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A Game Based Approach on Eliminating Computer Energy Waste

by

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ABSTRACT

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A GAME BASED APPROACH ON ELIMINATING COMPUTER ENERGY WASTE

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Energy reduction is one of the main challenges that countries around the world currently face. Two serious games were implemented with waste-oriented feedback, for the work environment (IdleWars) and for the home environment (EcoScreenCatcher). These games were competition oriented games designed to raise awareness of computer-based energy consumption. Both games deployed "*in the wild*" and were evaluated quantitatively and qualitatively. IdleWars is a pervasive and competition-oriented game. Workers' pro-environmental or wasteful behaviour is reflected in their game score, and displayed through eco-feedback visualisations. A two-week field deployment revealed that the physical and competitive elements of the game work well in engaging participants. The design was successful in catalysing and polarising existing social dynamics. Participants developed tactics and appropriated the game and extended its rules, sometimes in a way that favoured engagement and fun rather than conservation behaviour. EcoScreenCatcher is a software-based competition-oriented game that calls attention to PC energy waste. Similarly to IdleWars, the human involvement in the feedback is an important design element. EcoScreenCatcher was deployed for over three weeks, with a total of 23 university students. Quantitative analysis showed that the game caused PC idle time reduction for players with four or more game friendships during the first week of playing. Post-study semi-structured interviews showed attitude changes and awareness of sustainability, as well as spill over effects to other appliances and to people who did not participate.

To better understand the perception of waste in the home, interview analysis was undertaken of a study already conducted (and not part of this work) by the University of Southampton and by Kingston University. The analysis showed that the majority of participants' appliances being on when not in use as waste, as well as not using a resource to its full potential. Waste perception is influenced by attributes such as comfort, cleanliness, culture, technological advancement, and age. Such a result shows that eco-feedback tools are not one-size-fits-all, and the human element combined with waste-oriented feedback has the potential to raise awareness and change behaviour.

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Chapter 1

Introduction

Countries around the world face three energy issues: limited fossil fuel resources; the need to secure a continuous energy supply; and the problem of climate change (MacKay, 2009). As stated by the US Energy Information Administration (2016), energy demand is expected to increase by 1.3%/year between 2010 and 2040. This increase implies the need to either reduce demand, or to provide an infrastructure capable of meeting this demand, or a combination of both. The motivation behind the current work is to reduce energy demand. Energy demand reduction can be achieved either by replacing old energy-inefficient electrical equipment with energy-efficient ones (structural approach), or by persuading people to change to a more eco-friendly lifestyle (user-centric approach) by adopting sustainable behaviour (Jahn et al., 2011). It is also possible to apply both approaches simultaneously.

The focus here is on the "user-centric" approach and results will contribute to "sustainable HCI". HCI is "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Hewett et al., 1992). "Sustainable HCI" is the part of HCI that is concerned with the design of eco-friendly technology, either at the technological level (e.g. hardware and software that aims at device reuse), or at the personal level (e.g. helping an individual adopt a sustainable lifestyle). A persuasive technology widely used in the "Sustainable HCI" research area is eco-feedback, which is "information presented during the product/user interaction that prompts the user to adopt energy-saving strategies" (McCalley and Midden, 1998).

There is an abundance of literature on the perception of sustainability and how these perceptions can influence eco-feedback designs. Abrahamse et al. (2005) reviewed the effectiveness of interventions of work published in social and environmental psychology venues. Strengers (2008) argued that behaviour change strategies should focus also on norms in domestic life by redefining habits. Chetty et al. (2008) argued that households focus on comfort, and keeping resource consumption low mainly for financial reasons.

Waters (2016) showed that thermal comfort in the UK has increased in recent years, resulting in greater energy consumption. Woodruff et al. (2008) focused on sustainability perception practices on green individuals in the US, whilst Desjardins and Wakkary (2011) reported on sustainability perceptions of kids, Dillahunt et al. (2009) on low-income households, Vyas (2012) on a middle-class Indian family, and Shrinivasan et al. (2013) on urban India. Pierce et al. (2010) developed a vocabulary of conservation interactions, but most eco-feedback designs focus on feedback on resource consumption.

Even though there are comments on waste (Pierce et al., 2010), Hargreaves et al. (2010) do not elaborate on how people perceive waste. A similar direction on waste has been proposed by Yang et al. (2016) with a system called "ThermoCoach", and by Yun et al. (2015) with a system called Intelligent Dashboard for Occupants (ID-O). ThermoCoach provides eco-feedback on energy consumed for temperature regulation in the household. It takes advantage of occupancy information (via Bluetooth and IR-based motion sensing) to provide personalised suggestions, and automation to reduce waste in the home environment. ID-O provides self-monitoring, and advice to eliminate energy waste, and a comparison with the work environment. Both ThermoCoach and ID-O studies focus on identifying waste internally and provide actionable suggestions on how to eliminate waste, but they do not provide waste-oriented feedback, unlike this work. The Chambers Dictionary defines waste as "useless or unprofitable spending". Understanding how people perceive waste is important for the eco-feedback community, due to the inherent aversion some people have to waste (Arkes, 1996), and their likelihood of takeing action to remedy waste (Strengers, 2011).

Prior work investigated wasteful behaviours in different contexts. For example, a number of projects focused on food waste. Ganglbauer et al. (2012) identified 7 dimensions of visibility for the elimination of food waste. Nguyen et al. (2015) identified three main reasons for wasting food in the home environment. Farr-Wharton et al. (2012) propose a colour coding technique as a way to raise awareness of food availability as well as reducing the amount of expired food waste. Finally, Yalvaç et al. (2014) proposed a mobile application called *EUPHORIA* that suggests recipes based on available food, to avoid waste combined with social aspects where people share their food creations with others. While food waste is unequivocally defined as food that is thrown away, this work focuses on energy waste, demonstrating that in such a context the definition is less clear.

In the context of electronic appliances, Kim and Paulos (2011) focused on e-waste and identified factors that influence e-waste reuse. Device aesthetics and design re-use ideas are important factors in device re-use. Murata et al. (2012) focused on the refrigerator and proposed *PerFridge*, an augmented refrigerator that detects when the door is open or closed, the state of items in the refrigerator, and food temperature. Based on this information, the system detects wasteful behaviours. In the work environment, Simon et al. (2012) proposed a game called *Climate Race*, which is based on a combination of implicit and explicit energy-related actions. The game tracks players' wasteful activity at room level, through sensors (e.g. switching off lights when not in the office). Based on this activity, players gain positive or negative points. This work focuses on energy-related waste and the implications it has for future sustainable HCI designs.

A convenient research vehicle to study waste-oriented electricity consumption is that used by computers. There are other approaches to reducing PC-based electricity consumption, such as reducing computer usage. In both home and work environments, this approach is difficult to implement due to limitations in identifying and quantifying when and for how long a computer should be on or off, and because it invades privacy. In the context of privacy, such an approach would require application tracking and task identification (i.e. what application is currently in use), which is considered intrusive. Software-based waste detection can be implemented and refined, and can be widely deployed in different environments such as home and work.

IT-related energy consumption and IT devices (desktops, laptops, peripherals) have more than doubled between 2000 and 2009, and this is expected to continue (Owen et al., 2011). Consumer Electronics (CE) and Information and Communications Technology (ICT) comprise 25% of energy consumption in the home (Owen, 2012). Both CE and ICT have extended to networking capabilities, enabling power status to be detected by software. Therefore, even though this work focuses on computers, its range can be extended to other CE and ICT appliances. In the context of computers and the home environment, Chetty et al. (2009) identified energy saving opportunities because computers are often left on and not in use for extended periods of time. Even though automation might be a potential solution, Rattenbury et al. (2008) suggested that ultra-mobility and PCs are highly integrated with household activities, making it difficult to implement in practice. Similar findings have also been reported by Bates et al. (2014), where low power modes were cumbersome to automate in practice because it is difficult to know in advance when a peripheral device is needed, e.g. a server or an external hard drive. This suggests that a manual approach is a more feasible solution. Since the cost of computer energy usage is relatively small, PC users do not have incentives to eliminate waste (Chetty et al., 2009). This shows a potential for behaviour change interventions to eliminate user-related energy waste in the home environment through the employment of a user-centric (energy demand reduction) approach.

Another place where significant energy may be saved is the work environment, where people spend a considerable amount of their time (Jentsch et al., 2011; Foster et al., 2012). This work focuses on open-plan office workplaces, mainly because of the popularity of these in commerce and industry. According to the IFMA (2010) report, open office (or open seating) is one of the most popular office layout types (70%) used by companies in the US. In such spaces, computers are an important tool for conducting work, and in most cases are personal (each OS login session is used by one employee). This provides an opportunity to investigate employees' behaviour individually.

During working hours, employees change the enterprise's energy consumption, e.g. by switching appliances on or off. This shows a potential to eliminate user-related energy waste in the work environment, through the employment of a user-centric (energy demand reduction) approach. This approach is important because it raises awareness, draws workers' attention to bad behaviour that leads to waste, and correcting this bad behaviour can have an impact on other environments, e.g. in the home.

PCs are widely used in the work environment. The time that a computer is left on while not in use is referred to as "idle time". Even though it may seem marginal, computer idle time is an important issue in the work environment. According to 1E (a company working on IT and sustainability) and the "Alliance To Save Energy" (a non-profit organisation) (PC Energy Report, 2009), 78% of workers in the UK regularly use a PC to conduct their work. 27% reported that they do not always shutdown their PC, 14% reported that they only occasionally shut them down, and 9% reported that never shut down their PC. This results in energy waste, additional energy costs for industry, and consequent carbon emissions. Waste is defined here as consumption of energy by employees and households when their computers are idle (on and not in use). Scenarios considered as use are: typing on the computer, moving the mouse, videos being watched, music being listened to. The current implementation does not consider the computer as in use when: downloading a file from the network, or conducting intensive operations on a Central Processing Unit (CPU) or Graphics Processing Unit (GPU).

Evidence of the magnitude of computer based energy waste was demonstrated when the University of Southampton held a blackout event on Friday 26 April 2013. This was part of a sustainability campaign and was conducted as a way to raise awareness of energy waste. Organisers requested all students and staff to switch off all non-essential electrical equipment at the end of that day. Volunteers searched all the buildings and, if a computer was left on without reason, they switched it off. During this time, they found 2151 computers left on out of 7192 in total. This indicates that 30% of the computers at the university might be left on overnight. Given that organisers **notified** all students and staff by e-mail to switch off their devices on that particular day, it would be expected that these numbers would be much higher on an ordinary day.

To estimate the energy saved by this event, the computer and monitor consumption was measured using the "Efergy Technologies EMS 2.0" meter. The focus was on frequent computer setups appearing on campus. Measurements were taken when the computer was idle (i.e. no processing intensive tasks running at the time of measurement), with the monitor being at 50% brightness. The consumption for both computers and monitors ranged from 150W (for high-end setups) to 40W for MacBook pro laptops. The average computer (one monitor and tower) at the University of Southampton consumes 95W[1]. Assuming that all 2151 computers were left on idling for 12 hours, the aggregate

[1] A high end PC (Viglen Genie Full) with a HannsG monitor consumes 110W + 40W = 150W, whereas a MacBook Pro laptop consumes

consumption will be 2151 x 95 x 12 = 2452.14 kWh, and if the costing was 16p/KWh, the overall cost wasted through idle time would be £392 per day. If this behaviour appears throughout the year (365 days) it would cost the university £143,080!

User-generated energy is small compared with the energy consumed by Heating, Ventilation, and Air Conditioning (HVAC) systems and industrial equipment. Studying intervention strategies and how those strategies could raise awareness of energy conservation among workers can be beneficial for the Sustainable HCI community. More specifically, there is potential in determining how intervention strategies can be applied at a group level, and how sustainable behaviour propagates among workers through peer pressure and social norms (Katzeff et al., 2013). There is also potential in discovering behavioural influence on other groups of people and environments, e.g. from work to home. The investigation of these research opportunities will enable the work environment to operate as an incubator for raising awareness about sustainability.

1.1 Research Gap

This section briefly reviews the literature, in order to identify the research gap. Most research related to sustainable behaviour and to sustainable HCI has looked at feedback on energy consumption in the domestic environment. Details of this are addressed in Chapter 2. Only a few publications tackled sustainable HCI in the work environment, by providing a concrete implementation. Pousman et al. (2008) proposed *Imprint*, a technology probe that provides visualisations based on the papers printed in the workplace, e.g. Number of pages, text the pages contain. The visualisations illustrate environmental issues but also social information from data taken from the documents. *Imprint* is the only eco-feedback system that is mainly based on software to provide its feedback. Most research in this area employs sensors to acquire feedback. Taherian et al. (2010) proposed the Cambridge Sensor Kit (CSK) monitoring system. This is able to provide feedback, automation (e.g. capability to switch off appliances), and comparative feedback. Schwartz et al. (2010) applied eco-feedback and a consumption reflection workshop as motivator to reduce energy. Their findings revealed that workers act sustainably if support is provided. Jentsch et al. (2011) proposed an energy conservation support system in the workplace. Sensors detect the status of the windows and appliances as well as room occupancy. Based on this information, a notification system informs the user if there is potential for saving energy. Energy conservation in the work environment has also been approached from a theoretical perspective. Yun et al. (2013) inspected 9 intervention techniques, which can be applied in the work environment, for the workers to adopt eco-friendly behaviour, and suggested design approaches for persuasive systems in the workplace. In this work a consumption-oriented mechanism is placed in a real work environment to raise awareness of energy waste.

Games have also been used with the aim of promoting sustainable behaviour in the HCI research area, mostly in the domestic context. For example, Reeves et al. (2013) presented a serious game[2], *Power House*, that simulated a virtual household and evaluated its consequences both in a lab study and in a field trial, reporting its success in reducing energy consumption. A few energy-related games were specifically targeted at children and adolescents. Gustafsson et al. (2009) argued that serious games make it difficult to transfer lessons from the game to the real world, and therefore proposed a casual game approach instead. They reported the design of a pervasive game for teenagers, played by activating and deactivating real appliances in the home (monitored through sensors in the plugs). A similar approach was proposed by Bang et al. (2007), who reported a combination of a casual game, that follows a classic video-game gameplay, with a pervasive[3] game in which players had to complete missions in the real world and verify their actions by taking pictures with smart phones. In this work, a serious game is deployed both in the work and home environments, targeting an adult audience.

In the work environment, games could also be beneficial as a way to incentivise workers to adopt sustainable behaviour. Simon et al. (2012) proposed a game designed to encourage sustainable behaviour at work that did not invade workers' privacy. *Climate Race* tracks players' activity in each room in the real world, through environmental sensors, e.g. switching off lights when not in the office. Based on this activity, players gain positive or negative points. Extra game points can be collected through specific collective actions, such as all players switching off lights when leaving the office. The two-week pilot study showed a decrease in energy consumption. Orland et al. (2014) proposed a virtual pet game called *Energy Chickens*. The health and size of the pets represent the energy consumption of appliances for each individual's devices. The study lasted for 24 weeks and reduced consumption by 13% on both work and non-work days. Both games are cooperation-oriented games. This showed the research potential for competition-oriented games in the work environment.

Games in general have the potential to achieve behaviour change. One reason is the normative influence players have on each other (Hamari and Koivisto, 2015). Frantz and Mayer (2009) showed that perceiving sustainable action is something that others (and not themselves) need to do, and even if they do it, they think their action is not sufficient. Games can provide specific steps on how to start and how to achieve a certain outcome. Finally, games require actions to be performed frequently. Given that such actions become a habit through repetition, Phillips and Gardner (2016) have shown that the frequency of habitual behaviour significantly increases.

Even though games have been used to motivate resource reduction, most in the area of sustainability in the domestic environment employ smart sensors in order to provide

[2] "Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." (Zyda, 2005)

[3] "Pervasive games extend the gaming experience out into the real world." (Benford et al., 2005)

consumption-oriented feedback. Quintal et al. (2013) employed centralised household monitoring and used an artistic video animation of a forest site as the feedback mechanism. Geelen et al. (2012) used the Wattson Energy Monitor to measure household consumption, provide feedback combined with a puzzle that provided building blocks to create structures. The more energy saved by the teams, the more blocks they get with which they can build bigger and nicer structures. Rodgers and Bartram (2011) employed a Kill-a-Watt monitoring unit to investigate three different ambient display visualisations. Quintal et al. (2010) developed an energy monitoring device using a clamp-on current transformer connected to the computers' audio input. The device is capable of detecting presence and people using facial recognition technology and provides personalised feedback. The only software-based approach to sustainability was suggested by Pousman et al. (2008); Willamowski et al. (2013), but applied to the work environment and was aimed at reducing paper. The basic principle of all these studies is the use of sensors to provide consumption-based feedback. This work focuses on computers and provides a software-based approach to providing waste-oriented feedback. As with other studies, two games were designed to motivate participants to reduce their consumption.

Through games, human involvement in feedback has the potential to change behaviour. Research has showed that feedback is considered one of the most important factors (Brett and Atwater, 2001). If feedback is considered useful, it is more likely the target behaviour will be achieved (Brett and Atwater, 2001). Kluger and DeNisi (1996) showed that social cues, like voice, can enhance the motivational aspect of feedback, whilst Short et al. (1976) showed that the medium that closely provides a face-to-face interaction can have an impact on how useful the feedback is perceived. A more recent study has shown that feedback provided by a person was considered more useful, trustworthy and enjoyed the most, than the one provided by an artefact (Walter et al., 2015). Even though studies have been proposed for human involvement in both home (Piccolo and Alani, 2016) and work (Schwartz et al., 2010) environments, the interaction has only occurred in workshops. The games in this work have been designed to involve human feedback as a reporting mechanism, to enrich that provided by the computer.

1.2 Research Objective and Research Challenges

The research objective is to investigate how game interventions and human involvement in feedback provision, for both work and domestic environments around computer-based energy waste, influences peoples' environmental behaviour.

A platform that tracks, processes and visualises computer status is to be developed. The innovative aspect of the visualisations is that it is waste-oriented (instead of just consumption-oriented) and involves the user in the feedback provision. The platform will be used as a tool to investigate interventions that make workers and household residents aware of energy waste and feel comfortable with their privacy. For the platform to be developed and be effective, research challenges need to be met for both work and home environments. Moreover, to better understand peoples perception of waste beyond computer consumption in the home environment, interviews already conducted as part of an unpublished study by the University of Southampton and Kingston University were analysed.

The main research challenge is incentivising workers and household residents towards sustainability. Engaging people in the work environment is more difficult compared to the home environment, mainly due to the lack of financial incentives exhibited by the latter (Carrico and Riemer, 2011; Katzeff et al., 2013). Different means are required to raise awareness and engage workers towards sustainable behaviour (Jahn et al., 2011; Jain et al., 2013). Simon et al. (2012) proposed a game as a way to incentivise workers to adopt a more sustainable behaviour, whilst Willamowski et al. (2013) proposed financial incentives, by enabling workers to use the savings achieved for other purposes. In the home environment, the cost of energy for computer use is relatively small, and users do not have incentives to eliminate waste (Chetty et al., 2008). Therefore, a waste-oriented game is a promising direction.

Studies have shown that games have potential in changing behaviour (Ro et al., 2017), raising awareness (Peng et al., 2010), and fostering learning (Hummel et al., 2011) in general. In the context of energy conservation, a game that involves physical interaction with household appliances is successful in educating and motivating teenagers and families in energy conservation (Banerjee and Horn, 2013; Gustafsson et al., 2010; Bang et al., 2007). There is also an indication that games played only on the computer (without any physical interaction) can be successful in changing behaviour to more sustainable energy consumption (Reeves et al., 2013). Games also have the potential for long-term behaviour change. More specifically, Ro et al. (2017) proposed a competition-oriented game using physical cards called: step, leap, focus, and innovation. The cards are used to claim credit for sustainable behaviour performed by participants to gain points. Each participant can choose the behaviour they want to perform. The study showed energy reduction for the participants who played the game, and increased effort to save energy in the household. Interviews conducted 13 months after the game ended, revealed persistence in this behaviour. In this work, a game is used with novel human-based reporting mechanism that uses social dynamics in the home and work environments as a way of expressing disapproval of energy waste. Game-oriented approaches to electricity consumption have been proposed in the home environment, resulting in promising results, some of them by using rewards (Geelen et al., 2012), whilst others not (Gustafsson et al., 2010).

There are two research challenges related to sustainability applied to work environments. The first of these is privacy. Privacy is important when designing eco-feedback technologies because such systems collect vast amounts of data and personal habits can be inferred from them (Froehlich et al., 2010). Two privacy concerns are visualisation and data ownership. At the visualisation level, normative feedback on a person's consumption pattern can be considered invasive (Orji, 2017; Pousman et al., 2008) and could potentially result in accountability and blame. At the data ownership level, where the data is stored and who owns and can access it, is worrying for the individual (Jahn et al., 2011; Schwartz et al., 2010). This work focuses on the privacy concerns at the visualisation level in the work environment. The second research challenge is the provision of feedback through interfaces and visualisations that persuade employees to consume less energy but are also non-invasive.

It is difficult to compare this work with previous eco-feedback studies, even though there are similarities. First, the feedback provided in this work is idle time-oriented and not consumption-oriented. Secondly, part of energy eco-feedback design is understanding how much electricity each appliance uses. This provides an opportunity for users to understand the consumption of each appliance and make informed decisions on whether to reduce their consumption. This work focuses on a specific behaviour that participants are required to follow (sleep, hibernate, or shutdown the computer, when it is not in use), and a specific appliance (the computer). Even though it is not easy to compare at the level of consumption, it is interesting to investigate potential reactions and changes in behaviour when such feedback is provided. Research outcomes of this work could potentially influence future consumption-based eco-feedback designs.

1.3 The IdleWars Game

"IdleWars" is an office based energy game that was developed in this study to address the financial incentives challenge. The game aims to raise awareness of sustainability with employees so that they reduce their energy waste in the workplace. More specifically, it aims to reduce the impact a person has on the environment by the provision of feedback that changes their behaviour. Feedback is defined as "actions taken by (an) external agent(s) to provide information regarding some aspect(s) of one's task performance" (Kluger and DeNisi, 1996). To tackle the privacy and the non-invasive visualisations (feedback) challenges, a field study will be conducted, followed by a focus group interview that verifies whether the visualisation provided during the game is appropriate for the work environment.

1.4 The EcoScreenCatcher Game

"EcoScreenCatcher" is a home environment based energy game that was developed to address the financial incentives challenge. The game aims to raise awareness of sustainability with computer users so that they reduce their energy waste in the home.

One research objective of this study is to identify potential differences between home and work environments in terms of intervention effectiveness, perceptions of waste around computer usage, and spill over effects. EcoScreenCatcher was the second design iteration and feedback mechanisms were largely influenced by lessons learned in the IdleWars study.

1.5 Research Contribution

The research contribution is in the research area of sustainable HCI in the home and work environments. This work develops a platform that tracks, processes and visualises computer status. This platform opens opportunities to provide feedback on energy waste in both work and home environments. The game aspect of the platform enables the involvement of the human element in the feedback by reporting wasteful behaviour. Deploying these platforms *in the wild* for work and home environments enabled me to understand how people perceive waste, interact with each other concerning waste, and how their environmental behaviour is influenced. *In the wild* design is an ethnographic approach that focuses on technology evaluation *in situ* rather than in a laboratory setting (Rogers, 2011).

This work also contributes to visualisation and to incentive identification. More specifically, it aims to identify data and visualisations that are considered non-invasive and raise awareness of waste in the work and home environments. Privacy is a major concern in the work environment. To be acceptable in the work environment, visualisations need to be non-invasive. Finally, incentives need to be identified that incentivise workers and home users to adopt a more sustainable behaviour with their PCs.

