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ORIGINAL PAPER

Study of user behaviour after eco-use feedback: the Green-Use Learning Cycle (GULC) as a new strategy for product eco-design

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Abstract The way users interact with systems requiring energy largely conditions their global environmental impact. Informing of the environmental consequences of usage of products/systems can generate increased awareness of its connection to environmental impacts, encouraging a change in user behaviour and resulting in products' global environmental impact. Various levels of product modification have been proposed, from simple information, through behaviour steering and persuasive technology. We focus on eco-feedback and distinguish three different modalities: neutral, positive and negative. Based on the conclusions of an experiment observing the consumption of paper towels, this article demonstrates: (1) An individual's general level of information about the environment has an influence on the effectiveness of the eco-feedback modality. (2) The effectiveness of a modality of eco-feedback diminishes over time. The potential of iterative user feedback combined with intelligent sensor embedded systems led to our defining the Green Use Learning Cycle as an innovative concept for eco-design. It underlines that products should be designed so that they can give feedback to users about the environmental performances of their usage (user adapts to product), and can analyse the dominant parameters of usage to be configured automatically to the environmental optimum throughout the life cycle (product adapts to user).

Keywords User behaviour · Global environmental impact · Eco-feedback · Eco-learning · Eco design

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1 Issues of sustainable consumption

Design and innovation have become essential factors of competitiveness on general public markets as varied as cosmetics, mobile and land phones, cars, spectacles or domestic appliances. Until the recent era of sustainable development, the material aspects of these products played an increasingly dominant role. Nowadays however, innovation also requires that products be eco-friendly with whole of the product life cycle, including raw material extraction, production, distribution, use and end-of-life. In this life cycle, impacts of the use phase are generally calculated for an "ideal" use that does not really exist. This is usually due to designers' lack of understanding of customers' actual use. The true challenge lies in identifying real uses and designing products and services which innovate accordingly [2].

The notion of usage comes from the wish to extend the notion of "use" as commonly applied in a process, i.e., integrating the final user into the design process [14]. Whilst use shows the functional dimension of tools designed by engineers, the notion of usage extends this to include people's relationship with technologies; usage focuses on the way in which people become involved with technologies, use them, dream about them and idealize them, projecting their needs and desires influenced by cultural artefacts. Reference is commonly made to Norman [15] to demonstrate the human capacity to be creative in diverting product usage. In our work, we take this concept and add the ecological dimension by considering the usage aimed at the reduction of environmental impact.

End of life processes, like the phases of use, logistics, maintenance and dismantling/recycling, are subject to studies aiming to better target the constraints related to these activities and integrate them upstream of design [8]. Ramani and colleagues [16] thus propose a matrix of the specifications related to sustainable development using a matrix of the functions of impacts of the downstream phases of the life cycle. There are generally too many constraints in products' specifications to leave any possibility of adapting the product to the user. "Usage" provides a first "space" where there is some leeway before over-precise functions have been specified. The Usage Coverage Model (UCM) has been developed to better locate sets of usage that are worth covering by the design solution [22]. Wever and colleagues [21] explain that adopting a user-centred design approach aims to improve the quality of the interaction between the user and the product.

The aim of the concept of eco-usage is to model real use and compare it to recommended use to determine products' true impact. The concept of "real use" in this work referes to that which happens in non-simulated situations, with users in their normal environment. The observation may show needs (real needs) that are not detectable otherwise. It may offer ideas for innovation in products and services [4,20]. A better understanding of real usage implies a better understanding of the real needs of users and an improved analysis of the product's true environmental performance [1,3]. The interest lies in designing products and services suited to the multiple types of users and usages. This article aims to examine this diversity of usage and evaluate the pertinence of combining different modalities of information feedback (environmentally conscious) over time.

2 Environmental impact and user awareness

In Europe, environmental policy is gradually adopted through regulations and laws entailing clearer information and communication to consumers. In France, article 85 of a project for a law resulting from "Grenelle 2" intended to modify the consumer code from January 1 2011 on, with the obligation to notify consumers about environmental issues. In Article L. 112-10, we find (translated from the original French): *From January 1 2011, the consumer must be informed by stamping, labelling, notices or any other suitable procedure, of the equivalent carbon footprint of products and their packaging as well as their consumption of natural resources or the impact on the natural environment caused by these products during their life cycle* (Law no. 2010-788, 2010). This text makes clear the new challenges of sustainable consumption. Feedback about the environmental impact of products in common use may result in consumers' increased awareness and thus in a modification of their habits of consumption.

For some time already, certain products such as household electrical goods, display notices giving their energy performance. This information is shown in terms of energy class and indicates the products' energy consumption to would-be purchasers. This labelling dates from 1992, but a reassessment of the classification resulted in an obligatory new label for household electrical equipment in 2011. The same insistence on consumer information has been true for the automobile sector since 2006: aiming to reduce greenhouse gases, an "energy/CO_2" label figures on all new private cars for sale. This label is based on the same principle as those relative to the energy consumption performance of household electrical equipment. These labels give buyers a good indication of products' average environmental performance according to average conditions of use, but they give no information about more specific usage, nor on ways of reducing the average environmental performance. However, it is important to emphasise that the users' behaviour plays an important role in this. Indeed, in the case of vehicles, fuel consumption and CO_2 emissions depend not only on the technical performance of the vehicle's various modules, but also on the way the user drives, or even on the sum of driving styles of all users. Eco-driving can thus influence 10–25% of a vehicle's consumption [5–7].

