Accounting for User Diversity in the Design for Sustainable Behaviour in Smart Offices

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***Abstract*— Human factors are essential in the promotion and success of energy efficiency initiatives in the workplace. The existing literature on the field has demonstrated that 'one-size-fits-all' solutions tend to fail because they overlook addressing user diversity and the different motivations to behave pro-environmentally. Thus, accounting for user heterogeneity appears to be a successful approach to improve the accuracy selecting and developing behaviour change strategies for different user profiles and work-contexts. This paper addresses the ideation and design process of an Internet of Things (IoT)-based physical object, a coaster, to foster energy awareness in an office-based workplace. Putting the diversity of users in the centre of the process, the Iot-design proposal links persuasive principles with user profiles in order to give personalised eco-feedback for each different user type. Insights on the inclusion of user diversity on the Design for Sustainable Behaviour (DfSB) theories are provided after conducting qualitative research to evaluate the relationship between users and the designed interactive coaster.**

Keywords*— Internet of Things, User diversity, Sustainable behaviour change, Tangible Interfaces, Persuasive Technology,

I. Introduction

Research in energy efficiency has increased in recent years due to increasing scarcity of non-renewable energy sources and the lack of energy awareness of people when over-using electricity. If the context is taken into account, while at private settings people seem to be more aware of their energy waste and expenditure, at shared or communal spaces, like the workplace, users' awareness diminishes considerably due to dilution of responsibility phenomena [1], [2]. This fact is in line with Pierce, Odom and Blevis when they stated that "the context can be a relevant factor to improve energy efficiency" [3]. In computing field, it is common to find two approaches to tackle such energy inefficiency: on the one hand, it can be improved through automation or a technology-led solution based on IoT [4]. On the other hand, energy awareness and sustainable behaviour change can be promoted, guided or mediated through technology. The idea that technologies could be designed to influence people's behaviour and attitudes emerged in the early 1990s, when Fogg introduced the term 'persuasive computing' [5].

In the context of technology, two main approaches are mainly used to classify persuasive interventions: (1) the seven persuasive principles provided by Fogg: tailoring, reduction, self-monitoring, suggestion and conditioning surveillance and tunnelling; and (2) the persuasive strategies proposed by Torning & Oinas-Kukkonen [6]: social comparison or competitions, surface credibility, normative influence, reminders, recognition, trustworthiness, cooperation, personalization, social role, real-world feel, 3rd party endorsements and verifiability.

In this work, we put the focus on human factors to improve the interaction between users and the technology designed to promote sustainable behaviour at workplace. Indeed, we consider that understanding human factors and diversity when approaching the design of tangible interactive objects is essential due to three main reasons: (1) to improve the eco-awareness about energy waste and sustainability issues; (2) to implement effective behaviour change strategies derived from persuasive principles to attain environmental sustainability; and (3) to promote the co-acceptance of new devices augmented with technology which aim at improving the energy efficiency through automation (Figure 1). Despite the existence of resources to address the diversity, He *et al.* argued that most of the technologies designed to influence certain behaviour offer the same design solutions and provide the same feedback to every individuals, neglecting that end-users may be in different stages of change, or may have different values, beliefs or motivations [7]. Hereby, one of the directions to improve the Design for Sustainable Behaviour (DfSB) [8] and persuasive interventions should be focusing on user diversity to maximize their effectiveness and impact through targeting specific user profiles.

Even though a completely technology-based approach could be able to improve energy efficiency without any intervention of the user, we consider that informing the user through interaction with persuasive technologies has beneficial consequences in people's overall behavior towards a sustainable way of life. Therefore, we consider that actually the interaction with an IoT device is a good opportunity to boost positive and sustainable behavior.

The paper is structured as follows: in the next section, we explore the related work addressing users' diversity. Then, we explain the ideation and design process of the Interactive Coaster (IC). Next, we highlight the findings, offering a discussion of them. Finally, we extract the main conclusions and we set future research lines of work.

