Personalised Eco-Feedback as A Design Technique for Motivating Energy Saving Behaviour at Home

Petromil Petkov
Chair for Information Systems
Technische Universität München
Boltzmannstr. 3, 85748 Garching, Germany
petromil.petkov@googlemail.com

Suparna Goswami
Chair for Information Systems
Technische Universität München
Boltzmannstr. 3, 85748 Garching, Germany
suparna.goswami@in.tum.de

Felix Köbler
Chair for Information Systems
Technische Universität München
Boltzmannstr. 3, 85748 Garching, Germany
felix.koebler@in.tum.de

Helmut Krcmar
Chair for Information Systems
Technische Universität München
Boltzmannstr. 3, 85748 Garching, Germany
krcmar@in.tum.de

ABSTRACT
In recent years, interaction designers have actively started addressing sustainability as a research topic. More specifically, persuasive applications, which aim at promoting pro-environmental behaviour, such as energy saving have been of growing interest in multiple research disciplines. Driven by the proliferation of smart meters and energy monitors as well as the rise of social media, researchers and designers of persuasive applications have developed a wide range of design solutions that address this issue. The majority of them, however, provide the same information to users irrespective of differences in their environmental concerns and different motivations to conserve energy. Our research addresses this gap. We design mock-up screens that provide feedback catering towards different pro-environmental values and concerns and ask users to evaluate them in a survey setting. The research aims at understanding what feedback different people find relevant and therefore attempts to bridge the gap between environmental psychology and HCI. At the same time it provides insights for the design of personalised eco-feedback related to energy consumption.

Author Keywords
Persuasive Applications, Sustainable HCI, Eco-Feedback, Environmental Concerns, Energy Conservation

ACM Classification Keywords
H.5.2 User Interfaces: User-centred design.

INTRODUCTION
Environmental sustainability related topics are receiving growing interest within the society, among researchers and among practitioners, such as Opower [48]. These topics have also grown into a significant research stream in the field of human-computer interaction (HCI) in recent years. In particular, research has focused on issues related to excessive domestic energy consumption, and different ways of addressing and reducing unsustainable practices. The growing body of work on this topic includes research on: energy conservation practices [39], users' acceptance of, and interaction with smart meters and energy monitors [15,45] as well as the design and evaluation of persuasive systems and applications that motivate users to conserve energy at home [15,19,24]. Persuasive technologies that provide feedback on user behaviour with the objective of reducing environmental impact are referred to as eco-feedback technologies [17].

Persuasive applications aim to change user's attitudes or behaviours through means other than enforcement and deception [35] and were first researched in detail by Fogg et al. at Stanford University [14]. To achieve attitude change, they provide thought-provoking information, apply gaming dynamics, or leverage social influence [14]. Technological developments in the last few years have created favourable conditions for the deployment of persuasive applications in different contexts. The rise of social media provides access to users' social graphs and preferences, thus creating opportunities for persuasion through social influence. Along with this, the proliferation of mobile applications extends the reach of persuasive applications by providing a platform that allows uninterrupted interaction with users. In the context of energy conservation, these developments, coupled with the availability of smart meters that deliver real-time data, and mobile devices with sensors create opportunities for providing meaningful feedback regarding energy consumption to users.

Despite these favourable developments, persuasive applications for motivating energy conservation have had variable success [17]. One reason for these results could be that the research prototypes provide generic information to different individuals although users are susceptible to different influences [28]. Therefore, it has been suggested that persuasive technologies should use different persuasion

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profiles to determine the most appropriate persuasion strategy [27]. Accordingly, our research investigates different mechanisms of individualizing information and feedback provided to users in persuasive applications.

Most of the existing research prototypes and persuasive applications which promote energy saving do not base their design decisions and recommendations on theoretically robust frameworks of human pro-environmental behaviour [20,39,45]. The lack of such formalised design approaches can result in ad-hoc findings that are not replicable and therefore reuse of even successful designs is complicated or impossible since the success factors remain unclear.