1.6 Report Structure

Chapter 2 surveys eco-feedback related research. The general concept of environmental behaviour is first described and its differences from pro-environmental behaviour. It then elaborates one way to encourage, promote and foster pro-environmental behaviour, called “persuasive technology”. It focuses on how HCI can approach sustainability through the use of eco-feedback, and how HCI approaches sustainability by employing it. Informational strategies widely used for feedback provision are then discussed. Research that has employed HCI and eco-feedback to achieve pro-environmental behaviour in domestic and work environments is summarised and discussed.

Chapter 3, provides the design behind the implementation of the IdleWars game. Chapter 4 describes the environment where IdleWars was deployed and discusses the findings.

Chapter 5 analyses interviews about waste. Chapter 6 presents the design of the EcoScreenCatcher game and elaborates on the similarities and differences with IdleWars. Chapter 7 describes the deployment of the EcoScreenCatcher game and discusses the findings. Finally, Chapter 8 describes possible future research directions.

Chapter 2

Background

Due to the severe impact on the environment by energy produced by fossil fuels, research on HCI and Ubiquitous Computing (Weiser, 1991) has focused on eco-feedback as a persuasive technology (Fogg, 2002) to motivate sustainable behaviour. This work contributes to the research area of sustainable HCI. This is achieved by designing an interactive system that applies eco-feedback persuasive technology, and behaviour change interventions, to promote pro-environmental behaviour. This chapter introduces the sustainable HCI research area, the differences between environmental and pro-environmental behaviour, and how eco-feedback persuasive technology can assist achieving pro-environmental behaviour by applying behaviour change interventions. It then discusses behaviour change interventions, how social norms can influence behaviour change, and summarises research related to the home and work environments.

2.1 Sustainable HCI

HCI is important in communicating measurements related to sustainability in a way that could lead to improving sustainability. Designing interactive systems, which can help people understand sensor data about resource consumption, is an HCI problem. HCI enables the users to correlate the results of their everyday activities with energy consumption. However, HCI is a broad area of research, so in the study will focus only on "sustainable HCI".

Sustainable HCI aims to design technology that minimises negative impact on the environment. Mankoff et al. (2007) classified sustainable HCI as: sustainability *in design* and sustainability *through design*. The former relates to the material design of products that try to reduce energy consumption, device re-use through optimised software, and the increase of device lifespan by simplifying repair. It further suggests the provision of a framework that promotes device re-use. The latter is related to people adopting a sustainable way of living; at the individual level, at group level, and as a society.

This thesis focuses on *sustainability through design*, more specifically at the individual and group levels. For individuals, feedback is provided about their performance in terms of computer idle and active time. At the group level, two games have been created to enhance engagement and interaction between users, as well as provide feedback that enables players to compare themselves with others.

The main genres of sustainable HCI research are: persuasive technology, ambient awareness, sustainable interaction design, formative user studies, pervasive and participatory sensing (DiSalvo et al., 2010). This work uses eco-feedback as a persuasive technology as the means to promote pro-environmental behaviour.

2.2 Environmental, Pro-Environmental Behaviour, Persuasive Technology and Eco-Feedback

Work related to behaviour change and technology ranges from transportation (Froehlich et al., 2009; Meschtscherjakov et al., 2009) to well-being (Consolvo et al., 2006, 2008; Schneider et al., 2016) and health (Poole, 2013). This work focuses on pro-environmental behaviour change. Environmental and pro-environmental behaviour are one of the main fields of study of environmental psychology. Environmental psychologists try to understand and, if possible, find, approaches that influence environmental and pro-environmental behaviour. Stern (2000) defined environmental behaviour "by its impact: the extent to which it changes the availability of materials or energy from the environment or alters the structure and dynamics of ecosystems or the biosphere itself".

In contrast, pro-environmental behaviour exhibits change that is beneficial for the environment. Kollmuss and Agyeman (2002) first coined the term pro-environmental behaviour, defining it as "behaviour that consciously seeks to minimise the negative impact of one's actions on the natural and built world". Stern (2011) separated those theories related to individual motives (e.g. rational-economic model (Simon, 1955)) from those focused beyond individuals (e.g. norm-activation model (Schwartz, 1977)). The rational-economic model focus on individual motivations is based on the premise that individuals aim to maximise utility and well-being. The norm-activation focus on altruistic motivation assumes that people can adopt pro-environmental behaviour if they are aware of the consequences of their actions to the environment (and therefore others), provided they also have a level of personal responsibility for their actions and their consequences. In this work, sustainable HCI is used as a tool to persuade people to adopt pro-environmental behaviour. Persuasive technology is applied in both the home and work environments, to help residents and employees adopt more sustainable attitudes and behaviour.

Persuasive technology connects psychology with technology aiming in this case at pro-environmental behaviour. Fogg (2002) defines persuasive technology as "any interactive computing system designed to change people's attitudes or behaviour". This allowed the employment of technology for making measurements, processing data and combining HCI principles with behaviour change interventions (see section 2.3) to enhance means of persuasion. In this work, eco-feedback persuasive technology is employed to help residents and workers adopt pro-environmental behaviour.

McCalley and Midden (1998) defined eco-feedback as "information presented during the product-user interaction which prompts the user to adopt energy-saving strategies". Eco-feedback is based on the hypothesis that people are unaware that their everyday activities and actions have implications on the environment (Froehlich et al., 2010). Based on this assumption, feedback can potentially lead to behaviour change, given that people to whom feedback is provided are motivated towards the desired behaviour. Ubiquitous computing is used as a means of tracking people's activities and their implications. When combined with HCI principles of communicating information in a way that can motivate people to adopt more environmentally friendly behaviour, this can lead to energy savings. Behaviour change interventions are employed as a means of information provision in HCI. The following sections elaborate upon the most popular behaviour change interventions, social norms but also research related to eco-feedback in domestic and work environments that provide concrete implementations.

2.3 Interventions that Promote Behaviour Change

Interventions that promote behaviour change can be divided into: informational strategies, which aim at "changing perceptions, motivations, knowledge, and norms, without actually changing the external context in which choices are made"; and structural strategies, which aim at "changing contextual factors such as the availability and the actual costs and benefits of behavioural alternatives" (Steg and Vlek, 2009). An example of the former strategy is a campaign about the health consequences of smoking, and an example of the latter is the increase in kWh price through additional taxation by government. This work will mostly focus on the informational strategies (see figure 2.1). Informational strategies that are applied before the behaviour are called antecedent interventions, whilst informational strategies applied after the behaviour are called consequence interventions. The most widely used informational strategies are information provision, goal setting, commitment, and feedback.

Information is a widely used intervention strategy in the area of energy conservation. There are two types of information provision: information about energy-related problems, and information that provides ways to address these problems (Abrahamse et al., 2005). According to Abrahamse et al. (2005), some ways to communicate information are: tailored information, and prompts. Tailored information is information designed for a specific person or group of people, and is applied exclusively to them. Prompts

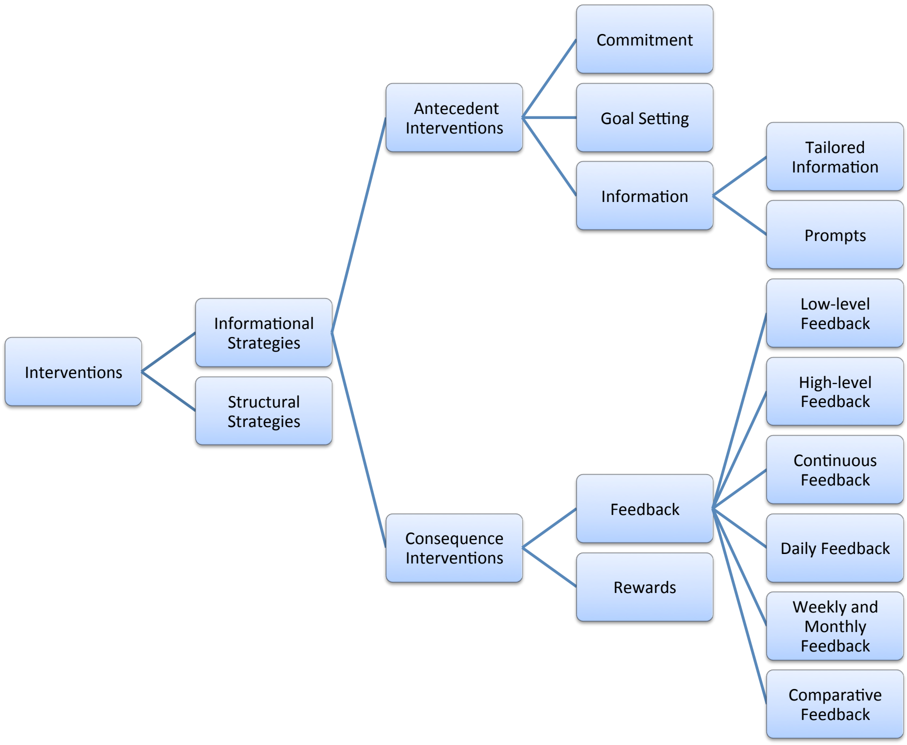


Figure 2.1: Types of antecedent and consequence interventions that promote behaviour change (based on information provided in (Abrahamse et al., 2005) and (Froehlich et al., 2010))

are short, written, verbal messages or signs that promote a certain behaviour (Froehlich et al., 2010). They are mostly positioned in places where the requested behaviour is required and act as a reminder.

In a commitment intervention strategy, a person or group of people are required to promise that they are going to adopt a certain behaviour. For example, Wang and Katzev (1990) showed that group commitment resulted in a 47% increase in recycled paper. Commitment has also been applied in combination with other informational strategies as, in (Darby, 2001) where a free ticket was provided combined with a pledge to incentivise habitual car commuters to use public means of transport.

Goal-setting intervention is rooted in the Goal setting theory (Latham and Locke, 1991) and requires the provision of an aim that people try to achieve (Abrahamse et al., 2005). It can be set by the researcher conducting the experiment or by the participants. Locke and Latham (2002) identified four functions of goals. The first is that goals direct participants to goal-related activities, whereas activities that are goal-irrelevant are discarded. Secondly, goals function as a stimulus (the greater the goal, the more effort is required). Thirdly, goals influence participants' persistence. Finally, goals can indirectly lead to action since they trigger "arousal, discovery, and/or use of task-relevant knowledge and strategies".

Feedback intervention is based on feedback intervention theory (Kluger and DeNisi, 1996) and provides information on the participant's performance, e.g. kWh of energy consumed. Feedback can be provided at specified time intervals, e.g. daily, weekly, monthly (Abrahamse et al., 2005). Based on the granularity of the information provided, feedback can be categorised as low-level and high-level. Comparative or group feedback enables the performance of two individuals to be compared, activating social norm factors (see below) (Abrahamse et al., 2007).

IdleWars and EcoScreenCatcher are games based on comparative feedback interventions. For the IdleWars study, this intervention was chosen to support the game design. This design decision was based on reports that competition is a powerful motivator and one way to trigger competition is through comparative feedback (Malone and Lepper, 1987). This incentivises all players of the game to perform more sustainably and activates social norms that can potentially influence behaviour change. In addition to comparative feedback, EcoScreenCatcher also employed prompts and daily feedback interventions. The former was introduced mainly as a way to make energy waste more visible to the user, while the latter as a way to track and record their daily progress .

2.4 Social Norms

Environmental psychologists have researched other factors that can influence behaviour. There are situations where peoples' actions can be different, based on the environment. An experiment conducted by Cialdini et al. (1990) shows that people are more likely to litter in an environment that is already littered. The environment this case acted as a social norm indicating (in the case of the littered environment) that littering is an acceptable behaviour.

Social norms are factors that influence environmental behaviour. More specifically, they are "rules and standards that are understood by members of a group, and that guide and/or constrain human behaviour without the force of laws" (Cialdini and Trost, 1998). The two categories of social norms are known as injunctive norms and descriptive norms. The former refers to behaviour that is socially approved or disapproved, whilst the latter refers to behaviour that is adopted by the majority of a group (Cialdini and Trost, 1998; Steg and Vlek, 2009).

This work addresses pro-environmental behaviour change intervention in both work and home environments. In the work environment there is a tendency for groups to be formed (friendships, people in the same cubicle, etc.). In the home environment, web technology is used to enable people to form groups and interact with each other. In both scenarios, social norms can potentially have an influence (positive or negative) on pro-environmental behaviour. The group formation shows the potential of socially-oriented persuasive strategies, e.g. collaboration, competition, comparison. These strategies take advantage of social influence for behaviour change motivation (Orji, 2017). Anderson et al. (2017) showed the potential for normative messages to influence long-term behaviour change. There is an abundance of publications on energy conservation via collaboration and comparison. This work aims to investigate whether the group of people (in work and home environments) are able to reduce the social norm of computer idle time and whether this had an impact (in terms of behaviour change) on them.

2.5 Dimensions of Computer Based Energy Conservation

This section focuses on studies related to computer-based energy consumption. McLachlan and Brewster (2012) investigated the impact on consumption of the different ways in which a pdf document could be read (auto scroll, down arrow key, right arrow key, mouse wheel, mouse drag, next page button, thumbnail navigation) on laptop and desktop computers. using two power settings (power save off, power save on). The experiment resulted in significant differences among the interactions, with the arrow key consuming the least energy. Researchers are now focusing on changing the GUI of devices to reduce consumption, using advances in display technology, and the introduction of Organic Light-Emitting Diodes whose consumption differs between the colours displayed. Dong et al. (2009) proposed models based on pixels, image, and code, that can estimate power consumption. These models enable users to choose between GUI usability and battery life, whenever needed. Harter et al. (2004) investigated the acceptance levels of energy reduction user interfaces, e.g. notification, reply menu, start menu, notes, control menu, battery check. The results showed that almost all participants preferred the energy-aware versions of popup messages because the darker background made the message more prominent.

Some studies focused on the environmental impact of the internet infrastructure as well as its carbon emissions. Preist et al. (2016) addressed the environmental implications of cloud infrastructure, where applications need to be designed with the impact on the wider infrastructure in mind, e.g. device, network, servers. Research suggests that design for sustainable HCI needs to avoid the introduction of new hardware (for measurement) as far as possible, due to its carbon production and transfer (Bates and Hazas, 2013). Improvements suggested are: using existing infrastructure (e.g. available computers), avoiding casings on hardware, and using embedded devices rather than PCs (Bates and Hazas, 2013). Embodied emissions for IT devices are important because the annual carbon impact of an IT device is small compared with the embodied carbon emissions (Bates et al., 2014). Schien et al. (2013) took into account models of consumption of digital media and models of audience behaviour to assess the impact of digital media on the environment. Chetty et al. (2009) investigated power management strategies on home computers, and showed that they are underused, with desktop computers left on more than laptops. The reason for this is the lack of financial incentive (energy reduction is small and therefore the cost associated with it), and the time needed for the computer to boot up.

2.6 Energy Conservation in the Domestic Environment

Jain et al. (2012) tracked energy conservation of a multi-storey building at Columbia University. They employed eco-feedback as a mechanism to promote energy conservation. Figure 2.2) compares an individual's current energy consumption with the previous 24 hours (24-Hour View), a bar chart of the last 7 days (Last Week) comparing it with the average consumption, and the current energy consumption with the last x days (To Date). The bars are coloured green, yellow, red if the user's consumption is below, within, or above, 20% of the average consumption of the building, respectively. The last two views enable the user to compare her consumption with a friend (the system requires consent from the friend for this to occur). The system also provides a reward system; the users gain points when they use energy for off-peak hours and lose points during peak hours. These points can be used to obtain different objects from a redemption web site. Finally, a disaggregation web interface is provided (see figure 2.3) that requires the user to define the active time of the appliance, which enables the energy consumption at appliance level to be calculated. The measurements showed a statistical relationship between users who decreased their energy consumption and their average login times. Analysis showed that users who employed historical comparison and visited the reward/points web page, logged in 3 times more compared with those who did not. This revealed a linkage between interface engagement and energy conservation.

The study was conducted at the university's halls of residence. This is similar to IdleWars, and therefore to the work environment; due to the non-financial incentives the eco-feedback interface needs to be developed to be effective. In particular, both students and employees do not pay for excessive energy consumption. Jain et al. (2012) recognised that non-financial incentives in eco-feedback could enhance energy conservation. They also showed how important a reward mechanism is in environments where energy cost is not a major concern; an example of such an environment is the workspace.

Rodgers and Bartram (2011) investigated three different ambient display visualisations, shown in figure 2.4 (phyllotaxis, pinwheel and hive), and aimed to provide an artistic approach to conveying energy conservation information. They mostly focused on the design exploration and not on the evaluation of the visualisations. The power and energy measurements were taken with two Kill-A-Watt power monitoring units, placed in a local server and providing information in near-real time. The visualisations were then presented on a 7" LCD screen. Two home environments (kitchen, home theatre) were simulated in the laboratory. The results were assessed using pre- and post-study questionnaires, participant observation during the experiment, system logs, and an interview

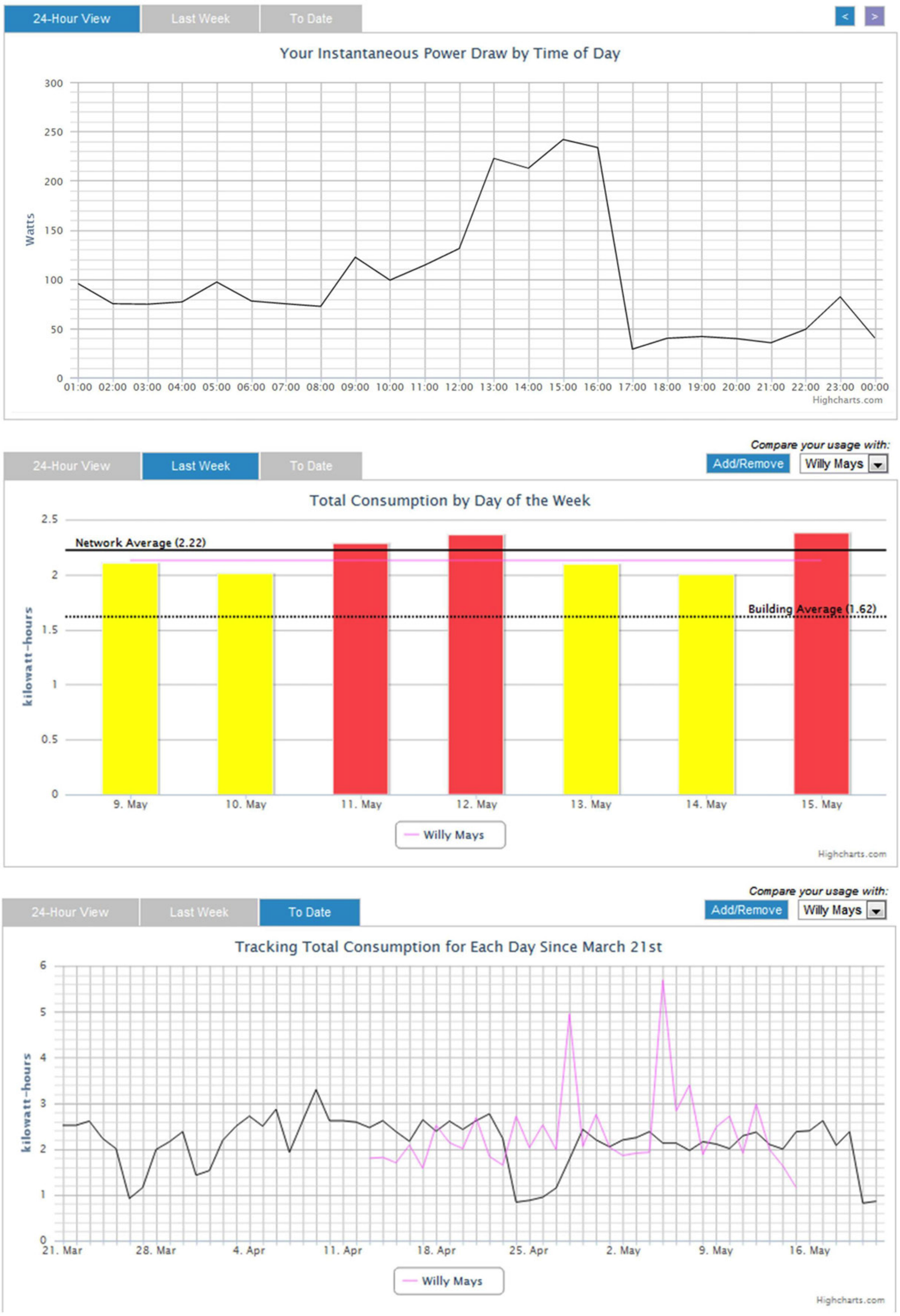


Figure 2.2: 24-Hour View, Last Week and To Date views (normative comparison with Willy Mays user) (Jain et al., 2012)

at the end of the study. 23 participants were involved, 14 of whom were female. 12 of the participants were between 19-29 years old, 8 of them were between 40-49, and one was over 50. The majority of participants were able to comprehend the visualisation without excessive disruption, and such a visualisation could be used to supplement traditional visualisations.

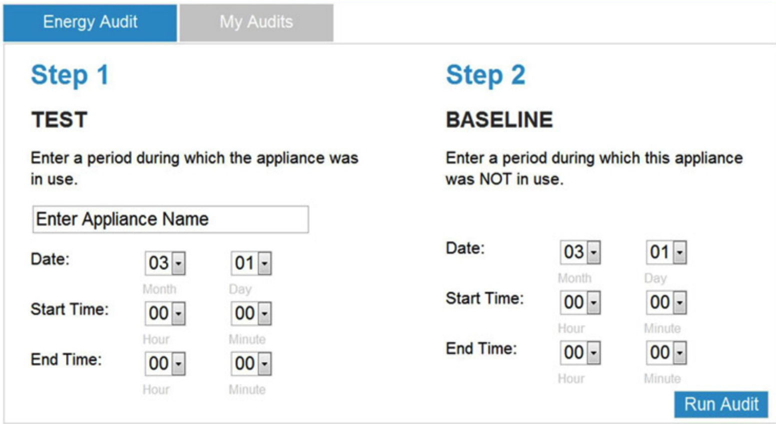


Figure 2.3: Disaggregation view (Jain et al., 2012)

Ambient display was also used in IdleWars and EcoScreenCatcher games, for demonstrating the performance of the players. Rodgers and Bartram (2011) found that artistic visualisations on ambient displays are appropriate for the home setting. They mostly focused on the ambient display factors (visibility, obstructiveness, visualisation comprehension, etc.) and did not provide a comparative evaluation of the different ambient visualisations. The meaning of the visualisation was not clear to all the participants, with only 11 fully understanding their meaning. Finally, the intense spinning of the elements of the visualisation (indicating the real-time power) made the visualisation distracting to some participants and difficult to comprehend at a glance.

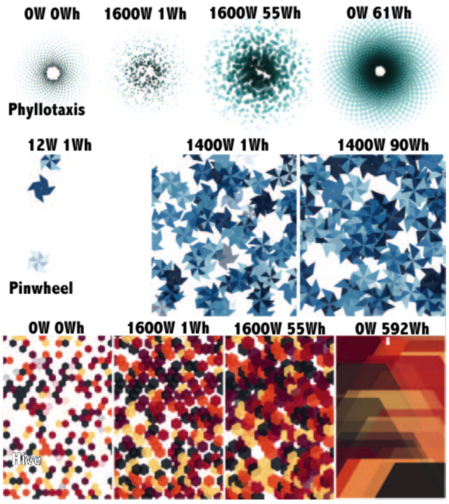


Figure 2.4: The Phyllotaxis, Pinwheel and Hive designs (The spin of the elements indicates the real-time power whilst the size indicates the cumulative energy use) (Rodgers and Bartram, 2011)

Quintal et al. (2010) proposed a low-cost, real-time, easy to install, system where real and reactive power is measured by employing a clamp-on current transformer connected to the computers' audio input. The system is capable of identifying presence and activity and face recognition using a web camera and the OpenCV library. This enables the computer screen to act as an ambient display when a motion is detected and as a dashboard demonstrating detailed personalised visualisations of a user when her face has been recognised. When there is no motion, the screen is black, but when there is motion, the screen displays the current and last 8 hours' energy consumption. When the user stares at the display, a dashboard with different visualisations is displayed showing the current consumption, today's total consumption, and a comparison of the of the current week's consumption with the average.