II. User diversity for sustainability

User diversity has been already studied in sustainable behaviour change field [9],[10],[11],[12],[13]. Coskun *et al.* reviewed literature and taxonomies based on diverse dimensions of the users, each of them providing recommendations and suggestions for the design and implementation phases [9]. Nevertheless, still has not been found a unified classification or framework to develop a flexible and multi-dimensional user taxonomy linking sustainable behaviour change or persuasive interventions with user types. Besides, there are few systems which apply behaviour change strategies derived from persuasive principles addressing user diversity. Hence, validating the impact of design for diversity on sustainable behaviour change is yet an open research question. To shed light on this topic, in this paper we describe the ideation and design process of an interactive physical everyday object, which includes specific persuasive strategies focusing on user diversity as well as transversal strategies to underpin the main persuasive principles behind.

As Coskun *et al*. stated, existing literature on user diversity for sustainable behaviour change involves three main topics: (1) theoretical frameworks of different user characterizations; (2) recommendations and design patterns directed to each user profile; and (3) application of personalized design strategies addressing different user types through digital or tangible interfaces to encourage behaviour change.

Next, we highlight three user characterizations, extracted from the compilation made by [9]:

- A profiling based on the designers' perspective about users' behaviour. Proposed categories are *Pinball* for the linear models of the human system, *Shortcut* for the self-regulating models, and *Thoughtful* for the learning models of the human system [10].
- A classification based on user's values and beliefs. This taxonomy involves the profiles *Egoistic*, *Altruistic*, *Biospheric* and *Social Influenced* [11]
- A profiling based on intentions, attitudes and subjective norms. In this taxonomy, the proposed profiles are *Enthusiastic, Worried, Undecided* and *Irresponsible* [12].

Although related work offers theoretical frameworks [13], and some conceptual proposals [11] which can guide the design process, the implementation of persuasive interventions on tangible devices taking user diversity into account is not fully implemented and validated yet. Besides, the recommendations proposed by the different authors are ambiguous to apply, in some cases. Thus, the physical object that we propose, the Interactive Coaster, aims to fill this gap.

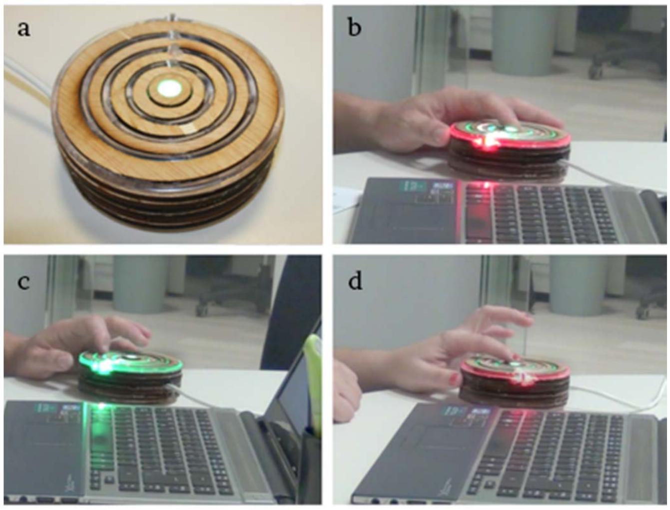

Fig. 1. A picture of the IC (a) and screenshots from the video recorded at the user testing session (b, c, d).

III. The interactive coaster

The IC is an everyday object intended to educate and motivate office workers reducing the energy consumption of the electrical devices that surround them in their desktop (e.g. laptops, mobile chargers, monitors, etc.). It has been designed taking the User-Centred Design methodology into account to improve the human-product interaction [14]. It is based on the user research to extract the design insights, the iterative evaluation of the prototypes and agile implementations of the findings.

The IC is a coaster, made of wood (Figure 1a) and includes concentric optical fibre wire that cast ambient light through RGB leds (it can be observed also in Figures 1b, 1c and 1d). The IC is connected to the Internet through a built-in microcontroller + Wi-Fi module[1], which enables receiving information about the energy consumption of desktop devices. It has been designed for simplicity, low energy consumption and intuitive use.