Our research addresses the above-mentioned problems in designing persuasive applications for energy conservation for users who are susceptible to different kinds of persuasion strategies. We propose classifying users based on their pro-environmental values as outlined by Stern's *Value-Belief-Norm* (VBN) theory [44]. Drawing from research on environmental psychology and different models of pro-environmental behaviour, the proposed design sets an emphasis on the differences of the environmental concerns of users, which are determined by their values – *egoistic*, *altruistic*, and *biospheric*. We realise that people often do not act rationally, according to their values; however human values are at the core of our design since they are significant determinants of valued objects, which ultimately determine what information is relevant for promoting behaviour change [44]. The proposed design guidelines for personalised persuasion strategies for different user categories are presented and empirically evaluated in a survey setting.

The remaining sections of the paper are organized as follows: in the next section we provide an overview of the current state of research on eco-feedback and different models of pro-environmental behaviour based on environmental psychology. We then outline the gap in the present body of research, and describe the design of mock-up screens, which form the basis for deriving the design guidelines. We evaluate the proposed designs by testing them in a survey setting. The findings from our evaluation and their implications are subsequently discussed.

LITERATURE REVIEW

Persuasive applications promoting energy conservation employ various motivational techniques to engage their users and guide them through the process of behaviour change. These applications focus on eco-feedback as a persuasive technique for motivating pro-environmental behaviours. The research draws on works from the field of environmental psychology, and in particular, applies the VBN theory [44] as a model for understanding individuals' motivations for environment-friendly actions.

Eco-Feedback

Feedback is a mechanism, through which people can monitor their performance in various activities and evaluate their progress over time [30]. Eco-feedback is a type of feedback that relates to behaviours aimed at reducing the negative human impact on the environment [17]. Research has shown that it is one of the most effective motivational techniques for promoting energy conservation at home. For example, in a comprehensive analysis of past studies, it was found that feedback on energy consumption at home potentially results in up to 15% in energy savings [10].

Eco-feedback applications are usually based on the assumption that individuals lack awareness and understanding about how their everyday activities affect the environment [17]. Therefore, eco-feedback applications not only present the amount of consumed or conserved energy as a feedback, but also have the potential to point out consequences of this consumption on the environment. Further, eco-feedback applications can provide comparisons between a user's consumption vis-à-vis that of their neighbours and friends as well as disclose devices or activities that are energy intensive. The manner in which individuals will react to the information content of the feedback provided is largely dependent on their motivation to conserve energy.

Environmental Psychology

Environmental psychology represents a broad range of scientific branches dealing with the complex interactions between humans and the environment [30]. One particular branch of environmental psychology is concerned with pro-environmental behaviours among humans, i.e., the minimization of the negative impact of human activities on the environment [30]. To explain the factors influencing pro-environmental activities, environmental psychologists have developed theoretical frameworks also known as models of pro-environmental behaviour. These models reflect the various approaches towards explaining how and why people act in a pro-environmental manner and can be broadly classified in – rational-choice models and norm-activation models.

Rational-Choice Models

According to the rational-choice models, also called attitude models, self-interest is the most significant determinant of environmental behaviour because of people's drive to seek rewards and avoid unfavourable situations [5]. Based on the premise that people act rationally, decision-making is thought to be an outcome of rational evaluation of expected consequences of the behaviour [30].

The earliest attitude models proposed that pro-environmental behaviour is the result of general attitudes, such as environmental awareness and concern. These attitudes, in turn, depend on knowledge about the environment [30]. Therefore, the rational-choice models assume that the clear communication of information about the negative impact of human activity on the environment is itself sufficient to provoke pro-environmental behaviour [7]. However it has been shown that such an approach is

flawed and general attitudes cannot be regarded as direct determinants of pro-environmental behaviour [4].

Shortcomings of the attitude driven models were addressed in the *Theory of Reasoned Action* [3] by introducing the concept of behaviour intention as a determinant of behaviour. The two factors influencing behaviour intention are attitude towards the behaviour and subjective norms [26]. Subjective norms consist of social factors describing the perceived social pressure to perform or not perform the behaviour [2]. The *Theory of Planned Behaviour* further introduced perceived behaviour control as one of the factors that influence behaviour intention. Perceived behaviour control is the individual's judgement about how well she can perform the behaviour. It might depend on personal capabilities, money, time or other relevant resources [2].

Hines et al. [21] extended the Theory of Planned Behaviour in the context of environmental behaviour by proposing the *Model of Responsible Environmental Behaviour*, which suggests that external situational factors are determinants of behaviour [5, 21].

