take in account, not necessarily covered or analysed in the reviewed works.

It will be shown that systematically addressing these attributes can contribute further to the research made up until now.

2.1. Eco-feedback and its many forms

Although feedback has been studied for several decades as a means to influence behaviour, it has changed in terms of the objective it pursues. According to Darby (2006), feedback has gone from functioning as a "correcting" tool, to include other goals such as the contibution to a "body of tacit knowledge", or "know-how about the supply and use of energy". It helps modify specific behaviours, which can result in habit modification and, more largely, the transformation of a particular action into an automatic reflex (internalization). It has been added to the array of strategies for product eco-design by authors such as Lilley (2009) and Wever et al. (2008).

In terms of the "shape" the ecofeedback must have, several authors have covered the different possibilites that can be envisioned. In the work of Froehlich (2009), ten different characteristics are listed: Data granularity, Frequenc, Measure unit, Presentation medium, Location, Visual design, Comparison, Social sharing, Push/pull, Recommending action. In the work of Fischer (2008), seven characteristics are proposed: Frequency, Duration, Content, Breakdown, Medium and form of presentation Comparison, Additional info. A more general characterisation, yet still in 5 points, is found in Darby (2006): Direct, Indirect, Inadvertent, Utility controlled, and Energy audit.

These lists are useful when deciding on the way the eco-feedback is conveyed, yet no specific combination of specific attributes has been proven to work universally. General tendencies have been discovered though, such as the fact that the message specific to the action to be changed is better; the message conveyed as near to the moment the action is taken is better; the message that demands little time to understand is better.

2.1.1. Eco-feedback and its many forms, case study

An exploratory experimentation was made in order to find important insights as to the reasons eco-feedback would (or would not) work. The product chosen was a desktop computer. The situation of use was a 4 hours period in a classroom, in which 12 computers were used by 12 students (ages between 20 and 22). Two groups of 12 students were observed for 6 periods of 4 hours each one, througout 2 months. The observation was unobstrusive via 4 videocameras placed on each corner of the classroom ceiling. Although the students and professors were warned of the presence of the cameras, a post-observation discussion with them showed they rapidily forgot the presence of the cameras. The eco-feedbacks chosen were two different messages informing on the effects of energy waste. They appeared one after the other on the screens in two use-moments: when the computer was switched on, and after 5 minutes of idleness. One of the messages urged the reader to switch off the screen if leaving the post for more than 5 minutes, the other to switch off the computer when leaving the computer for more than 10 minutes. The two messages are shown in Figure 1. The first message is bright red and the second is bright yellow-orange. The eco-feedbacks were sent only to one group, as follows: it was observed initially for 2 periods without sending eco-feedback; then, for 2 periods, the eco-feedback was sent, and then for the last 2 periods the message wasn't sent in order to understand if users remembered. The other group was observed throughout 6 sessions also.

Figure 1: Messages sent in public computer experimentation.

The observation was aimed not so much to achieve an actual dramatical change in behaviour, but to understand the perception of the students. They were not briefed before the messages and they were not told they would be observed specifically to check if the messages were obeyed of not. The idea was to verify if the students would react by inner motivation.

The results of the observations showed that the students continued their usual behaviour despite the messages. This will be further developed in the next section. In terms of the shape of the message, the post-experimentation questionnaire showed the students remembered the general idea of the text, and in less proportion the images shown. Since both had the same quality and quantity, these attributes were explored via the students' profiles.

2.2. *Searching user understanding by understanding the user*

The nature (or "quality") of feedback has been traditionally determined in accordance to what is called "behavioural models". In the work of Froehlich et al. (2010), the models are divided into "norm-activation" and "rational choice" models. The first is further extended by the author into "value-belief-norm" models. The "rational choice" models are subdivided in attitude, responsible environmental behaviour, and rational-economic models. This last one is also considered by the classification given in He et al. (2010). In addition to rational-economic models, he considers "information", "prositive reinforcement", and "elaboration likelihood models". Other authors, such as Wood and Newborough (2003), Fischer (2008) have focused just in measuring the effect of a feedback depending on the form it is conveyed (its "shape"). The latter also considers the motivations of the person receiving the feedback to change. In other works, such as in McCalley (2006), one type of behavioural justification (in this case, goal-seeking and social motivation) is chosen to test different ecofeedback shapes and qualities. Other, more phsycology-oriented works, such as Corradi et al. (2013) the nature of the message is classified in terms of the mental process involved: cognitive effort or choice based. The first needs supporting cognitive functions (such as forgetting a device is in stand-by mode and thus leaving it on, wasting energy). The second doesn't put the cognitive process under stress (e.g.,when choosing a washing machine that saves energy).