The focus of Quintal et al. (2010) in terms of HCI was on the ambient display and how visualisations are shown based on the surrounding activity. No lab experiment was conducted for the evaluation of the prototype. It has limited connectivity. In most cases, the wired mains supply is in places away from human activity; this could potentially have an impact on presence detection.

Pink et al. (2008) employed an approach based on sensory ethnography (Pink, 2015). The study involved 20 households. Social scientists and system designers first spent an evening with the families and performed semi-structured interviews. The interviews investigated how people understand sustainability and energy and described their routines and activities performed in the household. On a second visit, a home video tour was undertaken and then analysed. Electricity sensors were later installed. The interviews showed that entertainment technologies, such as televisions, iPads, and mobile phones, played an important role in creating family and home feelings. People moved around the house and interacted with technology either by switching them on/off or by carrying it with them. This helped to identify non-negotiable household routines and therefore design systems that do not challenge these routines, except where the system provides a better solution that does not influence convenience of the household. The qualitative study informed the design of an intervention concerning space heating. The mobile application developed allows remote control of the household temperature as well as an acclimatisation functionality. The latter automatically reduces the average temperature of the household by 1℃ a week until it reaches the minimum of 18℃. At any point, participants can use their mobile phones to override the temperature setting. Part of the intervention are "heat me" bags that can be filled with blankets, clothes, and suchlike, and be placed next to a radiator.

The main contribution of (Pink et al., 2008) is the argument on how sensory ethnography can contribute to sustainable HCI, and how it can contribute to the third generation of HCI described by Dourish (2010). Sensory ethnography believes in the interconnectivity of the senses that go beyond of mainstream ethnographic approaches of watching, listening, and writing (Pink, 2015). Dourish (2010) said that HCI on environmental issues is currently focusing on changing individual behaviour and consumption patterns, and argued that HCI needs to also focus on changing political and cultural contexts. Pink et al. (2008) argued that instead of applying intervention to existing routines, they need to be applied to re-making such routines. Even though a detailed description of the intervention is provided, these authors do not provide any evaluation and therefore whether such a routine-based intervention actually leads to behaviour change.

StepGreen.org is a constellation of technologies aimed at promoting sustainable behaviour in the home environment (Mankoff et al., 2010). It integrates with social networks, such as MySpace and Facebook, enabling it to visualise and share with friends the progress of the participant, as well as some energy (and therefore money) saving recommendations. This information acts as a commitment, a reminder, and an advertisement platform for potential users. Actions were also advertised on the Web site in different forms, using a table as well as a tag cloud. By clicking on an action, participants can get further information about an action and also commit to performing that action. Actions are atomic tasks that the user can perform to reduce their consumption. Each action has a popularity indicator and also a monetary incentive and environmental incentive as CO_2 emissions. An online survey is conducted with people living in two metropolitan areas, who rate 78 actions concerning how likely they are to perform them. This questionnaire informed the design of the StepGreen.org system, so that it has low impact action that most people reported performing. An additional design decision is to have frequent feedback via a social network applet, as well as goal-setting feedback, where action performed or to be performed is displayed. After a couple of actions, the impact of these actions are projected forward for the rest of the year. The StepGreen.org visualisation can be seen in figure 2.5. The system was deployed "in the wild" for three weeks and used by 32 participants. Participants had to complete a pre-study questionnaire related to their behaviour on energy saving, and lifestyle habits (car and home ownership). At the end of the study, they had to complete a post-study questionnaire (repeating the energy-saving questions from the pre-study questionnaire and enriched with queries related to the evaluation of the system), as well as post-study interviews. The pre- and post-study questionnaires showed no big differences in attitudes. The follow-up interview revealed that people would like more flexible visualisation, e.g. feedback where they could compare their performance with friends, and more information about their own performance, e.g. ecological footprint. The fact that social network friends can see the actions visualisation on the profile page of their social network, triggered some privacy concerns. The site was successful in informing the participants on easy actions to perform, and getting information on the impact they had on the environment. The use of social networks was successful as an interaction support method.

The stepGreen.org site records attitudes but not behaviour. There is no guarantee that people who reported performing an action, actually did it. Having an action-based visualisation on peoples' social network profiles might influence the number of actions they actually perform. The positive aspect of the system is that it raises awareness of multiple environments such as home and car. Both EcoScreenCatcher and IdleWars support comparative feedback, and information is provided only to small groups of people. In the case of IdleWars, information is provided only to workers on the same

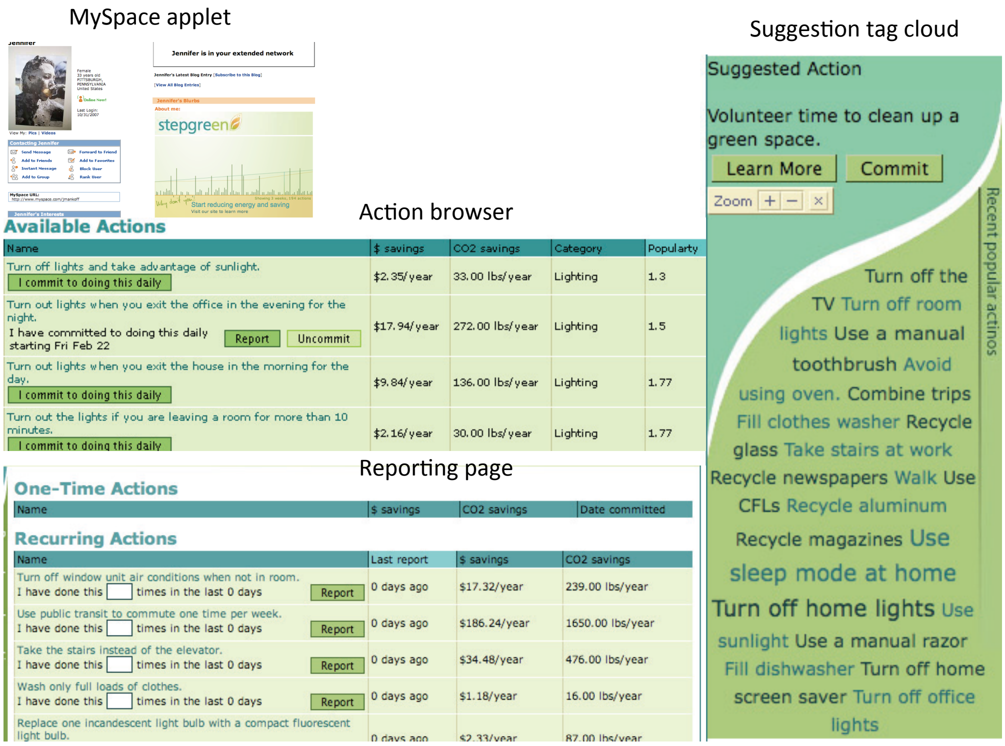


Figure 2.5: The MySpace applet, action browser reporting page and suggestion tag cloud of StepGreen.org site (Mankoff et al., 2010)

floor, whereas EcoScreenCatcher provides information only to common Facebook friends who play the game.

Quintal et al. (2013) performed a 15-week study to investigate an artistic eco-feedback interface called WATTSBurning, aimed at maintaining user awareness and tackling consumption rebound effects. WATTSBurning is the third design iteration. The first iteration showed that participants who decreased their consumption the most were the ones with a high level of interaction with the eco-feedback system (Quintal et al., 2013). The second iteration showed a decrease, and then a steep decrease, in interaction after two and four weeks of using the system respectively (Pereira et al., 2013). The pilot WATTSBurning visualisation provides a video animation of a forest site. Increasing household consumption causes the clouds of the animation to move across the screen faster. The number of animals displayed indicates the number of appliances that are currently switched on. Even though there was no statistically significant reduction in energy, the artistic visualisation increased the interaction compared to the "traditional eco-feedback" visualisation. The final version employed a tablet as a means of showing the visualisation. The tablet shows both the artistic "Energy Awareness mode" (default option), and the numeric "detailed consumption mode" visualisations. The tablet provides real-time and historical consumption data. As seen in figure 2.6, the artistic visualisation consists of a flourishing landscape for low consumption, up to a landscape on fire for high consumption with three stages in between. When the back button is pressed the “detailed consumption mode” is activated (see figure 2.7). The user can choose to see the consumption by day, by week, and by month. The home tab shows the total consumption as well as the consumption in real-time. For the evaluation of the system, baseline data was collected for two weeks and then a semi-structured interview conducted after 22 days of using it. The system continued to be used after the interview for a total of 15 weeks. Qualitative analysis showed that the system raised awareness of electricity consumption, that participants better understood the consumption of each appliance, and that the interface is more popular to men and youngsters. There was no statistically significant reduction in consumption, and there was a decrease in interaction after using the system for five weeks.

Figure 2.6: The WATTSBurning artistic visualisation“Energy Awareness Mode” indicating the current household consumption, image 1 signifies low consumption whereas image 5 signifies high consumption. The threshold of high and low consumption is determined based on the baseline consumption of that particular day Quintal et al. (2013)

(a) (b)

Figure 2.7: The WATTSBurning “Detailed Consumption Mode”. (a) the home screen showing the current real-time consumption, total consumption of the current day/week/month and comparisons between similar periods of time. (b) the day/week/month tabs showing a detailed consumption chart over the specific period Quintal et al. (2013)

Quintal et al. (2013) tried to tackle rebound effects in eco-feedback systems by employing an artistic eco-feedback visualisation in a long-term study. In contrast, this work aims to engage participants by letting them actively play with each other as part of a game.

While the efforts of Quintal et al. (2013) to investigate long-term behaviour change and interactions, this work focuses on ways to designing eco-feedback systems for different environments (work and home) using different communication channels (social networks, emails). Within the limited time frame, this study focuses on informing the design of future eco-feedback systems by taking into account idiosyncrasies of communication channels and environments, by conducting short-term field studies.

Gustafsson et al. (2009) proposed "Power Explorer", a pervasive mobile-based game aiming at helping children interact with household appliances and understand their power consumption. The mobile application can notify the user if consumption is being exceeded in the home, and if there is a challenge request, e.g. a player asks to play a duel. Of the four modes of interaction with the system, the first is the "habitat", and it shows an avatar in a virtual environment, where characteristics of the environment change based on current household consumption (turning an appliance on grows weeds, and off grows flowers). More flowers mean better health for the avatar, while more weeds make it sick. The sky represents the CO_2 emissions. An increased number of emissions produces a greyer sky.

The second interaction is the "pile" (see figure 2.8 left). It is a "king of the hill", like our leader board, based on the level of CO_2 emissions of the participants. The third interaction is the "Rainforest duel" (see figure 2.8 middle). This interaction enables participants to compete with each other, as well as helping them understand the power consumption of household appliances. The duel presents the two avatars on a race track at the middle of the rainforest. The aim of the duel is to be the first to cross the Finish Line and avoid obstacles on the way. The higher the power used by the house, the faster the avatar runs on the track. Excessive speed for extended periods causes both avatars to drown from a tide. The aim is to balance speed with finishing first, but without drowning.

The "polar duel" (see figure 2.8 right) is a fighting game where avatars try to knock the each other off the iceberg by throwing objects with different weight. The weight of the object again depends on the power used by the house. By opening a high power device, players can throw a big object and *vice versa*. Again the combined power consumption of both players increases the heating of the environment, causing the iceberg to melt. The game had 15 players (12-14 years old). The pre- and post-study questionnaires showed a significant change in energy saving attitudes. The consumption logs show average savings of 16% during the game period (1 week), and a persistent 14% reduction after the game (10 weeks), but this was not statistically significant. This result shows that a pervasive and casual game could lead to long-term behaviour change. Even though the game is designed for saving the environment, e.g. by providing CO_2 information, some participants still focus on the financial aspect.

Gustafsson et al. (2009) showed the potential of pervasive games (like IdleWars and Eco-ScreenCatcher) on long-term behaviour change. The study was designed for teenagers only, and required the presence of parents for safety reasons. No information has been provided on how parents reacted to the intervention, even though they did not (actively) participate in the study. Parents are the ones controlling the appliances that consume the most energy in a household, e.g. cooker, hob, and the reduction possibly came to a larger extent from the parents. The appliance power consumption test showed limited indication of learning. The authors suggested that participants were interested in learning only about the consumption of appliances related to them. This limitation restricts the participants from learning about the power consumption of devices that potentially contribute more to the overall power consumption of the household.

Figure 2.8: The "Power Explorer" interactions. The pile (left), the rainforest duel (middle) and the polar bear duel (right) (Gustafsson et al., 2009)

Gustafsson et al. (2010) evaluated a similar game called "Power Agent", a pervasive competition-oriented game aimed at teenagers and their families. Each player is an agent that needs to co-operate with family members and other agents from the same team to achieve a goal. The goals are energy conservation actions that need to be performed between 5 pm and 10 pm. The interaction happens through mobile phone. The boss of the agent "Mr Q" informs the player/agent on her new mission (using both voice and animation, see figure 2.9 B). An example of a mission is "Unplug wall sockets from entertainment equipment when not in use". The agent proceeds by playing a warm-up track. The track is a platform game such as "Mario Bros" from Nintendo, where the player needs to collect batteries (see figure 2.9 D). As each battery is collected, the player obtains instructions on ways to succeed in her newly assigned mission (see figure 2.9 E). Feedback on the task is provided in the morning of the next day from "Mr Q". The players completing the mission were praised, whereas the ones that did not were encouraged to try harder. The player is also able to access their home energy consumption (see figure 2.9 F), the individual efforts within the team (see figure 2.9 H), and a comparison of the performance of both teams' visualisations (see figure 2.9 G). Optionally, participants can use the cameras of their mobile phones to take a picture of the energy conservation action they performed. These pictures then are presented with the household consumption visualisation. The game is played for 10 consecutive days in two different cities, forming two teams. The energy monitoring continued for 57 days after the end of the game, but only for one of the teams. The results showed that the game was engaging, and motivated participants and their families to change their consumption throughout the duration of the game. The source of the motivation is the competitive nature of the game and peer pressure, where non-performing participants received messages to try harder. No long-term behaviour change effects were shown.

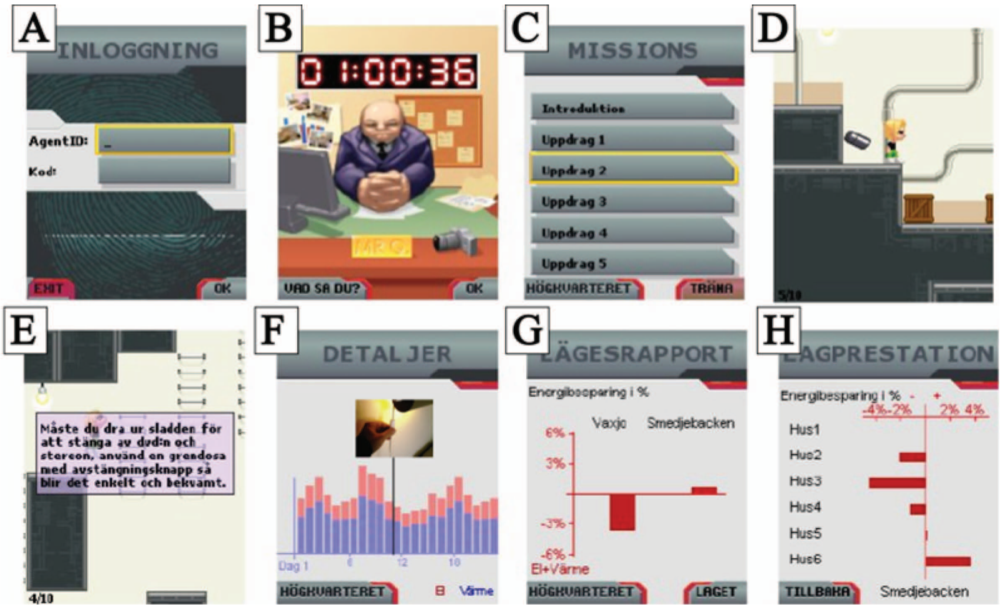


Figure 2.9: The "Power Agent" interactions. (B) Mr Q gives a new assignment, (C) list of missions, (D) warm-up track, (E) instructions on how to save energy on the new mission, (F) personal household consumption, (G) team oriented results, (H) task performance within the team (Gustafsson et al., 2010)

Power Agent is very similar to the EcoScreenCatcher game developed in this work (see Chapter 6 for more detail). Both use competition for motivating participants to change their behaviour, both provide suggestions on how to reduce power/energy, and both tackle energy consumption in the home environment. The difference is that EcoScreen-Catcher focuses on computer energy consumption, provides prompts, waste-related feed-back, no time restrictions, and more importantly, players interact with each other directly whenever a computer is wasting energy. Participants in the EcoScreenCatcher game are not part of a team; therefore, there is no peer pressure.

Geelen et al. (2012) proposed a game for the household called "Energy Battle". It consists of energy consumption feedback of the house (see figure 2.10), team-based ranking, ways on how energy may be conserved, and a puzzle (see figure 2.11). Participants form groups and co-operate. The more energy teams save, the more blocks they get and consequently bigger and nicer structures can be built. Each household is provided with a Wattson device providing direct power consumption feedback, and an online platform where participants need to upload their consumption data manually. The game has two main aims: save as much energy as possible, and build nice structures in the puzzle. The team that saved the most is awarded a prize of €754 and the team with the best puzzle construction awarded €250 worth of vouchers. 17 student households participated in the study. The system was evaluated in three stages: first a two-week baseline period, then four weeks playing the game, the final stage being one month of measurements. The system was evaluated with post-study questionnaires and semi-structured interviews. Analysis showed an average decrease of 24% in energy consumption during the game period, with a rebound effect afterwards in most of the households. The interviews (eight months after the study) showed that some of the behaviour became habitual by some participants. Some participants developed tactics to tackle energy conservation, such as avoiding home. The ranking was important to participants performing well, but it worked as a disincentive for those who featured at the bottom. Suggestions on how to conserve energy were limited to low-consuming appliances, which resulted in participants not considering high-energy appliances, e.g. washing machine, as a way to reduce consumption.

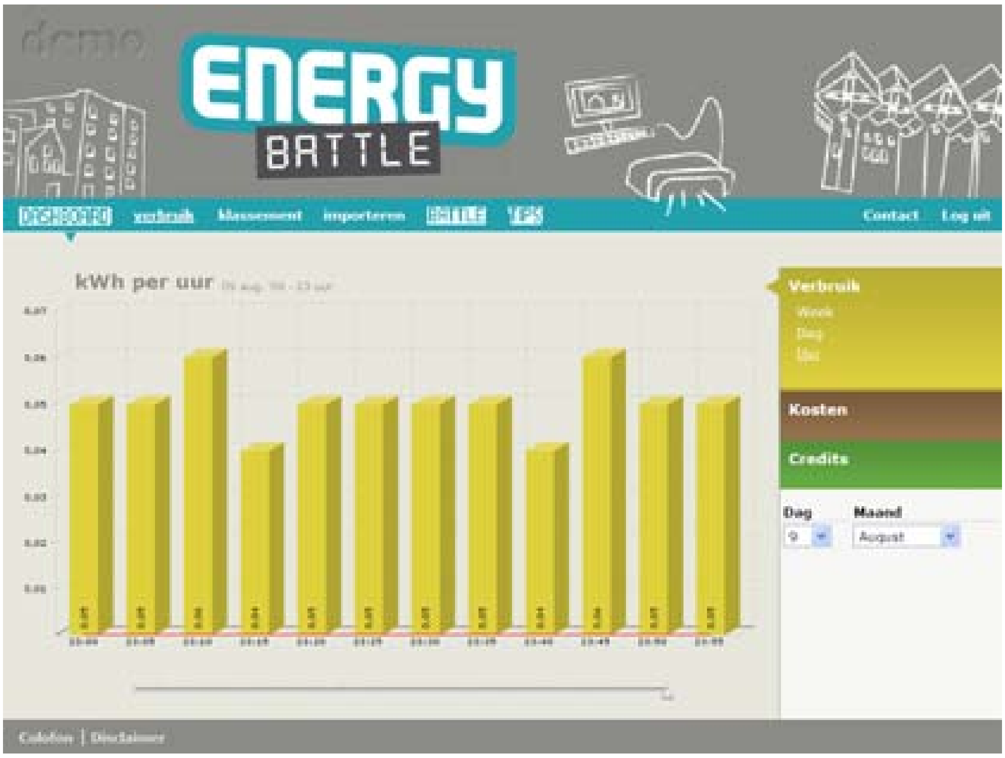


Figure 2.10: Electricity consumption over time from the Energy Battle game (Geelen et al., 2012)

"Energy Battle" uses a game combined with rewards to incentivise energy conservation. Even though the incentives above resulted in short-term energy conservation, it also triggered extreme measures where participants reported avoiding their houses. Gustafsson et al. (2009) stated that such extreme practices are highly unlikely to continue after the game. Both "IdleWars" and "EcoScreenCatcher" games focus on simple and less extreme conservation practices, which are the elimination of waste by identifying wasteful behaviour (more specifically, the computer being on and not in use). One difference that might influence long-term behaviour change is the rewards mechanisms. Both "IdleWars" and "EcoScreenCatcher" do not provide prizes to winners. Therefore, motivation

Figure 2.11: Puzzle, part of the Energy Battle game (Geelen et al., 2012)

is solidly feedback and game-based. The duration of the deployment of both games was short, and behaviour change persistence was not taken into account, something that could be investigated in the future.

2.7 Energy Conservation in the Work Environment

The following paragraphs summarise research on energy conservation in the work environment, which implemented a system. Only Yun et al. (2013) focused on the theoretical perspective by inspecting nine intervention techniques that can be applied in the work environment; it is therefore omitted.

Pousman et al. (2008) proposed Imprint, a technology probe that provides a semi-public display that presents visualisations (see figure 2.12) of printer usage and the documents they print by employing a ludic engagement design strategy (Gaver et al., 2004). "Technology probes ... combine the social science goal of collecting information about the use and the users of the technology in a real-world setting, the engineering goal of field-testing the technology, and the design goal of inspiring users and designers to think of new kinds of technology to support their needs and desires" (Hutchinson et al., 2003). Ludic designs are those that try to engage users through ludic activities, which are "activities motivated by curiosity, exploration, and reflection rather than externally-defined tasks" (Hutchinson et al., 2003). The system consists of a print server, a custom document parser, and an end user application. A Kill-a-Watt electricity usage monitor was used to measure a printer's energy consumption.

Figure 2.12: Tagcloud (top left), Hot or not (top right), What's ur neighbourhood? (middle left), What are the printers doing? (middle right) and Imprint's footprint visualisations (bottom) (Pousman et al., 2008)

Work proposed by Pousman et al. (2008) is similar to IdleWars mainly because it provides visualisations of resource consumption (paper and energy), and is mainly a software-based approach, where software is used for tracking workers' resource consumption. The system provides a playful and informative way of conveying an energy conservation message, without being invasive. As a technology probe, its effectiveness for energy conservation or engagement was not assessed. The system is analogous to IdleWars and EcoScreenCatcher games, because ludic designs and games have common characteristics, such as fantasy and spontaneous actions (Gaver, 2009).