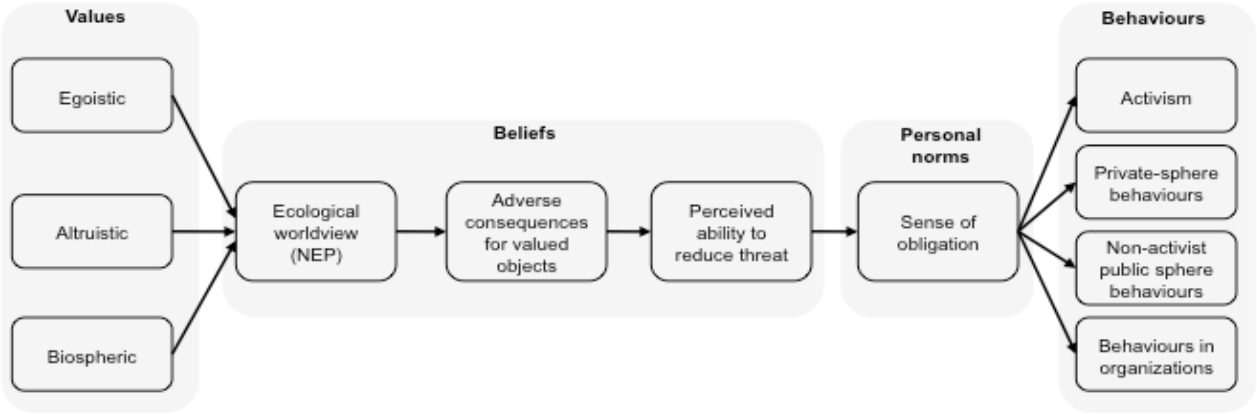

Figure 1: Stern's Value-Belief-Norm Model [44]

Norm-Activation Models

In contrast to the rationalist, attitude-driven models, the norm-activation models view social motives as the most important determinants of pro-environmental behaviour [5]. Such motives, e.g., those of avoiding conditions harmful to others, rely on the basic premise that moral or personal norms directly influence pro-social behaviour. According to the *Altruism Theory* by Schwartz [42] moral obligations to behave in a pro-social manner are central drivers for environment friendly behaviours.

Value-Belief-Norm theory (VBN) by Stern [44] is a popular representative of the norm-activation models, which builds on *Value Theory* [23], Altruism Theory [42] and *New Environmental Paradigm* (NEP) [12]. VBN states that behaviours result from five sequentially chained variables: personal values, ecological worldview, adverse consequences for valued objects, perceived ability to reduce threat, and personal norms (Figure 1), whereby each variable affects the variable that is directly dependent on it, and may also affect variables that are indirectly dependent on it [44].

Individuals can have different kinds of personal values. Environmental concerns, and therefore, the motivation for pro-environmental behaviour are caused by three different value orientations that individuals might exhibit [44]: egoistic, altruistic, and biospheric [30].

Egoistic values relate to the needs and wants of the individual. Therefore egoistic environmental concerns can rise from beliefs that environmental damage can adversely affect the self. Examples for egoistic-driven motivation are saving energy to save money or avoid local air pollution that negatively impacts individual's health. In contrast, altruistic values focus on avoiding threats for other people. An example for altruistic behaviour is preserving natural resources such as water for future generations.

Biospheric values are concerned with harmful influences on nature and wildlife. Therefore, a person with predominantly biospheric values would attempt to save energy (and so reduce her negative impact on the climate) upon understanding that climate change destroys the habitat of animals such as polar bears or can cause irreversible damage to the ecosystem.

Values alone are insufficient to provoke pro-environmental behaviour. According to the VBN theory, the individual should acknowledge that their environmental concerns are real and exist in the real world. Three factors address individual's environmental concerns: (1) one's general beliefs about the relationship between humans and environment (NEP); (2) beliefs that valued objects are threatened; (3) beliefs that one can reduce the threat to valued objects through their behaviour. These beliefs activate the sense of obligation to take action (personal

norms). Ultimately these feelings of obligation lead to acting in a pro-environmental manner [44].

Social Influence

Contextual factors have a significant impact on pro-environmental behaviours [44]. Such contextual factors are social influence, advertising, regulations, monetary incentives, constraints by the technology or the environment. Several studies have shown that social influence has significant impact on users' motivation to conserve energy [15,33].

