

COPING WITH USER DIVERSITY: UX INFORMS THE DESIGN OF A DIGITAL INTERFACE THAT ENCOURAGES SUSTAINABLE BEHAVIOUR

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ABSTRACT

Human factors play a key role on the improvement of energy efficiency at the workplace. However, to mitigate this recurrent issue most of the approaches rely on ‘one-size-fits-all’ solutions which the literature on HCI evidenced that fails addressing the user diversity in office environments. Therefore, this paper emphasises on the relevance of boosting the User Centered Design (UCD) and enriching the User Experience (UX) as pivotal means to enhance the user engagement on digital interfaces that promote sustainable behaviour at work. To accomplish this goal, a digital interface that offers a range of strategies and functions directed to the different user archetypes (user diversity) has been designed and evaluated quantitatively and qualitatively. The analysed data shed light on the relevance of enhance the UX to design positive interactions which is a predictor of future system usage and engagement. The diversity of users and the impact of the UCD on the Design for Sustainable Behaviour are discussed throughout the paper. Besides, we propose future lines of work on designing digital systems able to adapt dynamically to user profiles during its usage.

KEYWORDS

User Centered Design, User Experience, Sustainability, Interface Design, Interaction Design, Design for Sustainable Behaviour.

1. INTRODUCTION

Energy waste is a major world issue that implies designing new strategies to promote sustainability initiatives. Special attention should be given to the whole lifecycle of the electronic devices and towards increasing the awareness of the citizens to reduce the energy consumption when using these devices. To maximise the latter initiative, the User-Centered perspective can be applied; overall taking into account that the human factors plays an important role on the energy consumption (Hekler et al., 2013). We understand the User Experience as a concept that embraces all aspects of the users’ interaction with the product, service and company. Moreover, satisfactory UX improves the perception of the system and can be considered an indicator of a better assimilation of the pro-environmental message (Law et al., 2009).

User Centered Design (UCD) can be considered as a methodology that includes a variety of research methods that involves the user from the beginning to the end of the process, offering a wide range of design tools that aims to understand the needs of the users. Furthermore, UCD also exposes a conception around the role of the user in the design process, giving importance to all the relative aspects about the understanding of the users (i.e. their diversity and their motivations) (Abrás, Maloney-Krichmar, Preece, 2004). UCD has been applied to inform the design in different areas ranging from healthcare (Sax et al., 2007) to software development (Vredenburg et al., 2002). However, to the best of our knowledge, the relation between UX, UCD methodology and the energy efficiency field has attracted little attention yet. Therefore, this paper presents the

application of such HCI methods to increase the awareness of workers about the energy consumption in their environment.

Our hypothesis is that addressing the diversity of users, the positive feelings derived from the UX may encourage the predisposition towards augmenting energy awareness. To shed light on this matter, our main contribution put the focus on the user diversity through the development and evaluation of a digital interface to promote energy consumption awareness with an improved UX for every user typology. Our proposed design process pretends to evaluate the impact of the UCD on the users and to understand the possibilities of the UX as a design attribute to raise the awareness of sustainability. The paper is structured as follows: Section 2 provides a short background on interface design for sustainable behaviour. Section 3 describes the research, the design method and evaluation of the proposal. Section 4 details the main findings and the discussion, and Section 5 closes the paper with the conclusions and future work.

2. BACKGROUND

Background analysis was undertaken systematically to understand the conceptual implications that should be taken into account in order to develop successful systems based on the UCD principles.

Firstly, we reviewed the existing literature about Design for Sustainable Behaviour (DfSB, a set of design techniques developed to affect users' behaviour) (Lockton et al., 2008). Next, we put the focus on the UCD approach. Finally, the diversity of the user characterisation (i.e. user profiles) was reviewed to understand the different approaches that could be followed to offer personalised strategies to increase energy awareness.

DfSB and behaviour change has been extensively studied in the literature. Overall in the design community (Lockton et al., 2008) and in the Human Computer Interaction (Wever et al., 2008). Hekler et al. (2013) identified three broad uses of behavioural theories from HCI scholars: 1) to inform the design of technical systems; 2) to guide evaluation strategies; 3) to define target users or screen participants for evaluation studies. Hence, Hekler et al. (2013) brought about to the HCI community the necessity of designers to understand the behaviour change models studied mainly by social scientists to better generate effective strategies.