The main purpose of the IC is to provide information of energy consumption of the connected electronic devices (the energy will be measured through a smart power strip) providing feedback to the user through the lights of the coaster. For that, the feedback should be given in two ways: a) providing different information through each ring of the coaster or b) using all the rings as a unified element providing the same information and feedback through all the lights of the IC. The lights of the coaster will show a different colour depending the energy expenditure. Energy waste will be defined considering the average of the energy expenditure of each user. The colour codification of the light system is: green, to inform that the energy expenditure is less than the average; yellow to inform that the energy

[1] https://store.arduino.cc/arduino-mkr1000

expenditure is raising the average; and red, when energy expenditure raised over the average of energy waste.

The tangible interactive elements of the IC are a three-modes selector, placed on the side of the coaster (See Figure 2). This selector will manage the different modes of use of the IC: each mode implements the persuasive interventions addressed to each user profile (based on the taxonomy proposed by Lockton *et al.* [10]). The IC also features a button in the middle which after its operation triggers different visualization-modes (eco-feedback) depending on the selected mode.

In the following subsections the ideation and design process are explained, which were developed taking a user-centred perspective into account [14].

A. Ideation process

The first step facing the design process of the tangible device was ideation. The goal is to establish an initial approach to generate new ideas, prototypes or mock-ups based on the users' needs. For that, the researchers carried out a session to extract the design ideas which could be applied to different everyday objects in office-worker's desktops. Taking the literature and the user research developed in the previous work [15] into account a brainstorming session was developed. After the discussion and evaluation of the first product ideas, those with higher number of votes were linked to different persuasive principles to provide a theoretical background for the initial designs.

Based on selected ideas, a few sketches were made augmenting everyday objects using interactive systems to provide ambient feedback through visual cues (e.g. a lamp, a pencil-holder, a USB Hub, etc.). Figure 2 shows the sketches developed at the ideation session. After analysing each of them, the coaster was selected as the most promising idea. The decision was made because the coaster accomplishes the following requirements:

- It is a useful everyday object.
- Most of the end-users have and use a bottle of water or a mug in their desktops.
- It fits in desktop environment without disturbing it.
- The dimensions of the coaster are big enough to build the hardware inside.

Fig. 2. First 3D render of the IC. The black rectangle on the side is the mode selector to change the feedback provided by the IC.

- The coaster's top surface let us to implement the light system in convenient and visible way.
- The coaster offers a wide range of possibilities to implement different design ideas on it.

B. Prototype development

After the ideation phase, the next step was to develop the first Low-Fi prototype of the IC. This early version was intended to provide an initial approach of the physical design of the coaster, the information that it would provide, and the main interactions that should be implemented on it.

The main challenge of the initial design of the IC was creating the appropriate product design, media and visual content provided to the users. Therefore, this version of the IC was issued focusing mainly testing these parameters, letting the technical development for a second version of the IC.

This early version of the device allowed us to setup the first test with users to validate if the proposed design (including the physical aspects, the information provided, and the interactions) are user-friendly.

C. User research

As previously stated, the aim of this initial prototype is its evaluation with end-users to validate the design choices and to include diversity in the final device. Following a qualitative approach, we sought to share the first design ideas and strategies with them, understand their opinions, beliefs and needs, and validate the preferences of which information type is preferred by users. Hereafter, the evaluation methodology is exposed.

The participants were 3 males and 4 females, ranging 27-45 years old. All of them work at a shared space, mainly using the computer (either laptop or PC) and besides, different electronic equipment depending of their jobs. They were not aware of anything related to the IC before the qualitative session. The research conducted with the 7 end-users following a semi-structured interview approach. The study was voluntary, and we delivered a consent form at to inform the users about the study and about their rights. The interviews were recorded with a

