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User perspectives in the design of interactive everyday objects for sustainable behaviour

Ane Irizar-Arrieta[*,a], Diego Casado-Mansilla[a], Pablo Garaizar[b], Diego López-de-Ipiña[a], Aiur Retegi[b]

[a] DeustoTech - University of Deusto, Avda. Universidades 24, Bilbao, 48007, Spain
[b] Engineering faculty - University of Deusto, Avda. Universidades 24, Bilbao, 48007, Spain

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ABSTRACT

Addressing efficient management of energy has become a central objective due to the scarcity of traditional energy sources and global warming. To cope with this overarching issue, some technological solutions such as Smart Grids, Internet of Things or Demand response are proposed. However, the majority of them overlooks the role of human beings in the equation. Moreover, the very nascent body of research combining human and machine intelligence proposes methods, frameworks, and guidelines which vary depending on the application scenario complicating the selection of gold-standards to ensure seamless cooperation between smart devices and people. Hence, the purpose of this paper is to provide a set of design-hypotheses to devise augmented objects that ally with their users to reduce energy consumption. We expect designers, engineers, makers or even hobbyists in the intersection between technology-enablers (through IoT) and behavioural scientists to benefit from them. To this aim, we describe the results of a long-term study in office-based workplaces, where participants were randomly assigned to different experimental conditions (persuasion, dashboard, and automation) to increase their energy-efficient behaviour. Grounded Theory analysis was applied over qualitative data collected during focus group sessions obtaining five themes around a central category. The resulting themes were linked to design-hypotheses for IoT devices which were then tested through the implementation of a new IoT object also conceived for the workplace.

1. Introduction

In recent years, the Human-Computer Interaction (HCI) and Persuasive Technology communities started to increase their attention to sustainability issues because environmental preservation is strongly dependent on human behaviour. In this field, a large body of previous research from the early XXI century has evidenced the value of persuasive feedback to foster behaviour change (Gustafsson and Gyllenswärd, 2005; Pierce and Paulos, 2012; Thieme et al., 2012). Persuasion for sustainability has its roots in the application of Fogg's framework Fogg (2003) for "computers as persuaders" to the topic of pro-environmental sustainability. Taking the existing context into account, this paper focuses on a single but widespread environmental issue, which is to reduce the energy footprint at the workplace, changing the way employees use private and shared electronic devices by augmenting them with IoT technologies. This interest is supported by scientific evidence, according to Brynjarsdóttir et al. (2012) who found that more than half of the papers they reviewed in their analysis of persuasive technologies tackled energy-related topics. In the same vein, DiSalvo et al. (2010) reviewed the body of knowledge on Sustainable HCI finding different genres overall focused on ambient awareness, persuasive technology and sustainable interaction design. Similarly, Pierce and Paulos (2012) stated that energy consumption was the primary focus on sustainable HCI works after reviewing 51 papers on the field. More relevant to our research was to understand that the analysis carried out on this topic revealed that there is a growing interest in augmenting legacy or new everyday devices with persuasive technology to help people to form eco-minded behaviours. In Fig. 1 different augmented objects devised to bring awareness about energy consumption through eco-feedback (i.e. a term coined by Froehlich et al. (2010) which provides the idea of informing users and make them reflect over resource waste through ambient feedback) can be observed (Arroyo et al., 2005; Broms et al., 2010; Casado-Mansilla et al., 2014; Cowan et al., 2013; Gustafsson and Gyllenswärd, 2005;

* Corresponding author.
E-mail addresses: ane.irizar@deusto.es (A. Irizar-Arrieta), dcasado@deusto.es (D. Casado-Mansilla), garaizar@deusto.es (P. Garaizar), dipina@deusto.es (D. López-de-Ipiña), aiur.retegi@deusto.es (A. Retegi).

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Fig. 1. Persuasive IoT objects found in the literature which were designed for promoting sustainable behaviour change through tangible or ambient interaction.

Holstius et al., 2004; Jönsson et al., 2010; Kappel and Grechenig, 2009; Laschke et al., 2015; Thieme et al., 2012).

Despite this growing interest on smart devices and persuasion for enhancing pro-environmental behaviour, the variety of possible sustainable actions, the desire or undesired willingness to make them, and the diversity of users (profiles, traits, interests, beliefs, etc.) make hard to find in the existing literature a set of comprehensive guidelines tailored for the specific purpose that the designer desires. Furthermore, scholars on Sustainable HCI field raised their concern about the feasibility of persuasion to maintain the target behaviour throughout the time (De Young, 1993; Knowles et al., 2014). A more recent review of the literature did also not found enough evidence to support the hypothesis that feedback through digital technology leads to lasting behaviour change (whereas, it found after reviewing 72 studies that feedback through digital technology has the potential to disrupt undesired habits) Hermsen et al. (2016). In conclusion, with exceptions, the majority of the studies do not last more than one month and, therefore, is still difficult to evaluate the real impact of ICT-based persuasion on behaviour change throughout the time.

Taking these open issues into account, this piece of research seeks to offer an ensemble of design-hypotheses that researchers on the area of sustainability, and specifically in energy awareness through IoT, might follow when approaching the design of persuasive systems. With this purpose, we conducted an empirical intervention instrumenting with sensing technology several capsule-based coffee machines in different work environments for more than one year. Three experimental conditions were evaluated which entailed leveraging various features on the appliances: (i) persuasive feedback; (ii) energy monitoring through a dashboard; and (iii) automated operation to avoid forgetfulness. After analysing the quantitative and qualitative data gathered from experiments and focus groups with the participants of the study, we are able to provide cues on how to transform the design recommendations into a real IoT device also conceived for office-based workplaces.

2. Related work

The selection criteria of the body of research reviewed was based on the idea that the targeted works should have presented a physical object aiming to promote sustainable behaviour change either by using aesthetics, ambient feedback, or tangible interaction. Besides, the works should have explicitly stated that their approaches contribute to the Internet of Things, Ubiquitous computing (UbiComp) or Pervasive computing fields. Furthermore, the studies where the physical interactive objects were conceived for the work environment were preferred over those more oriented to private settings. However, in some cases, these were complemented with devices designed for other use contexts.

Power-aware Cord is an electrical power-strip in which the cord was augmented to expose the electricity being consumed in real-time through ambient light. The bigger the energy drawn by the power-strip plug, the brighter the cord is (Gustafsson and Gyllenswärd, 2005). In this work, the light is used emotionally and qualitatively, aiming at symbolising the energy in a more understandable way than the abstract information that offers the raw energy data (e.g. kWh). Very similar to the Power-aware cord, Quintal et al. (2017) devised a common two spots type F wall socket redesigned with two main goals: to process consumption data by using a microcontroller and to provide the capability to display just-in-time visual information (through the ambient LED's built-in on the socket that changed from green to red by comparing the real-time consumption with a baseline for the device it is connected to). Waterbot is another device that provides ambient feedback about water usage in a kitchen's sink through visual and auditory reminders (Arroyo et al., 2005). While using ambient light to offer visual reminders, it also uses the sound as an eco-feedback technique to motivate the water saving. Similarly, 'Show-me' displays the amount of water that is being used during the shower through an LED strip assembled to the shower's stick (Kappel and Grechenig, 2009). These three ambient displays apply ambient light to visualise the impact of some common misbehaviour in the use of basic resources such as electricity and water metaphorically.

Stroppy Kettle is an augmented appliance that aimed to break the user's kettle overfill behaviour applying barriers to goal-attainment and punishment. This approach is based on the idea that rational information is not enough to change the desired behaviour. The barrier is applied to only who performs the negative behaviour (Cowan et al., 2013). Besides, the punishment as a behaviour change strategy is also remarkable through the creation of a barrier to habit execution.