This practice of labelling is becoming more and more widespread in other sectors. Now consumer products and food in their turn give the consumer information about their environmental impact. This CO_2 label or environmental notice takes account of products' greenhouse gas emissions and packaging throughout their life cycles. The French General Commission on Sustainable Development declares that purchases made by French households contribute from 40 to 70% to climate change [11]. This range takes account of emissions throughout the whole of product life cycles, from raw materials' extraction to dismantling or recycling. The General Commission gives a few examples:

– 1 litre of mineral water generates around 120 g equivalent CO_2
– 1 bar of chocolate generates around 250 g equivalent CO_2
– 1 tee-shirt generates around 4 kg equivalent CO_2.

These figures and new government guidelines show the environmental challenge posed by consumer goods, and demonstrate the importance of giving consumers sound information as to the ecological footprint resulting from their everyday lifestyle.

Since 1 January 2011, the obligatory notice of energy consumption has also been applicable to the real estate sector. This labelling concerns real estate (non LCB Low-consumption building) for sale. Just as for electrical household appliances, an energy classification enables buyers to better determine the energy performance of their future real estate purchase. The scale ranges from A to G that represents consumption from 50 to over 450 kwh/m^2/year. This classification is meant to update the value of real estate, and must therefore be clearly visible for consumers. Low-consumption building programmes present a real environmental challenge. However, it is important to note that even if a house or apartment is labelled LCB, this does not guarantee that it will match the energy performance stipulated by the label (and the law) as this performance will depend on the usage made of the property. These houses and apartments are designed according to supposed rather than actual usages. "Green" brochures are given to owners who move into such buildings in order to guide and encourage them to use the building according to the energy consumption it was designed for. This shows that there is a need to help or even coach the occupant if the energy performances declared by the constructor are to be obtained.

2.1 Eco-feedback: a solution for coaching consumers?

The information available to consumers can sometimes fail in making the consumer understand the impact of its behavior. In the case of notices informing the average CO_2 footprint of a given product, for example, how can this be translated for consumers into something meaningful for their everyday use? How can they understand the consequences of the way they use the product? How can we give them the means of modifying their behaviour? What form should this information take? Should it be information helping them to optimise the environmental impact generated during a product's use phase?

From the point of view of the industry: do industries now propose technological products that respect the requirements of energy performance? Does the interaction between user and product always correspond to the use foreseen by the manufacturer and what usages form the basis of these performances?

Qualitative surveys and studies [19] show that there are "good and/or bad practices" (Fig. 1). The case dealt with in these studies concerns selective waste disposal and whether or not users have learnt about this practice. The survey shows that there are four motivations that create a virtuous circle:

- Must-do (environmental awareness)
- Know how-to-do (knowing the rules)
- Can-do (material possibility and cognitive capacity)
- Want to-do (benefits related to systematic practice)

With regard to eco-feedback solutions set up in many domains of application (automobile, consumer products, real estate, etc.) this article examines the modes of feedback (information) that are the most suitable for encouraging more sustainable consumption during a product's use phase. From