Willamowski et al. (2013) proposed the Personal Assessment Tool (PAT), similar to the Imprint system, aimed at reducing the number of pages printed in the work environment. Their main focus was to raise awareness and incentivise workers towards paper sustainability through eco-feedback provision. Figure 2.13 shows the PAT system as an ambient display widget depicting a flower that appears on the side of the screen all the time. The number of petals attached to the flower indicates the sustainable behaviour of the user (the more, the better). The widget can also provide detailed information by accessing its expanded view. Figure 2.14 is an example of this view, in which the user is able to see her performance, based on the total cost of print jobs, using a virtual currency. The cost is categorised by month, application, and time. The study lasted for six months with 50 participants. The results showed reduction in paper consumption but statistical analysis was not able to verify the result was due to the PAT system. Qualitative analysis showed that users engaged with the system and revealed organisation issues that could potentially result in greater paper reduction.

Willamowski et al. (2013) built on the work of Pousman et al. (2008) by providing personalised and comparative interventions. The authors incentivised workers to reduce paper waste by allowing the participants to decide optionally how to invest the savings achieved. The limitation of this research is that the statistical analysis was not conclusive that the reduction was caused by the PAT system, and that participants were colleagues of the authors. This could have led to biased responses, and therefore misleading qualitative findings.

Figure 2.13: PAT widget that appears on the users screen indicating her printing behaviour (Willamowski et al., 2013)

Figure 2.14: Expanded PAT widget, provides a higher granularity of the users behaviour in a graphical form (Willamowski et al., 2013)

As with IdleWars, Schwartz et al. (2010) focused on the work environment. The differences are that IdleWars uses software to measure sustainable behaviour, but does not use sensors, and that IdleWars focuses on feedback and a game to incentivise workers. Schwartz et al. (2010) mainly focus on the identification of the attitude workers have towards energy conservation. They pointed out a lack of energy conservation research in the work environment. They applied business ethnography (Nett et al., 2008) participatory action research approach to a hierarchically structured organisation with over 950 workers. The research was conducted in four stages. In the first stage, off-the-self smart meters were installed in two offices, and their consumption measured for five months. In the second stage, a “reflection workshop” discussed the measurement results. In the third stage, the smart meter infrastructure was updated to support device-level feedback as requested by the workers, and the results of the feedback studied. In the final stage, an online questionnaire was sent to all the members of the organisation about energy use in the working environment. The majority of devices in the organisation were monitors, PCs, and laptops, and most of the appliances were of the same type and brand. During the trial, a workshop was conducted to discuss participants’ consumption patterns. The workshop motivated workers to adopt an eco-friendly behaviour. Figure 2.15 shows that, following the workshop, the after-worktime consumption was significantly reduced. When consumption feedback stopped, after-worktime consumption returned to its previous levels. Given the fact that feedback was provided before the workshop without considerable energy consumption improvements, this reveals that negotiation and social interaction is an important part of energy conservation in the workplace. This shows that negotiation and social interaction is an important part of energy conservation in the workplace.

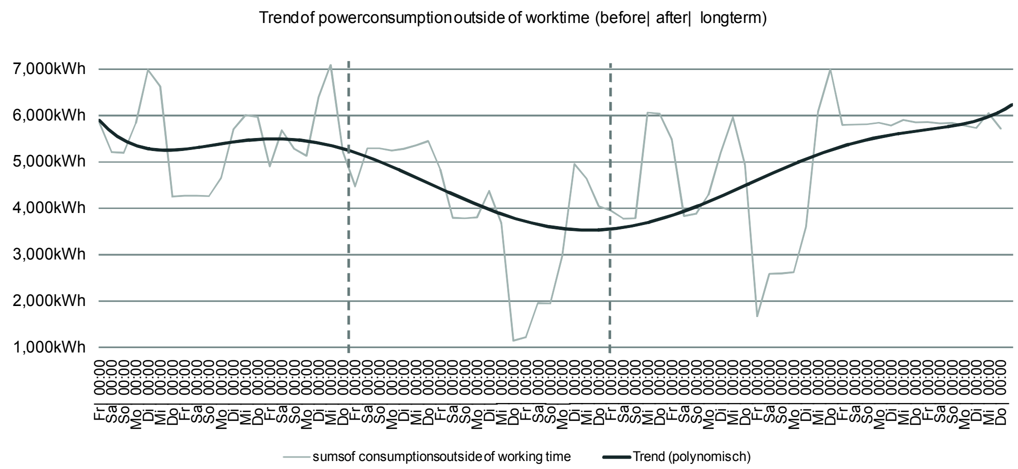


Figure 2.15: Trend of power consumption out of main working times over all three phases of investigation: three weeks before the workshop, three weeks right after the workshop and several weeks after. (The days of the week are expressed in the German language) (Schwartz et al., 2010)

Even though Schwartz et al. (2010) were one of the first to identify the lack of research on energy conservation in the work environment, they mostly focused on data collection, its granularity, and workers' privacy issues. They provided some guidelines on information that could help workers reduce energy waste, but they did not elaborate on visualisations and they did not frame their work with relevance to eco-feedback. The visualisations shown in the "reflection workshop" resulted in a friendly but provocative reaction by one of the interviewees, who commented about the lack of sustainable behaviour by another employee. This highlights the need for research on visualisation that is non-invasive and does not cause conflicts between participants. One potential reason that there was an increase in energy consumption after the reflection workshop could be the lack of access to the visualisation and therefore lack of continuous feedback. As reported, the participants had access to the visualisation only during the reflection workshop. The equipment used for energy measurement is costly; this limits the granularity of the visualisation, which contradicts the preference of the participants for energy consumption feedback at device level. During the reflection workshop, the participants identified energy consumption in the workplace as more energy waste-oriented than energy consumption-oriented, mainly because workers reported devices being unnecessary active, even though they do not pay for their energy consumption in the workplace.

Simon et al. (2012) proposed a unobtrusive game called *Climate Race* based on implicit interaction with their energy consumption. The game employs the EnergyPULSE system for tracking players' room activity (Jahn et al., 2011). Some events occur over time, e.g. switching off lights when not in the office, leaving lights on when not in the office, and not using electric lights while an employee is in the office). Based on these actions, players/workers accrue positive and negative points following a social comparison process. *Climate Race* also provides prompts in the form of notifications and goals, encouraging the achievement of certain behaviour. Workers are able to get notifications and feedback through a mobile and a desktop version (see figure 2.16). Five participants volunteered to take part in the study. Data was first collected for three months, followed by an evaluation for two weeks (10 working days). Finally, post-evaluation questionnaire surveys and semi-structured interviews were conducted. During the game period, the results showed that there was a decrease in electricity waste during non-working hours. The majority of participants reported that the game did not influence their productivity. On the other hand, the notification mechanism distracted some workers. The authors designed the game to form one group, where everyone co-operates to achieve a goal. Participants also reported that they would welcome a competition between groups.

Climate Race is similar to IdleWars in that both games aim to incentivise workers to consume less energy. However, *Climate Race* is based on a sensor platform to track performance, whereas IdleWars uses software. Then, *Climate Race* is a co-operation oriented game, whereas IdleWars is competition oriented. One of the drawbacks of *Climate Race* is that it was conducted on a small number of fellow researchers from

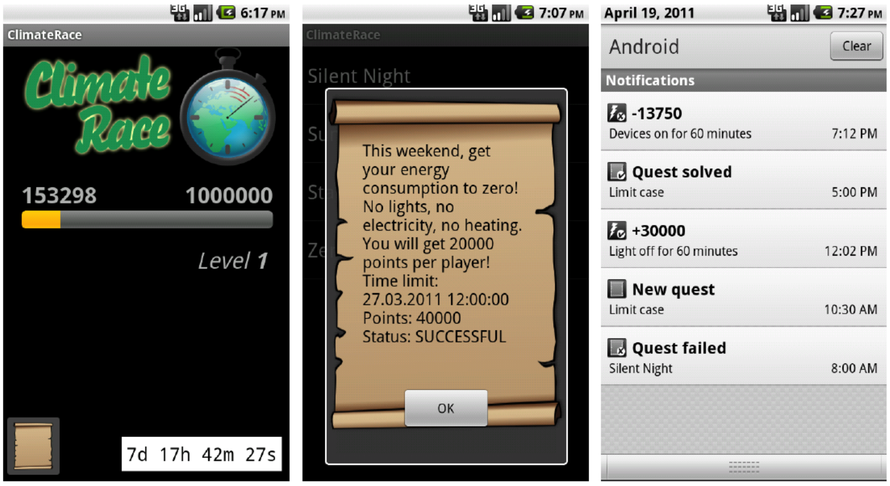


Figure 2.16: Screenshots from the mobile game client: The main screen (left), quest details (centre) and individual notifications (right) (Simon et al., 2012)

the same institute and this might impact the level of intrusiveness the participants reported. Even though the authors tried to make the game as unobtrusive as possible, one participant observed that the notification mechanism disrupted her from working.

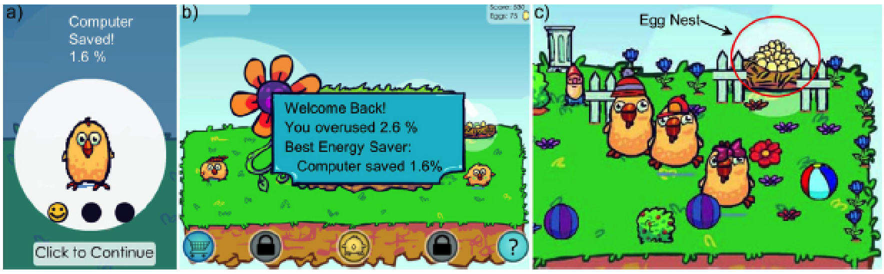


Figure 2.17: Screens taken from the *Energy Chickens* game (Orland et al., 2014)

Orland et al. (2014) proposed a serious game in the work environment, called *Energy Chickens*. The game was trialled in a mid-sized office complex, with 57 workers participating for 27 weeks. *Energy Chickens* is a web-based game that follows a typical virtual pet gameplay dynamic (Connolly et al., 2012). Animated chicken characters are used to represent the energy consumed by individual devices in an office (through device-level current sensors). Big and healthy chickens indicate pro-environmental behaviour, while small and sick ones indicate increasing consumption. As the game progresses the “Graph view” and “Mountain view” links appear. The former shows the user a visualisation with their personal consumption, while the “Mountain view” enables them to compare themselves by watching the chickens of other players. The participants were separated in two groups, game with 41 participants and no-game with 16. The game group were asked to sign a consumption reduction pledge. For first five weeks, device-level consumption was collected. For the next eight weeks (phase 1), for the game group only, the game started and prompts were used in the form of posters (displayed to both groups). Phase 2 lasted six weeks, where all prompts removed for both groups. During the final eight weeks, only measurements were taken. The study revealed that the game intervention can achieve 13% consumption reduction from the initial baseline.

Even though the study showed an important reduction in energy consumption, it is not clear that this was caused by the game. Preliminary interventions like signing a pledge, as well as prompts used as part of the study, have already been reported as resulting in sustainable behaviour (Winett et al., 1978; Wang and Katzev, 1990). Moreover, in the work environment, increase in energy consumption is also related to increase in productivity, e.g. staying overnight working overtime. In the current game design, this results in a decrease in the health of the chicken, penalising productivity. Thus interventions should aim at eliminating energy waste. The IdleWars game tackles this by operating at a software level and is therefore capable of identifying whether there is computer-based energy waste.

Jentsch et al. (2011) proposed an energy-saving support system that is both unobtrusive and requires minimal effort. A mobile phone is employed to remotely activate and deactivate each device on demand. On the phone, an image of the energy-using device is displayed with a traffic light icon, the colour of which indicates the energy saving potential. Clicking on the traffic light shows the reason for potential energy saving and the actions that need to be taken for this to be achieved. The prototype sensed: the position of the room's windows by employing two contact sensors (top and bottom of each casement), the electricity consumption of wall sockets by using ploggs (smart wall plugs), and presence of people by employing a dance mat controller. The plogg enables the system to detect device status (on or off), and to remotely activate and deactivate devices. To evaluate the system, the authors conducted a preliminary study with 31 volunteers, which took place during an IT fair, enabling them to get immediate feedback. 24 participants characterised the system as useful to help them save energy. On the usefulness of the features, participants reported that "remote control of devices", "overview of devices on the phone", and "energy-saving tips", were the most popular with 21, 19, and 14 votes respectively.

This system differs from IdleWars in not being a game, and focusing on devices and sensors other than PCs. Moreover, IdleWars, as a game, enhances interaction with workers, activating social norms, whereas in the system proposed by Jentsch et al. (2011), the worker interacts only with the system. The limitation of their research is that it has only been applied in an explorative study. It would be interesting to see the results in a field study and what the workers' reactions would be when the system identified energy waste. The cost for this approach, applied in the work environment, would be high. It acts as an expert system and suggests the user act when there is energy saving potential. Even though this may result in energy reduction, it makes the user passive and this can potentially restrict them from adopting energy-saving behaviour in other environments (Thøgersen, 1999). Finally, since participants were visitors to an IT fair, they were familiar with technology and were keen on adopting new ideas related to technology.

Taherian et al. (2010) proposed an energy monitoring system called *Cambridge Sensor Kit* (CSK). Data is collected and stored locally (at the point where the measurements are taken) to a Bifferboard[1] device. Bifferboard is a Linux-based low consumption computer and is configured to work as a server. It is capable of providing feedback with visualisations (time-series data) via Web pages and (historical, summarised, real-time) data via Web services. It is also capable of measuring human engagement by capturing the Web pages visited. At a global level, people are able to compare their energy consumption via a Web interface. The measurements of the last 24 hours are excluded for privacy reasons. This architecture was applied in both domestic and office environments. In the home environment, they provided measurement annotation and enabled the assignment of individuals or a shared group of people. In the office environment, due to regular occupancy patterns, it is easy to identify the baseline energy usage. This enabled the system to identify human-driven power usage, which is the difference of the aggregate power usage from the baseline energy consumption of devices (that are essential for the safety, security and well-being of the users and the environment). One of the experiments conducted, requested all 22 residents of the 2^{nd} floor of a work environment (computer laboratory) to switch off the lights and unplug desktop machines and monitors and other personal equipment. This experiment resulted in a 4kW drop in the power consumption compared to the week's baseline. In a second experiment, volunteers on the same floor switched off their devices in non-office hours. Energy reduction was measured but was not as pronounced as with the first experiment. This research pointed out the potential energy savings of 55%, given a predefined duty cycle.

The work of Taherian et al. (2010) mostly focused on the monitoring system and less on ways of presenting the captured data. The innovative aspect was that the system is able to capture behaviour in both home and work environments. It compares with IdleWars mainly in the research conducted to identify consumption by workers, and the energy saving potential it has if people switch off appliances overnight. Even though decentralised architecture provides an additional level of network connectivity, fault-tolerance, and security, by providing localised data storage, it adds complexity to synchronising the measurement timestamps, which is required for the provision of normative information at a global level. The experiments revealed that human-driven power usage is an important factor for energy conservation, but it did not justify the absence of privacy concerns even when the last 24 hours are excluded. No research findings were provided, even though feedback provision via Web Pages, Web services, Public displays, engagement tracking, and energy individualisation are mentioned, mainly because the project is in its early stages. Moreover, employees preferred group-based comparison than employee-based comparison (Jahn et al., 2011). The authors proposed remotely shutting down

[1] http://www.bifferos.co.uk/

computers from the mains at night by employing wireless actuating switches. Shutting down the computer remotely makes the employees passive and feel that they do not contribute to energy conservation. Their impact on the company's electricity consumption with an automatic computer shutdown would be minimal. Eco-feedback can enable employees adopt environmentally friendly behaviour, and potentially propagate it in other environments, e.g. domestic.

Dixon et al. (2015) evaluated the effectiveness of a comparative feedback intervention campaign at Cornel University between buildings. Six mixed-use (office and lab areas) buildings competed against each other to reduce energy consumption. The intervention lasted from December 2010 to November 2011. The feedback mechanism included participation rates updated weekly and accessed online, weekly emails indicating the participant's contribution to the energy reduction cause, consumption statistics provided online (via the stepGreen (Mankoff et al., 2010) and CALS Green Web site), and posters. The system was evaluated by conducting pre- and post-study questionnaires. Participants completing the questionnaires got the opportunity to participate in a lottery. The authors extended the stepGreen system to enable people to reflect on actions they performed to save energy, individually and collectively. An additional web site provided an aggregate metric, based on the percentage of participation from occupancy rates, projected savings from actions committed, and energy saving updates people made weekly. The results showed that buildings participating in the study had a 6.5% decrease in energy use over the year, whereas the ones that did not had a 2.4% increase. The pre- and post-study questionnaires show a significant increase in reports of energy conservation behaviour in the comparative feedback group, and increase in perceptions of descriptive norms and perceived behavioural control, e.g. how easy or difficult was to perform a certain behaviour (Ajzen, 1991).

One of the limitations of the study is possible bias since only "green" individuals may have participated, who are more committed toward a certain behaviour. This study yielded a promising direction for long-term behaviour change (one year) in a competition-oriented intervention for environments where there were no financial incentives. The study also showed that e-mail is a promising communication tool in work environments. Given that the study lasted for one year, it would be interesting to see how energy saving activities, as well as energy reduction, developed thereafter.

Chapter 3

IdleWars: Game Design and its Rationale

This chapter reports the design rationale of the IdleWars game by taking into account the main contrasts between the workplace and domestic environments. Moreover, it describes how to best apply lessons from prior work on the design of the IdleWars game followed by the description of the game and how it is implemented.

3.1 Design Rationale

The first notable difference between home and work environments is the lack of incentives: employees generally do not have financial benefits coming from lower energy bills (Jahn et al., 2011; Foster et al., 2012; Jain et al., 2013). Another key difference is that workplaces often have a richer social dimension than in a domestic context, not only because generally there are more people in an office than a home, but also because these multiple social groups and layers (e.g. friends, teams, divisions, departments, cross-cutting projects, etc.) may co-exist among workers.

Finally most studies on eco-feedback employ additional hardware for taking measurements. This hardware is subject to green house gas emissions. Researchers suggest that sustainable HCI designers need to avoid introduction of new hardware (for measurement) as much as possible due to embodied carbon involved to production and transport (Bates and Hazas, 2013).

Against this background, a game is designed. The game designed aiming at balancing competition and collaboration to leverage and influence social dynamics, in a way that can be steered towards pro-environmental behaviour. Moreover, it was recently reported that games in the workplace have potential to provide motivation for employees to reduce their energy consumption (Simon et al., 2012). This work focuses on waste

Figure 3.1: A participant *busting* the *idle* computer of another player by scanning the QRCode on the IdleWars screen saver.

around personal computer usage for several reasons: first, in the work environment the computer is mostly a *personal* tool and only its owner has the responsibility of switching it on and off, so it is possible and easy to track *individual behaviour*, in contrast to shared equipment (e.g. from shared printers to coffee machines to corridor lights), for which apportionment would be more difficult or even impossible. Second, monitoring the PC can be achieved *purely in software*, without any additional hardware. This has multiple benefits, first of all, it helps to keep deployment costs low, reduce installation complexity, make the system easily scalable and finally reduce additional embodied carbon emissions by not requiring additional hardware for measurement.

3.2 IdleWars Game

IdleWars, the game designed, tracks the computer status for each player. When no mouse movements or keystrokes are detected for more than five minutes, the computer is considered inactive, or “idle”. In such case, a screensaver appears on the computer screen, showing a QR code, a short URL, and an additional alphanumeric code, as illustrated in figure 3.1. Any player (other than the computer owner), can then “bust” the idle computer by scanning the QR code with a smartphone, or by manually typing the short URL or the alphanumeric code in any Web browser (in case a smartphone is not available). Following the busting action, the screensaver of the idle computer changes to show the *profile picture* of the person who busted the computer, as illustrated in figure 3.2. At any point, the “owner” of an idle computer, whether busted or not, can close the screensaver and resume the normal operation by moving the mouse or pressing any key. If the idle computer is busted, the owner will see a full-screen profile picture of the player who busted them when they return to their desk. Once a computer has been busted by one player, it cannot be busted by anyone else.

Busting is a pro-environmental action aiming at triggering the descriptive norm of switching to a lower power setting (i.e. sleep, hibernate, shutdown) the computer. Conversely, leaving a computer idle represents a wasteful behaviour, which in our game makes the player vulnerable to being busted by other players. The game via the busting action provides a means of expressing undesirable behaviour. The system tracks the time (in minutes) that a computer stays busted – this time is roughly related to the amount of energy that would have been saved by switching the computer off. Even though switching off the computer can easily be implemented, it was rejected due to the intrusiveness and data loss such an action might cause. The total time busted (which can be considered “time rescued”) by each participant, the total number of busting actions, and the percentage of the individual idle time are used to calculate three separate player rankings displayed on the IdleWars leader board, as shown in figure 3.3. All metrics and ranking orientations are designed to give emphasis to positive behaviour (rather than highlighting negative behaviour).

The leader board provides players with comparative and continuous feedback about their behaviour. It is displayed on a public screen in the workplace where the game takes place, and it is also accessible as a Web page. Users can only access the Web page version by logging in. The name of the player logged in is highlighted making it easier to read. The public display was deliberately designed not to be interactive, so it does not support scrolling, and it shows only the top performers from each ranking. The number of top participants shown depends on the size of the screen available for deployment. The choice of a public display, to be placed in a trafficked location in the workplace, aims at encouraging casual conversations and triggering gossip related to the game, with the hope to further motivate workers towards the desired behaviour. Potential public

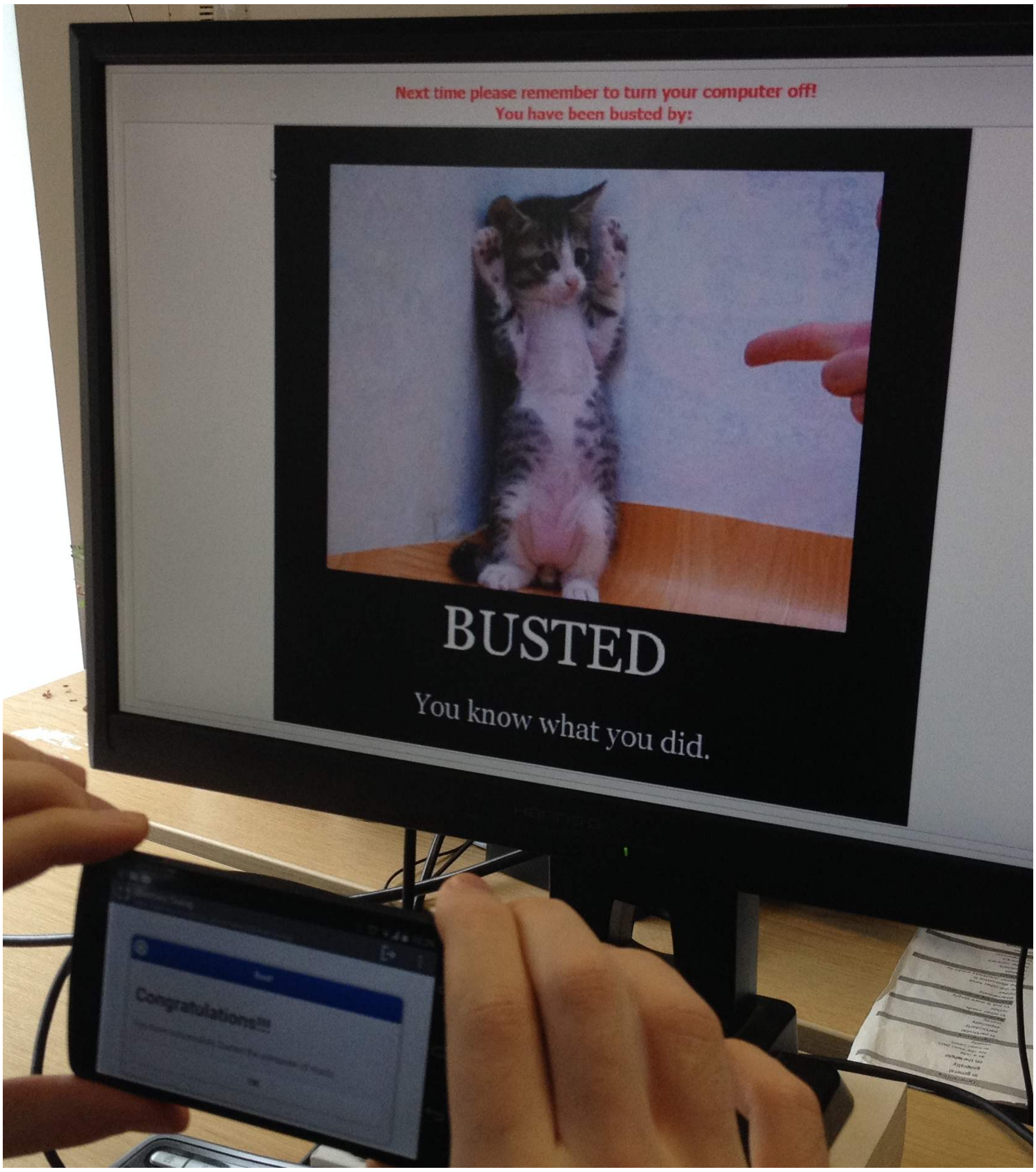


Figure 3.2: A *busted* computer showing the profile picture of the player.

display technologies need to be energy efficient like e-ink[1] but due to time limitations for the current prototype an LCD monitor is employed.