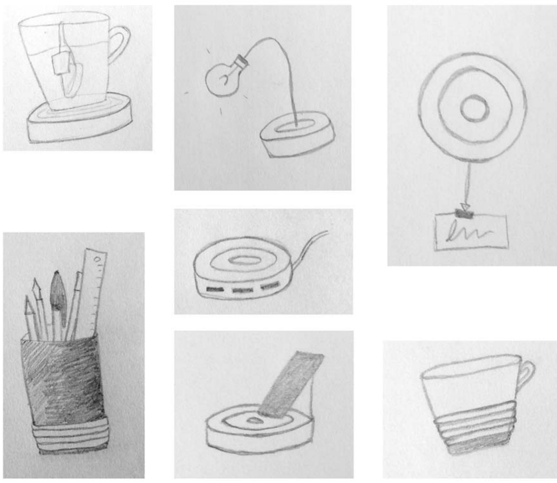

Fig. 3. First sketches made at the ideation session.

video-camera aiming at the interaction of the user's hands with the coaster (the camera was visible for the users and they had been informed about the recording process). The interviewees were initially provided with free time (2-5 minutes) to interact with the device and then, we started asking questions. We asked them about their opinion of the IC, which metrics were preferred to understand their energy consumption, which kind of feedback was more understandable for them, how they comprehend the coding of the provided information, etc. Figure 1 shows a series of pictures of the Interactive Coaster during the session. At the end of the interview, the users were invited to fill out a 6-item questionnaire, based on the survey defined by [16]. The survey aims to gather the users' perception about the persuasive technology in a 5-point Likert-scale questions. These points are related to different subjective issues about the technology and the device: the enjoyment of technology, the likelihood of use, the helpfulness, the improvement (or not) of the quality of life, the ease of use of the device and the energy saving through it (this last point is adapted from the original purpose that was Time Saving).

The analysis of the qualitative sessions was based on the review of the video recordings. We transcribed the most relevant ideas that emerged from the interview. After that, extracted data was compared by two researchers to ensure inter-rater reliability [17]. Finally, the main conclusions were ranked, selecting and highlighting the most relevant insights from the sessions. Although more evaluation is needed to validate users' insights and the design, the ideas that emerged during the analysis were promising. The main conclusions extracted from the qualitative evaluation of the first prototype of the IC were:

- Most of the respondents expressed interest in the multi-modality selection of the IC.
- Explanatory cues on the device are not needed if the metrics of the light rings of the IC are consistent with real-world analogies (e.g. smaller rings associated to devices with low energy consumption).
- The learning curve of how the device works is gradual and fast. However, basic information is needed at the beginning to understand the feedback and the interaction with the IC.
- Aesthetics play a paramount role for the user: the visual design as a factor to enhance the adoption, continuous use and maintenance of the device was highlighted.
- Individual metrics (e.g. your e-consumption) are preferred to external consumption (e.g. the overall consumption of the building) or comparative metrics among users.

The results extracted of the questionnaires are positive and are in consonance with qualitative findings: the obtained average score in all items is above 4 (the maximum score on the questionnaire is 5) in all the cases. Taking these findings into account, the most low-rated points were ease of use (4.142 points, *SD*=0,69) and helpfulness of the technology in saving energy (4.142 points, *SD*=0,69). This provide relevant insights which should be implement in future iterations over the prototype and on the future interaction design phases.

D. Selecting persuasive principles

Although the first review of persuasive interventions has been done in the previous sections and design phases, this phase aimed at extracting the most relevant strategies addressed to each user profile that should be applied to the selected device (the coaster). Taking the wide assortment of strategies and principles available in the literature into account we focus our approach in the persuasive interventions proposed by [3] and [18]. Their filtering and selection process was paramount for the final design of the IC.

The first step consisted of a review of the main principles provided by literature. The filtering was done through a collaborative document. It was filled out by 5 researchers on the HCI field, whose had previous knowledge and background in persuasive technology, behavioural theories and user diversity for the sustainable behaviour change. Each expert had to link each principle with one or more user types (based on the characterization provided by [10]). In the next step, a meta-review of the information obtained from the researchers was done, adding the votes and identifying the strategies that reached an unanimity in the previous matching process (i.e. when all the researchers linked one persuasive principle to the same user type among Pinball, Shortcut and Thoughtful).