Narrowing the lenses on the HCI for sustainability, we reviewed the related work of digital interface design. Although we can assume that the following works were developed with the users in mind, there is no evidence of the use of the UCD methodology as it was defined in (Abrás, Maloney-Krichmar, Preece, 2004). Two recent works in this area are highlighted: 1) *Kilowh.at*, a web based application developed to increase the energy awareness through comparisons (Hedin & Zapico, 2017). 2) Another web based application that offers to office workers persuasive techniques like online feedback self-monitoring, advices, comparison and control functions to promote the sustainability at the workplace (Yun et al., 2017).

The User-Centered research puts the focus on the knowledge extracted from the potential users. In addition, assumes the diversity of the people. Thus, the analysis of the different targets and user types is one of the first steps to develop useful interactive systems. The importance of understanding the user diversity is already explored by the literature (Coskun & Erbug, 2016). Different authors assume different dimensions of user diversity based on theoretical models or well-defined methodologies (Coskun et al., 2014; He et al., 2010; Halko & Kientz, 2010; Kaptein et al., 2008; Lockton et al., 2012). Therefore, we can find different characterisations depending of the lens used by each researcher. However, due to the lack of consensus about how to deal with diversity, we cannot consider any of them as the gold-standard to inform the classification of multi-users. Our design proposal has been implemented with features extracted from the highlighted related work. The mix of strategies proposed by Yun et al. (2017) helps to reach the different target users and complements each other. One of our contributions on top of the state of the art is the addition of control features to our digital interface. Thus, the possibility to manage remotely energy-consuming devices and appliances. Finally, the UX as a design strategy to promote the acceptance towards the interface and the provided message has been applicate. Some studies explored the theoretical implications and the need of the UCD and the UX on the design of sustainable interfaces (Haines et al., 2015; Wever et al., 2008). As commented before, we have not found any work in the corpus of literature reviewed where is included the UCD methodology as a relevant technique of the sustainable interface design. Indeed, we have not been able to find scholars relating the impact of the UX on the energy awareness of the users. Therefore, we cannot calculate yet to what extent the UCD and the UX are effective on DfSB. To try to contribute to solve this, we developed a system that faces the diversity of users through the methodology DCU, offering a desirable UX.

3. SYSTEM DESIGN

We have developed an interface following the UCD methodology and taking into account the theoretical background reviewed that involves the DfSB. The proposed interface is an early design to test the hypothesis that relate UX, user diversity and pro-environmental awareness. The steps followed based on the embraced methodology are: 1) initial research with users, 2) first Lo-Fi prototype, 3) heuristic evaluation of the first prototype, 4) Hi-Fi prototype design and 5) evaluation of the Hi-Fi prototype with users. These phases are explained below.

3.1 Early research with users

In the initial phase, we carried out user research with the aim of understanding the potential users' insights to extract design requirements. We ran a Focus Group (Kitzinger, 1995) with 2 groups of 6 workers each. The goal was 1) to discover the latent needs of the users in energy efficiency field (e.g. to comprehend what devices are the most used and when) and 2) to find problems that are related with energy consumption and to know the users the best as possible. In the session, we asked to the participants to rebuild their workday through pictograms and photos that showed work spaces and devices which would be potentially located in these areas (i.e. card sorting methodology). After completing this task, we introduced a set of open topics to encourage the debate and discussion about sustainability issues and energy efficiency at the workplace. Figure 1 shows the reconstruction of the workday done by a pair of users.

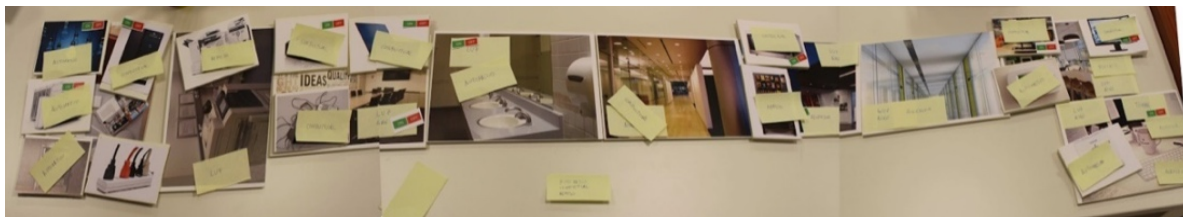


Figure 1. One of the work day reconstruction done at the Focus Group ordered as a timeline of the working day.