Watt-lite Jönsson et al. (2010) and Energy-Aware clock Broms et al. (2010) are two works that aim to explore tangible data and non-obtrusive interaction to reduce energy consumption. Both works implement displays through playful interactions and visualisations to engage the users and let them explore the energy-related data to improve the understanding of the energy. Although these works do not address behaviour change as a principal objective, they are intended to reach the awareness and the motivation of the individuals in a social context (e.g. families or workplaces). Social-coffee maker (Casado-Mansilla et al., 2014) applies social norm strategies to improve the awareness of employees in shared spaces, increasing the motivation through the influence of the group and peer pressure. The coffee maker published tweets whenever someone left it switched on after preparing a coffee as well as it tweeted its daily energy consumption in order to be tracked by its followers on the Social Network. Thieme et al. (2012) devised BinCam, a social persuasive rubbish-bin with a built-in camera to motivate tenants to adopt recycling habits and reduce food waste. This work also applies social influence to foster awareness through behaviour change. Besides, it uses a Social Media network to provide social pressure, punishing the individuals who performed the adverse action through the publication of their bad habit in the site. Interactive living plants were designed by Holstius et al. (2004). The authors created a robotic analog of a plant that mimics photo-tropic behaviour, combining living organisms and technology. These plants were used to display information as they do in their natural context, implementing emotional and qualitative information in the interface and improving the impact of the display in the individual's awareness through intuitive and organic interactions and visualisations. Also using tangible interactions through shaping memory alloys, Laschke et al. (2015) created The Never Hungry Caterpillar, a device aimed at avoiding energy waste from keeping TVs, screens and similar electronics products in standby mode unconsciously. The Caterpillar is a power socket that mimics a living animal that is connected to the device. When using the devices typically, it moves smoothly, as if it was breathing. However, whenever the device is put in standby mode, the device starts to twist in awkward ways as if it was on pain and the only way of overcoming that "pain" is by switching the device off completely.

There are also some products commercially available in this area. Wattson[1] from DIY Kyoto shows the overall electricity use in numbers and colours. This energy monitor captures real-time information of the energy consumption displaying it in different metrics, both quantitative (kWh and economic value) and qualitative (glows in colours depending on the quantity of electricity used). Another product that can be found in the market is the Ambient Orb.[2] It is a frosted-glass ball that illuminates a varying degree of colours to represent critical peak demand conditions on the smart grid. Finally, the Nest Thermostat[3] is an intelligent device that aims to learn the user's heating and cooling habits to help optimise scheduling and power usage. The machines reward the users with a Leaf if they set up the temperature according to the Nest recommendations to save energy. Although the temperature can be set by automated processes, the rewards offer a motivational approach addressed to the user, aiming at improving the desired behaviour and motivating the user to maintain the sustainable habit.

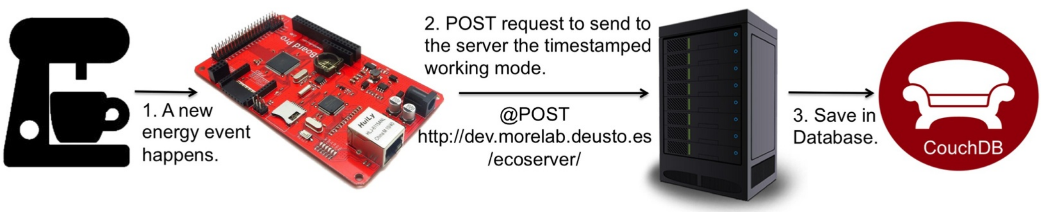
The majority of the works reviewed devised everyday things taking into account the emotional bond that final users may create with the object or the objective that these pursue. Besides, the behavioural approach is mainly focused on the improvement of the ease of use, being the barriers and obtrusiveness significantly less applied (e.g. stroppy kettle). Furthermore, existing research mainly targets individual awareness rather than groups. It promotes an easy and intuitive positive use of smart objects to facilitate the interaction to adopt or maintain the targeted behaviour. Besides, there is a unanimity of works that decided to apply the central or direct route of persuasion for providing nudges instead of the peripheral one (Cialdini, 1993). It means that the body of research aims at making people reflect on their actions rather than nudging them to do actions subtlety (e.g. using emotions as triggers or subliminal priming). Finally, most of the works were only tested during short periods with exceptions on the context of the household. Sustainable HCI field demands more long term results to examine ICT-based persuasion results over longer periods as some voices raised their concern about the feasibility of persuasion to maintain the target behaviour throughout the time (De Young, 1993; Knowles et al., 2014).

3. Long-term study

We carried out an experimental intervention of one year designed to test the effectiveness of persuasive techniques to raise energy efficiency awareness in the mid and long-term in office environments. To this aim, we designed a between-group field study related to the use of electrical coffee machines separated into two phases: baseline creation and piloting. In the former stage, we calculated the energy consumption baseline of the coffee maker. In the latter stage, we continued monitoring energy consumption. Still, we introduced three different experimental conditions linked to the appliances to cope with energy inefficiency: Persuasion, Web-based dashboards, and automation.

3.1. Initial setup and baseline creation

In general terms, we embedded energy measurement equipment within the electrical capsule-based coffee machines of fifteen different workplaces distributed between two big cities of Spain (Madrid, Bilbao). Specifically, the tracking and monitoring of energy were done by embedding in each coffee maker an Ethernet-based Arduino board with an energy meter that was able to send the consumption data to an own remote server (Casado-Mansilla et al., 2016) (see Figure 3.1).



The energy consumption data flow from the Arduino microcontroller to the remote server where the data was stored for future processing and analysis.

The reasons why we selected coffee machines for the field study were: *1)* they are pretty common in work environments and are an element of shared use; *2)* they consume large amounts of energy compared to other work appliances such as monitors or laptops (A report on appliances' consumption holds that some models of coffee machines can exceed the electricity consumption of A-class ovens or A++ refrigerators along the year because of continuous pump pressure maintaining and water heating (Nipkow et al., 2011)). More than one hundred people were recruited from the different fifteen work-offices that participated in the long-term study. They were all recruited following a snowball procedure, and their participation was voluntary (we raffled an energy monitoring system among participants who completed the whole study).

During the initial set-up of the experiment to calculate the energy baseline, five out of the recruited fifteen groups dropped out the long-term study before its completion.[4] Having evaluated the impact of this dropout rate on the validity of the experimental results according to Slack et al. (2001), we decided to carry on with the remaining ten groups ($N = 90$) which are described in Table 1.

In order to help with the understanding of the different participants' profiles, in Appendix A we describe the groups and some of their main characteristics.

3.2. Between-groups intervention

As have been observed in Table 1, the random assignment of the experimental conditions among the ten workplaces remained as follows: *1) Persuasive feedback (4 workplaces)*: a combination of real-time ambient feedback and subtle visual hints to support the user's decision-making about when to switch off the appliance; *2) Energy-dashboard (3*

[1] http://www.diykyoto.com/ .
[2] http://www.ambientdevices.com/about/consumer-devices .
[3] https://nest.com/thermostats/nest-learning-thermostat/overview/ .

[4] The main reasons for attrition during this experimental phase were: *1)* some groups changed or ended their business activity during the piloting; *2)* other groups changed from capsule-based coffee maker to filter-based appliances being the researchers unable to track individual usage of the coffee machines; finally *3)* whereas we raffled an energy monitoring system some work-groups decided voluntarily to not follow up with the experiment - recall that no pecuniary rewards were given.

Table 1
The column's name refer to: name of the groups that participated in the study, the city (BIO - Bilbao or MAD - Madrid), the treatment they were assigned to, the type of work which is performed within these groups, the number of users of the coffee-maker in each space and the average age of them.

	Treatment assigned	Type of workplace	Participants & average age
Bailen (BIO)	Persuasion	Coworking	8 (33)
Comunica (BIO)	Automation	Administrative services	8 (35)
Computing (BIO)	Dashboard	Tech. Research group	4 (28)
IEEC (MAD)	Dashboard	Tech. Research group	4 (42)
Life (BIO)	Automation	Tech. Research group	12 (28)
Mobility (BIO)	Persuasion	Tech. Research group	15 (28)
MORElab (BIO)	Automation	Tech. Research group	9 (28)
ServGen (BIO)	Dashboard	Administrative services	3 (43)
Techabout (BIO)	Persuasion	Tech-based SME	4 (33)
Tecnilogica (MAD)	Persuasion	Tech-based SME	23 (38)
TOTAL			**90**

Fig. 2. The three different experimental treatments that were randomly assigned to the participating groups.