Mankoff et al. [34] developed a prototype of a persuasive application that added social components to feedback about user' energy consumption by integrating relevant data on a user's profile page on the social networking site MySpace. Their idea evolved into a "green" online community called StepGreen.org [33] that employed social public commitment and competition dynamics to motivate people save energy. The results showed that social feedback can be an effective form of persuasion that engages users in energy saving.

Similar results were obtained by Foster et al. [15] whose Facebook application for energy saving had a positive effect on the energy consumption of eight households - their energy usage reduced significantly due to socially mediated encouragement and competition. Advantages of socially "enabled" eco-feedback are that it satisfies an individual's need for social status through competition [46], motivates through peer pressure [36] and taps the unconscious human strive to comply with the actions of like-minded individuals [9,46]. It is particularly successful if the provided feedback is related to people that the individual considers important [1].

Despite the effectiveness of social influence in eco-feedback and pro-environmental behaviours, previous research has not examined the relationship between social influence and the other pro-environmental values, and the extent to which they interact with each other in determining users' intention towards environment friendly actions.

RESEARCH GAP

Design decisions in persuasive applications for motivating environment-friendly actions such as energy conservation are often taken intuitively, rather than being theoretically determined [17]. Applications are often designed to provide the same feedback to different people [20], therefore contradicting theories such as VBN, which suggests that different people value different things depending on their environmental values.

Individuals' motivations to behave in a more sustainable and environment-friendly manner will depend on the kind of environmental concerns they have. Therefore, the information used to persuade them to change their energy consumption behaviour should be adjusted accordingly. However, the current genre of applications for energy conservation is pre-dominantly based on the notion of resource management, i.e., the representation of energy consumption is in abstract units, such as kilowatt hours (kWh) without detailed explanation about the consequences of this consumption). These applications assume strong user motivation to save energy and a high level of expertise with regards to energy saving [45].

Our research attempts to bridge the gap between environmental psychology and the design of persuasive applications in the context of energy saving. Based on the VBN, we identify three different individual values – egoistic, altruistic, and biospheric. These values are used to determine the information (feedback) that is considered relevant by individuals, and should therefore be presented to them so that their beliefs about the threat for valued objects and the ability to reduce this threat are activated. Therefore, this research is guided by the basic proposition:

> *Feedback that is tailored towards an individual's motivation for pro-environmental behaviour will be more effective in influencing energy conservation.*

Based on the above proposition, it is conjectured that users' preference for energy consumption related feedback is presumably determined by their individual values. Since contextual factors such as social influence may have different meanings to different people depending on their beliefs and attitudes [44], a further goal of this research is to provide insights on how eco-feedback can be enhanced by incorporating information that captures social influence.

RESEARCH DESIGN

The process of deriving design guidelines for energy consumption-related feedback consists of incorporating individual's values (motivations for pro-environmental behaviour) into the eco-feedback. We developed mock-up application screens providing eco-feedback, which cater to egoistic, altruistic or biospheric environmental concerns that users have. In addition to the three screens providing feedback relating to environmental implications of energy consumption, a fourth screen was developed which provides social norm related feedback.

The designs of these mock-up screens are tested by measuring the extent to which users perceive the screens to be useful and are satisfied with the information content in them. Our overall research design can be summarized as follows:

1. Theory-driven design of the mock-up screens containing eco-feedback tailored to specific environmental concerns, and one providing social norm-related feedback
2. Measuring users' environmental concerns (arising from different values) and susceptibility to social influence using validated scales (questions).
3. Getting users' feedbacks and preferences regarding the mock-up screens through an online survey.

4. Analysing the survey data to refine design guidelines, and outline the implications of this research.

Mock-up Screen Design

People with different values have different environmental concerns [43], and therefore should be provided different eco-feedback [20, 45]. Accordingly, we developed different mock-up screens to reflect the differences in egoistic, altruistic and biospheric environmental concerns. Each screen displays the weekly consumption of a single household, and the different impacts of this consumption. To design the screens, we used the valued objects that were empirically derived by Schultz based on the three value classes (Table 1) [41]. The screens were developed through a theory-driven design approach [8] by combining designs from research prototypes and commercial products. Each screen was further divided into three parts, each of which contains eco-feedback about one particular valued object from the respective value class.