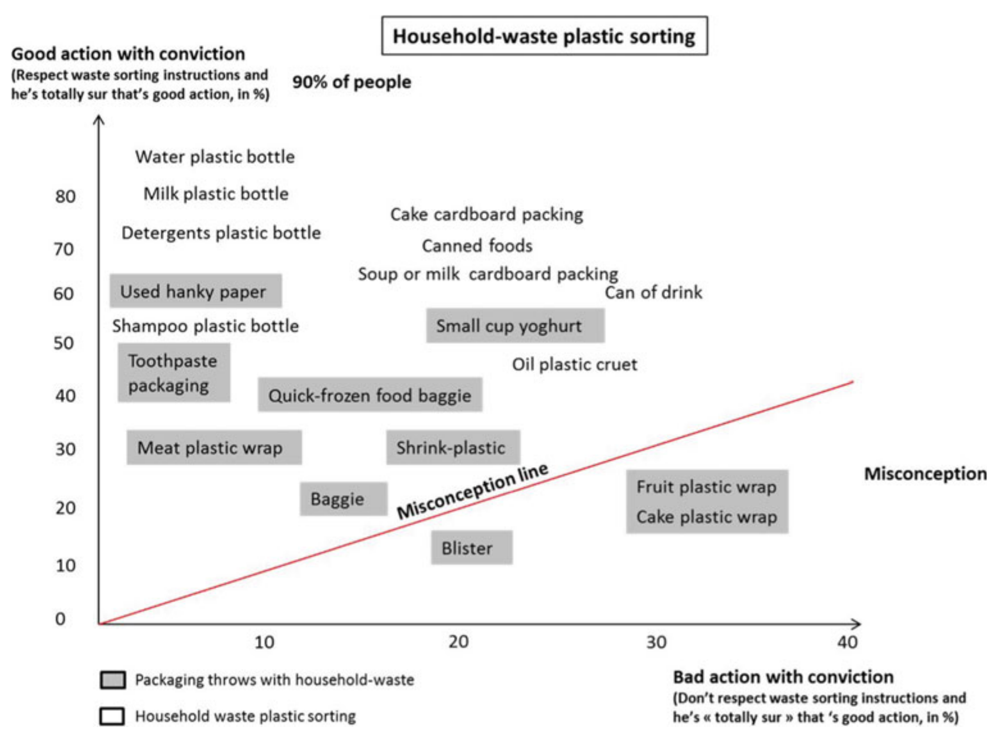

Fig. 1 Translation of mapping of "Good and bad practice" in selective disposal of packaging [19]

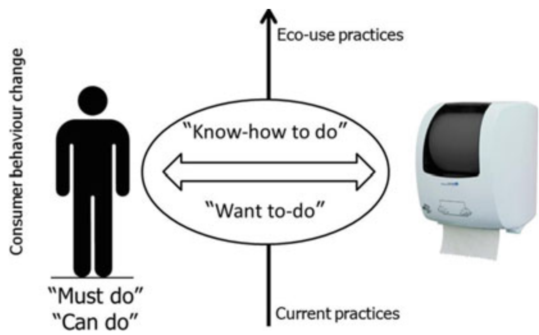

Fig. 2 Consumer behaviour change four motivations user/product

the user and product's individual "Must Do" (environmental awareness) and "Can do" (material possibility and cognitive capacity), the idea is to generate new "Know-how to do" (knowledge of the regulations) to reach a common and shared "Want to-do" (benefits related to systematic practice) (Fig. 2).

2.2 The communication between user and product

Several studies on user interaction with the product have been made. Yet, it is the methodology proposed by [10] we will use for the behavioural study in this work, as it has specifically focused on the ecological part of product. This methodology comprises three levels of product-user intervention aiming at more eco-friendly usage. Figure 3 shows the three levels that impact the user's decision; they start with simple feedback, through incentive and finally to constraint. The first level "eco-feedback" aims to inform users about their consumption. It is a guide towards changing behaviour. Examples of eco-feedback are the notices and labels that inform users about how best to use the product.

The second level "Behaviour steering" encourages the user to use the product according to the manufacturer's recommendations. The product's architecture comprises support and modes of use that incite the user to better understand how it should be used. An example can be seen in computers offering the possibility to regulate energy consumption by choosing to switch of the screen after a certain time, or in toilets with two flush modes, using more or less water. The final level, "Persuasive Technology" obliges consumers to use the product in the best way without seeking their consent. The product is designed to work only if it is used as desired by the manufacturer; the user is not free to choose to a different usage. This guarantees a change of behaviour. Examples are lights in a room that switch off automatically as well as so called "intelligent" systems whose sensors work without the users' direct control. These modes of feedback were used in an experiment conducted with cellphones [9]. It appears that they depend on three variables:

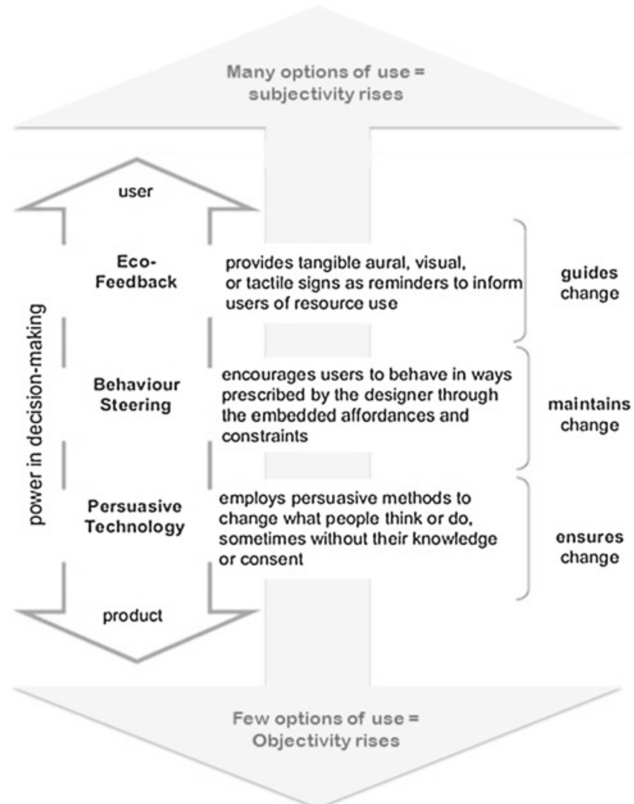

Fig. 3 Strategies for designing sustainable behaviour (partly based on [10])

- Users' degree of commitment and consent
- The seriousness of the consequences of decisions and actions taken
- The context of the user/product interaction

Lilley [9] concludes that up to now, no one mode of feedback can be more highly recommended than another. This is supplemented by the work of Wever et al. [21], whose work hinges on functional adaptation, eco-feedback, scripting and forced functionality.