18 out of 93 strategies reached the unanimity on one or another user profile. Hence, the final step was to select a subset of the persuasive interventions to be implemented on the IC to evaluate them (these final selection criteria is explained in the "Mapping strategies with user profiles") section.

E. Mapping strategies with user profiles

As explained in previous sections, the final selection of the strategies that were going to be implemented in the IC needed to accomplish certain selection criteria. The main requirements were: 1) implementation of three different persuasive interventions addressed to the three user profiles defined by Lockton *et al.*[10]: Pinball, Shortcut and Thoughtful; 2) definition of transversal persuasive strategies (directed to all the user profiles) which act as a reinforcement of the personalised strategies; and 3) selected strategies must provide positive experience and feelings when interacting with the device in order to improve acceptance, desire to maintain the behaviour and adherence to the device.

1) Persuasive Principles linked to user types

The persuasive interventions to be implemented in the IC must be selected taking the user diversity into account. After reviewing the user characterization, its definition and design recommendations for each user profile, 3 out of the 18 filtered persuasive principles (where we found a matching unanimity among experts in persuasive technology) were selected and linked to each user profile.

For the linear models of the behaviour, the *Pinball* people, the persuasive intervention applied was Reduction [5], [18]. It is linked in the design with the feedback through a unified colour of all the lights of the IC every concrete time frame (e.g. every hour). For self-regulating models of behaviour, the *Shortcut*, the selected strategy was Suggestions [5], [18]. The related design feature to apply to this strategy was the implementation of visual alerts (red blinking lights) when the average of energy expenditure is raised. For the last user typology, the learning models of behaviour (Thoughtful people) the selected strategy was Self-monitoring [5], [18]. The feature designed to implement this strategy was the historic energy consumption visualization through the lights of the IC. The Table 1 links the user profiles with the selected persuasive strategies and design interventions applied in the IC.

2) *Transversal Persuasive Principles*

Following the requirements for strategy selection presented in the previous section, we decided to apply some principles in the design to underpin the personalised or addressed strategies for specific user profiles. The transversal strategies applied act as a reinforcement of the main strategies and were Cooperation [18], Physical attractiveness [5], Personalisation [18] and Tailoring [5], [18]. To address Cooperation theory, the power of the IC is turned on and off by turning the IC from the upper side to the bottom side. The rationale behind is to engage the user with saving energy by turning off the power of the device (e.g. when leaving the work or during the breaks). To cope with Physical attractiveness principle, the feature addressed is visual design itself, developing pleasurable and aesthetic design of the device. The use of wood for the cover and the rounded shape of the IC enhances the aesthetic appeal of the prototype. Besides, the rounded visual signals of the RGB lights improve the visual design making it more appealing. The Personalisation principle is applied with the 3 modes of use based on the user characterization proposed by [10]. Finally, the Tailoring principle is applied through the 3-mode selector. Regardless we seek to match custom-persuasive principles to specific end-users, the user is always free to select the mode that he/she prefers.

IV. DISCUSSION

When designing for energy efficiency, the materialisation of energy waste comes a paramount factor to motivate and co-educate users [19]. The visualisation of the energy can be an effective way to provide information to the users and in consequence, to promote the awareness about the energy expenditure. There are some works in the literature which propose augmented everyday-objects offering eco-feedback to aware users about the waste of energy resources: the Power-aware cord [20], Show-me [21] and Social Coffee Maker [22] are examples of them.

In the design of interactive systems, it is always important to understand users' needs. However, this turns into a strong requirement in the context of raising the awareness about the environmental concerns, and forming new behaviours in consequence. This is the major drawback of the approached reviewed. One of the key factors of the presented work is the user-centred approach followed through the whole methodology. Thus, the aim is to fully understand the individual, its diversity, and to design personalised strategies to offer satisfactory experiences based on the insights extracted from the qualitative sessions. The iterative design process followed to devise the IC, based on continuous evaluations (with and without end-users) and agile implementations, has proved to be a relevant methodology to cast light on the impact of user-centred design on the appropriate and tailored selection of persuasive strategies to promote sustainable behaviour change.