Egoistic	Altruistic	Biospheric
Me	All people	Plants
My health	Children	Marine life
My lifestyle	My children	Animals
My future	People in my country	Birds

Table 1: Valued Objects for Different Environmental Concerns [41]

The screen addressing egoistic environmental concerns (Figure 2, left) contains information pertaining to the components My Lifestyle, My Health, My Future [41]. The lifestyle component presents monetary savings due to decreased energy consumption during the previous week. Since the saved amount of money may be negligible and can decrease user's motivation [47], we presented the long-term savings as a consumer lifestyle product – an iPod. The health component relates energy consumption to the air quality – an environmental aspect that people have interest in [29]. It is not only a visible effect of the excessive consumption but also assumes some damage to individual's health. Finally, to depict the impact of the consumption on the user's future, we use a modified version of "Here is your 2020" [24] reformulated in terms of costs for food.

For the mock-up screen addressing altruistic environmental concerns (Figure 2, right), we employed a "newspaper from the future" metaphor [24] to present the long-term negative impact of user's energy consumption on other human beings. Eco-feedback about the altruism-related valued objects All People, My Community, and Children [41] is displayed as three news articles.

The third mock-up (Figure 3, left) addresses biospheric concerns. The three different parts of the screen relate to the valued objects Animals, Plants, World Ecosystem [41]. As proposed by Schultz, we replaced Marine Life and Birds (as they both can also be classified as Animals) with World Ecosystem. Moreover, our intention was to emphasize on user's impact on the Earth's ecosystem as a whole.

Inspired by the "Polar bear" visualization of UbiGreen [16], the Animals component illustrates how the excessive energy consumption damages the habitat of polar bears. In the Plants section, we used the easily comprehendible and widely used representation of trees [22, 37]. In contrast to the negative charged Animals component, here we neutrally highlight the resources (trees) necessary to compensate for the energy consumption and so indirectly touch on user's concerns. The last section of the mock-up screen provides more holistic perspective on the impact of energy consumption and is influenced by the ecological print visualization by the Global Footprint Network (GFN) [18].

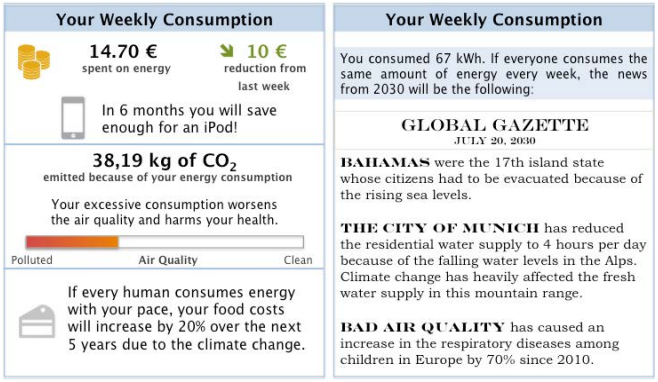

Figure 2: Egoistic Screen (left), Altruistic Screen (right)

The fourth mock-up screen (Figure 3, right) was designed to provide social influence related feedback. Although at first sight the social components may appear to be more closely related to the egoistic motivations (e.g., complying with the actions of the own group [9] or gaining social status [46]), they could also contribute to higher engagement of users with motivations other than egoistic.

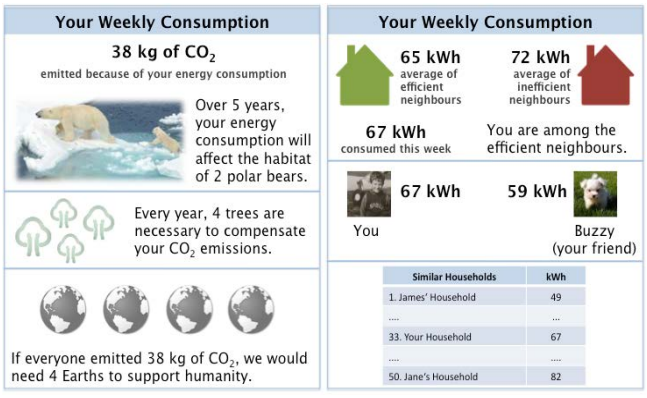

Figure 3: Biospheric Screen (left), Social Screen (right)

Making people with predominantly altruistic or biospheric motivations aware that they are not alone in their efforts to conserve energy is essential. Showing them that there are other committed individuals puts their actions in larger

context and thus increases the willingness to sustain their behaviour [11].