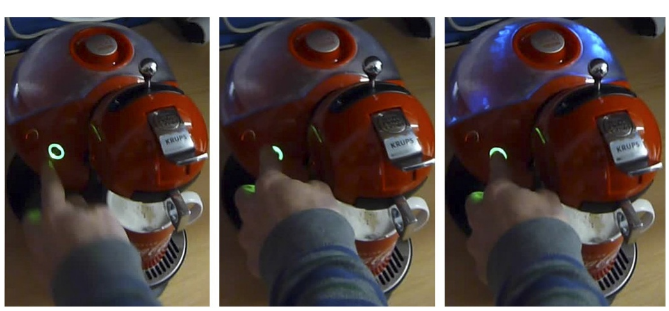


Fig. 3. The persuasive coffee makers provided just-in-time visual cues to help users in energy efficiency decision-making. On the first image, a user approaches its finger to switch off the device. In the second and third pictures, the augmented appliance detects the motion close to the button and informs the user to not switch it off by activating a built-in visual alert. As can be observed in the first picture of Fig. 2, the subtle message to prevent the operation of the appliance is "Please, leave me on".

workplaces): participants were provided with a Web site to track their energy consumption associated to the appliance (i.e. self-monitoring and rational information through comparisons with historical energy data); and *3) Automation (3 workplaces)*: coffee makers were modified to autonomously switch the appliances off whenever they were not in use (i.e. the rationale behind automation was providing a sense of comfort to the users relieving them from the task of switching the appliance on and off). The three experimental conditions are depicted in Fig. 2. As the persuasion condition holds the hypothesis of this study, it has been represented in Fig. 3 for a better understanding of its operation.

It is important to emphasise that both persuasive feedback and automation rely on an underlying ARIMA model, which is a statistical method for time series forecasting. Thus, the smart coffee makers were able to predict the number of users that were about to use the coffee maker in 1-hour slots during the day (Ventura et al., 2014). With this information, in the persuasive condition, the appliance suggested users operate the on-off button (e.g. Fig. 3), while in the automation condition, the appliance switches on or off deliberately without human intervention to minimise the energy waste.

3.3. Quantitative results

At the end of the study, it was demonstrated quantitatively that the IoT-based Persuasive treatment helped to save most energy than the other two treatments (Mansilla, 2016). Specifically, we found that the IoT-based Persuasive treatment helped to save most energy than the other two treatments reducing the energy waste by 44.53%. The Automation treatment also helped to reduce energy waste by 14.19%. Finally, the Dashboard approach did not lead to a reduction of energy waste remaining with a similar percentage as the beginning of the experiment. For the sake of better understanding, we refer to "save energy" to the fact that the coffee makers diminished the quantity of wasted energy due to the generalised abuse of standby mode on these appliances (i.e. substantially reducing the time that a coffee machine is switched on but is not preparing coffee). This amount of energy is not negligible since the coffee makers are periodically maintaining the pressure pump ready to be used or heating the water for the next coffee cup.

Because of this finding, we wanted to grasp detailed qualitative information from users to understand the causes of the persuasive intervention being more effective than automation or dashboard.

3.4. Qualitative analysis

While science has a strong reliance on quantitative and experimental methods, there are many complex, socially-based phenomena in HCI that cannot be easily quantified or experimentally manipulated. Within HCI, there is the recognition that the focus on tasks is not enough to design and implement an effective system. Therefore, identifying users' emotional and social drives and perspectives; their motivations, expectations, trust, identity, social norms, and so on are paramount for creating more than 'just appealing' designs (Adams et al., 2008). Hence, at the end of the between-group study (i.e. when the experimental conditions were removed from all workplaces), we ran several focus group sessions with participants who volunteered to join the dynamics from each of the study-groups of Table 1 according to Merton et al.'s. guidelines Merton et al. (1990). We managed to have 'at least' one representative from each of the ten remaining groups. Audio data from each session were recorded and manually transcribed for further analysis through Grounded Theory (GT) (Charmaz, 2006). In the following, we describe what GT is and how we applied this methodology to the data obtained from groups who interacted with the coffee-makers augmented with IoT-based persuasive systems to extract design-insights that help to inform the design for similar everyday intelligent devices created in the future. Following the specifications

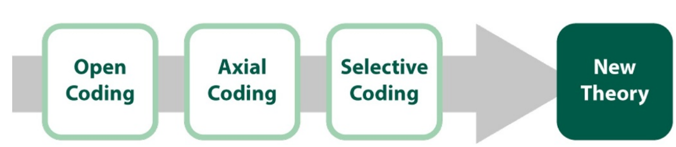


Fig. 4. The different phases of applying Grounded Theory over qualitative data coming from all three experimental conditions.

Table 2
Set of unitary codes along their axial categories extracted from people who interacted with the IoT-based persuasive coffee-maker.

Interaction	Attachment / Confidence	Mediator / Emotion	Context	Behaviour
Automation	Similarity	Group Awareness	Extrapolate behaviour	Acceptance
Satisfaction	Adherence	Generate discussion	Export to other devices	Adaptation
Understandable	Pleasure	Elicits Interest	Hawthorne effect	Pro-environmental self-perception
Comfort elicits awareness	Trust	Group inefficiency (−)	Private vs. Public setting	Aware of B. change
Comfort elicits efficiency	Dependency (−)	Media equation	Patterns	Group awareness
Comfort elicits inefficiency (−)	Disregard (−)	Proudness	Mirror effect	Comfort elicits awareness
Misunderstanding (−)	Expandable behaviour		Social-proof	Sense of control elicits efficiency
Disgruntlement (−)	Non-expandable B. (−)		Behaviour at home	Comfort elicits inefficiency (−)
Subject-expectancy effect (−)	Preservation			Consistency (−)
Efficacy vs. Efficiency	Proudness			Dependency (−)
Efficacy	Acceptance			Durability
Aesthetics	Transparency			Efficacy vs. Efficiency
Inefficiency (−)				Incomprehension (−)
Intelligent system				Learned helplessness (−)
Playfulness				Group inefficiency (−)
Data to take decisions (−)				Scale Consumption
Need of insightful data (−)				Low durability (−)
Different HCI model (−)				Obsolescence
Personal vs Group data				Patterns
Tailoring				Tailoring
Nudges				Unaware of behaviour change (−)
Useful				

exposed by Hekler et al. (2013) about the epistemic status of design guidelines, and due to the limited amount of empirical data, in this work, the guidelines derived from the study will be named as “design hypotheses”, which will need further validation.

3.4.1. *Grounded theory-based approach*

According to Charmaz and Belgrave (2007), GT is an established method for studying qualitative information where codes are generated from the data rather than relying on pre-existing categories. Thus, it can be considered as an inductive method. It includes Open, Axial, and Selective Coding as phases to generate a new theory, as can be observed in Fig. 4. We applied this methodology to analyse the qualitative data extracted from the focus group sessions to produce design insights for creating augmented persuasive IoT devices that promote energy efficiency practices taking into account the social phenomena of the workplace context.

There are other methods with a recognised reputation in HCI for analysing qualitative data, such as Content Analysis Kabicher et al. (2008) or Thematic Analysis Brown and Stockman (2013). We selected GT because this methodology allows us to construct theories, concepts, hypotheses and propositions starting directly from the data and not from the *a priori* assumptions, from other investigations, or existing theoretical frameworks.

The purpose of the GT’s Open Coding phase after transcribing the qualitative data is to identify entities, to group them into categories, and to describe relevant properties and dimensions pertaining to a category. The codes are extracted iteratively from the data in the process of analysis. Then, Axial Coding identifies relationships between initial categories as well as conditions, context variables, and resulting consequences. Finally, Selective Coding focuses on deliberately setting a focus on the analysis. Thus, core-category is selected. As suggested by Armstrong et al. (1997), inter-rater reliability of the extraction of the codes and grouping them into categories was assessed by two researchers along the whole process of the GT analysis.

In the Open coding phase, 132 unitary codes were extracted. Attributes such as frequency, target, intensity or duration were annotated together with each of the emerging codes (some samples of the codes extraction can be observed in Table B.3 in Appendix B of this paper.) These samples provide an example of the quotes and the codification process we carried on.