2.3 Types of eco-feedback

According to Lilley (Fig. 3), the consumer's power of decision-making is useful for understanding how to adapt product design to the desired interaction and usage. The strategy of change developed evolves along the product-user path : from piloting change to ensuring that change has taken place.

However, this is not the only evolution that appears when strategy passes from being product centred (Persuasive technology) to being centred on users' power of decision (eco-feedback). There is also an obvious change from objectivity towards subjectivity. In other words, on the product function-

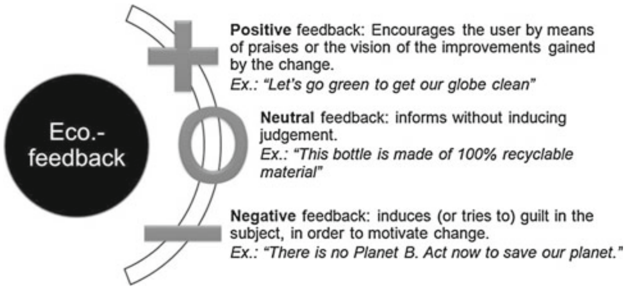

Fig. 4 Different types of eco-feedback

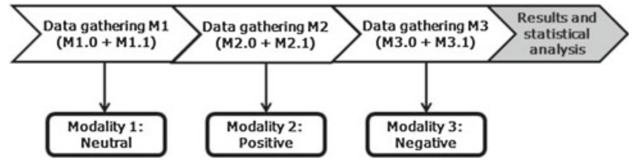

Fig. 5 Experimental protocol and sequencing of feedback modalities

ing side, possibilities for action are limited. A lamp designed with movement sensors which will only switch on when the sensors detect movement, cannot act in any other way. On the other hand, an eco-feedback strategy that reminds users about their consumption may result in different decisions on the part of the user, including indifference to the reminder (Fig. 3).

We thus arrive at the conclusion that the nature of the information contained in eco-feedback, the first level of modification, cannot be considered as always the same, nor can it ensure the same results (whatever the nature of those results may be). In this article, we distinguish three modalities or natures of eco-feedback (Fig. 4):

1. Neutral eco-feedback: gives information without making any judgement on the use of the product. This leaves users totally free to draw their own conclusions and make whatever modifications to their usage they find pertinent.
2. Positive eco-feedback: gives information adding a sign of motivation to encourage more eco-friendly behaviour. This can work using different strategies, e.g., presenting a positive scenario resulting from an ecological usage of the product, congratulate the user for changing towards an ecological usage, etc. Plays on affirming users' virtues and values.
3. Negative eco-feedback: gives information adding a tone of disapproval, seeks to motivate through fear of what might happen if action is not taken. Often focuses on the negative scenarios that could result if the product is not used ecologically. Plays on guilt.

In this article we set up an experiment to measure the fluctuation of consumption in a panel of product users. For this experiment, the product we retained was the "paper towel" because:

– As a consumable, it is easy to measure the environmental impact of its use
– There is a large enough panel of consumers to be representative of various user profiles, and a high frequency of use
– Everyone knows how to use it so no specific training is necessary

This paper towel distributor distributes pre-perforated towels one at a time. The study is based on observation of users' interaction with the product in situ. To this end, measuring equipment (cameras and movement detectors) were set up to gather data on the individual consumption of panel members.

The study protocol takes place over two measurement campaigns each comprising a different panel of users using the product in different locations. The data on individual consumption are collected from both campaigns before and after sending feedback in one modality and then doing the same with a second and third mode of feedback. For the first campaign, the chosen sequence of modalities was neutral, positive and negative (Fig. 5).

For the neutral modality M1, a first data collection gives the consumption reference for the panel (the sequence of measures M1.0) The number of days of the first sequence M1.0 is the same for all the sequences of the other modalities, so that they can be compared with each other. Next a mail containing the neutral modality is sent individually to each panel member. The neutral modality gives only the number of paper towels (sheets) consumed during the M1 sequence M1.0. No other information is given (Table 1). A second sequence of measures is carried out after modality M1 M1.1 has been sent. Between each session of measures for modalities M1, M2 and M3, there is a pause of 2 days. During these two days, no measures are taken. We followed the same protocol for the other modalities (Positive M2, see sample email in Fig. 6) and Negative M3.

In order to inform users, mails corresponding to each modality were sent individually. The Positive modality M2 was presented to users as a scale representing 3 categories of consumption. The first scale shows individual consumption in number of towels consumed compared to the rest of the panel, the second shows the cost of the number of towels consumed and the third scale shows the consumption in grams of CO_2. The Negative modality M3 takes the form of a message giving the number of towels consumed during the M3.1 measurement period with figures recalling the results of such consumption. The number of towels is related to all the environmental impacts on the entire life cycle of a sheet of paper. The tone of the message purposely raises questions in order to catch the users' attention (amount of water and wood consumed with reference to one person's consump-