Previous research by the authors has provided evidence that different people prefer different social comparisons with regard to energy saving [38]. For example, some people prefer being compared to a group of similar consumers (for example, neighbours) or being ranked among similar households, while competitive individuals are interested in one-to-one comparisons with their peers [38]. The design of the social feedback screen reflects these differences and therefore contains a normative comparison with the average consumption of neighbours, one-on-one comparison with a friend, and a ranking of households with similar consumption patterns.

Online Survey

We conducted a survey to evaluate the effectiveness of the mock-up design. Users' environmental concerns were assessed using a 7-point Likert scale comprising 13 questions from Joireman et al. [25]. Social influence was measured by adapting items from the Susceptibility to Interpersonal Influence Scale [6]. Table 2 provides the measurement items applied in the survey.

Egoistic Concerns
A clean environment provides me with better opportunities for recreation.
Protecting the environment will threaten jobs for people like me.
Laws to protect the environment limit my choices and personal freedom.
Environmental protection is beneficial to my health.
Altruistic Concerns
Pollution generated here harms people all over the earth.
We don't need to worry about the environment because future generations will be better able to deal with these problems than we are now.
The effects of pollution on public health are worse than we realise.
Environmental protection will help people have a better quality of life.
Environmental protection benefits everyone.
Biospheric Concerns
Modern development threatens wildlife.
Over the next several decades, thousands of species of plants and animals will become extinct.
Claims that we are changing the climate are exaggerated.
While some local plants and animals may have been harmed by environmental degradation, over the whole earth there has been little effect.
Social Influence
I would start saving energy if I am sure my friends approve it.
It is important for me that others like my energy saving efforts.
If other people can see me saving energy, I would do as they expect.
I like to know what behaviours make good impressions on others.
I achieve a sense of belonging by doing what others do.
I often identify with other people by behaving in a similar way.
To make sure I do the right thing, I would observe what others do.
If I have little experience with saving energy, I would ask my friends about it.
I would consult other people to help them choose the best energy saving alternative for them.
I would gather information from friends and family before I begin my energy saving efforts.

Table 2: Survey Items

Following these, we obtained users' feedback regarding the screens by showing them each mock-up screen and asking questions regarding the usefulness of the screens and the extent to which they were satisfied with the information provided on the screens. The questions measuring satisfaction were adopted from Liang et al. [31], while usefulness scale was obtained from Lund [32]. Respondents further indicated their preference regarding each of the three feedback items in a given screen. Usefulness and satisfaction are the most commonly used measures for usability and are good predictors of a user's intention to use an application. The final section of the survey asked them to rank the four different screens in terms of usefulness, and provide standard demographic information such as age, gender, household size, and level of education.

RESULTS

Respondents for the survey were recruited using various mechanisms. Emails requesting participation were sent to students registered in the under-graduate and post-graduate courses in a larger German university. Additionally, information regarding the study and a survey link were posted on researchers' Facebook profiles. We obtained 118 responses, out of which 77 were complete and therefore used in our analysis. Table 3 provides demographic information of survey respondents.

People were classified into groups for high or low egoistic, altruistic and biospheric environmental concerns, and high or low social influence. We calculated the average scores for egoistic concerns, altruistic concerns, biospheric concerns and social influence based on respondents' answers to the corresponding questions. We then classified people having a score higher than the mean value for egoistic concern into the *High egoistic concern group* and people having scores less than the mean value into *Low egoistic concern group*. Each of these groups were then analysed for differences in usefulness and satisfaction.

Demographic Variable	Categories	Frequency (N=77)
Age	15 - 24 25 – 34 Greater than 35	20 50 7
Gender	Female Male	37 39
Education	High school degree Bachelors	6 23

	Masters	44
	PhD	4
Household Size	Single	18
	Two persons	28
	Three persons	17
	Four or more	14

Table 3: Demographic Details

Table 4 reports the descriptive statistics of the dependent variables (usefulness and satisfaction) for the different categories.