We found first that users hold forth comparative metrics to understand their energy consumption. In addition, we discovered that simple and easy visual metaphors were preferred to visualize the information in an effective and fast way. Besides, positive reinforcement was more likely to be accepted than the negative one. Another insight extracted from the session was that the automated processes designed to improve energy efficiency should be complemented with manual control systems and that the information about systems and processes status must be shown to the users. The hybrid approach between automation and manual control was the most liked one by the users. This latter finding is in line with Casado-Mansilla's work (2016). The author found that a complete automation of the systems in favour of energy efficiency might spark a rebound effect on users causing generalised distrust on technology. Thus, preventing subjects from controlling devices and appliances is associated with a reduction of the participant's confidence in technology as a means to solve all current environmental problems.

Having obtained the initial insights, we developed *Personas* (Harley, 2015) and *Scenarios* (Aoyama, 2007) to visualize and understand the potential archetypes of users. Our *Personas* were implemented with attributes extracted from the user research and from the mix made from literature: the attributes based on the behaviour types (Lockton et al., 2012) and based on the values and beliefs of the user (Petkov et al., 2011).

3.2 Design

Because of the use-context of the digital interface is the workplace, we decided to develop a web-based application. That could be consulted easily through a desktop computer. The Lo-Fi prototype of the system was developed with Balsamiq Mockups¹ on two phases. Firstly, the main system requirements were reviewed

¹ Website of the tool used to design the first Lo-Fi prototype: <https://balsamiq.com/products/mockups/>

to define the functions of the interface. Secondly, the focus was put on user diversity with the application of Lockton (2012) (Pinball, Shortcut and Thoughtful) and Petkov's (2012) (Egoistic, Altruistic, Biospheric and Social influence) theories. The relation between the user characterisation, and the strategies or features defined for each user type are presented in Table 1.

Table 1. Relation between user characterisation and the features developed on the interface.

User Profile	Definition	Feature
Pinball	Linear models of behaviour	Usability, plain language, automation options
Shortcut	Self-regulating models of behaviour	Comparisons between peers, public ranking, goals
Thoughtful	Learning models of behaviour	Information about energy consumption, tips, suggestions
Egoistic	Users with egoistic values	Information about the money savings
Altruistic	Users with altruistic values	Information about long term impact of the energy waste
Biospheric	Users with values related to ecosystem	Information about the impact on the animals and plants
Social influence	Users influenced by peers	Comparisons between peers, public ranking, goals.

At the Lo-Fi prototype the objective is to set up the Information Architecture of the interface and define the main elements and their placement and structure on the interface. As the first approach, all the elements of this prototype are provisional.

Following the UCD methodology, before iterating over the prototype the first evaluation should be done. For that purpose we developed a Heuristic Evaluation (Nielsen, 1994), in order to find usability errors, design problems and non-well defined aspects. We found 10 errors according to Nielsen's methodology for refinement: among them, four were not serious, five serious and one critic error. The most important errors were related to the website's navigation, correct understanding of the text tags and the coherence between the elements of the system and the information provided. Once the preliminary evaluation was finalised the next step was to iterate over the first refined version, developing a second prototype with more detail on the elements and content and implementing the improvements extracted from the Heuristic Evaluation.

The first Hi-Fi prototype was developed with Axure RP² software resulted on a desktop web application with all the final elements defined but with limited functionalities. The prototype is available at AxureShare³.

In this first iteration over the Lo-Fi Prototype the main objective was to have ready the setting of the main processes to evaluate it with real users. Figure 2 shows different screenshots of the digital interface created.