Table 1 Actions and durations of measures of the protocol

Mesure X	Designation	Duration
Measure M0	Reference measure	2 days
Measure M1.0	Measure before modality no.1	5–10 days adjustable
Analysis M1.0 + sending modality	Mode M1 = NEUTRAL	5 days
Measure M1.1	Measure after modality No.1	5–10 days adjustable
Measure M2.0	Measure before modality No.2	5–10 days adjustable
Analysis M2.0 + sending modality	Modality M2 = POSITIVE	5 days
Measure M2.1	Measure after modality No.2	5–10 days adjustable
Measure M3.0	Measure before modality No.3	5–10 days adjustable
Analysis M3.0 + sending modality	Modality M3 = NEGATIVE	5 days
Measure M3.1	Measure after modality	5–10 days adjustable

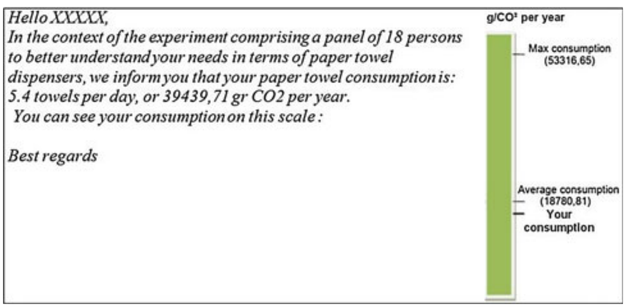

Fig. 6 Email sent for modality M2 Positive

tion). The following section shows the results obtained after two experimental campaigns based on 3 tests of about one month each.

3 Experimental campaigns and statistical analysis of data

In order to have a reliable evaluation of impact of the 3 modalities on impact on users, a statistical study of the data was carried out using SPSS software. The statistical tests mainly concerned the question of the existence of a phenomenon of "learning" (persistence of the influence from one modality to the other) among the three modes.

The statistical analysis was carried out for each campaign and as we shall see, the conclusions enabled us to consider the data as independent. The results of the two campaigns show an important influence on users' performance in reducing the consumption of paper towels. On the other hand, these results highlight a phenomenon that we call remanence, which we explain in the second part of this section.

3.1 First Campaign

The first campaign comprised a panel of 18 users 6 women and 12 men, executives aged from 25 to 51 years. Table 2 presents a synthesis of the consumptions observed during campaign 1, extrapolated to a year. The measures were taken according to the established protocol, that is, measurement before and after sending the modality to users. In order to read the results more easily, daily consumption was extrapolated to annual consumption that gives a clearer indication of users' margin of progress (if the consumption were regular).

The consumption of Modality 1 presents an improvement of 21.68% between measures taken before and after the neutral mode was sent. This shows the positive impact on panel members when they are given actual figures of their own consumption. The second modality "Positive" also shows an improvement in the consumption of paper, but there is less impact because the reduction of consumption is only 7.17% on average over the whole panel. The third modality "Negative", (that raised questions), generated an improvement of 20.94% in paper consumption. It was presented as a way of shocking users with the true environmental impact of their consumption (Table 2).

In order to check whether there is a "persistence of influence" among modes, the slope test is applied to measures M1, M2 and M3 (Table 3). This means to check if the initially implemented modes have a lingering influence on modes that come afterwards. Pearson's correlation, usually noted as r, indicates the influence between two variables and also specifies the weight of this influence by its value. It is considered that the relation between variables MX.0 and MY.0 is perfect if $r = 1$, very strong if $r > 0.8$, strong if $0.5 < r < 0.8$, average if $0.2 < r < 0.5$, weak if $0 < r < 0.2$ and non existant if $r = 0$. The tests applied successively to measures M1, M2 and M3 give the results shown in Table 3:

– $r = 0.812$ which means that the relation between M1.0 and M2.0 is strong. The change between measures M1.0 and M2.0 is minimal. The value of sigma indicates the validity of the correlation. The value L Sigma is lower than 0.05, which means that we can reject the null hypothesis and conclude that the association or co-occurrence observed between M1.0 and M2.0 really exists within the panel.

Table 2 Annual consumption according to modalities M1, M2 and M3 : campaign no.1

Campaign no.1	Cons M 1.0 paper/year	Cons M 1.1 paper/year	Cons M 2.0 paper/year	Cons M 2.1 paper/year	Cons M 3.0 paper/year	Cons M 3.1 paper/year
TOT	2,265.4	1,774.25	1,410	1,308.95	1,301.9	1,029.3
Reduction or increase between campaigns (MX.0MX.1)/MX.0%		−21.68%		−7.17%		−20.94%

Table 3 Slope test M1, M2 and M3 : campaign no.1

Paired samples correlations					
		N	*r*	Sigma	Conclusion
Pair 1	Cons M1.0 and Cons M2.0	18	0.812	0.000	No persistence of influence between M1.0 and M2.0.
Pair 2	Cons M2.0 and Cons M3.0	18	0.592	0.010	Modality M2.0 has no influence on the measures taken in M3.0.
Pair 3	Cons M1.0 and Cons M3.0	18	0.702	0.001	No phenomenon of persistence between M1.0 et M3.0.