Following the constant comparative method (Charmaz, 2006), a saturation of codes and categories were reached in the Axial phase, according to the two researchers. At this stage, five categories emerged from the initial codes: 1) interaction, 2) mediator|emotion, 3) attachment|confidence, 4) context, and 5) behaviour. As an example, Table 2 shows the codes from the people who interacted with the IoT-based persuasive appliance that emerged during the Open and Axial phases as well as the thematic categories in which these were grouped.

Finally, the purpose of the Selective coding phase is to define the central category as the catalyst for the thematic categories. We elucidated that the central theme of the theory was the relationship between the people (employees) and the augmented IoT-based appliance to cope with energy inefficiency jointly. This central theme encompasses the other five axial categories, as can be observed in the diagram of Fig. 5.

According to Charmaz (2006), the diagram is devised to organise the nascent theory and to see the relative power, scope, and direction of the categories in the analysis as well as the connections among them for linear narrative purposes. Therefore, the diagram should not be understood as a predictive or causal model that is mandatory to be followed to succeed in creating new IoT systems. What the incipient theory aims to bring attention is that for ‘Behaviour’ change to occur (final theme) by means of ‘Interacting’ with IoT objects (initial theme), categories such as (Mediator|Emotion), (Attachment|Confidence) and Use-context shall be taken into account when designing IoT-based persuasive systems. Thus, IoT augmented Things in the workplace context should provoke certain emotions to users, mediate between conversations among human beings, create a sense of attachment to them, and generate confidence to bring pro-environmental awareness or effectively change the behaviour. Furthermore, not all the paths interlinking the categories have to be pierced. In fact, those connections between themes that we considered non-compulsory have been depicted with a dashed lines.[5]

4. User perception-based design hypotheses

As mentioned before, we applied the GT to the data obtained from

[5] We considered Emotion|Mediator and Confidence|Attachment as non-compulsory themes because we were unable to guarantee according to our analysis whether these themes that shared unitary codes could be merged or separated in sole categories as Interaction, Use-context or Behaviour. Further qualitative investigation through constant comparison and theoretical sampling (methods proposed by Glaser and Strauss (2017)) should be carried out to decide on the unification or separation of these emerging themes.

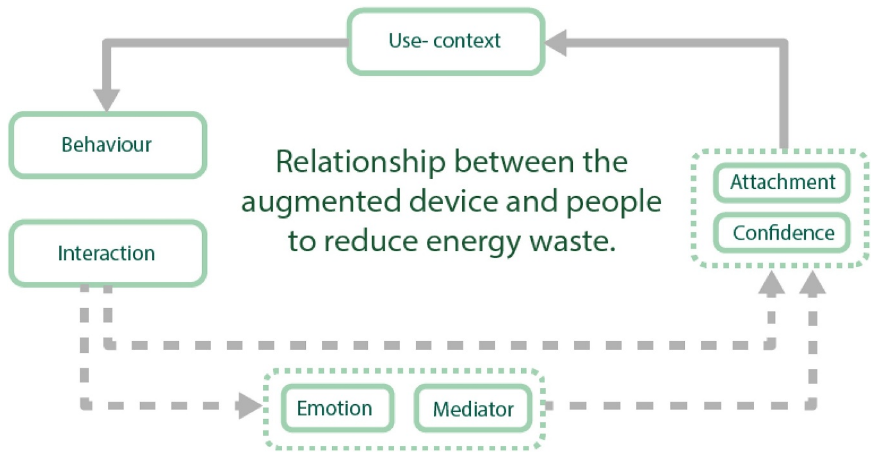


Fig. 5. The emerging theory obtained by analysing the qualitative data coming from all three experimental conditions through Grounded Theory.

groups who interacted with the coffee-makers augmented with IoT-based persuasive systems to extract design-insights that help to inform the design for similar everyday intelligent devices in the future. Several quotes for all the conditions were gathered. Still, for this paper, only relevant quotes from participants that interacted with the persuasive IoT-based coffee maker are reported in this section regarding each of the five/seven emerging themes. These quotes are jointly offered with a discussion over the implications that the themes have for the design of augmented objects that promote sustainable behaviour, offering design-hypotheses in order to facilitate the implementation of the exposed ideas for future designs.

4.1. Interaction

This category covered one of the most recurrent topics in the focus group sessions, and it captured the majority of unitary codes in the GT analysis, as can be observed in the first column of Table 2. Notably, we received positive and pleasant feedback when participants evaluated the interaction with the Interactive coffee maker. *“What did serve us well, were the red LEDs on the periphery of the coffee-maker to make us to the idea of how we were going”* or *“I think the visual feedback from the device has also given us clues as to how to go about doing it.”* In the referred table, the reader can also observe negative symbols between brackets when feedback was considered unfavourable. For instance, *“there were times when it turned red too quickly … we think it turns red very fast for the coffee we drink … that will be 4–6 coffees a day … and then it is red”.* However, constructive criticism to improve the proposed design was provided by some people, P1: *“I lacked some audible eco-feedback when I put my mug on the appliance. Something like the NFC/RFID-based readers that one can find in the turnstile of the Metro stations that give you feedback about your pass checking”.* Surprisingly, some participants that interacted with the persuasive IoT appliance missed some of the aspects that were implemented in other experimental treatments, P2: *“I would like to have a Web-dashboard where I could track my kWh”.* The overall conclusion of this category is that people felt satisfied with the feedback received because it was intuitive and helpful to behave in an energy-efficient fashion.

Design-hypothesis: According to the conclusions extracted in the previous paragraph, and with our own experience in this experiment, to improve the intuitiveness in the different users, the designers should be aware that the ’one-size fits all’ approach will not cover all user needs. As an example, the persuasive IoT-based coffee-maker was the most efficient according to the quantitative data. However, the users missed features of other treatments with lower or none effectiveness (Quintal et al. (2017) also reported a similar situation. After receiving ambient visual cues to promote energy awareness, participants in their study missed other extra features such as using historical data, social comparisons, presenting the impact on the environment or the energy origin). Such finding let us understand that it is impossible to please everyone with one design even when it seems to be just right for the envisaged purpose.

Further, in the qualitative phase, it is more than probable that some of the interviewees will miss features that the literature reckons that do not work for changing the intended behaviour in the mid and long term (e.g. provide kWh without comparisons, or provide financial incentives). These opinions should be taken with extra care in the design phase because they may blur the goal of changing the behaviour. We argue that this design-insight is comparable to other contexts of HCI beyond IoT. Still, we consider that a designer should be firm with the interactive proposal if it has been validated through appropriate design methodologies.

4.2. Mediator/emotion

Whereas the majority of the feedback provided about the interaction was positive, the proposed persuasive design provoked polarised emotions that were voiced in the focus group sessions. For example, P3 stated: *“Despite the suggestions of the augmented appliance to leave it on, I felt cross leaving the coffee maker switched on after preparing a coffee”*. The opinions of P4 were more positive: *“I loved to know that we have a smart appliance in the office”* or P5: *“It is funny to have one (the appliance)… for me, it is like it was another member of the department”*. This latter quote resounds to the ‘Media Equation Theory’ that states that media and computers are sometimes treated by people as if they were real humans (Reeves and Nass, 1996). Moreover, P5’s comment and that of P6:*“The coffee-maker sparked conversations about energy consumption among colleagues. Overall during the initial weeks of the set-up”* correlated with the idea that augmented smart objects may have the role of mediators to bring about reflections and conversations centred in the topic that the designer wants to change.

Design-hypothesis: We want to emphasise the idea that augmented objects seem to be more than mere relays of eco-feedback, and they should be conceived as new interactive actors in these situated environments. This idea is not new in IoT Atzori et al. (2014) and was thoroughly investigated by Nass et al. (1997) when personal computers started to be widespread. In the case of the persuasive coffee maker, sometimes office employees considered the device as a new ally to cope with energy inefficiency, and they responded to smart object personalities as the same way they responded to human personalities. The peculiarity of these new actors is that they can cause mixed emotions to users. These emotions are important because they are predictive factors for technology adoption and technology appropriation.