All these behavioural models are used as essential information to design eco-feedback. Nevertheless, as has been discussed for several yaers now (Hines et al. (1987), Fransson and Gärling (1999),Gatersleben et al. (2002)), the relation between ecological awareness and actual actions towards impact reduction is not always straightforward. They argue that a general environmental attitude seems relevant when the effort is minimal. Also, the financial ability to change must not be challenged, although it appears that economic variables are not the dominant ones either.

This work argues the reason for this impredictibility is that the user's behaviour in terms of environmental issues cannot be isolated from the rest of his/her life. As discussed in Hofstetter et al. (2006), environmental behaviour is nor only bounded by physicological constraints (which the behavioural models explore), but also by physical constraints. The authors propose six: Costs, time, space, other scarce resources, information, and skills. These should be considered when designing the product, but also when designing the eco-feedback in order to improve the possibilities of success.

2.2.1. *Searching user understanding by understanding the user, case study*

In the exploratory experimentation a pre-observation questionnaire was made in order to understand the students motivations in terms of the environment, and define what will be called "eco-profile". The questionnaire was designed using as references works such as DEFRA (2007), but aiming at simplicity. The profiles were built upon five dimensions, shown in Figure 2. The sensibility dimension is based on the work of Millet et al. (2001): in the case of "value", the person will act because of a deep internally-driven motivation that would override a certain level of discomfort in the search of ecological impact reduction; the "criteria" level refers to a person that would act in a ecologically friendly way if what is demanded does not interphere or disturb other priorities she may have (save money, time, etc.). The "constraint" level refers to a person that will not act in an ecologically friendly way unless she has no other choice (e.g., law).

The results of the pre-observation questionnaire showed that students had in general a low level of knowledge, a "criteria" based sensitivity, and were not

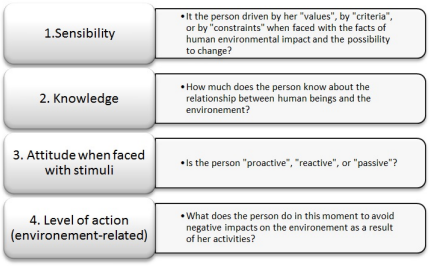

Figure 2: User dimensions for eco-profile

doing a lot in this moment for the environment. In term of proactive, reactive or passive reactions, it dependes on the situation presented in the questionnaire. In relation to their reactions to the message, it was shown that despite the fact that it attracted the attention of the users, two strong beliefs worked as counterweights to change: in the case of the ”switch-off computer” message, the students believe it should not be done as the computer's inner components may be damaged by a frequent switching off. As for the ”switch-off screen”, students didn't believe it really consumed a lot of electricity and so dismissed the invitation. These results show that user profile and target environmental impact in use are not the only categories to take in account when designing an eco-feedback. An eco-feedback framework to compensate this is proposed in the next section.

3. Eco-feedback framework *EcoFF* and design aid method *EcoDeM*

The previous section has shown what has been done to understand how eco-feedbacks work. Several approaches have been made, considering both sides of the information flow: the nature of the eco-feedback, and the user. Nevertheless, in this work, it is argued that important factors, not necessarily explicit in the nature of the ecofeedback, or that of the user, are also essential. Three eco-feedback attributes and four ecofeedback analysis categories are proposed in order to design eco-feedbacks. These build what will be called the ”eco-feedback framework” (EcoFF).

3.1. Eco-Feedback Framework, EcoFF

The framework proposed, EcoFF, defines ecofeedback according to three mains aspects and five ecofeedback analysis categories. The three aspects are a simpler classification of what has been proposed up until now. Instead of having the numerous characteristics of the eco-feedback considering independently, EcoFF proposes the regrouping in a more compact and esier to remember way (Figure 3). All of the following three aspects are interdependent and respond in turn to the 5 ecofeedback analysis categories explained afterwards.

a. Shape: The shape speaks of the architecture of the mode of eco-feedback transmission.

b. Quality: Quality determines the cognitive part of the message, how will it be explained. The EcoFF considers that although the universe of possibilities should lie on theoretical grounds related to the behavioural models, it should rest open to implementation depending on the response of the user. This means, e.g., that an ecofeedback quality in the form of goal-seeking motivation should be able to change to social-oriented motivation. The change depends on the 5 ecofeedback analysis categories of the EcoFF.

c. Quantity: The frequency of the eco-feedback and the length of time it is used. As has been communicated in other works (Serna-Mansoux et al. (2012)), the message must be renewed even if it works in the beginning. The frequency can be ”unadapted”, and ”adapted”. On the first one, the ecofeedback is launched each time use situation is launched, regardless of the user's actions. The second one can be defined by the user (e.g.,to be launched either each time his/her actions result in an ecological impact that could be avoided, the first time the use situation is experienced). The length of time of each eco-feedback is proposed to be defined either automatically or by the user. The first changes the messages as a result of the follow-up of the user's environmental impact (e.g., if the user was reacting to message in the beginning, but in time he/she starts using the product in ecologically unfriendly ways that could be avoided).