Factors		Count	Dependent Variables	Mean (s.d.)
Egoistic	High	36	Usefulness	4.49 (1.27)
			Satisfaction	4.39 (1.55)
	Low	41	Usefulness	4.49 (1.39)
			Satisfaction	4.56 (1.57)
Altruistic	High	44	Usefulness	3.97 (1.76)
			Satisfaction	4.10 (1.84)
	Low	33	Usefulness	3.06 (1.32)
			Satisfaction	3.03 (1.44)
Biospheric	High	42	Usefulness	4.86 (1.35)
			Satisfaction	4.84 (1.59)
	Low	35	Usefulness	4.48 (1.77)
			Satisfaction	4.53 (1.77)
Social Influence	High	40	Usefulness	5.30 (1.37)
			Satisfaction	5.06 (1.56)
	Low	37	Usefulness	4.68 (1.38)
			Satisfaction	4.30 (1.54)

Table 4: Descriptive Statistics

We further test whether there is any significant difference in terms of the reported usefulness and satisfaction of the screens among the group with high concerns and the group with low concern (for each of the four categories of concerns). Table 5 reports the results of ANOVA (analysis of variance) testing for the four screens. The first row of Table 5 indicates that for the egoistic screen there is no significant difference (in terms of usefulness and satisfaction) between the high egoistic concerns group and the low egoistic concerns group. Similarly, there is no significant difference for the biospheric screen. However, for the altruistic screen, people having high altruistic concerns report significantly higher levels of usefulness and satisfaction with the screen. Similarly, for social influence screen people who are more susceptible to social influence report significantly higher usefulness.

Screen	Variable	F	Significance
Egoistic	Usefulness	.000	.986
	Satisfaction	.233	.631
Altruistic	Usefulness	6.623	**.015**
	Satisfaction	7.711	**.007**
Biospheric	Usefulness	1.132	.291
	Satisfaction	.648	.423
Social Influence	Usefulness	3.845	**.054**
	Satisfaction	2.110	.151

Table 5: ANOVA Results

We further asked respondents to rank the screens, and individual items within the screens in terms of their preference regarding usefulness. Table 6 and 7 report the results. Table 6 indicates that the egoistic screen is the top preference (ranked highest by 39 respondents), followed by the screen providing social influence related feedback, while the altruistic screen is preferred least.

Screen	Rank 1	Rank 2	Rank 3	Rank 4
Egoistic	39	22	11	5
Altruistic	4	6	16	51
Biospheric	9	24	37	7
Social Influence	25	25	13	14

Table 6: Screen Rankings

Table 7 should be interpreted as follows: on the egoistic screen the first item (on the top of the screen indicating the money saved) is ranked best by 49 respondents.

Screen	Item 1	Item 2	Item 3	Total
Egoistic	49	21	7	77
Altruistic	20	30	27	77
Biospheric	14	39	24	77
Social Influence	54	12	17	77

Table 7: Preference of Feedback Items within each Screen

Feedback regarding monetary savings is preferred most within the egoistic screen. The altruistic screen indicates no significant difference in terms of the feedback that is preferred by users. Within the biospheric screen, the feedback regarding the implications of the individual's energy consumption on plant life (number of trees needed for compensating) is considered more important, whereas the feedback item regarding polar bears is considered the least important. Within the social influence screen, the most preferred feedback item was the information about the comparison between the individuals' energy consumption and that of their neighbours.

DISCUSSION

Understanding what feedback different people find relevant was the primary focus of this research. In particular we were interested in examining how individuals with different environmental concerns react to the different mock-up screens with the intention of getting insights into designing more effective eco-feedback applications for energy savings. Our results show that most respondents ranked the egoistic screen as highest. However, the number of individuals falling in the high egoistic group is actually lower than the number of individuals in the low egoistic

group. This can be due to several reasons. First, it could be due to some social desirability bias in the responses, where people answer the questions in a manner that reflects them in a positive light and they do not want to appear selfish or only concerned about their own welfare. Secondly, it could be that the information provided by the egoistic mock-up screen is more proximal, and therefore users can relate to it better, and feel that they can influence this information through their actions. For instance, information regarding monetary savings has a very direct and near-future impact on an individual. This is also supported by the fact that the screen providing altruistic information is least preferred by most respondents, although the size of the high altruistic environmental concerns group is the largest.