Table 4 Annual consumption according to modalities M1, M2 and M3: campaign no.2

Campaign no.2	Cons M 1.0 paper/year	Cons M 1.1 paper/year	Cons M 2.0 paper/year	Cons M 2.1 paper/year	Cons M 3.0 paper/year	Cons M 3.1 paper/year
TOT	1,026.95	1,320.77	662.70	822.50	881.25	665.05
Reduction or increase between campaigns (MX.MX.1)/MX.0%		+22.24%		+19.43%		−24.53%

There is no persistence of influence between M1.0 and M2.0.

- Pearson's correlation, r is equal to 0.592 for measures M2.0 and M3.0, there is a relationship of high intensity. Measures M2.0 and M3.0 are almost the same. The value of Sigma being 0.010, the test is acceptable. Mode M2.0 thus has no influence on the measures taken in M3.0.
- $r = 0.702$, Pearson's correlation gives a strong link between measures M1.0 and M3.0. The Sigma is equal to 0.001, the null hypothesis is rejected, the co-occurrence between M1.0 and M3.0 does exist. There is no phenomenon of persistence between M1.0 and M3.0.

This slope test allows us to specify that there is no phenomenon of persistence among the modalities. Moreover, a "rest" period of 2 days between each measure was respected in order to avoid encouraging this phenomenon and to allow the users to resume their usual consumption habits.

3.2 Second campaign

The second campaign took place in a different location with a new panel of users. This panel was made up of 14 persons, 10 women and 4 men. Table 4 presents a synthesis of the consumptions observed during campaign 2, extrapolated to a year. Their socio-economic level was that of technicians aged from 25 to 59 years. The sequencing chosen for this campaign was neutral, Negative and Positive. This change in the order of modalities should allow to determine whether the order of presentation of modalities influences the panel's consumption, shown in Table 4.

It is impossible to specify whether or not there exists a phenomenon of learning by panel users between modes M2 and M3 and modes M1 and M3. If we look more closely at the figures in Table 4, there is no emphatic variation of consumption between M3.0 and M2.0, and M1.0 and M3.0. After the 2 days pause between measures (when no measures were taken) to enable users to return to their usual consumption habits, it appears that consumption is stable, no learning thus takes place between these modalities.

4 Results remanence

The different tests carried out previous to this study generally show that it is not possible to prefer one modality of eco-feedback to another. This is also what [10] showed through his case study on cell phones.

If it is not possible to determine whether one modality is more efficient than another in getting users to reduce their

Table 5 Slope test M1, M2 and M3: campaign no.2

Paired samples correlations					
		N	r	Sigma	Conclusion
Pair 1	Cons M1.0 and Cons M2.0	14	0.539	0.047	Modality 1 had no influence on the measures of M2.0
Pair 2	Cons M2.0 and Cons M3.0	14	0.403	0.153	Modality 2 had no major influence on the measures of modality 3
Pair 3	Cons M1.0 and Cons M3.0	14	0.392	0.166	Modality 1 had no major influence on the measures of modality 3

Table 6 Distribution of user profiles according to level of information and account taken of the environmental dimension in their everyday consumption

Categories	Number of users in study	Number of users panel 1	Number of users panel 2
Not informed	25	16	9
Informed	7	2	5

consumption, is it possible to determine whether there are user profiles which are more sensitive to certain modalities? We deal with this question in the following paragraph and contribute complementary results about the role of information in modifying consumers' behaviour.

4.1 User profiles

Before implementing the measurement phases M1, M2 and M3 with the two panels of users, a questionnaire was given to them. This contained 11 questions aiming to evaluate their knowledge in terms of sustainable development and better understand the consumption habits of each individual. The questionnaires were based on the work of [12,13] on the role of the environment in the business world. They enabled us to distinguish users who were informed about the challenges of sustainable development and who had solid knowledge to put these principles into practice on an everyday basis. The other category was made up of consumers who had not been sufficiently informed to consider all the criteria related to sustainable development. Reading the questionnaires resulted in Table 6 over both panels of consumers.

The following stage consists of checking for each of the user profiles whether or not the modalities influence their paper consumption. For this, each consumption is compared to a consumption of reference which is that measured before sending modalities M1, M2 and M3. If we observe the figures in Table 7, the user profiles can be linked to certain modalities of eco-feedback which imply a reduction in consumption. The profile "Not informed" responds well to modalities M2. For this group of users, the M1 feedback modality is not suitable and seems rather to have result in over-consumption. This is consistent with the detailed observation of both panels.

However, the Informed profile shows a reduction of 33.08% for feedback modality M1 "neutral" over both panels, but when the results of each panel are examined in detail, the panel of users tested show differences. Panel 1 reacted better to the Negative modality M3 (−54.2%) and panel 2 reduced its consumption under the effect of Positive modality M2 (−48.4%). This reduces the importance of mode M1.

The results allow us to draw conclusions about the trends of modes of eco-feedback to which certain user profiles are sensitive. Table 7 shows the different results between the two panels of users tested. The major difference between the two panels comes from the socio-professional category of the individuals concerned. One future perspective for this study would be to refine user segmentation by including other criteria such as family situation and socio-professional category in order to determine whether these criteria have an impact on the modification of consumers' behaviour.