Another relevant matter to address when designing for diversity is the flexible categorization of the user profiles. Thus, a user may fit into different profiles depending on relevant factors such as environmental conditions, mood or context. The assumption that an individual will maintain the same behaviour invariably during the time may reveal a narrow focus when designing tailored interfaces, devices or strategies. Thus, focusing on understanding of the individual in a flexible context (despite the prevalence of a dominant profile) seems to be a better option to get the best from the user and eventually attain or form certain behaviour. In the case of the Interactive Coaster, a mode selector has been implemented to let the user decide which operating mode (type of feedback received) fits better with their needs in each moment. We reckon that the approach followed in this work to address the user diversity still need improvements since it is only based on one dimension of the individual (the behaviour). One reflection that emerges is the need of being able to offer more accurate strategies to cover the diversity and the complexity of the individual. To face this issue, we envisage the development of multi-dimensional taxonomies, involving several dimensions like users' pro-environmental behaviour, values of beliefs, stage of behaviour change, to cite some, linking them with specific design strategies. Whereas this flexibility could be feasible for digital interfaces, it is still unclear how to approach them on tangible devices that are constrained by its physical design. Another limitation of this research can be the work environment and context.

TABLE I. THIS TABLE SHOWS THE RELATION AMONG THE USER PROFILES, THE PERSUASIVE STRATEGIES AND THE DESIGN FEATURES APPLIED IN THE INTERACTIVE COASTER

User Profile	Persuasive Strategy	Design feature
Pinball: Linear models of the human system. the users included in this profile cannot make decisions by themselves [10].	Reduction [5], [18]. A system that reduces complex behavior into simple tasks helps users perform the target behavior, and it may increase the benefit/cost ratio of a behavior.	Traffic light analogy through LED lights to provide feedback each hour.
Shortcut: Self-regulating models of the human system. This user category wants the easiest way to do things [10].	Suggestions [5], [18]. Systems offering fitting suggestions will have greater persuasive powers. People are more likely to engage in an activity when it is closely related to what they are currently doing.	Visual alerts or warnings when energy consumption is high (when it raised the average consumption).
Thoughtful: Learning models of the human system. These users are clever and they know what they want [10].	Self-monitoring [5], [18]. A system that keeps track of one's own performance or status supports the user in achieving goals. The goal is to allow people to monitor themselves to modify their behavior to achieve a predetermined objective or outcome.	Historic energy consumption visualization through coloured lights.

Considering the requirements of the everyday work-tasks, the high energy expenditure is not a reason to stop working or modify certain behaviours at work. Thus, is important to understand that the main motivation raises on promote the awareness of the users to improve the behaviour when the context is able to do it (e.g. using stairs, turning off the screen at work-breaks, etc.).

V. CONCLUSIONS AND FUTURE WORK

This paper describes the ideation, design and creation of an interactive coaster which promotes energy awareness through persuasive strategies taking user diversity into account. The main contributions of the ideation and design phases are: (1) the implementation of different design features based on persuasive principles which were addressed to each user profile. The features were selected involving the users in the process; (2) the development of a tailored but flexible interaction with the users which provides freedom to adequate the feedback received through a built-in three-mode selector; and (3) the application of transversal and complementary behaviour change strategies in the design to act as a reinforcement of the main custom-based feedback. Besides, the personalized User Experience derived from the design can be added value to potentially improve the acceptance of the IC and the persuasive strategies. Moreover, this can be a promising factor to delve into, linking the interaction design with personalised experiences.

In conclusion, this research seeks to enhance design for diversity as a pivotal feature to form pro-environmental behaviour through persuasive principles. Although our approach is focused on the improvement of the awareness rather than in concrete change, we must take into account the behaviour change process of the individuals to guide the design of effective strategies [5]. Future work aims at testing and evaluating the final prototype of the IC in the long-term to assess its appropriateness making a change on users' mindsets to reduce energy consumption.

VI. ACKNOWLEDGMENTS

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