4.3. Attachment/confidence

As well as the previous category, again, two themes were brought together by participants, and therefore they are presented into a single category. On the one side, attachment to the smart persuasive appliance was found on several participants that were upset when we communicated to them that the smart devices were about to be removed, P7: *"I will miss the appliance. I changed my perception of it... from being a bare device to consider it as something that is doing well for the environment"*. On the other side, confidence in the technology was a recurrent theme because of the long time that people shared with the device daily (one year), P8:*"I will always heed the eco-coffee machine's advice without any doubts... whenever it says 'leave me on', I leave it on without thinking twice"*.

Design-hypothesis: We acknowledge that to strengthen these two themes, the augmented everyday objects should be designed to remain close to the people to keep the positive influence on the users throughout time. For that, it is important to provide dynamic feedback that maintains the engagement (this finding is in line with the critical review about persuasion and eco-feedback pursued by Hermsen et al. (2016) which was partially addressed by Lu (2018) in the context of contextual adaptive IoT systems). Moreover, the information provided by the IoT objects have to be clear and transparent and efforts should be put on making the IoT objects to become a relevant authority in the field of application (in this case, many users trusted in the coffee-maker information. Thus, Cialdini's authority principle of persuasion played a leading role in this case (Cialdini, 1993)).

4.4. Use context

The context of use is defined as "the actual conditions under which a given artifact is used in a normal working situation". According to Pierce et al. (2008), there are two important dimensions when designing eco-feedback technologies for use-contexts: dweller control and third-party control. The workplace lays into "low dweller control, high third-party control". Surprisingly enough, the comments from experiment participants were not only related to the place they work, and therefore, where they use the coffee machine daily. Instead, the majority of opinions pointed out that some behaviours that one does or learn in one use-context (e.g. at work) and export them to another, maybe different, use-context (e.g. home settings - "high dweller control, low third-party control"). For example, P9 stated: *"Because here [at the workplace] I switch off the coffee-maker, when I'm at home I pay more attention to energy efficiency"*. However, care must be taken when designing objects to form new behaviours in a specific context, P10: *"Sometimes at home, I forget the coffee maker switched on because at work I'm used to leaving it on since it (the augmented appliance) beg to me to do so"*.

Design-hypothesis: the IoT designers of persuasive everyday things should take into account the spillover effects (Nilsson et al., 2017). The spillover effect proposes that engaging in one behaviour affects the probability of engagement or disengaging in a second behaviour (consciously or unconsciously). Therefore, the formed behaviours may be beneficial at one use-context (in our case in the workplace) but are offering detrimental consequences in other contexts (e.g. at home when no intelligent devices are there to remind the user to do sustainable actions). Hence, they should be designed with the context in mind and take into account all the consequences that may appear in on-the-wild fields. For that, we suggest using unconventional probe tools Nielsen (1994) or diary studies (DeLongis et al., 1992) in the design phase.

4.5. Behaviour

According to the last column of Table 2, this category, along with that of interaction, was the most popular topic in the conversations that aroused in the focus group sessions. The participants that interacted with the Persuasive condition were found to be the most aware individuals of the energy inefficiency issue at the workplace, which was in line with the quantitative data presented. Moreover, the comments from participants offered initial hints of behaviour change, P11: *"We were fully aware of our misleading behaviour at the beginning of the experiment because the coffee maker turned red due to excessive energy consumption"* or P12, *"The coffee maker has made me aware of energy consumption. Now... sometimes after preparing a coffee, I take two steps back to double-check if I've left the appliance on or off"*. The voices from participants that assured that the newly formed behaviour will remain throughout the time were the most relevant finding, P13: *"Somehow I have started forming a habit... even if it is something unconscious"* or P14: *"At the end, we all have got used to switching off the appliance. I believe that we will maintain this easy course of actions"*.

Design-hypothesis: one of the main problems that designers of IoT for pro-environmental behaviour may find in successful studies (such as the one reported here in terms of energy-reduced), is to witness a relapse effect when the researcher completely removes the experimental conditions. The same might occur even when participants diminish the use of the ICT-based intervention after the novelty effect disappear. Such design-insight is pretty much in line with Pereira et al. (2013) or Peschiera et al. (2010) who reported evidence on response-relapse patterns on studies related to eco-feedback and energy awareness interventions. Thus, the question we raise is: What would be the contingency plan if there were no hints or advice to facilitate the decision-making anymore? Or, if the rewards finished suddenly? Or, if the gamification process became annoying to participants because of its repetitiveness? Etc. The designer of augmented everyday objects should carefully plan the longitudinal extent of his/her system and reflect upon foreseeable consequences of feedback removal. A proposal would be to taper the feedback off during intervals instead of doing it abruptly or creating context-aware gradually adaptive systems based on the most up-to-date user status (this latter approach was studied experimentally in a controlled environment by Lu (2018)).

5. Applying emerging guidelines on a new IoT device

Each of the categories derived from the analyses represent a thematic design-hypothesis, enabling researchers to build effective interventions in the workplace that place in the centre the relationship between people and the augmented device to reduce energy waste: from how people will interact with the device, through the emotions which the device may arise, the conversations that the device itself might foster among users, the confident or attachment to the suggestions provided by the intelligent device, the environment or context where the device will be used, and finally, the behaviour to be promoted. With this conceptual framework, in the following, we implement each of the design-hypothesis on a new everyday IoT object that aims at improving the energy efficiency of equipment in workstations in an office-based work environment. Firstly, ideation and development of the prototype are introduced to contextualise the theoretical implementation. Then, the emerging theory is applied in the context of the presented device, linking each of the five emerging themes with the different design features and design decisions.

5.1. The interactive coaster

To deepen in the research and understand the practical issues that emerged in the theoretical approach, an interactive IoT prototype was developed. The Interactive Coaster (IC) is a device intended to help the users become more aware of the energy that they use through the electronic devices that surround them in their workspace (e.g. a computer, monitor or the mobile phone charger). The IC supports the user in the daily routine at work by periodically showing visual information about their energy consumption level and also serves to its primary

Fig. 6. The IC showing some of the states that can display.

function (i.e. act as a coaster for placing on top of it a coffee mug or a bottle of water). Besides, it also provides alerts to use the devices more efficiently (e.g. to turn off the screen when it is not used (during breaks), foster the usage of the sleep mode, or switch off the computer when leaving the workplace during longer periods). To do so, the IC is connected to a smart plug that collects the energy consumption of the whole workstation. The IC (which can be observed in Fig. 6), is a rounded coaster made of wood and includes concentric methacrylate circles that cast light through RGB LEDs. A coaster was selected among other design ideas due to its high visibility in the desktop environment. Besides, it is always visible and can be used by everyone at any moment. To improve the effectiveness of the feedback provided, the diameter of the coaster is slightly higher than an average mug or glass. In this way, the individual can (almost) always observe the outer lightring, although a recipient is on top of it.

The lights of the coaster show a different colour depending on the average energy expenditure. Green is used to inform that the energy consumption is low; yellow to report that the waste is raising; orange to alert that the user is close to its average consumption and red when energy usage has overtaken the average consumption of previous days. The IC features different modes and visualisations to enhance user awareness and motivation about energy efficiency. *1)* A historical energy consumption visualisation (when the user pushes the central button of the IC the four different circles of the coaster show a different colour depending on the energy expenditure of each time unit - previous day, current week, current month, current year); *2)* an automatic visualisation alerts about the energy consumption consumed during the workday; *3)* a vibration alarm buzzes when different energy expenditure levels are exceeded (the colour coding remains the same as current consumption or historical information); *4)* "party mode" lights a visualisation with random colour coding, aiming at offering playful value through colourful and animated visual effects; and *5)* a "snooze mode" is activated when the user flips over the Interactive Coaster switching off all the lights until it is flipped over again. The IC is able to connect to the Internet extracting all the information about energy consumption through a Wi-Fi module built-in the System on Chip (SoC), which controls the whole operation of the IoT device.