More traditional users classifications, such as gender or socioeconomic levels, showed no significant results.

4.2 Remanence

For the purpose of our work, we propose the term *remanence* to define the persistence of a phenomenon after the instigator of this phenomenon has disappeared. In this case study, *remanence* will only last for a certain time, after which the consumption of towels returns to numbers similar to (or larger than) that observed before the implementation of the eco-feedback strategy. In this experimentation, we extract the *remanence* by calculating the *Constant growth rate* of a certain period (in this case the period of measurements). This means that if consumption grows the *remanence* is non-existing. Whereas if the consumption decreases, the *remanence* rate is then the negative value of the calculation.

$$R = \left(\frac{Con_y{}^{\frac{1}{p-1}}}{Con_x} \right) (-1) \quad (1)$$

Where Con_y indicates the consumption measured the first and second days of the modality; Con_x is the consump-

Table 7 Evolution of consumption M1, M2 and M3 according to user profiles

Categories	Modification of consumption in panel of study (%)	Modification of consumption in panel 1 (%)	Modification of consumption in panel 2 (%)
Not Informed	M1: −13.25	M1: −17.50	M1: 13.60
	M2: −15.42	**M2: −18.50**	M2: −13.80
	M3: −5.89	M3: −4.30	**M3: −17.7**
Informed	**M1: −33.08**	M1: −50	M1: −5.90
	M2: −2.06	M2: 80	**M2: −48.40**
	M3: −20.95	**M3: −54.20**	M3: 21.70

The percentages in bold are the most significant consumptions for each group

Table 8 Groupings of users according to the influences of modalities M1, M2 and M3

Campaign no.1	1st and 2nd days[a]	2 last days[a]	Remanence
M1	103	118	Non lasting (growth in consumption)
M2	69	119	Non lasting (growth in consumption)
M3	101	81	4%
Campaign no.2	1st and 2nd days[a]	2 last days[a]	Remanence
M1	57	61	Non lasting (growth in consumption)
M2	64	24	63%
M3	44	65	Non lasting (growth in consumption)

[a] After modality (paper consumed for sample group)

tion measured 1–2 days after stopping eco-feedback (the two campaigns having different periods, of 9–10 days for Campaign 1, and of 4–5 days in Campaign 2); p is the period of time between Con_y and Con_x.

A positive result will be only indicative of the lost of *remanence* of the message. A negative result will inform of the rate of *remanence* the message is having.

Other curve models can be adjusted when more data is available. The key point in this observation is that the *remanence* is shown to exist or not, thus giving information on the performance of the feedback being used.

Following the analysis of the results of our experimentations, we detected a *remanence* that diminishes over time concerning individuals' consumption of paper towels. This varies according to the type of information between the two panels. The experimental protocol for the first campaign is based on measurement over 10 days, and for the second campaign over a 5 day period.

Table 8 shows panel members' consumption of paper towels for each of the campaigns of the behavioural study on the two days following the sending of the modality (M1, M2 and M3) as well as on the last two days of measurement. The comparison between these two columns in the table shows the impact of the eco-feedbck on user behaviour over time. The values for the *remanence* rate have been converted to positive values in order to understand better the concept.

The experimental protocol chosen sent the feedback modalities by mail once the first measuring phase was over (measures MX.0). Sending the modality by mail gave decentralised feedback on user consumption.

For both campaigns, an increase in consumption was observed between the first two days of measuring and the last two days for modalities M1 and M2. On the contrary, modality 3 shows a reduction in user consumption. Modality 3 being the Negative feedback, the influence of the modality had a stronger impact which was more marked over time. This configuration was repeated for the second measurement campaign.

The increase in paper consumption after 5–10 days of observation shows that it is necessary to implement continuous and followed up feedback for users. The feedback modality chosen here was not directly on the product and was not in real time, so there was no stabilisation of consumption after the modality had been sent. In order to make up for this phenomenon, real time feedback that is physically present on the product would probably have a longer lasting influence on users usage performance.

5 Eco-product design and the importance of feedback: the Green-Use Learning Cycle (GULC) concept as a new strategy

The many and varied user profiles and their knowledge of the environment and the challenges it presents imply that eco-feedback should be adapted and adaptable to users interacting with products. The vision of sustainable development is strongly supported by eco-designed products and by integrating functions aimed at communicating better with users. Right from the design phase, products should integrate functions allowing an exchange of information between product and user, the product being adapted to users' usage and users learning from eco-feedback information delivered by the product. In this perspective, we thought of the paper towel dispenser as a product to determine the potential environmental impacts on usage performance and ecological usage footprint of redesigning this product to be eco-learning. The different tests carried out during this study highlighted the necessity of designing products based on a new concept, encouraging eco-learning usage. In fact the potential of iterative feedback with the user combined with intelligent systems with embedded sensors resulted in our defining the GULC as a new concept for designing eco-products.

The choice of the most suitable feedback for the usage of the product is proposed in the context of understanding user profile level of awareness as well as the type of feedback which could be included in the product's functioning. The detailed analysis of the reactions of the groups defined by their "informed" or "not informed" profiles have shown that the neutral feedback modality is not effective. However, we have also shown that the negative feedback modality has the highest *remanence*. We can thus already take these two discoveries into consideration when designing innovating products.