Besides the homepage, the digital user interface contains four sections: Information, Control, Social and User-Settings. The Homepage shows the average of the energy consumption of the worker connected devices through colour and shape coding in the logo of the website which resembles to a tree leaf. The Information section offers information about energy efficiency through different metrics and through different content. The Information section has three subsections 1) Data: it provides concrete information on energy expenditure through different approaches. 2) Suggestions: it offers to the user ideas and tips to be more efficient through the information detected in the monitoring of the devices. 3) More Information: it shows other related complementary information such as articles, tips and other advices. The Control section is intended for the remote controlling of the appliances associated to each user. In this section the devices linked to the system are shown (e.g. thermostat as can be observed in Figure 2b). An 'Add Device' button is inserted in case there is still no linked elements or whether the user aims to link a new one. The Social section is intended to persuade a type of user whose values are closely related to the social influence, according to the defined strategy. This section offers to the user the possibility to interact with other people, add groups of friends and make comparisons with other users. The Social section also contains a sub-section relative to Friends (where the users can interact with others), another one to provide social comparison as persuasive reinforcement and finally, one subsection where users are able to track the goals and achievements on their energy performance. The last section of the interface is the User Settings. It aims to improve the UX through the customization of some elements and functions.

The design was done following the structure defined at the first Lo-Fi prototype, and refining and implementing the main elements needed in the structure. The look and feel of the interface and the visual design

² The website of Axure RP software: <https://www.axure.com/>

³ The Hi-Fi prototype can be visited here: <http://wsobk2.axshare.com/-c=2>

has been separated from the design of the prototype, with the aim of not interfering with the users at the evaluation phase. We tried to maintain the simplicity defined at previous phases, prioritizing the legibility and the understanding of the content rather than aesthetics. The typography and the iconography are the main elements of communication and the green colour is a constant that involves the interface with the sustainability concept.



Figure 2. User interface of the Hi-Fi prototype: a) the Information section, b) Device Control section, c) Social section and d) User-Settings section.

4. EVALUATION

The evaluation with users at early stages of the design process helps to validate the decisions made and to focus the design in the correct way before problems arise, avoiding the development of systems with deficiencies. The main objective of this first evaluation of the Hi-Fi prototype was to get the opinion of the users about the system and to know if it offers good usability and UX. We did a usability test (Corry et al., 1997) with a semi-structured interview (Whiting, 2008) and, furthermore, we handed out the System Usability Scale (SUS) questionnaire (Brooke, 1996) for the users to complete. This tool is an 10 item questionnaire that evaluates the usability of the system. The goal was to triangulate the evaluation through different methodologies to increase results reliability according to Mackay & Fayard (1997).

Participants were selected by convenience and they did not have previous knowledge of the work carried out nor the digital interface itself. The main objective was to find users ranging 25-50 year-old who were regular users of computers, Smartphones, applications and web environments. The evaluation was done with a small user sample ($N = 5$). This sample is enough to discover most of the usability problems (Lindgaard & Chattratichart, 2007) but is not enough to extract statistical conclusions nor to cover the whole spectrum of user diversity. Participants were 2 males and 3 females whose ages were between 30-35 years ($M = 31.6$), and the Standard Deviation (SD) was small ($SD = 2.302$). All the participants signed a consent form at the beginning of the evaluation session.

4.1 Procedure

The evaluation session was done with the high fidelity prototype. It started with a brief introduction where the purpose of the assessment was explained. The first objective of the session was to carry out 4 specific task with

the digital interface with the ‘Thinking aloud’ methodology. After ensuring the correct understanding of each task, we proceeded to start them and record the start time and the audio to capture the user insights. Whenever a user had completed one task or the time limit expired, the task was tagged as finished and we proceed to the next one until completing the total. Then, some open questions were asked to the user about their opinion on the application, its usefulness and its degree of difficulty among other aspects. Finally, each user filled out the ten item-based SUS questionnaire to measure the usability of the interface.

4.2. Results

The percentage of error in tasks-accomplishment is a quantitative data that indicates the usability errors of the system. The percentage of error of the 20 tasks (4 tasks per user that have been executed by 5 users in total) executed in the usability test was 0. This is a positive fact that triangulates accordingly to the other two tests: the SUS questionnaire and the qualitative data.