As *privacy* was reported to be an issue of concern in the work environment (Jahn et al., 2011; Simon et al., 2012), in IdleWars the idle time is presented in terms of percentage of the total time the computer is on. In this way, the information about the total time each computer is active or idle is kept private. Feedback is provided only through the leader board, and through the game screensaver indicating that the computer was left idle wasting energy, which acts as an ambient display.

[1]http://www.eink.com/technology.html

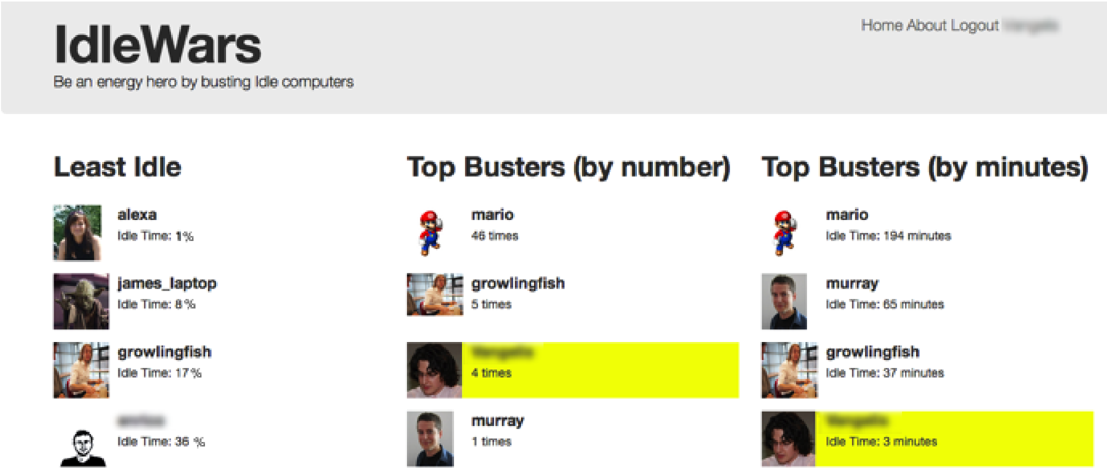


Figure 3.3: The IdleWars leader board.

3.3 Implementation

From a technical point of view, IdleWars consists of two components: a client and a server. The IdleWars *client* runs on each player's computer, and it is responsible for detecting the computer status (active, idle), for sending this information to the server every two seconds, and for displaying the QRcode or the buster's profile picture. The client is implemented as a combination of a standalone cross-platform application, written in C++ using the Qt framework, and a custom screensaver, developed natively in C++ for Windows and in Objective-C for MacOS. Every time the client sends the current status to the server it gets informed, in turn, about having been busted (provided the status be idle).

The IdleWars *server* is implemented as a Web application, written in Python, leveraging the Django Web framework. Data is stored and processed using a PostgreSQL database. The server collects the status information of each player's computer; it calculates the player's ranking, and it renders the leader board. The busting action is implemented on the server as an HTTP POST request. The leader board public display is provided through a computer running a standard Web browser automatically refreshing every minute. A low power Raspberry Pi computer is used for energy efficiency.

3.4 IdleWars client accuracy

An experiment has been conducted to identify whether idle events were detected on the server side. The experiment conducted on a Windows 7 machine and lasted for 4 hours. During this period specialised software[2] was used for tracking the time mouse movements and keystrokes happen at a global level on the client side. The data is then

[2] http://www.codeproject.com/Articles/7294/Processing-Global-Mouse-and-Keyboard-Hooks-in-C

compared to the data events stored on the IdleWars *server*. All idle sessions identified both on the server and client side are shown in Table 3.1. The first column of the table identifies the side the event was detected. The second column shows the time of the last event (keystroke or mouse movement). The third column demonstrated the calculated time that the screen saver was activated (e.g. second column + 5 minutes) for the client-side row and the time the IdleWars client notifies the server that the computer is idle for the server side row. The fourth column specifies the time of a new event happened, indicating the end of the idle session.

Table 3.1: The accuracy of idle (CI) event detection on the server side compared with the client.

Side	**Last event detected**	**Screen saver activation time**	**Time of new event**	**CI duration**
client	15:40	15:45	16:05	00:20
server		15:41	15:58	00:17
client	16:05	16:10	16:18	00:08
server		16:06	16:14	00:08
client	16:24	16:29	17:11	00:42
server		16:25	17:06	00:41
client	17:12	17:17	18:19	01:02
server		17:12	18:15	01:03
client	18:23	18:28	18:49	00:21
server		18:24	18:45	00:21

The table shows that all idle events were successfully detected on the server side. In some cases the length of the idle events detected on the client side is different compered to the server side. The difference fluctuated between 0 - 3 minutes. This difference is mostly based on the time the screensaver takes to activate/deactivate, the network latency and the throughput on the server side.

To detect how accurately the length of the idle events is detected on the server, a second experiment is conducted. In this experiment, a conventional timer is employed to create nine idle sessions on a windows 7 computer. Three idle sessions lasting accurately for one, two and three minutes respectively by using a conventional timer were created. Then the length of the sessions captured and calculated on the server side is compared. Figure 3.4 shows the mean and standard deviation of sessions with one, two and three minutes in length respectively. This means that for small idle sessions (e.g. from one to three minutes) the idle time calculation is accurate whereas for long idle time sessions (e.g. 20 minutes or more) the duration recorded might fluctuate from zero to three minutes.

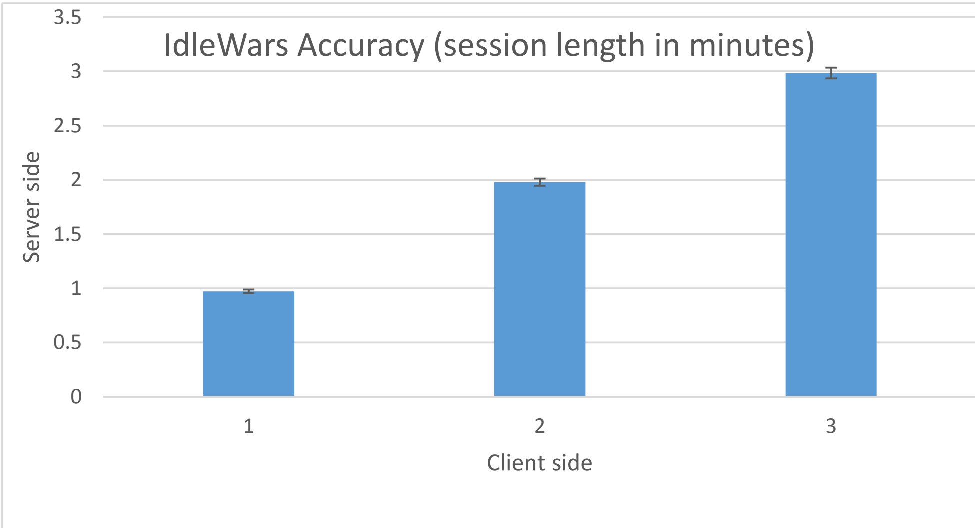


Figure 3.4: The x-axis represents the length the computer was idle on the client side (in minutes), the y-axis represents the length of the idle session (in minutes) calculated on the server side. The tip of the bar represents the average value whilst the error bar represents the standard deviation ($\pm\mu$)

Chapter 4

IdleWars: A Pervasive Game to Promote Sustainable Behaviour in the Workplace

This chapter reports on the initial deployment of IdleWars in the work environment in order to assess whether the game dynamics would engage people and to observe whether any changes would occur concerning computers' idle time. Work in this chapter is published in International Conference on Entertainment Computing (ICEC) (Tolias et al., 2015b).

4.1 Deployment

The trial lasted for two weeks, and it took place at the Centre for Sustainable Energy (CSE), a non-profit organisation working on sustainable energy & policy. The organisation has 50 employees, most of them located in one workspace: an office including two communicating large open spaces, see Figure 3.1 for a partial view. This setup allows each player to easily see and scan the computer screen of other workers. Computer usage is an important part of the office work, main activities are e-mail, writing reports and searching the Web for information. At one end of the working space, there is an open plan kitchen, used to warm up and consume meals and to make hot drinks. The leader board semi-public display was installed in front of the kitchen, to make it visible and encourage people to talk about the game and the ranking over lunch and coffee breaks.

4.1.1 Participants

A total of 27 participants (15 females) registered but only 22 (12 females) installed and used the system. All participants are educated at degree level and some have post-graduate qualifications. Ages range from the late 20s to early 40s, with most in their 30s.

4.1.2 Method

The trial was approved by the organisation's management, and recruitment took place through an email sent to all employees, and through an announcement at a staff meeting. Participants were asked to register on a Web site, and at the same time provide consent to participate in the research. Therefore only employees participated/registered in the study signed the consent form. The game software could also be downloaded from the site, at the end of the registration process. An experimenter assisted participants in the installation process.

Automatic interaction logs were collected throughout the duration of the trial. After the end of the trial a focus group interview was conducted. The focus group took place over a lunch break, and it lasted approximately one hour, it involved 8 of the players, together with one employee who did not play but expressed interest.

4.2 Findings

In this section, findings from the focus group interview and information on system usage is presented based on the automatic interaction logs. The focus group session was audio-recorded and later transcribed and analysed using an approach inspired by thematic analysis (Braun and Clarke, 2006). More specifically, two researchers read the focus group transcript to make sense of the whole then preliminary themes were identified by each researcher by using an inductive (without taking into consideration themes from other studies) and semantic (where themes identified based on the semantic content) analysis. Then researchers spent much time together discussing the data and comparing the themes that result in five final themes.

4.2.1 Interaction logs

Interaction logs were automatically collected by the system, including: idle and active time, bust attempts, and Web page views. During the ten working days period, computers were left idle for 2605 minutes overall, corresponding to 8.25% of the total time they were on. If busting a computer represents shutting it down, participants would have saved 155 minutes of computer idle time, corresponding to 5.6% of the total idle time. In total, 12 participants out of 22 busted a computer at least once. Most activity happened during the first week with 19 busting actions, whereas in the second week only 9 took place. I found that the total 28 busting actions took place on just 9 computers, which got busted from 2 to 5 times.

4.2.2 Engagement

The focus group revealed great levels of engagement with the game. Participants reported running and having fun, for example: *"Yes. There was a lot of noise when P4 was sprinting across the office, shouting 'no!' [because his computer was about get busted by another participant]" [P6].* 'Fun' was also mentioned explicitly: *"...you know, it's quite fun to have someone's profile picture coming up as Bill Murray saying 'you suck'." [P4]* This comment refers to the profile image used by another participant, shown in Figure 4.1. Indeed, another sign of engagement was the *appropriation* around the use of profile images. While it is suggested to participants to use a picture to represent them (an avatar), three of them chose instead an image with humorous text (a so-called "image macro" in Internet slang). This is because these participants realised that the profile picture would be displayed on the screen of a busted computer, so they used it to deliver a message to the people they bust. This practice was widely accepted and characterised as fun by the participants, as the previous quote illustrates.

Apparently, our participants became so engaged that tension mounted around the risk of having one's computer busted: *"...it became quite a tense office, because if anybody did leave their desk and left it [the computer] on, there'd be quite a few people around it just... waiting." [P5]* This quote also indicates the development of tactics, such as players paying attention to who gets up from the desk. Another participant also described a similar tactic, to see who is in the kitchen (which is part of the office open plan) and then check whether their computers are idle: *"If you keep an eye on the kitchen... see who was in the kitchen, and then go and look at their desk." [P1]*

In contrast to the above report of the game generating 'tension' someone else told me that the game also had a stress relieving effect: *"I think particularly because we have got lots of work on at the moment, it's always nice to have something.. ..stop you [from] stressing." [P7]* The game, then, acted as a welcomed distraction from everyday issues.

To sum up, many of the comments from the focus group provide an indication of how engaging the game was and how the work environment became a more active place relieving workers from stress. The focus group also reveals how participants devised new ways of using the system to interact with each other and tactics on how to score more.

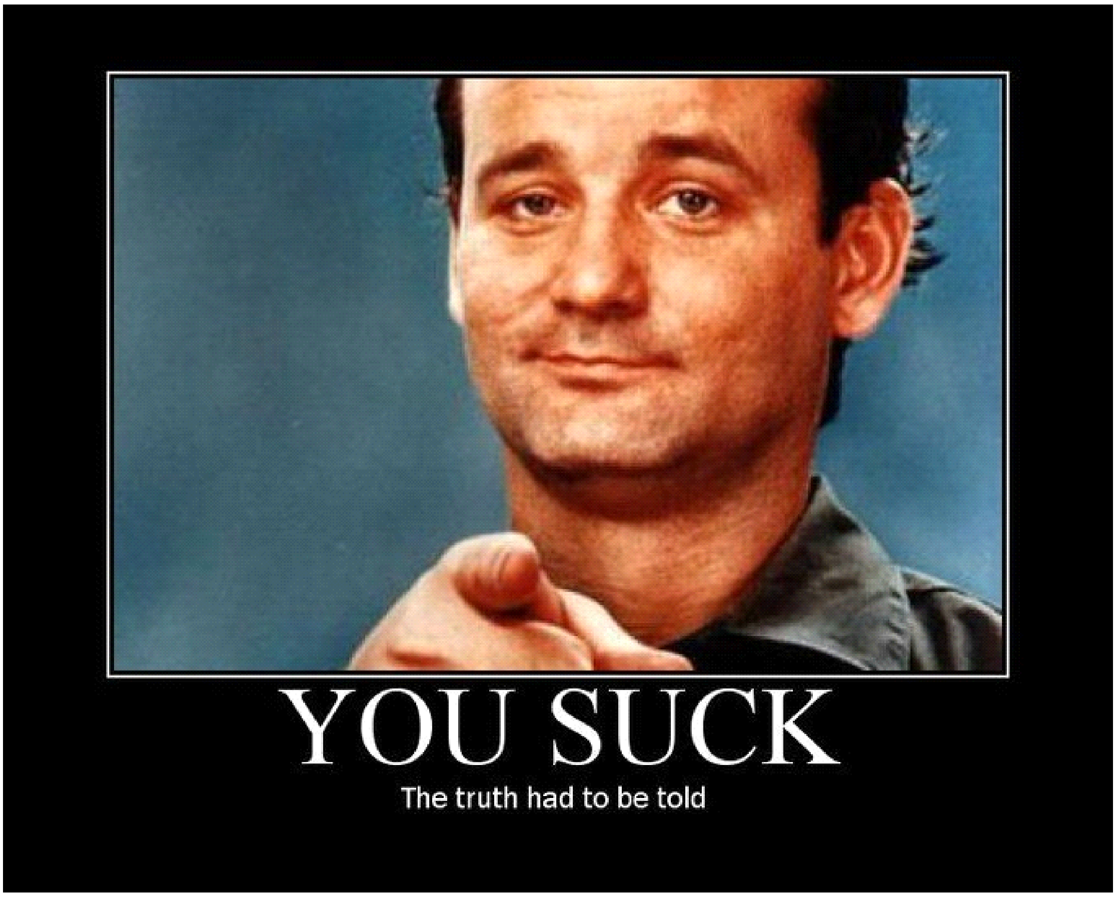


Figure 4.1: Participants used profile image to convey a message to players they bust

4.2.3 Gameplay

From the focus group, it became apparent that during the game participants focused just on the numbers of times they busted other players as a score for the game and not the number of minutes they busted others, or the number of minutes their computer was idle (as described in the Game Design section). One participant explained to us that the number of times they busted others was perceived as a metric for one's own "active" gameplay while the number of minutes busted depended more on others' behaviour:

"I think there's inherently a bit more glory within sort of the number of times that you've busted, [...] because it's quite arbitrary, how long it takes somebody to come back to their computer. It's not like that's your victory as a buster.." [P5]

Another participant reinforced the idea: *"I looked at that [the idle time] briefly, but I suppose... not such an interesting bit, for me. It was more the action [of busting] that was the interesting bit." [P6]*

Someone else still related the busting action to direct competition: *"Well, there's the point of the busting, yes [...] You can sort of say, oh, 2-0 or whatever. It's easy to* *compare." [P2]* This quote, as well as several other comments made throughout the focus group, suggest that our participants were very sensitive to the competitive aspect of the game. This interest in competition can be noticed also from the following suggestion:

"..this idea of the visual league table, you could have it so that you have the... you have four league tables showing who's winning the idle time, who's winning, you know, whatever... and then a combined thing, so you had an overall champion as a separate column." [P4]

At the same time, another participants highlighted a conflict between competitive, individualistic behaviour and sustainability:

"I think I have a bit of a thing about this being, like... there is a theory that, you know, if you encourage people to take a competitive, individualistic approach, you're kind of encouraging them to behave in a particular way which actually, in a holistic sense, isn't that good for being sustainable. So kind of bringing out certain characteristics of them, and..." [P1]

I also learned that another co-worker, who did not take part in the focus group, declined to take part in the game because they disliked this mismatch between sustainability and competition: *"There was somebody who didn't play out of principle, because they thought it shouldn't be.. .. shouldn't become a competitive [activity]" [P1]*

In summary, the gameplay was dominated by the number of times participants busted others, and that went well with the competitive attitude most participants had during the game. However, some participants called attention to the contrast between individualistic attitude typical of competition and sustainable behaviour.

4.2.4 Awareness and Behaviour Change

The game triggered a discussion in the workplace about computer power management, as that was perceived to be directly related to energy waste. Participants realized that they could save energy by deactivating their computers in different ways: *"We had a discussion about what the difference between hibernation and sleep was, didn't we? And somebody broke down which one was better. Mark did some sums" [P7]*

The influence of the game extended even to those in the office who did not participate in the game. One of them told me how he got influenced by the activity around the game: *"Having all these other people participating around me made me more aware of my behaviour [around energy waste]" [N-P1]*

The discussion also highlighted technical issues related to computer power management:

"..it took so long to come back up if you hibernated your computer. So I think maybe it's a bit unrealistic to tell people they need to hibernate, because if you're away for five minutes, that's a bit of a pain.." [P1]

Other participants mentioned that different computers (running different versions of the operating system) had different power management options and different problems. For example, some applications would not reconnect to their servers after computers were resumed from sleep or hibernation.

Moreover, the focus group revealed that the game had also undesirable effects on power management. It turned out that setting computers to automatically sleep or hibernate after five minutes was considered as "cheating" in the context of the game. One of the participants told us: *"I did [configure my computer to automatically hibernate], and then I got pressured that I was cheating, and then reverted back." [P4]* another one confirmed: *"It's no fun [to configure your computer to automatically hibernate]. That's the thing. it was no fun if anyone was able to do that." [P6]* Configuring the computer to hibernate automatically was deemed not acceptable by the rest of the participants because it would take the fun of busting away. As P6 explains, if everyone activates this automation none of the games will become idle, and therefore it would become impossible to play the game.

The negative effects of the game on power management went even further. Some of the participants had the habit to switch off their monitor (albeit not the computer) when leaving their desk. However, this would make it impossible for other players to bust the computer, so they were pressured into foregoing this habit:

"P6: I think we're all in the habit of just turning off our monitors. So you had to undo that, because really we are used to turn off the monitors..
P4: ..To enjoy the game."

The discussion stimulated by IdleWars extended beyond energy consumed by computers, to a more general level. In part this generalisation was prompted by the understanding that computers consumption could be quite minimal:

"Is the expectation that the benefit will come on saving energy for the monitors, or is it from the kind of discussion that might happen around it? [...] Because actually, the amount, you know, we would have saved is vanishingly small, presumably, isn't it?"[P2]

So participants also considered energy waste, automation and behaviour change related to other office appliances, such as shared printers, or lights, as demonstrated by the following exchange:

"P4: We don't switch the lights off [...]. I used to always do it... the ones in the kitchen. I gave it up. They never get done.
P7: Are they not motion-sensitive?

P4: No. No, you can switch them [the lights] off. So you' re right... you know, we don't do things we could do."

On one hand, the IdleWars game raised awareness in the workplace about computer power management, and more in general around energy waste. On the other hand, contrary to the design intention, it stimulated participants to forego pro-environmental behaviours such as setting computers to automatically hibernate or sleep or turning off monitors when not in use.

4.2.5 Productivity

As our deployment took place in a work environment, productivity and efficiency emerged naturally during the focus group. For example, participants contrasted the engagement and fun components of the game with issues of office productivity: *"I didn't think it actually, like, increased the office productivity or whatever, but it got a lot of laughs." [P4]* Similarly, participants commented about the duration of the game trial in relation to how distracting the game was:

"I think probably two weeks... two or three weeks is probably the perfect time period, because it... because beyond that it would get both distracting... or overly distracting to an office space, probably, and it would kind of peter out a bit." [P5]

Productivity and efficiency issues were also brought up in relation to computer power management (as mentioned above). In particular, some participants reported that they found it annoying and unproductive to put their computers to sleep or hibernate because of the time it takes to reactivate them:

"It is a bit annoying. You often do... I find I often leave my desk for five minutes. I get back, and if my computer has... you know, if I've put it to hibernate, or it's hibernated automatically, it does take like a minute and a half to get back online again. [...] sometimes you can't wait that long." [P4]

More in general, some participants commented that the activity of looking for idle computers to be busted could become a distraction, especially because players would wait to attempt an ambush:

"I guess you might delay your return from the kitchen if you see someone's left on their computer and think, ooh, [that computer may become idle]." [P7]

At the same time, other participants suggested that the game could be, and often was, well integrated with the natural practices of taking short breaks, especially when working on a computer screen:

"...because we all sort of get up from our computer every now and then and have a little screen break, so I don't think that we've really wasted a lot more time than we would,

Figure 4.2: An example of timeline visualisations shown to participants in the focus group. Each row corresponds to one day of the deployment, while the horizontal axis represents the the time of the day. The colour represents the status of the computer: white is off, green is on and in use, yellow is "idle" and red is "busted"

you know, looking out the window for the... to give your eyes a rest. [...] It's not a bad thing, necessarily" [P1]

Summing up, participants commented on how the game may influence the office productivity, mostly in terms of the extra time required to restart a computer from sleep or hibernation and also in terms of distraction. On the other hand, it was also observed that the gameplay could easily be integrated in natural breaks workers take at the office.