The coaster has been designed following a user-centric approach, and its design was addressed in a previous work of the authors Irizar-Arrieta et al. (2018). A summary of the steps followed to design the IC from scratch were: 1) the first ideation process, where the goal was to establish an initial approach to generate new ideas, prototypes or mockups based on the users' needs; 2) the development of a 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; 3) user research with the device, where we sought to share the first design ideas with them to understand their insights; and 4) the refinement of the prototype, implementing the design with the ideas emerged from the qualitative study. During the design process (third phase), we involved seven end-users following a semi-structured interview approach after letting them interact with the early versions of the IC. Expressly, the interviewees were initially provided with free time (2–5 min) to interact with the device, and then, the two researchers started asking questions. We asked them about their opinion of the IC, which metrics were preferred to understand their energy consumption, the colour-coding preferred, which kind of feedback was more understandable for them, where they would place the coaster within their workstation, etc. With this information and the qualitative insights from the GT approach, we finalised the design of the new IoT object. In the following section, we shed light on how the nascent theory and its design-hypotheses were implemented in the IC.

5.2. Implementing the emerging theory on the IC

The central idea extracted from the results of the Grounded Theory analysis sets the basis of the incipient theory about the relationship between the augmented IoT device and people to reduce energy waste. The five/seven design-hypotheses of the emerging themes (interaction, mediator/emotion, attachment/confidence, use context, and behaviour) are used as drivers to face the design phase in the ideation and development of the IC.

5.2.1. Interaction

The interaction was one of the most relevant topics in the evaluation sessions. Therefore, it should be a key driver to improve the relationship with the device. To facilitate the understanding of the ”Interaction” term and to avoid comprehension issues, we consider it necessary to clarify the approach of the terminology used in this work. In this context, interaction is understood as the actions and relations between an individual and an interface. To go in-depth through this generic conception of the term, the approach proposed by Diefenbach et al. (2013) is used, where the Interaction term is classified through three different levels: 1) the Why level, the most general. This is related to the experience, emotions, and subjective impression when interacting with something; 2) the What level, related to the functionality of any interaction, and 3) the How level, related to concrete operations, motor-actions and elementary attributes. Following the design-hypothesis from the Interaction theme (i.e. "One size does not fit all" He et al., 2010) and the Diefenbach's rationale explained above, we devised the IC through a user-centric approach, developing an iterative process of design and evaluation and involving the user in the process. The heterogeneity of the individuals and their different needs, emotions or perspectives were specially addressed in the evaluation sessions to extract design features to implement in the IC. Hence, different features were implemented, aiming at offering different and complementary strategies to cover the needs of the existing different user stereotypes/segments. Thus, automatic visualisation of energy expenditure, the historical visualisation of the average consumption of different time units, and alarms or warnings when certain expenditure is raised. These design strategies were developed taking into account the research developed by Lockton (2012) and Petkov et al. (2012) where they offer specific design solutions addressed to the user diversity based in the behavioural models of the human system (Lockton, 2012) and the personal norms, values and beliefs (Petkov et al., 2012). In essence, in the IC different interactive approaches were implemented, offering end-users a wide range of feedback to address the diversity of needs (e.g. messages with different cognitive load, context-feedback in time through the warnings, delayed feedback through automatic visualisation and feedback on-demand through historical energy consumption). We can not ensure that with this, we have covered all user needs, but we believe that this approach will reduce the end-user expectations considerably on missed features. Further explanation about how the IC addresses the user diversity can be found here (Irizar-Arrieta et al., 2018).

5.2.2. Emotion/mediator

The emotions were another factor that emerged from the relationship between the device and the individuals. As the qualitative results showed, feelings and emotional bonding are inherent to the relationship with the device, and thus they must be taken into account when designing interactive smart artifacts. The idea of the device as a

Fig. 7. People at workplace placing the IC on different locations of their desktop.

mediator of conversations or interactions around energy efficiency is also linked with the feelings derived from this emotional bond. That is, if the values offered by the device resonate with the emotional needs of the user, the device can act as a mediator not only to conversations but also for the behaviour that the device aims to change.

The IC implements the emotional factors through product design. The top side of the IC has been designed taking into account the idea of the tree trunk and its rings. This strategy offers a visual metaphor that is intended to impact the emotional side of the individual. In order to strengthen this metaphor, the material selected for the case was wood. Besides, the visual design of the RGB lights and the appealing party mode are features intended to enhance the emotional properties of the device through design patterns.

The mediator theme was also implemented on the IC through its intended placement on the workstation to foster high visibility of the device at any moment by its owner and close colleagues and peers. Furthermore, we implemented a colour-coding that resonates with the traffic-light analogy. This corresponds to an emotional codification based on the work proposed by Gao and Xin (2006); Valdez and Mehrabian (1994).

5.2.3. Attachment/confidence

Attachment and confidence are abstract and complex factors closely related to the relationship between the device and the individuals. Therefore, special care must be put when addressing these concepts to avoid strategies that may cause a negative effect on them. A variety of strategies can be followed to improve the level of attachment of the user towards the IC and gain confidence in the long term. Taking into account the design-hypotheses, the device should be located close to the user or, at least, in his/her field of view (whilst being careful not to create continuous attention theft). In this regard, the device has been designed to be small and easy to be moved to one place or another within the workstation in order to not be obtrusive to employees (See Fig. 7).

The confident theme is implemented by offering consistency over the visual information provided and openness. On the one side, we explain to the users that what they observe with colours in the IC is an analogy of the real energy consumption being monitored by a smart plug connected to their workstation. To provide adaptive feedback as suggested by Hermsen et al. (2016), the IC calculates the maximum target consumption for each day providing different colour-based interactions depending on how close the user is to exceed the calculated target. On the other side, we offer them the option of visualising the energy consumed in a digital time-series graph to corroborate that the visual cues built-in the device correspond to the power being drawn (see Fig. 8).

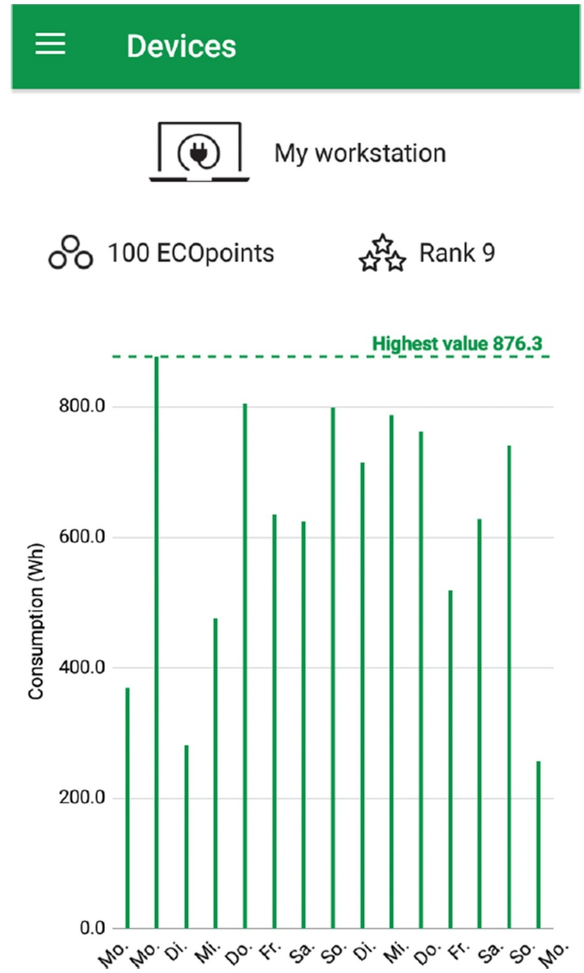


Fig. 8. An example of one of the Web-based graphs. Users are able to select the time interval and the energy data frequency (15mins, 1h, 1day) of their associated smart plug. In this example, the user has selected observe its consumption in a daily-basis.

5.2.4. Use context

The Interactive Coaster is intended to promote energy efficiency in an office-based work environment and therefore, the limitation of this narrow context should be taken into account. To minimise the potential negative spillover effects related to a cause-effect design (e.g. forgot to switch off the monitor at home because the user does not have a blinking coaster in its private setting), the IC is designed to provide overall awareness about energy-efficiency. Although the device is not designed to send alerts at specific moments (e.g. vibrate if the user is about to go home in order to recall him/her to switch everything off), it is possible for users to learn how the IC works and to see the existing causal relationships between their everyday actions and work patterns and the different colours that the IC shows. Through the everyday visualisation, the users are invited to reflect on their behaviour and energy expenditure rather than expect triggers and alerts from the coaster at specific moments during the day. Therefore, the IC's objective is to enhance overall awareness and eventually energy savings rather than recall a specific undesired action continuously. We believe that this design is prone to provide positive spillover effects in other contexts.