The altruistic screen was designed to provide information that was more distal and therefore probably the respondents felt that they could not influence it effectively through their actions. The information presented may have seemed too unrealistic or futuristic to users. This feedback type can be improved by embedding real sensor data presenting the current state of the environment, such as pollution or temperature. Another reason why the altruistic screen was favoured least can be that the feedback provided was textual, while the feedback provided on the other screens are represented visually. This indicates that textual representation is not as engaging as visual presentations, and future designs should employ more graphics.

The feedback regarding the impact of energy consumption on trees was the most preferred feedback on the biospheric screen. While the other two feedback items were presented the negative impact that the user has on the environment, the tree representation was neutral. This indicates that people prefer positive rather than negative reinforcements in persuasive applications. These findings reflect a deviation from the propositions of the rational-choice model which states that a clear communication of negative impacts is sufficient for bringing about attitude change. Therefore, eco-feedback should outline how the user can contribute to the preservation of their ecosystems rather than reiterate how harmful their current actions are.

The preference for comparison with neighbours on the social-feedback screen reflects the importance of descriptive messages, which are missing in the second and third feedback within the same screen. Therefore putting comparisons with neighbours, friends or peers in context through descriptive messages, e.g., framing them as competitions or collaborations with the goal for improving the local community may be more effective.

Finally, it was observed that there are indeed some differences among the preferences of people with low and high environmental concerns. For instance, people with high altruistic environmental concerns indicated significantly higher levels of usefulness and satisfaction with the altruistic feedback, and also people who are more prone to social influence are likely to find feedback regarding social comparison useful. However, even the group with high altruistic concerns tend to prefer the egoistic and social screens rather than the altruistic screen. Based on the above findings, we propose the following general design guidelines for eco-feedback applications:

- Applications should be designed to provide proximal feedback (direct implications to self, short-term, near future implications).
- Visual feedback (information provided through pictures and graphical displays) is likely to be more effective.
- Applications should provide a mix of different kinds of feedback (egoistic, biospheric, altruistic, social influence) rather than providing only one kind of feedback.
- The feedback provided should be localized and contextualized (like information regarding a users' own community, neighbours, local plants and animals, etc.).
- Feedback should be framed in a positive or neutral way rather than presenting the negative impacts of users' energy consumption behaviour.
- Users' environmental concerns should be determined first in order to provide them with relevant feedback.

LIMITATIONS

The implications of our findings must be considered in the context of certain limitations. The finding that most respondents prefer the egoistic screen could be influenced by the demographics of our respondents. Our respondents were mostly young individuals less than 35 years old and more than half of the respondents lived in single or 2-person households. This could have resulted in them preferring the egoistic feedback rather than how their actions affected children, or the global ecosystem (altruistic feedback). Responses from people having families with children would have probably resulted in slightly different findings.

The use of mock-up screens could have resulted in some of the insignificant results pertaining to usefulness and satisfaction. Participants were asked to rate the usefulness of an interface and their satisfaction with and interface without having used it. Therefore, the results are more reflection of the users' perception rather than their actual behaviour. Using a working prototype in a longitudinal field test can give a better assessment of how people's environmental concerns can be addressed through eco-feedback, and motivate them to change their consumption behaviour.

FUTURE WORK

This research provides some initial guidelines on designing persuasive applications that aim to change energy consumption behaviours. Future research can validate the proposed design guidelines in a real life setting by designing working applications and evaluating them in a

field setting. Capturing users' interaction with such an application and correspondingly measuring their energy consumption over a prolonged period of time will provide better insights into users' motivations and their reaction to different kinds of eco-feedback. This can be done by designing interactive applications that use actual energy consumption data (measured through smart meters or obtained directly from the utility providers) and using it to provide realistic feedback that is interactive and changes over time to reflect changes in consumption levels.

CONCLUSION

Our study shows how environmental psychology can play an important role in informing the design of persuasive applications that motivate energy saving behaviour. Based on the proposition that users' environmental concerns stem from different environmental values and therefore, different users will be motivated by different kinds of feedback, our research provides theory-driven guidelines for designing such persuasive applications. These guidelines are derived based on the findings of an empirical study conducted with prospective users of such systems. Overall, this study contributes towards existing research in persuasive applications and technologies and can form the basis for designing more effective mechanisms for providing eco-feedback and persuading behaviour change in future.

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