4.2.6 Privacy and Social Dynamics

As detailed above, the IdleWars client tracks when the computer is turned on and the users' activity in terms of mouse movement and keyboard strokes. It is expected that some users may consider this information sensitive, as it can suggest when a person is at their desk or away, and when they are working on the computer. This information is presented in aggregate form on the game leaderboard, so our participants were exposed to it throughout the duration of the trial. However, to further elicit their reflection on possible privacy issues, toward the end of the focus group, a printout of detailed data collected by our software is given to each player. The data was displayed in the form of a colour coded timeline, where white (or "no colour") indicates that the computer is off, green indicates the computer is turned on and active, yellow that the computer is idle and red that it is busted. An example of this visualisation is shown in Figure 4.2.

Participants were told about the information that they were about to receive, and then printouts were handed out individually on A4 pieces of paper folded in half, so that the data would not be visible until the individual would open the fold. This strategy was adopted to observe whether participants would keep the papers semi-folded, so that only the data "owner" would be able to see it, or whether this data would be openly shared on the table. In other words, I wanted to observe whether our participants would consider this data private or not.

Very quickly everyone fully opened the folded paper, and shared the visualisations very freely, even showing each other any particular features they would notice. This response can be considered as an indication that, at least within this group, the data was not considered particularly private or sensitive. When explicitly asked about any privacy issues related to IdleWars two of the participants explained such attitude:

"So form that point of view, you feel that, like, this data is not sort of threatening, because it's clear that it's just about your computer being doing something or not. Like, you as a person, moving around... [P3]

"Well, it's a game, you know... a game. I think that's going to be done over a couple of... you know, two or three weeks." [P4]

Privacy was also mentioned by our participants during the focus group in relation to another aspect of the game. As stated above, under "Awareness and Behaviour Change", some participants had the habit of switching their computer monitor off (leaving the computer on) when they walked away from their desk. In one instance, one of the players guessed that one of the computers with the monitor turned off was idle, and hence it could be busted. Therefore, the player turned the monitor on, so that he could scan the QR code on the screensaver and bust the computer. During the focus group, the player disclosed that after doing this action he felt uncomfortable, and never did it again. Other participants appeared in agreement that turning on the monitor of a colleague who left it off would feel intrusive in terms of privacy. It was considered even more so, when the monitor turned off belong to someone higher in the organisational hierarchy: *"you know, I can't imagine going up to our chief exec and turning his screen on to bust him." [P4]*. At the same time, nobody considered it to be privacy invasive to get close to a turned-on monitor displaying a QR code to bust it.

In summary, participants did not feel that the computer activity collected by IdleWars invaded the individual's privacy to any concerning extent. However, some of the behaviour promoted by the game in conjunction with a specific practice in the workplace where it was deployed raised some privacy concerns.

4.3 Discussion

The game design was successful in engaging participants, as demonstrated by the interaction logs, by the focus group and by the appropriation around the use of the profile images. IdleWars sparked discussion around energy waste and conservation: participants explored different options for computer power management (sleep and hibernation) they had not considered before and confronted their shortcomings. At the same time, the game turned out also to encourage *some* anti-conservation behaviours, namely discouraging users from automatically setting their computers to sleep and from turning off their monitors. It is worth emphasising, then, that the game *generated discussion* (about energy waste and PC power settings) and *behaviour change* (e.g. setting the computer to automatically sleep or hibernate), even though not necessarily for the better (e.g. forego the habit of switching the monitor off when leaving the desk).

Despite the engagement, though, there is not statistically significant differences in idle time. This result could be explained by the combination of pro-environmental and wasteful behaviours that were encouraged by the game, as well as the fact that the organisation where the game was deployed already has a strong pro-environmental culture. Indeed, a computer idle time of only 8.2% is quite low, and it is clear from the logs that none of the participants left their computer on overnight.

More specifically, the game design was successful in catalysing and polarising existing social dynamics in the work environment where it was deployed: our participants collectively interpreted how the game was supposed to be played, to the point of making up additional rules (e.g. it is *forbidden* to automatically put one's computer to sleep). The main **implication** of these findings, is that they demonstrate the potential of games in the workplace to engage workers around sustainability issues, to stimulate discussion, and even encourage behaviour change.

4.3.1 Physicality and Visibility

Based on the focus group, the main factors behind the success of the game in engaging participants seem to be its physical elements and its competitive nature. The *physicality* contributed to make the gameplay *visible*. Participants *saw* others "sprint" across the office to save their computer from being busted. Scanning a QR-code to bust a computer is *gesture* that everyone in the office can *see*. The idle and busted screensavers, as well as the leaderboard, are visible in the workplace, making everyone aware of the status and activity of everyone else.

The IdleWars leaderboard also made players' behaviour visible, revealing in this way the pro-environmental or wasteful behaviour of the individual, and potentially even the amount of time one spends at their desk. Somewhat surprisingly, our participants did not express any concerns about privacy, even when exposed to the high-resolution data collected behind the scenes by the IdleWars infrastructure. While such an attitude may be, in part, due to the nature of the group who attended the study, perhaps close-knit, and relatively flat in terms of hierarchy, it can also be possibly explained by the playfulness and limited duration of the game, as suggested directly by our participants.

These results, then, bear an **implication for future research**, opening up a question about how similar visibility could be achieved at a larger scale. Would it be possible to make this type of games work at all, for example, in larger companies, where teams are not co-located? Further research could explore the application of remote collaboration paradigms, such as ambient displays that show when a remotely located computer becomes idle and then gets busted.

4.3.2 Action-Reaction in the Gameplay

Being "active" seems to be a key for our participants. They found the idea of gaining points for busting someone else rewarding because they relate it to the prowess of the buster. In contrast, gaining points because the person busted left their computer inactive for a long time was perceived as depending just on the fault of the another person, therefore not very appealing. Similarly, setting computers to sleep automatically after few minutes of inactivity was considered *cheating* – it is an individual responsibility, one needs to remember to turn off the computer, so they can be caught if they forget. Automation, instead, was found not to be *fun*. This effect is perhaps encouraged or amplified by the feedback provided by IdleWars. The action of busting a player is instantly rewarded by the feedback of having one's profile picture displayed on the screen of the "victim". The appropriation observed around the use of the profile pictures further indicates that our participants valued this action-reaction sequence.

The lack of interest in the number of minutes busted can also be explained by two other elements. On one hand IdleWars does not provide instant feedback about the minutes busted. Simply adding a minutes counter on the busted screen could make the score more salient to the players. On the other hand, a busted computer could be unlocked by anyone and busted again after five minutes. This issue made it possible to score repeatedly. It could be limited by making the unlocking of a busted computer password-protected so that only the computer owner could perform it. These two factors imply that in IdleWars the metaphor that busting a computer is similar to switching it off was not well presented, and this shortcoming negatively influenced the game dynamics. One strategy to limit this type of issue could be, for example, to include in the game explicit suggestions about pro-environmental behaviour.

At one level it could be argued that the undesired effects be simply caused by a design limitation, which resulted in a misalignment between the (perceived) game goals and the desired behaviour. However, more in general, it is worth calling attention to the potential conflict between individualist competition and sustainability goals, often framed in terms of altruistic and cooperative behaviour. Indeed, at least one worker from the organisation where the game is deployed refused to take part because she felt the two attitudes should not be combined. This question highlights an opportunity for further research.

4.3.3 Productivity Trade-offs?

Similar to other studies about energy conservation in the workplace (Katzeff et al., 2013), a tension between saving energy and productivity on the job emerged in our focus group. IdleWars encouraged our participants to put their computer to sleep or into hibernation, but they realised that such practice has the potential to reduce their productivity because it takes time to reactivate the computer and resume work when one is back at the desk, or because of software glitches. Some of these issues are strictly technological (rather than behavioural), and probably related to dated software and hardware. While hardware upgrade is likely to have a considerable environmental cost, a software solution (e.g. having applications that reconnect to servers in seamless fashion after computer sleep) could be attractive, if at all possible (Blevis, 2007).

The IdleWars gameplay in itself was also pointed out to be a source of distraction: a few *keen* players admitted they would sometimes linger away from their desk to try and bust others, or they would run and scream in the office distracting bystanders. These are probably extreme cases, and indeed, the reports from other participants suggest the gameplay was often integrated into the natural work breaks that take place in any workplace. However, these occurrences point at another inherent tension: between job productivity and an engaging, entertaining game.

We draw two **implications** here. First, to contain the distraction caused by games like IdleWars, more efforts could be made to refine their design, using timed activation to fit within prescribed pauses, or limiting the daily amount of playing. Second, given that the aim is to help players *learn* a pro-environmental behaviour, an alternative strategy could be to frame such games as episodic, short term activities lasting just one or two weeks. The game could then become one of a number of activities (e.g. workshops) designed to draw employees attention to sustainability issues in the workplace, all to take place over a specific period. Creating anticipation for the event, by advertising it in advance, could help the engagement, as it happened in our deployment. This duration-limited approach would also be in line with the engagement naturally tapering off after the first week.

4.3.4 Lessons Learnt

From this study, we see that physical interaction has potential in raising awareness and behaviour change but it needs to be carefully designed for not being disturbing, invasive and cause issues in workers' productivity. Moreover, a single score metric that directly reflects player's performance can have more potential in being more influential. Finally, image appropriation revealed the need for participants to convey a humorous message to participants they bust.

Running a study in the work environment had obstacles. First, is the difficulty in convincing a company to run a study that requires an unknown software to run on their corporate computers. Second, is the evaluation of the system. The optimal approach to qualitatively evaluating the system is by conducting one to one interview with all participants. If this type of interview happens during work hours it will result in big man-hour loss from the company. Whereas having interviews outside work ours was not a very popular option among participants due to their busy schedule. These limitations directed our next study to focus in the home environment.

4.4 Conclusion

In this Chapter describe an initial deployment of IdleWars, over two weeks in a medium sized organisation. The deployment revealed that the physical and competitive elements of the game work well in engaging participants. More specifically, the design was successful in catalysing existing social dynamics in the workplace where it was deployed.

The introduction of a pervasive game as an extension of feedback was engaging, with participants describing it as being fun and appropriated/extended its rules, sometimes in a way that favoured engagement and fun rather than conservation behaviour. Some participants engaged with the game to the extent that they developed tactics on how to find the idle computer (e.g.: by watching who gets up from the desk and who is in the kitchen). Even though engaging, the game also made participants focus mostly on the number of times busted others. The human involvement in feedback provision design decision reveals potential in raising awareness of workers not playing the game. More specifically, the study shows that visibility of the interactions occurred in the workplace have the potential of behaviour spillover effect to workers not playing the game (but are present when the game interaction occurs).

IdleWars triggered discussion around computer power management options and their adoption, and more in general on energy waste in the office. In contrast, setting computers to automatically sleep after few minutes of inactivity (which is desirable in terms of sustainability) was considered "cheating" because it takes away from the game challenge. While these results point out that our specific game design needs to be revised to better align the game rules with the underlying sustainability goals, they also indicate that pervasive games like IdleWars *can* be effective tools to raise the attention to sustainability issues in the workplace, paving the way for further HCI research in this domain.

Chapter 5

Challenging the Definition of 'Waste' around Eco-feedback

To better understand the perception of waste in the home, an unpublished study is further analysed focusing on waste perception. The study conducted between the University of Southampton and Kingston University. In particular, the study was conducted in 2013 by Enrico Constanza, Tim Harris (Kingston) and Graça Brigthwell (Kingston, at the time of the study). The main focus of the aforementioned study is to evaluate if the annotation and interaction consumption data provided by the *Figure Energy* (FE) (Costanza et al., 2012) system help users to better understand their household consumption. The interview triggered discussions on how people perceive energy related waste. Contribution of this chapter is the analysis of the interviews focusing on how people perceive energy waste in the household.

FE is an electricity consumption visualisation tool. It provides an innovative tool to test *what if* consumption scenarios via the practice view, an interactive time-based plot of the average power consumption of the household called logger view and real-time consumption information of the house via the live view. An interesting part of the study is the practice view where participants can annotate the consumption plot. This annotation gave the opportunity for the participants to reflect on their consumption behaviour and how they perceive waste during the post-study interview.

5.1 Method

In the study reported here, the FE system was trialled with 12 households. Participants were recruited by a combination of convenience sampling and snowball sampling from a suburban area in the south of England. As an incentive to participate, householders were given £10 at the start of the trial and a further £40 on its successful completion.

Participants were asked to use the FE app at least once a day for 5-10 minutes, to annotate their energy consumption logs.

In order to encourage engagement with the system and reflection on the energy data, participants were emailed one brief online questionnaire each week of the trial, asking them questions related to their own energy use. For example, one such question was: "If you had to reduce your electricity consumption by 10%, how would you do this?" Post-study interviews were conducted with 1 or 2 members of each of the 12 households. The interviews focussed on their experiences with the system, and the related energy consumption activities. Interviews were recorded and transcribed verbatim and the transcripts used to inform the generation of themes for the analysis presented below. The analysis used an approach inspired by thematic analysis – the analysis started by categorising the material at the sentence level, focussing in particular on issues related to energy waste. The codes were later grouped in broader categories presented in the following section.

5.2 Results

When asked what they were going to do in order to reduce their consumption, all participants mentioned appliances that were on and not in use implying what they consider wasteful, the most frequent examples mentioned were mainly appliances that do not consume a lot of energy, like TV and lights, for example: *"RACHEL: ... if the TV's off he will put the TV on sort of as a...[...], and then he might go off and do other stuff, but there'll always be, you know, the TV will be [on]"*. Waste was also considered appliances that are plugged in (consuming energy) and not in use, for example: *"HELEN: ... [...] I mean I use the microwave maybe once every three, four days so there's no reason for it to be on all the time, you know."*

Strengers (2011) expressed that avoiding lights being on when not in use might be based on the attention of energy-saving campaigns towards lighting as an easy saving and less inconvenient practice to perform. Our findings show that switching off lights and unplugging appliances is also rooted back to their childhood when their parents unplugged the TV from the mains and switch off the lights for safety and financial reasons respectively, for example: *"BORIS: [...] And there was often an apprehension that they [the TVs] might burst into flame or something. And the general guidance was, you know, don't...if you're going away unplug the telly. ..."*

Similarly an unconscious influence from parents to children has also been mentioned by one of our participants: *"CHLOE: [...] So I think although our electricity consumption, ours was a lot less because obviously there was only two of us when we first got married. I don't think it was a conscious thing. I think it was just that we were products of our parents and that was the way they lived and you brought it into your own life when you* *got married".* A similar habitual perception of switch it off when you are not using it is reported by Rachel as well: *"RACHEL: [...]...I suppose it's...when you're a child you get nagged about switching lights off and things like that ...'*

With the appearance of fluorescent bulbs and its characteristic start-up surge there was a new perception formed from childhood that it is financially beneficial to leave the lights on than switching them off and then on after a short period of time. *"I mean, I remember as a child people joking that it costs more to switch a light on rather than...you know, if... It costs less to leave it on than switch it off and on, ..."* Such a focus on eliminating waste in terms of lighting lead as a reference point of being environmentally friendly (Strengers, 2011) and habitual (Pierce et al., 2010). A similar comment related to using lighting waste as a reference point in wasteful behaviour for offices, for example: *"KATHRYN: [...] You go through a town and how many offices have all their lights on in the middle of the night, and you think: why, why do you need that?"* A similar perception like the start-up surge was also reported for TVs. One participant refrained from switching off the TV because of the wrong perception of TV consumption patterns: *"KATHRYN: ...I keep telling them to turn it [the TV] off, you know, because I think they think it takes... [...] but I think Matt thinks that it takes more to start it up and I don't believe that's true, having looked at it that's not true at all. You could just turn it off".* The FE system helped to better comprehend their appliance consumption behaviour.

Others mentioned waste with regards to utilising a resource related to the house climate and water heating, for example: *"JUSTINE: ... it's not as if we go out of the house leaving every TV on, everything else on and with the windows open and the heating on, and the hot water on...we don't do that so I can't see how we would dramatically change something".* Waste was also considered as not using the washing machine in its full capacity, for example: *"LORRAINE: ... Ultimately we don't...I don't...we don't foolishly put washing on when we've only got a few bits to do, you know. We do make sure we've got a full load before we do it. So that's just a bit unusual to us that we... "* and *" KATHRYN: I did think: we do a lot of washing, and I've tried to make bigger loads because a lot of the time I look at the load and it's not really worth doing. [...]"*

An ingrained effort towards avoiding waste has also been reported by Hargreaves et al. (2010); Hirsch and Anderson (2010); Pierce et al. (2010) and Woodruff et al. (2008). Framing and justifying an activity as wasteful has potential in leading to behaviour change (Strengers, 2008). Participants framed the benefits of avoiding waste and therefore changing behaviour in financial terms: *"RACHEL: Well I wouldn't...I...there are things that we struggle to afford which I would rather have than money going out the door on things that aren't very enjoyable. I'd rather have money to spend on things that I want [...], things that make me happy whereas boilers and washing machines and tumble dryers don't really float my boat."*

5.2.1 Attributes that influence waste perception

From the interviews we saw that there are consumption scenarios that are widely considered as waste (e.g., switching off appliances when not in use). The interviews also revealed scenarios with a diverse perception of what waste is and it depends on different attributes. These attributes are comfort, security, cleanliness, culture, convenience, effort vs financial and technological advancements and age.

Peoples' perception of waste co-occurs with their perception of comfort. More specifically, one of the participants reported that the house was dark even during the daytime. This forced her to have the lights on but when she leaves the room she switched them off because the latter is considered waste. *"SARAH: [...] it's quite dark, so we tend to always need lights on through the back of the house during the day. So we, you know, we've become more aware of leaving...switching lights off as we come out of a room."*

Making occupants feel and be secure made participants re-consider their perception of waste. One interviewee that is emotionally attached to her cat reported that she leaves the hall light on overnight to comfort her. *"FAITH: [...] so being the big softie I am I leave the hall light on for her, just completely ridiculous I know"*. The same interviewee reported that whenever her cat is stressed, she leaves the radio on to help her cat relax. *"FAITH: But I leave the radio on for her, I've started to do that in the last two days...no, yesterday and today, I started to leave the radio on for her because she's been a bit stressed."*

Perception of cleanliness played an important role in how people perceived waste. An interesting example is when the participants' daughter put her clothes in the wash after wearing them just once, the mother tired to convince her that it is wasteful. *"But I did say to my daughter, you know, Why have you put them in the wash? and she said, Well I've worn them all day. I said, You haven't spilt anything down them and they're not dirty. And they smell fresh still. You can still smell the comfort on them for goodness sake. I'm sure you can wear them tomorrow."*. Therefore, even though frequent washing is considered waste it is justifiable if someone works on the labour sector. *"Keith: [...] I have work clothes to wash... [...] Keith: ...and I'd have so many so they have to go... Elaine: ...and they get so dirty as well."* This combined with the insight of home makers define what is considered clean and what is not (Strengers, 2011), and therefore what is wasteful as well.

Perception of waste is also influenced by cultural norms. In the UK, it is considered socially unacceptable not to offer visitors a cup of tea or coffee, and even worse to refuse someone one. *"CHLOE: You have family coming at the weekend and you know, the first thing you say is, would you like a drink and you put the kettle on and then you know, an hour and a half in, would you like another drink and you put the kettle on again! [...]*

That's ridiculous. You know, and probably used all of the water because we had family coming and we were making endless cups of coffee and tea".

Financial and technological advancements (e.g., washing machines) re-defined what it is considered convenience and therefore waste. More specifically, interviewees identified that even thought people were not environmentally aware they had a more sustainable behaviour compared to the current lifestyle mainly because of the lack of technological advancements. One of the main reasons reported is that high energy consuming appliances like washing machines and tumble dryers were not available or very expensive to buy, this made home makers to hand-wash their garments: *"CHLOE: [...] you know we're lucky, we're not from when my mum was younger and you know, she had a twin tub and things like that. We have got, you know, good appliances that we can still live sort of good lives because we haven't got to stand at the twin tub anymore. And I think we have probably got a little bit lazy, you know, and not thought about it".*

In several cases interviewees mentioned waste in households occupied by elderly people revealing that age is an important attribute that influences how people perceive waste. An interesting example is Helen and the fact that her mother constantly has the light on in the garage. *"HELEN: My parents would be a prime example to do this; they have a garage where they leave the light on the whole entire day. Every time I go round I turn it off. Mum's like, leave it and I'm like, you don't need it on, you've got a light in the garage; you're not even in the garage. She likes it leave it on. It's just ridiculous."* Chole's mother high consumption patterns considered as wasteful because she had earnt the right to maintain or adopt such practices: *"CHLOE: [...] she's like, I worked all my life for it, I'm going to have it."*

5.2.2 How feedback changes perceptions of Waste

As mentioned earlier participants focused on practices that tend to get associated with waste but are not the highest consumers in the household (e.g. lighting). One participant interviewed had an inaccurate perception of how much the lights consumed but interacting with the FE interface helped him to understand how much the lights consumed compared to other appliances *"A:You know, then you're likely to do that. I mean I was struck with the...by the lighting because I always thought lights, you know, lights would cost a lot, but there...there was no real peaks with lighting at all."* A similar finding has been reported by Pierce et al. (2010) where participants did not have a clear perception of how much each appliance consumed, leading to failed attempts to reduce consumption and therefore money expenditure.

Providing feedback on energy consumption not only revealed which appliances and practices consumed the most, for an effective consumption reduction, but also raised awareness on wasteful behaviours: *"KATHRYN:[...] So, you know, it's like: oh my God, I've* *used so much electricity. And that just makes me feel a bit wasteful really, for probably just sticking one thing in an oven, it's a lot of electricity. So, yeah, it did make me think".*

5.2.3 Consumption Apportionment Challenges

In several interviews participants reported that they had identified the 'wife' or 'mother' as the main consumer of energy. Often it was the very 'wife' or 'mother' to make such point: *"CHLOE: I was thinking actually, I think I've been nagging the girls, shouting, 'Turn that off, you don't need that on! You're not in that room!' And I'm thinking actually, no, as soon as I noticed as soon as I walked in at 4 o'clock it was actually...and I was the only one in here at 4 o'clock that actually was me using the most electricity! [laughs]"* As demonstrated by this quote, the responsibility was often related to a certain sense of 'guilt'. We also learned that the identification of the main consumer was based on who interacts with the most energy consuming appliances in the household. These were often washing and cooking appliances, so it was interesting to note that it was only the *operation* of the appliance that was taken into account, not the *purpose*, i.e. cooking dinner.

5.3 Discussion and Implications

Findings of this study are inline with other studies, Arkes (1996) showed that people have an ingrained attitude towards avoiding waste. We found that an exception to this is the elderly people were even thought they identified some practices as wasteful they did not take action to remedy them mainly because of the additional effort required from their part. Activities related to cleanliness (e.g. washing clothes, tumble dryers) are one of the biggest household electricity and water consumers (Strengers, 2008). Goldstein et al. (2008) revealed that activity-based social norm activation related to towel reuse (and therefore cleanliness) contextualised as saving the environment lead to using the towels more than once before washing. In this context, we argue that normative feedback that redefines waste at activity level (not only electricity consumption) reveals a rich opportunity for behaviour change.

From the interviews we saw that there is a diversity of household occupant attributes that influence waste perceptions. Most eco-feedback technologies are limited to just resource consumption provision and no additional information added over time. This resulted into making participants loose interest on the eco-feedback mechanism (Hargreaves et al., 2013). We argue potential solutions to the profile diversity and interest decline problem is tailored feedback (Daamen et al., 2001) were either energy and health experts or other motivated knowledgeable individuals (Woodruff et al., 2008) can provide their suggestions on ways to conserve resources by taking into account attributes that influence waste perceptions of the occupants and their resource consumption.