5.2.5. Behaviour

The Interactive Coaster has been primarily designed to enhance awareness and to serve as an energy ally to the user. Although the promotion of the pro-environmental behaviour is the objective, the implications of the use context place the performance of the action as a consequence of the awareness generated by the eco-feedback (this is in line with Azjen's Theory of Planned Behaviour where intentions are the pivotal determinant for behaviour to occur Hardeman et al., 2002). Therefore, and taking into account, the design-hypothesis of this theme, the potential relapse effect derived from the elimination of the technology at the end of the experimental phase should be less unfavourable. Besides, the own energy usage patterns learned by users after having interacted with the coaster for a short period could drive to more sustainable actions. Moreover, these might be more likely to stick because the behaviour change is not linked to the device but to the motivation and new energy-related knowledge of the individual.

6. Conclusions

In this article, the qualitative data derived from a set of focus groups after carrying out a longitudinal experiment on energy awareness at the workplace were analysed using the Grounded Theory approach. GT analysis was applied to produce new insights into the design process of novel persuasive physical interfaces or augmented everyday objects that promote energy-efficient behaviour change that sticks throughout the time at the workplace. The emerging theory presents five categories: 1) interaction, mediator/emotion, 3) attachment/confidence, 4) context, and 5) behaviour. Each of these categories derived from the analyses represents a thematic design-insight, enabling researchers to build effective interventions in the workplace that place in the centre the relationship between people and the augmented device to reduce energy waste (the central category of the emerging theory). In a linear fashion the emerging theory shed light on how design IoT devices taking into account the interactions that users will have with them, through the emotions which the device may arise, the conversations that the device itself might foster among users, the environment or context where the device will be installed and used, and finally, the behaviour to be promoted. To gather more data and deepening on this research line, a new interactive IoT device (a coaster) was developed by implementing one by one each of the themes extracted from the user perception-based theory. The difficulties of addressing the mapping from theory to design have been pointed out throughout the article. We deem that the endeavour of designing a new device within the premises of the theory has enriched the framework substantially since we demonstrated that it can be applied on a real interactive design. As a future line of work, the evaluation of the effectiveness of the new IoT device will provide new arguments and enhancements over the validity of the themes. We expect designers, engineers, makers or even hobbyists in the intersection between technology-enablers (through IoT) and behavioural scientists to benefit from the presented work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Offices and bussines description

Bailen: It is a coworking space in an old building in Bilbao where architects, urban planners, designers, and multimedia producers coexist. All the people who work in this space are in a room with shared tables, leaving the coffee area in a separate room. In addition to the coffee machine, there are other appliances: microwave, dishwasher and water heater for tea. In this type of space, it is easy to forget a device switched on and be in this state unnoticed during all the time in which the room is unoccupied.

Comunica: It is an administrative office within a university in Bilbao. Each of the people who work there develops management or communication functions and therefore has a personal desk. The coffee machine is hidden in a cupboard and every time they want to use it they have to carry out the following process: open the cupboard, turn on the coffee machine, put the capsule, make the coffee, remove the capsule, the cup and leave everything clean, for last, close the closet again. Being so specific and conscious of the process of preparing a coffee, it is difficult for people in this space to leave the appliance on. The reason for having the coffee machine hidden is because it is a space where many outsiders get in and employees do not want to have the device in view to visitors.

Computing, Life, Mobility, and MORElab: The four groups do research in computer science and belong to a research center attached to a university in Bilbao. The four groups are arranged in separate places within a clear space of 2000 m^2. Being such a large place, there is no interaction between the groups or visual contact as the researchers develop their functions in semi-isolated cubicles. As they are different groups, each of them has a coffee machine for personal use that is located in one of the free tables corresponding to their work units. In each group, there are members who have visual contact with the coffee maker and others who do not. As a particularity, it should be taken into account that the members of the Mobility group usually coincide when it comes to making the coffee break, while in the other groups, each person usually prepares the coffee individually. Some of the groups have a microwave and refrigerator.

ServGen: It is a workspace that serves as the secretariat of a research center attached to a university in Bilbao. In this space, there are several offices for private use and common rooms where administrative staff works. The coffee machine is placed in one of these spaces. Only one of the workers has direct visual contact with the device.

IEEC: It is a research group related to computer science and education belonging to a university in Madrid where its members are divided into 2 separate offices. Their coffee machine is located inside a working laboratory along with other mechanical machines such as drills and lathes. This laboratory is separated from the two offices, therefore there is no visual contact with the appliance. Hence, it is easy to leave it switched off due to absentmindedness.

Techabout: It is a cabin located in a business incubator of technology-based companies in Bilbao. Being a small room does not have separate spaces and therefore the coffee machine is on top of a piece of furniture in the center of the room. Each of the people who work there has their own table and they all have visual contact with the coffee machine.

Tecnilogica: It is a technological company in Madrid with a diaphanous space of about 1500 m^2 where the workers are grouped in round tables organized by ongoing projects. The space of the coffee machine is separated into an adjoining room that is a full kitchen. In addition to all the appliances that can be found in a conventional kitchen, this space has vending machines. In that place, people can eat or relax because there are tables, sofas, and access to the outside. There are many people in the company who usually have coffee together at the same time.

Appendix B. Transformation from quotes to codes in GT

Table B1
Three samples of the Open coding phase: From the quote, to the intermediate action to the final codes.

Quote	Intermediate Action	Unitary Codes
I have continued to use the coffee maker as I did before and it has not meant any change to how I have used it or even thought about it	* Showing comfort and transparency about the research * Ensuring that he/she has not changed the way the coffee maker is used	* Transparent measurement. * Consistency * No change in conscious habit
To me personally, it has not made me more efficient / conscious with other energy consumption devices	* Ensuring that you have not changed efficiency habits * Showing security when it comes to saying that you have not extrapolated the habit to other devices * There is no self-perception of behavior change with other electrical appliances.	* do not extrapolate * change of non-conscious habit
but now, having the visual stimuli there. Even though there are times we say: "why is it red if we have not done anything" ... then having it invites you ... to say ... uh I'm going to turn it off.	* Attributing to the interaction of the coffee maker the improvement in the efficiency of the group * Showing contrariety to interaction at certain times	* useful interaction * initial disappointment * adaptation

References

Adams, A., Lunt, P., Cairns, P., 2008. A qualititative approach to HCI research. In: Cairns, P., Cox, A. (Eds.), Research Methods for Human-Computer Interaction. Cambridge University Press, Cambridge, UK, pp. 138–157.

Armstrong, D., Gosling, A., Weinman, J., Marteau, T., 1997. The place of inter-rater reliability in qualitative research: an empirical study. Sociology 31 (3), 597–606.

Arroyo, E., Bonanni, L., Selker, T., 2005. Waterbot: exploring feedback and persuasive techniques at the sink. Proc. of CHI'05. ACM, pp. 631–639.

Atzori, L., Iera, A., Morabito, G., 2014. From" smart objects" to" social objects": the next evolutionary step of the internet of things. IEEE Commun. Mag. 52 (1), 97–105.

Broms, L., Katzeff, C., et al., 2010. Coffee maker patterns and the design of energy feedback artefacts. Proc. of DIS'10. ACM, pp. 93–102.

Brown, N., Stockman, T., 2013. Examining the use of thematic analysis as a tool for informing design of new family communication technologies. Proceedings of the 27th International BCS Human Computer Interaction Conference. British Computer Society, pp. 21.

Brynjarsdóttir, H., Håkansson, M., Baumer, E., DiSalvo, C., Sengers, P., PierceJames, 2012. Sustainably unpersuaded: how persuasion narrows our vision of sustainability. Proc. of CHI'12. ACM, pp. 947–956.

Casado-Mansilla, D., López-de Armentia, J., Ventura, D., Garaizar, P., López-de Ipina, D., 2016. Embedding intelligent eco-aware systems within everyday things to increase people's energy awareness. Soft Comput. 20 (5), 1695–1711.