The five ecofeedback analysis categories are proposed as follows:

1. user relationship to the product,
2. product type,
3. context of product use,
4. type and of ecological impact of product use, targeted ecological impact
5. feasability of follow-up.

Whereas the user profile and the ecological impact of use have been intensely taken in account, the targeted ecological impact, the product type, the context of use and the feasibility of follow-up (as it is defined in this work), are rarely considered. The technical challenges

are affected by these ecofeedback analysis categories, and ignoring them might arguably result in a theoretical conception that fails when applying it to problems in reality. Specifically, in terms of the targeted ecological impact, it is normally defined as the reduction of current impact. Nevertheless, a target limit must be taken in account to guide the user's improvement curve. This is further developed within the EcoIL Cycles concept, in Serna-Mansoux et al. (2012). Regarding the concept of product type, it has been traditionally regarded in terms of the product function (Löbach (1976)), user's comprehension of product as a whole (Norman (2002), Cagan and Vogel (2002)), but not in terms of the use situations. Having as target the optimal use in terms of the environment, a new classification is needed. This work proposes three attributes to define a product type:

1. the intensity of use (everyday use, periodic use, sporadic use, circumstancial use, use during a long period of time, short-term use, etc.),
2. the technical nature of use (high level technology would require the user to have certain knowledge, the low level technology would be universally easy to use),
3. and the functionality life-span of the product (how long is the product supposed to function, how does the function is envisioned to evolve (or not), how is the product envisioned to add or substract functions as its life advances, etc.).

As for the context of use, is has been traditionally understood a thorough listing of the objects in the product ecosystem should be made. When the ecological impact is targeted, the context of use is usually enriched with the compilation of the energy (or other ressource) consumption (input) on the one hand, and the output of any pollutants on the other. The habits of use are recorded as well. All this is useful for the product design, but for the ecofeedback design, other types of contextual information is needed. The context of use for ecofeedback design must have as main objective the understanding of how the user operates the rest of his/her product world. This means getting to know the gestures and product architecture that he/she prefers and understands better. The user might have a tendency to prefer button-activating products, rather than switching on-off. He or she would do the maintenance of the rest of the products intituively, or following written instructions (or even following illustrative figures with no text). This helps in finding insights on the "shape" and "quality" of the eco-feedback.

Lastly, the feasibility of the follow-up should be considered as important as any other dimension. The feasibility considers not only the array of technical solution for the follow-up, but also the ecological impact of them. Since highly technological solutions have frequently an important negative impact on the environment, a analysis of any added component should be considered in terms of its expected success, such as the authors propose in Serna-Mansoux et al. (subm. nov 2012).

Figure 3: Eco-feedback framework, **EcoFF**

3.2. Eco-Feedback Design Method, EcoDeM

Using the framework in the previous section, a method to design eco-feedback is proposed. It considers building a grid based on the analysis of the 5 ecofeedback analysis categories of the eco-feedback and deciding from the technical solutions available in terms of quality, quantity and shape, the best fit. The discussion through out the method should be made by a team composed of the product development stakeholders. Figure 4 shows the general approach of the method, which is developed as follows:

I. Analyse the product and the user according to the 5 categories of the EcoFF. In a parallel process, map all the technical solutions for the eco-feedback (according to its 3 aspects) that can be realistically done by the enterprise developing the product.

II. Build a grid for the 5 categories and a morphological matrix (references found in Jack (2013) and Otto and Wood (2001)) for the techinal solutions that can be considered. The constraints should include the enterprise strategy and technological limits.

III. Consider the best alternatives from the morphological matrix, that would adapt to the product analysis.

IV. An assessement of the ecological impact of the alternatives should be made. Previous work made by the authors and in review (Serna-Mansoux et al. (subm. nov 2012)) proposes an assessment that not only considers the impact of the technical solution for the ecofeedback, but also its projected success.

V. The best or set of best alternatives can be then developed and tested.

Figure 4: Eco-feedback Design Method, **EcoDeM**

This method supports the eco-feedback design by focusing on its performance, rather than on the performance of the product. It adds important information to the design process and, by means of the EcoFF, provides a simplified yet useful approach.

4. Discussion

An exploratory study to understand how ecofeedback performance works has been presentd and a framework for analysis that will help in its design proposed. They are under experimentation, and further refinements are expected. Nevertheless, their main contribution lies in the theoretical simplification of the eco-feedback analysis. Further work could be developed to better understand the physical constraints in consumption and how they can be useful when addressing the quality of the ecofeedback. This would be in situations where the user is part of a greater system (e.g., as electrical grids in a neighborhood, public use appliances, etc.) or belongs to special groups of users (sick, old, or handicap people, children, etc.). On the other hand, the development of unobstrusive follow-up is also an important path to explore. Since people could use the product differently if the observation equipment gets in the way of the gestures they usually have, means of detecting without forcing the user to change the ways it manipulates a product are important to discover.

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