The main conclusion drawn from the semi-structured interview was that most of the ideas provided were positive related to the acceptance of the application. Only two ideas revealed negative aspects (confusion and difficulty of concrete elements of the interface). We argue, that proportion-wise the 92.3% of positive insights gives an overall satisfactory evaluation of the digital artefact. The SUS questionnaire is evaluated in a score range from 0 to 100, where 0 is the lowest score and 100 the highest. The average score obtained among the 5 participants was 85,50 ($SD = 4.808$). As the data reveal, the score in all the questionnaires was above 80, which is why the usability of the designed interface was validated (according to the creators of the instrument, a SUS score above a 68 would be considered above average).

Although the general conclusions of the evaluation are satisfactory we need to take into account the limitations of the evaluation process. Thus, it is highly recommended to perform another usability test over time and with more users to expand the sample.

5. FINDINGS AND DISCUSSION

Next, the main aspects extracted from the development of the research, design and evaluation are detailed and discussed.

From the previous research to the final evaluation the qualitative data reveals that the users perceived the system as necessary and interesting. The insights extracted from the users indicate that this application would be easily embraced to help supporting the everyday lives of the users in the workplace. Overall facilitating the understanding of the energy consumption and connecting with it, which is a major issue in work environments.

The usability of the system is validated through the instruments used in the evaluation phase. The zero error rate at the usability test (task-accomplishment), the high score of SUS questionnaire (much higher than the general average) and the qualitative data extracted from the semi-structured interview established that the system is understandable and easy to use for the users. The simplicity can be a tool to make easy to understand the messages and to manage the energy processes and devices. The plain text tags and the synthesis of visual communication can enhance the learnability and the effective use of the system, helping to get a positive UX.

The data extracted from the evaluation shed lights on the potential that the UX and the usability may have to generate positive impact towards forming more sustainable behaviours. Indeed, users seems to be more disposed to receive messages through these kind of easy and personalised systems. The content provided was evaluated of high-value which might be also an indicative factor of the link between UX and the positive perception of the content provided towards increasing energy awareness.

As mentioned throughout this paper, the UCD can helps improving more efficient systems and interfaces with the user-centered research methodologies. The results show a positive feedback of the system designed with UCD methodology. Although development needs to be iterated, we can state that the designed interface is based on the needs of the users and that it is according to their mental model.

The used tools were focused on the evaluation of the usability and the UX of the digital interface. That give us the understanding of the relation of the users with the system, and indicate the effectiveness, legibility and learnability of the interface. These aspects may help on the validation of the interface, however, we do still need to understand whether the messages and content provided by the interface changes or not the user attitude towards energy efficiency. Thus, making people more aware about sustainability issues and hence

influencing pro-environmental behaviour change. Furthermore, the differences between the approximations of the literature pose a reflection on the categorization of users in which it is necessary go in depth. The different dimensions reviewed need to be developed and implemented in flexible user profiles, including all types of people and the different states of change in user behaviour.

6. CONCLUSIONS AND FUTURE WORK

In this paper, a digital interface designed, developed and tested applying UCD methodologies was devised to increase the user awareness related to energy efficiency at work. The user diversity has been approached in the interface proposed by adopting the mix of the user classification based on the reviewed theoretical background. The system was evaluated with more than XX users through three different methods to extract knowledge about the impact of the UCD and UX on the user predisposition towards the usage of proposed interface and increment of the workers' environmental awareness. The findings validated the usability of the system which puts in relevance the usefulness of the UCD as a methodology. Moreover, it draws into provide a positive the UX as a means to engage users towards more conscious behaviour.

The future research lines should aim to improve the proposed interface, improving the prototypes in quick iterations. Besides, the design process must be complemented with continuous evaluations with users. In fact, the number of participants need to be increased to statistically assess its potential to increase energy consumption awareness at workplace. Research-wise, we envisage the generation of flexible user profiles (i.e. adaptive profiles which can be slightly modified throughout the time) based on behavioral theories. This will involve the understanding of all the stages of the pro-environmental behaviour to change to adapt our digital interface to them. For that, we need to understand the different dimensions already defined and to develop characterisation standards.

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