Casado-Mansilla, D., López-De-Armentia, J., Garaizar, P., López-De-Ipiña, D., 2014. To switch the coffee maker or not: that is the question to be energy efficient at work. Proc. of CHI'14 (E.A.). pp. 2425–2430.

Charmaz, K., 2006. Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis. SAGE Publications.

Charmaz, K., Belgrave, L.L., 2007. Grounded Theory. The Blackwell Encyclopedia of Sociology.

Cialdini, R., 1993. Influence (rev): The Psychology of Persuasion. HarperCollins.

Cowan, B.R., Bowers, C.P., Beale, R., Pinder, C., 2013. The stroppy kettle: an intervention to break energy consumption habits. CHI EA '13. ACM, pp. 1485–1490.

De Young, R., 1993. Changing behavior and making it stick. Environ. Behav. 25, 485–505.

DeLongis, A., Hemphill, K.J., Lehman, D.R., 1992. A structured diary methodology for the study of daily events. Methodological Issues in Applied Social Psychology. Springer, pp. 83–109.

Diefenbach, S., Lenz, E., Hassenzahl, M., 2013. An interaction vocabulary. describing the how of interaction. CHI'13 Extended Abstracts on Human Factors in Computing Systems. ACM, pp. 607–612.

DiSalvo, C., Sengers, P., Brynjarsdóttir, H., 2010. Mapping the landscape of sustainable HCI. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, pp. 1975–1984.

Fogg, B.J., 2003. Persuasive Technology: Using Computers to Change What We Think and Do. 18 Morgan Kaufmann Publishers.

Froehlich, J., Findlater, L., Landay, J., 2010. The design of eco-feedback technology. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, pp. 1999–2008.

Gao, X.-P., Xin, J.H., 2006. Investigation of human's emotional responses on colors. Color Res. Appl. 31 (5), 411–417.

Glaser, B.G., Strauss, A.L., 2017. Discovery of Grounded Theory: Strategies for Qualitative Research. Routledge.

Gustafsson, A., Gyllenswärd, M., 2005. The power-aware cord: energy awareness through ambient information display. Extended Abstracts of CHI'05. ACM, pp. 1423–1426.

Hardeman, W., Johnston, M., Johnston, D., Bonetti, D., Wareham, N., Kinmonth, A.L., 2002. Application of the theory of planned behaviour in behaviour change interventions: a systematic review. Psychol. Health 17 (2), 123–158.

He, H.A., Greenberg, S., Huang, E.M., 2010. One size does not fit all: applying the transtheoretical model to energy feedback technology design. CHI '10. ACM, pp. 927–936.

Hekler, E.B., Klasnja, P., Froehlich, J.E., Buman, M.P., 2013. Mind the theoretical gap: Interpreting, using, and developing behavioral theory in HCI research. CHI '13. ACM, pp. 3307–3316.

Hermsen, S., Frost, J., Renes, R.J., Kerkhof, P., 2016. Using feedback through digital technology to disrupt and change habitual behavior: a critical review of current literature. Comput. Hum. Behav. 57, 61–74.

Holstius, D., Kembel, J., Hurst, A., Wan, P.-H., Forlizzi, J., 2004. Infotropism: living and robotic plants as interactive displays. Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques. ACM, pp. 215–221.

Irizar-Arrieta, A., Casado-Mansilla, D., Retegi, A., 2018. Accounting for user diversity in the design for sustainable behaviour in smart offices. 2018 3rd International Conference on Smart and Sustainable Technologies (SpliTech). IEEE, pp. 1–6.

Jönsson, L., Broms, L., Katzeff, C., 2010. Watt-lite: energy statistics made tangible. Proc. of DIS'10. ACM, pp. 240–243.

Kabicher, S., Kriglstein, S., Figl, K., Motschnig-Pitrik, R., 2008. Using eportfolios enhancing for learning through computer-mediated interaction in a course on HCI. Symposium of the Austrian HCI and Usability Engineering Group. Springer, pp. 113–124.

Kappel, K., Grechenig, T., 2009. Show-me: water consumption at a glance to promote water conservation in the shower. Persuasive '09. ACM, pp. 1–6.

Knowles, B., Blair, L., Walker, S., Coulton, P., Thomas, L., Mullagh, L., 2014. Patterns of persuasion for sustainability. DIS '14. ACM, pp. 1035–1044.

Laschke, M., Diefenbach, S., Hassenzahl, M., 2015. "Annoying, but in a nice way": an inquiry into the experience of frictional feedback. Int. J. Design 9 (2), 129–140.

Lockton, D., 2012. Models of the user: designers' perspectives on influencing sustainable behaviour. J. Design Res. 10 (1/2), 7.

Lu, C.-H., 2018. Iot-enabled adaptive context-aware and playful cyber-physical system for everyday energy savings. IEEE Trans. Hum. Mach. Syst. 48 (4), 380–391.

Mansilla, D.C., 2016. Promoting long term energy-efficient behaviour in work environments through persuasive technologies. Universidad de Deusto Ph.D. thesis.

Merton, R.K., Fiske, M., Kendall, P.L., 1990. The focused interview : a manual of problems and procedures, second ed. The Free Press.

Nass, C., Moon, Y., Morkes, J., Kim, E.-Y., Fogg, B., 1997. Computers are social actors: a review of current research. Hum. Values Design Comput. Technol. 72, 137–162.

Nielsen, J., 1994. Guerrilla HCI: using discount usability engineering to penetrate the intimidation barrier. Cost-Justifying Usability. pp. 245–272.

Nilsson, A., Bergquist, M., Schultz, W.P., 2017. Spillover effects in environmental behaviors, across time and context: a review and research agenda. Environ. Educ. Res. 23 (4), 573–589.

Nipkow, J., Bush, E., Josephy, B., Pilone, A., 2011. For a tasty but efficient coffee. Proc. of ECEEE 11, 1453–1470.

Pereira, L., Quintal, F., Barreto, M., Nunes, N.J., 2013. Understanding the limitations of eco-feedback: a one-year long-term study. International Workshop on Human-Computer Interaction and Knowledge Discovery in Complex, Unstructured, Big Data. Springer, pp. 237–255.

Peschiera, G., Taylor, J.E., Siegel, J.A., 2010. Response–relapse patterns of building occupant electricity consumption following exposure to personal, contextualized and occupant peer network utilization data. Energy Build. 42 (8), 1329–1336.

Petkov, P., Goswami, S., Köbler, F., Krcmar, H., 2012. Personalised eco-feedback as a design technique for motivating energy saving behaviour at home. Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design. ACM, pp. 587–596.

Pierce, J., Odom, W., Blevis, E., 2008. Energy aware dwelling: a critical survey of interaction design for eco-visualizations. Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat. ACM, pp. 1–8.

Pierce, J., Paulos, E., 2012. Beyond energy monitors: interaction, energy, and emerging energy systems. Proc. of CHI'12. ACM, pp. 665–674.

Quintal, F., Barreto, M., Luis, F., Baptista, V., Esteves, A., 2017. Studying the immediacy of eco-feedback through plug level consumption information. 2017 Sustainable Internet and ICT for Sustainability (SustainIT). IEEE, pp. 1–4.

Reeves, B., Nass, C.I., 1996. The media equation: how people treat computers, television,

and new media like real people and places. Cambridge university press.
Slack, M.K., et al., 2001. Establishing the internal and external validity of experimental studies. Am. J. Health Syst. Pharm. 58 (22), 2173–2181.
Thieme, A., Comber, R., Miebach, J., Weeden, J., Kraemer, N., Lawson, S., Olivier, P., 2012. We've bin watching you": designing for reflection and social persuasion to promote sustainable lifestyles. Proc. of CHI'12. ACM, pp. 2337–2346.
Valdez, P., Mehrabian, A., 1994. Effects of color on emotions. J. Exp. Psychol. 123 (4), 394.
Ventura, D., Casado-Mansilla, D., López-de Armentia, J., Garaizar, P., López-de Ipina, D., Catania, V., 2014. Ariima: a real IoT implementation of a machine-learning architecture for reducing energy consumption. International Conference on Ubiquitous Computing and Ambient Intelligence. Springer, pp. 444–451.