Even thought there was a differentiation of what is considered waste there was a common denominator which I call *"widely perceived waste"*. Widely perceived waste is when there is resource consumption were the owner or other occupants of the household are not benefited from it. The well defined waste reveals a rich opportunity to reduce consumption without any compromise in comfort and it will be the first step towards sustainability. For this reason, similarly with IdleWars our next study is going to focus on waste oriented feedback that involves the human element in the feedback provision for the home environment.

5.4 Conclusion

This Chapter presents the analysis of the interviews of a deployment using FE visualisation tool. The focus of the analysis is around waste in the household. The analysis showed as waste by the majority of participants appliances being on when not in use as well as not using a resource to its full potential. Waste perception is influenced by attributes like comfort, cleanliness, culture, technological advancement and age. Interaction with the FE system raised awareness and helped to understand the impact each appliance has on the overall household consumption. This analysis shows the potential for future eco-feedback designs aiming at waste instead of consumption. Both software and humans can contribute to the identification of waste at the individual by taking into account attributes influencing waste perception from each person individually and try to challenge this perception gradually.

Chapter 6

EcoScreenCatcher: Game Design and its Rationale

This chapter introduces the design rationale of EcoScreenCatcher, a software-based competition-oriented serious game that calls attention to the waste of PC energy at home. EcoScreenCatcher is derived from IdleWars and aims to test how well it transfers as a game and in human feedback provision. Its design was informed from lessons learned in the IdleWars deployment. The main focus of this chapter is therefore to stress the similarities and differences between the design of IdleWars and EcoScreenCatcher.

6.1 The EcoScreenCatcher Game

Both EcoScreenCatcher and IdleWars detect when the player is working on her PC and therefore how many minutes she is idle. In the context of busting (catching will be used instead of busting from now on), only one person at a time can catch a computer. Feedback mechanisms are a leader board and a screen to keep users informed of their performance. The information provided has been changed for both feedback mechanisms. These changes will be discussed later.

EcoScreenCatcher employs the same infrastructure as IdleWars for computer activity identification (Computer Active and Idle) and applies it in the home environment. Because of the distributed nature of dwellings, catching a computer happens remotely (with the press of a button in the Web browser). For the same reason a public display is not provided as a feedback mechanism. Since participants in the IdleWars study focused mostly on the number of times they bust (caught) a computer, a single leader board was created for EcoScreenCatcher. The single leader board metric encompasses all aspects of the game (number of catches, computer idle time, and minutes the computer is being caught). This aims at making the metric for computer idle time more attractive.

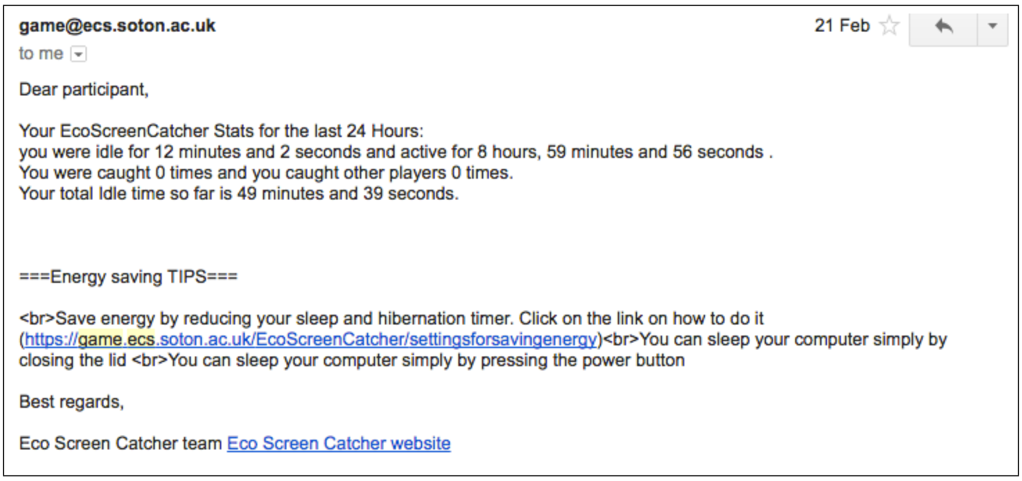
Whenever a computer becomes idle, the screen saver shows a timer indicating the time the computer was idle, for the EcoScreenCatcher game, and a QR code with a message, for the IdleWars game. The timer is used to draw the user's attention to the time the computer is idle. Finally, EcoScreenCatcher uses the Facebook API to enable a user to easily register, play the game with Facebook friends, and communicate with each other.

6.1.1 Feedback Mechanisms

The feedback mechanisms are employed daily and are comparative, and sent via email (see Figure 6.1) and the Web-based leader board respectively (see Figure 6.2). An email is sent at 2am summarising the computer's active time, idle time, times caught, during the previous day, and its performance since the beginning of the week (starting Monday). It also contains a link to a Web page with information on how to sleep or hibernate the computer as well as the differences between them.

The leader board is only accessible to registered users (login required). Each user starts with 10000 points, based on each week having 10080 minutes, and this represents a rounded version of it. Each point represents approximately a minute. For every minute a player leaves her computer idle, a point is removed from her score. Points are gained only if she catches a computer. More specifically, she gains a point for each minute the computer is caught. Every Monday the score resets to 10000 to give more opportunities to participants featuring low in the ranking to have a fresh start.

Next to the leader board is the "cheater's leader board". Participants feature here only if they catch a computer and have not installed the EcoScreenCatcher client. When the user leaves her computer idle (e.g. after five minutes of inactivity) a screensaver with a timer appears on her screen showing a counter indicating the time the computer is idle (see Figure 6.3).


game@ecs.soton.ac.uk 21 Feb
to me

Dear participant,

Your EcoScreenCatcher Stats for the last 24 Hours:
you were idle for 12 minutes and 2 seconds and active for 8 hours, 59 minutes and 56 seconds .
You were caught 0 times and you caught other players 0 times.
Your total Idle time so far is 49 minutes and 39 seconds.

===Energy saving TIPS===

Save energy by reducing your sleep and hibernation timer. Click on the link on how to do it (https://game.ecs.soton.ac.uk/EcoScreenCatcher/settingsforsavingenergy)
You can sleep your computer simply by closing the lid
You can sleep your computer simply by pressing the power button

Best regards,

Eco Screen Catcher team Eco Screen Catcher website

Figure 6.1: Daily email sent to participants at 2am summarising the time the computer is active or idle and providing some energy conservation suggestions

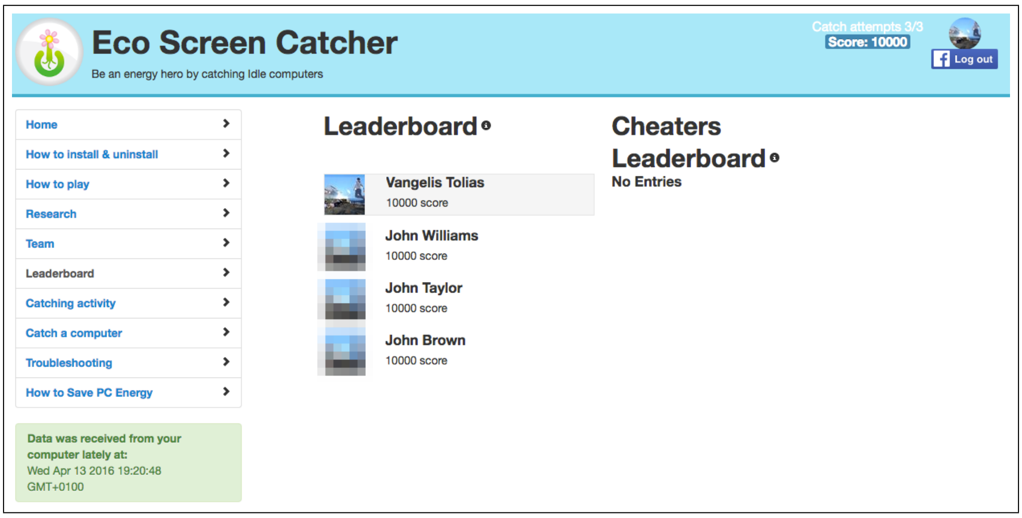


Figure 6.2: EcoScreenCatcher leader board, showing participants and their respective scores

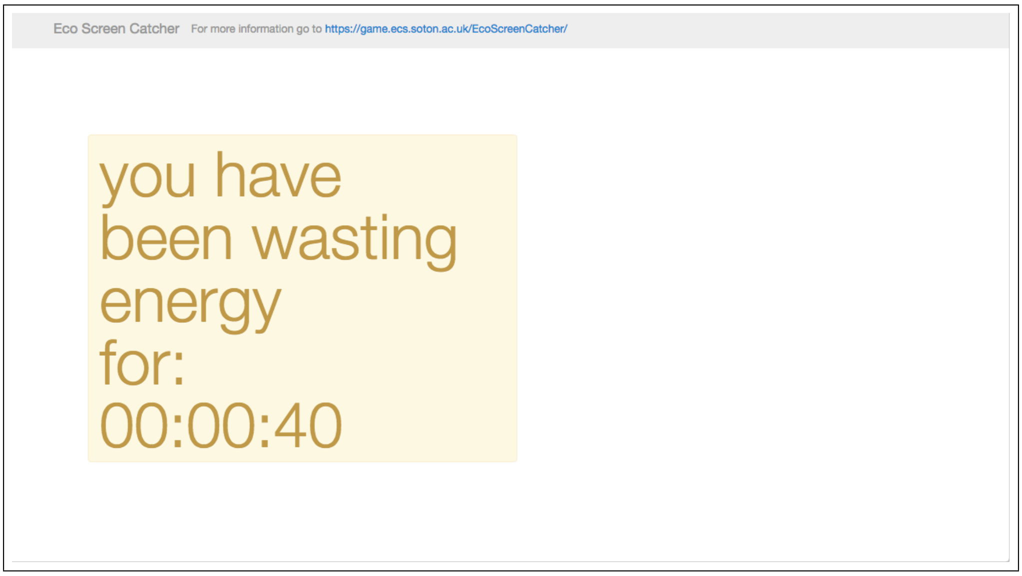


Figure 6.3: After 5 minutes of inactivity, the screen saver appears indicating the time the computer is idle

The game contains three feedback mechanisms. The first is the “Catch a computer” (see Figure 6.4). This page shows all the user’s Facebook Friends that play the game, and the status of their computers. By “friend” we mean Facebook friends taking part in the study. The frame with white, red, yellow, blue background indicates that the computer is switched off, idle, caught and active, respectively. Players can catch only idle computers. The number of catch attempts is limited to three an hour. This gives other players the opportunity to catch idle computers as well. The second feedback mechanism is the “Catching activity” (see Figure 6.5). This page shows a summary of the catching activity for each participant as the number of times a participant got caught and *vice versa*, as well as when this happened. The third feedback mechanism is shown in Figure 6.6. Whenever the player is caught by another, the Facebook profile image appears on the screensaver of the idle computer next to the timer. It is important to note that this feedback mechanism is directly triggered by human action, rather than automatically.

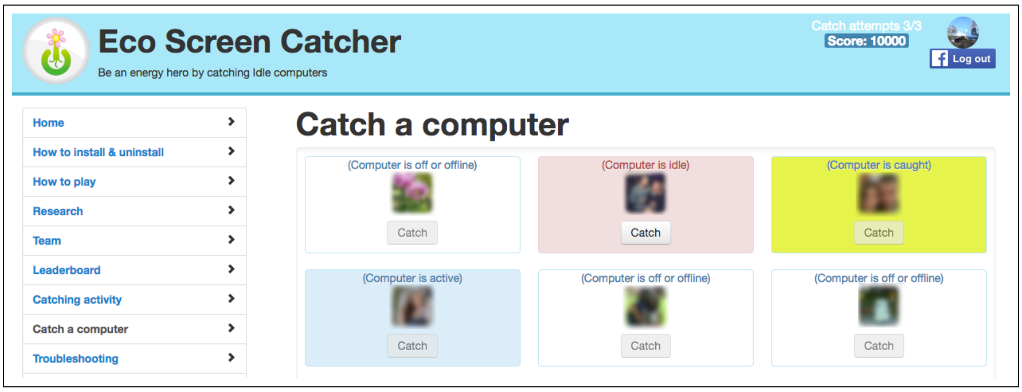


Figure 6.4: Catch a computer page showing all friends and the status of each computer

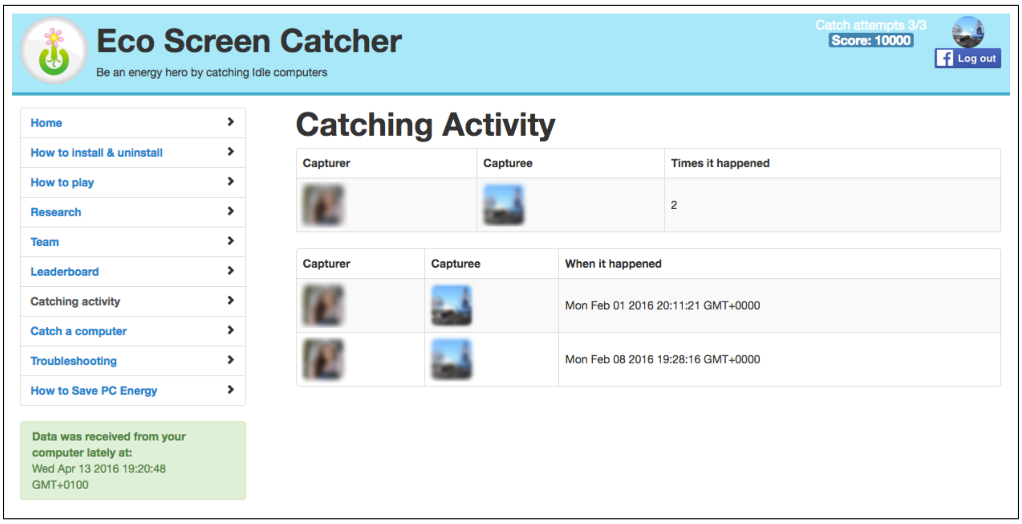


Figure 6.5: Catching activity page summarising how many times and when a participant got caught and *vice versa*

6.1.2 Communication

Participants can communicate with each other in two ways. The first is located at the bottom of the Web site as a "comments Facebook plugin"[1]. Participants use this area ad hoc by asking questions and getting replies. The second approach following successfully catching a computer. The catcher is optionally able to send a message to the person she caught. The form for providing the message appears immediately after catching

[1] https://developers.facebook.com/docs/plugins/comments

Figure 6.6: Screensaver indicating how long the computer has been idle and the Facebook profile picture of the person who caught it

the computer successfully (see Figure 6.7). The message will appear at the top of the screensaver, as seen in Figure 6.8).

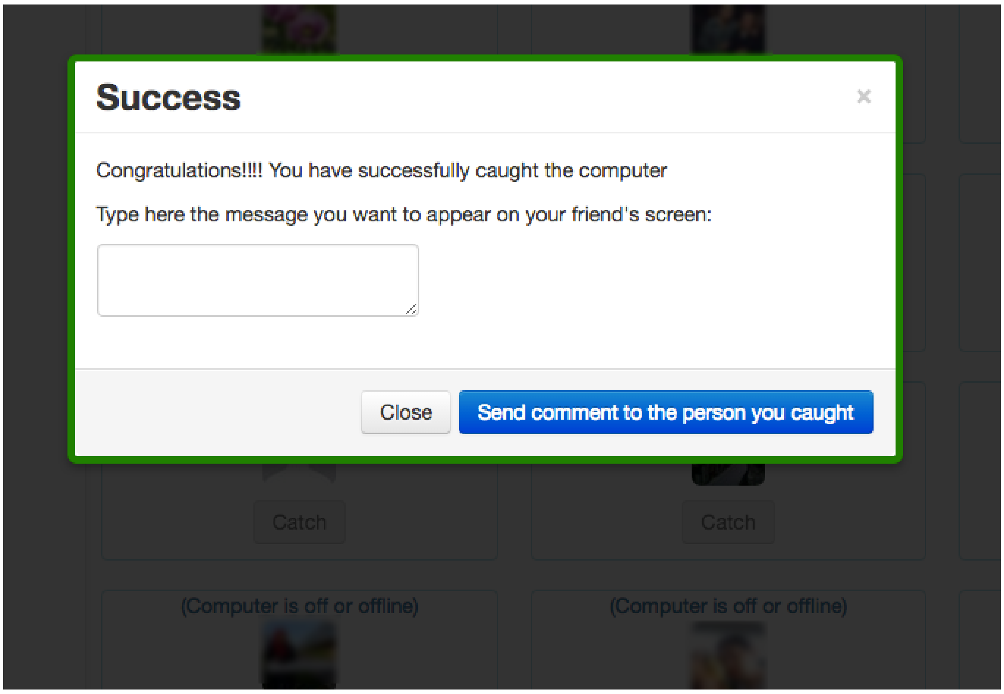


Figure 6.7: Message form that appears after successfully catching

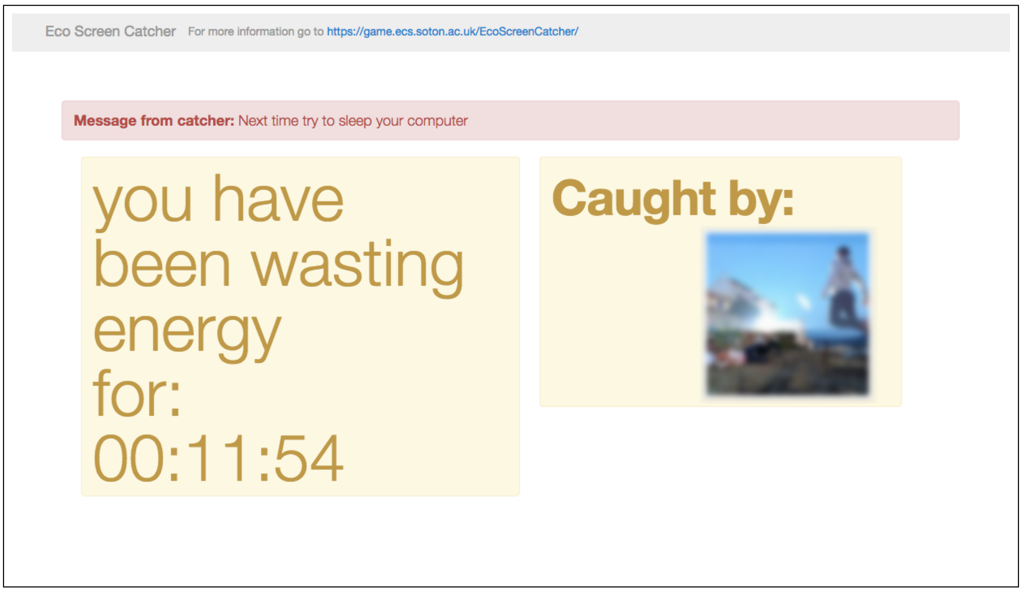


Figure 6.8: Personalised message from catcher appears on the screensaver of the computer caught

Chapter 7

EcoScreenCatcher: Promoting PC Sustainable Behaviour at Home

This chapter reports on the initial deployment of EcoScreenCatcher in the domestic environment and on observations of changes that occurred of computers' idle time. To validate the design, EcoScreenCatcher was deployed in the wild for three weeks with 23 university students.

7.1 Deployment

To evaluate the game, a field study was performed. In addition, interaction logs were collected throughout the duration of the study. The deployment lasted for three weeks. During the first week, participants installed the EcoScreenCatcher software on their computer and received daily emails on their computer's activity and idle performance, comparative feedback from the leader board page, and feedback via the EcoScreenCatcher screensaver on how many minutes the computer was idle since the owner last used it. For the second and third weeks, the "catch a computer" page was made available and participants began catching each other. Every Monday their score was reset back to 10000 points. During software installation the OS sleep and hibernation timers were set to default values for fairness and to facilitate behaviour comparison between participants.

7.1.1 Participants

Figure 7.2 shows that the age of the participants ranged from 19 to 29 (M = 22, Mdn = 21). 12 out of the 23 characterised themselves as females and the rest as males (Figure 7.1). The majority of the participants were undergraduates (University of Southampton and Solent University), from a variety of disciplines (Mathematics, Computer Science, Politics, Law, Management, Linguistics), originating from a variety of countries (UK, Canada, India, Malaysia, Indonesia, Vietnam, Romania, Japan, Kenya).

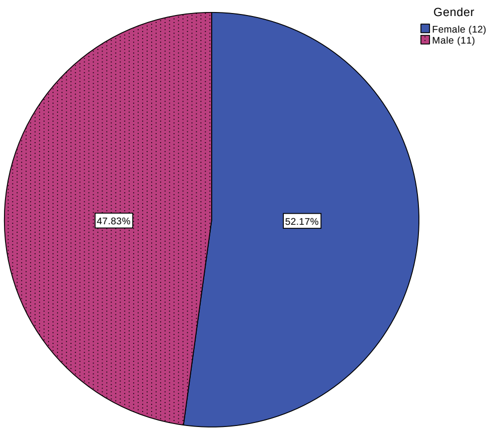
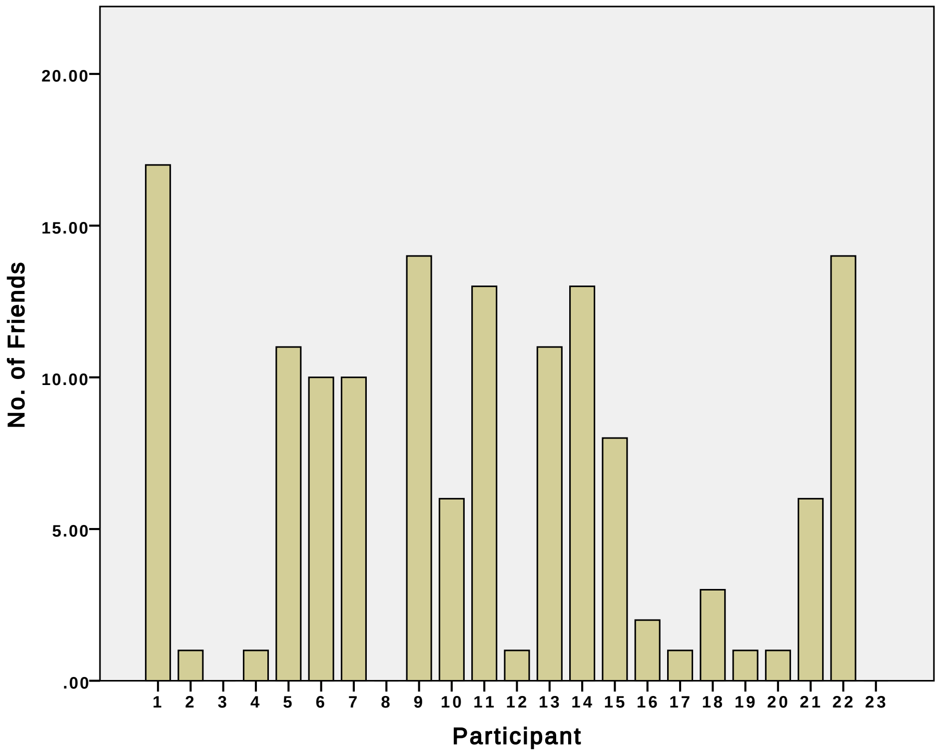


Figure 7.1: Gender of participants in this study



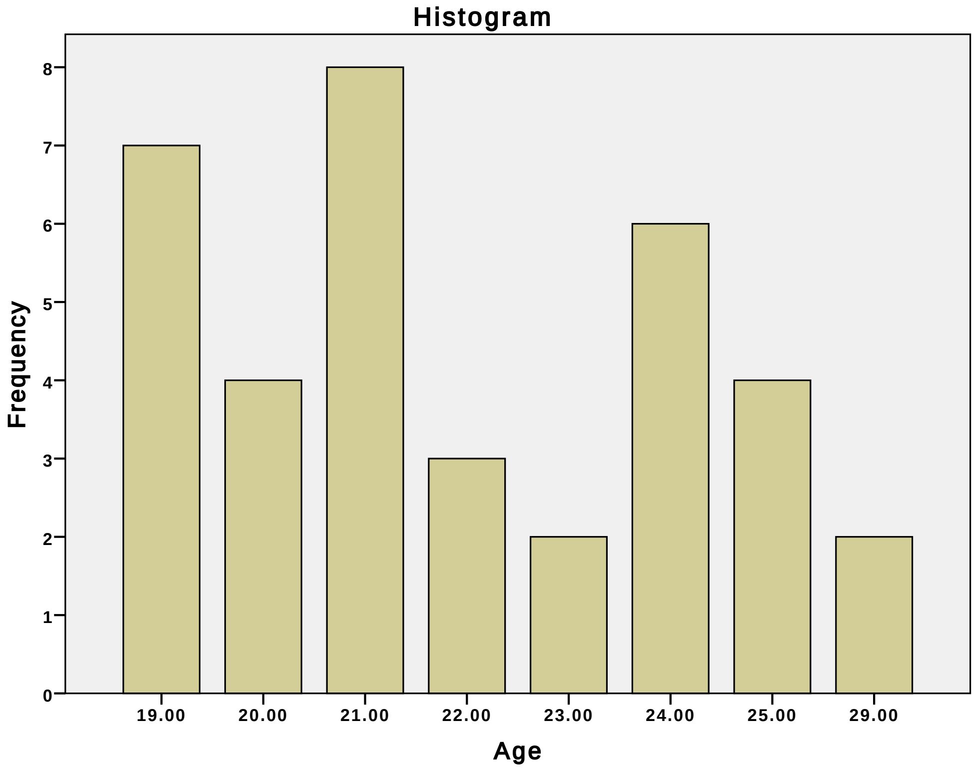


Figure 7.2: Ages of the participants

7.2 Evaluation Methods

Both qualitative and quantitative methods were employed for the evaluation of the game. Online pre- and post-study questionnaires were collected as well as logging data. This log data comprised game Web pages the participants visited, when their computer was active, idle or caught, messages exchanged between participants (using the platform), who caught whom, the battery level of the computer (for laptops only), the operating system version, and the IP address of the client computer. All log information was timestamped. At the end of the study, all participants were invited to the university campus for one to one semi-structured interviews. The interviews lasted from 30 to 60 minutes, and were recorded and transcribed *verbatim*, and the transcripts used to generate themes for analysis. The analysis approach, inspired by thematic analysis, started by categorising the material at the sentence level. At the end of the interview, all participants were paid £30 ($40) for their time.