The design of a product obviously takes account not only of its technical functionality, but also of the perceptions and possible interactions of users. In considering an eco-design approach, it is thus important to adapt different design strategies to the different types of product users with a view to ecological usage. In the case of the paper towels, by following up user performance, we could envisage a product adaptable to different contexts of use by changing the feedback modality and its level of decision making power (from "feedback" to "persuasive technology").

The GULC Concept is illustrated in Fig. 7. It aims to drive the user towards an ecologically friendly interaction with the product [18]. The GULC concept method is applied over four phases.

Firstly, we analyse the product's ecological impact if it were used in an ideal way. This "ideal usage" serves as a reference point for measuring the real-use impact of the product while interacting with the actual user. Secondly, we must define how the power of decision will be proposed initially. According to the usage sought and the type of product, different levels of power of decision (Fig. 3) may be chosen. When choosing a particular type of feedback, the order, frequency and eventual change in the message should be considered. The third phase follows up user performance unobtrusively. This enables a comparison of "ideal use" vs. "real use", resulting in information as to the success of the feedback strategy chosen. The data retrieved is stocked to be re-used in the fourth phase. In the fourth phase, opportunities for improvement or updating are implemented and

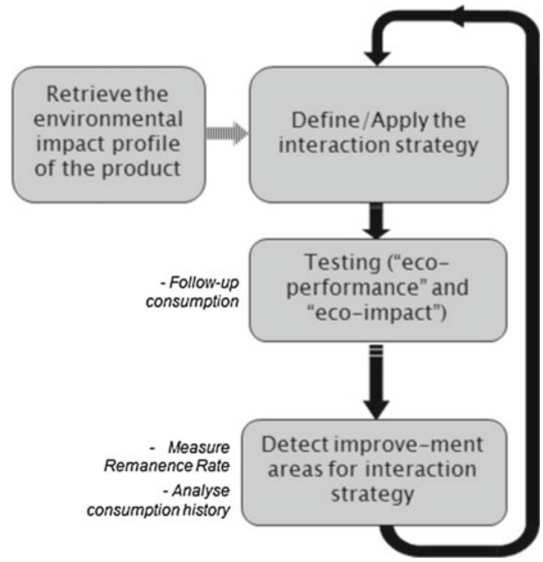

Fig. 7 Green-Use Learning Cycle (GULC) concept method

the cycle is completed with the re-application of the strategy. User behaviour is observed in terms of the consumption of the targeted unit (this might be be energy, material, resources, etc.), and the *remanence* is evaluated, along with feedback performance (if the power-decision level chosen for the strategy has taken this into consideration). The GULC concept goes beyond the static application of a feedback strategy for eco-use. It considers the evolution of users' performance and product functionalities over time. In real situations, the product should adapt to the fact that users change, learn or even forget how to use a product. The GULC concept can now develop dynamic interaction to achieve minimal environmental impact.

6 Conclusions and perspectives

Through this experimentation on modalities of feedback for users on their environmental performance, we have dealt with the question of the ecological assessment of products and services. Indeed, we propose going beyond the regulatory requirements in order to provide users with relevant feedback to enable them to become consumer-actors, aware of the ecological consequences of their behaviour. Moreover, we encourage designers to no longer list ecological impacts as averages, but in terms of differing types of usage. The study tries to show the necessity of implementing eco-feedback that follows up users in order to obtain long lasting positive effects on the usage performance of those who use paper towel distributors.

We have shown that a person's level of environmental awareness influences the efficiency of the modality of eco-feedback. We have also shown that the efficacy of a modality of eco-feedback diminishes over time; this decline which we call *remanence* is different for eco-feedback which is neutral, positive or negative. In our case study, negative feedback proved to have a positive *remanence*, while the other types of feedback proved negative. For this experiment, it means that even though different types of feedback may have similar impacts while they are being communicated, people only retain their new "eco-learnt" behaviour after negative feedback. The discovery of this kind of insight, that can vary from product to product, can play a part in determining general feedback strategy. We have shown that it was possible to modify user behaviour on an everyday product (moreover, a product that did not impact their own budget, but that of their employer), by providing suitable incentive feedback on their consumption. It would be pertinent to compare this type of work with that of Schmalz et al. [17] in order to optimise product design.

This concept is based on the fact that products must no longer be developed simply to correspond to an "average" usage considered as final, but must be designed :

– So that the product can give users feedback iteratively (throughout its life cycle) on the environmental performance of their usage (thus enabling the user to adapt to the product)
– So that users may understand and analyse the dominant parameters of product usage (and their evolutions) in order to configure the product to its environmental optimum throughout its life cycle (enabling the product to adapt to the user).

The main contribution of our work lies in the proposal of a methodology for improving existing products designs in the use phase. This methodology enables the observation of real life situations and the follow-up of users. This follow-up shows a more accurate view of the circumnstances under which the environmental impact of use phases is being made. The product development team can thus develop strategies which will be more useful than the ones based on an averaged theoretical use.

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