The study was advertised on Facebook groups (e.g. SUSU, free and for sale, Computer Games Society @ Southampton University, and gumtree Southampton). 36 respondents expressed interest and registered, but only 23 installed and used the system throughout the study. Some of the reasons registrants dropped out of the study were: fear of the program being a virus or an unauthorised person having access to their computer; the program not working on their computer or stopped working; they thought the software was working but apparently it did not; and because the process (program installation, questionnaires, interviews) was time-consuming. Three participants did not befriend other participants to play the game (from now on the term game friendships will be used). These participants did not experience the game (due to the lack of friendships) but did encounter the feedback mechanisms (e.g. daily emails, the screensaver indicating how many minutes their computer was idle). Three other participants had friendships, but either their client stopped working or the participant started playing during the first week of the study, resulting in them not having the required data for the group log based analysis to be performed. Given that they played the game, these three participants were included in the questionnaire and qualitative analysis. We took advantage of this situation to define three groups for the study, the "game" group (n = 20), the "individual" group (n = 3), and the "game elements" group (n = 23).

In summary, the game group included participants who had one or more friends and on whom data was collected throughout of the study (participants with data missing from more than five days are excluded). The "individual" group consisted of those participants with no friends. The "game elements" group included those in the game group as well as those exposed to the elements of the game but for whom there was not enough data to be included in the statistical analysis. For this reason, participants from the game group are used for the log based statistical analysis whilst participants from the game elements group were taken into account only for the questionnaire and qualitative analysis. Figure 7.3 shows the relation between the all these groups.

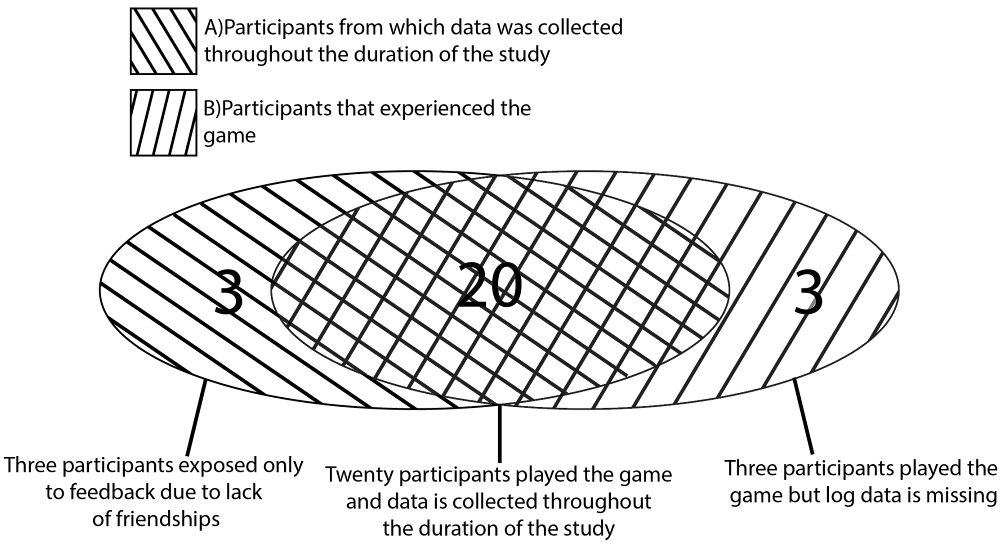


Figure 7.3: The Venn diagram indicates the groups used in the study, set $A \neg B$ represents the participants that belong to the individual group, set $A \cap B$ represents participants that belong to the game group and set B represents participants that belong to the game elements group.

7.3 Findings

7.3.1 Questionnaire

Of the 36 people who expressed interest and registered, 11 did not respond to the post-study questionnaire. A total of 25 profiles were successfully associated; 23 of these belonged to the game elements group, while 2 belonged to the individual group.

A multiple choice question asked participants if they knew what computer sleep is. The available options were: "Yes, computer sleep is a power state that consumes less energy than hibernation power state", "Yes, computer sleep is a power state that consumes more energy than hibernation power state", "Yes, computer sleep is a power state in which the computer does not consume energy at all". Before the study, 14 participants chose the correct answer ("Yes, computer sleep is a power state that consumes more energy than hibernation power state"), while 21 replied correctly to the same question on the post-study questionnaire. All 7 participants who learned what computer sleep is, belong to the game elements group.

A similar pattern exists for the hibernation query. A multiple choice question asked participants "Do you know what computer hibernation is?" 14 participants answered correctly on the pre-study questionnaire, and 20 on the post-study. Participants who replied wrongly before the study and correctly after were part of the game elements group.

In both the individual and game elements groups there was knowledge on computer-based power settings and how to sleep and hibernate the computer. The questionnaire showed that the system helped people learn. When they were asked "How often do you sleep or hibernate your computer during the day?", 12 provided the same response to both the pre- and post-study questionnaire, 9 increased their use of sleep or hibernation, while 4 decreased. The questionnaire did not enquire of the shutdown rate, therefore it is not clear whether the reductions reported were because participants were not working sustainably or because they switched off more often.

The majority of the game elements group enjoyed catching a computer, followed by watching the leader board. They also mentioned other options: "*Running to touch the pad to stop being idle*"; "*Being told how much time I'm wasting*"; "*Seeing my computer idle time*"; "*Avoiding being caught*". The popularity of each game feature is shown in Figure 7.4.

Most of the registered users had laptop computers (30) and shut down the computer by clicking the shutdown button from the operating system. This action is popular on both laptop and desktop computers (see Figure 7.5 and Figure 7.6). For laptop computers,

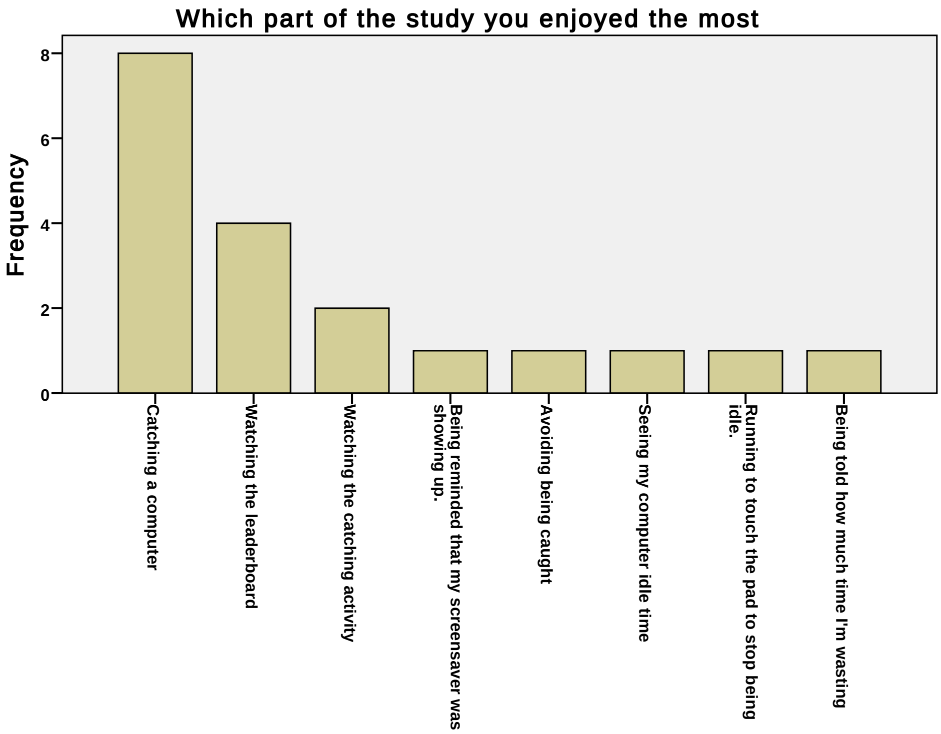


Figure 7.4: The popularity of each feature of the system

the most popular action is closing the lid[1] before the user departs, whilst desktop users sleep their computers.

7.3.2 Interaction logs

Interaction logs were automatically collected by the system, including idle and active time, catch attempts, and Web page views. During the second and third weeks, there was a 25% and 23.4% reduction of the total idle time compared to the first week, for the game group. In total, 15 participants out of 20 (game group) caught a computer at least once. Most catching activities happened during the second week with 51 successful catches, while in the third week 31 were caught. The 82 catches in total took place on 17 computers, which were caught from 1 to 14 times.

The log files show that the median percentage of the computer idle time reduced during the second and third weeks compared with the first week (see Figure 7.8). This histogram takes into account participants who have friendships with one or more participants (game group). It indicates a trend that the game had an effect on participants' behaviour. Figure 7.7 shows that, for the game group, laptop computers have a high percentage of computer idle time (6.4%) during the first week, reducing in the second week to 5.4%, while the third week was the lowest reported at 4.1%. On average the desktop

[1] Closing the lid of a laptop computer can sleep or hibernate it depending on hardware capabilities and software settings.

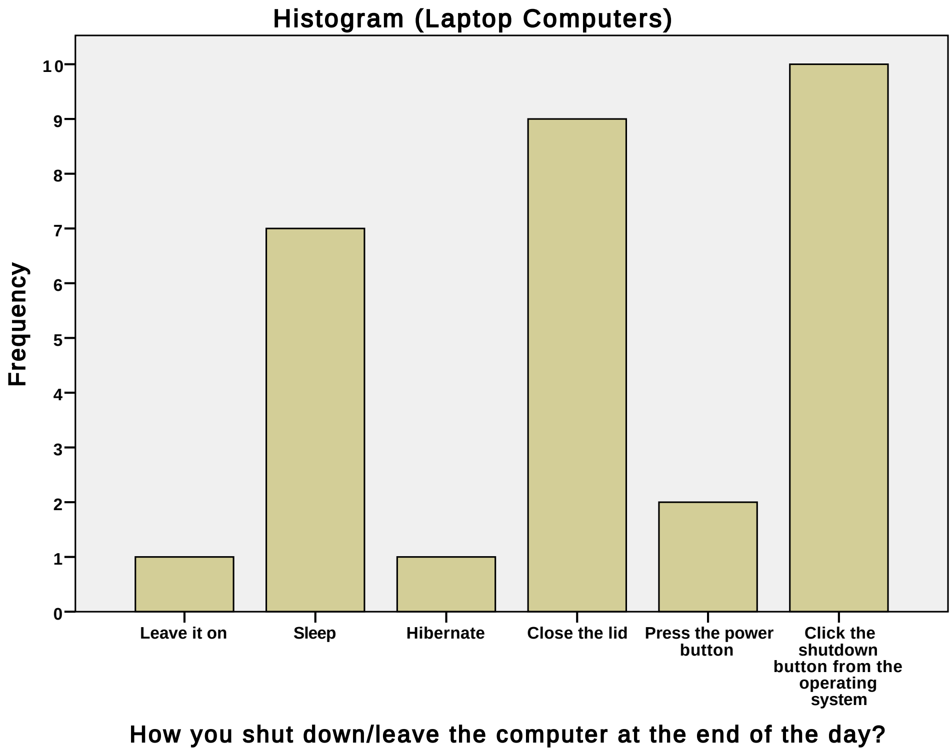


Figure 7.5: How laptop-owners shut down their computers before they installed EcoScreenCatcher

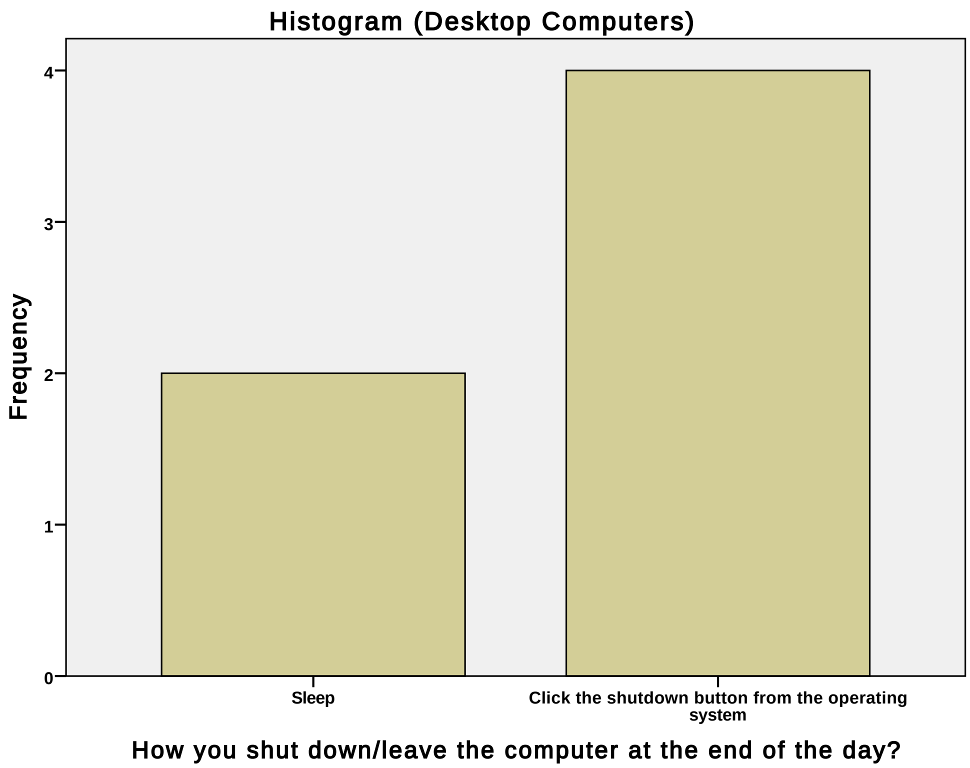


Figure 7.6: How desktop-owners shut down/sleep their computers before they installed EcoScreenCatcher

computers had a decrease during the second week (4.6%), but increased in the third week (11.7%). The best performance, of laptop computers in the third week, might be due to the convenience provided by laptops from closing the lid.

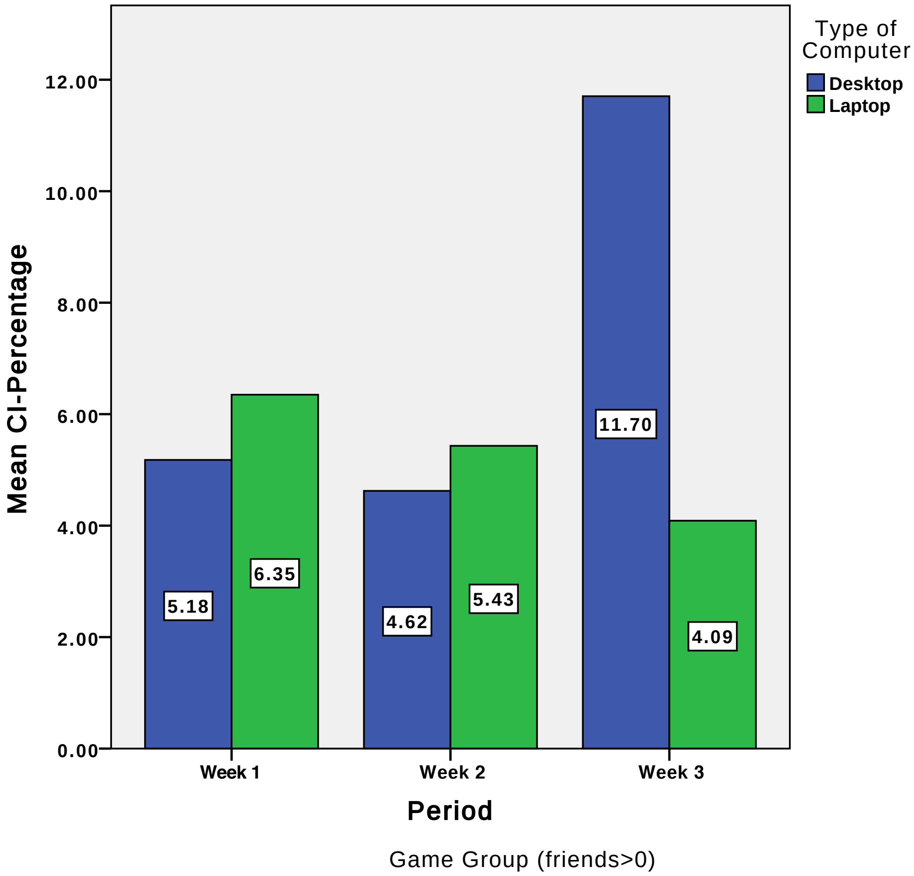


Figure 7.7: Mean percentage of computers during the 1st, 2nd and 3rd week

7.3.2.1 Attitude change

The main interest is to examine whether the game intervention reduced computer idle time. To test for this, a Kolmogorov-Smirnov test of normality was performed. The test showed that the data does not follow a normal distribution. Therefore, a Wilcoxon signed-rank test was performed, which is a non-parametric equivalent of paired samples t-test (Wilcoxon, 1945). No statistically significant results were found between the first, second, and third weeks, (comparing each pair of weeks) for the game group. If only participants who had four or more friends in the game ($n = 12$) are considered, a significantly lower computer idle time was seen on the second week ($Mdn = 87.2$ mins) compared with the first week ($Mdn = 133.4$ mins), $z = -2$, $p < 0.04$, $r = -0.40$. A trend was also noticed (not statistically significant, though) for participants with one or more

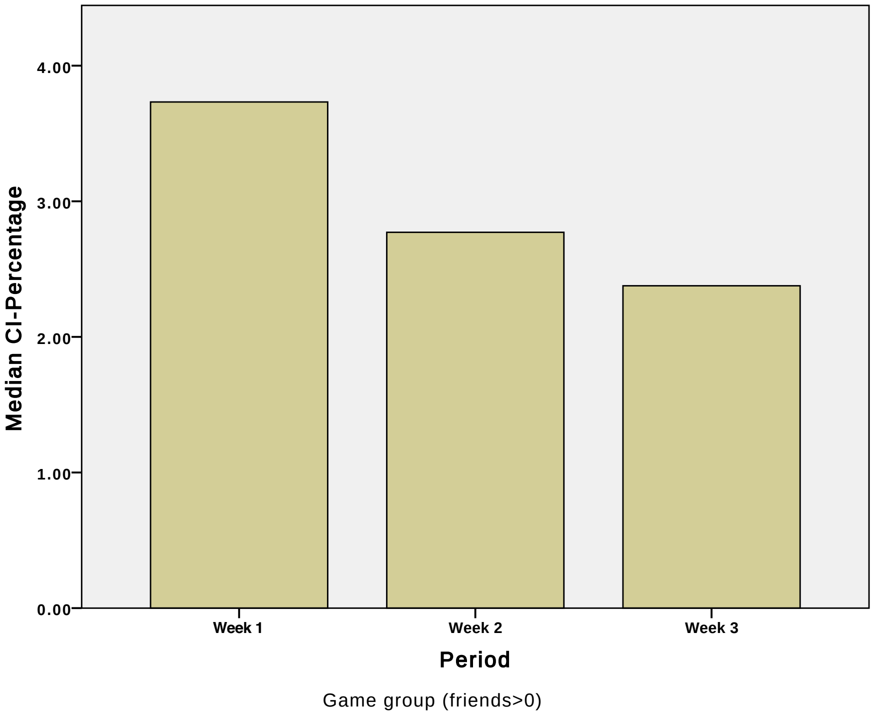


Figure 7.8: Median percentage of computers during the 1st, 2nd and 3rd week for the game group

game friends (game group) to have less idle time in the second week than in the first (z = –1.9, p = 0.05, r = –0.4).

To better understand what parameters influence behaviour, the number of catches each participant performed was examined. Participants from the game groups who caught two or more friends (n = 8) showed significantly lower computer idle time in the second week (*Mdn* = 87.2 mins) compared with the first week (*Mdn* = 137.2 mins), z = –2.5, $p < 0.01$, r = –0.6. A similar pattern exists with other variables. More specifically, participants from both game and individual groups having four or more page views on "catch a computer", or "catch activity" or "leader board page" (n = 17) showed significantly lower computer idle time in the second week (*Mdn* = 60.7) compared with the first week (*Mdn* = 132.8), z = –2.4, $p < 0.016$, r = –0.4. This trend indicates a correlation between Web site engagement (in the context of page views) and waste reduction.

A similar correlation exists between Web site engagement and low idle time from participants only in the game group. Participants from the game group having more than three page views on "catch a computer", or "catch activity" or "leader board page" showed significantly lower computer idle time in the second week (*Mdn* = 83.7 mins) compared with the first week (*Mdn* = 132.8 mins), z = -2, $p < 0.04$, r = –0.36. A statistical analysis of the individual group was not performed due to insufficient cases. Finally, to evaluate the possible difference in attitude between groups having multiple friends and that having one or none, a Mann-Whitney U Test (Mann and Whitney, 1947) between the groups was performed. The computer active and idle time for the first, second and third weeks was taken into account but there were no statistically significant results (more information on the tests is in Appendix A).

7.3.2.2 Atributes Influencing Computer Usage

An interesting finding is the difference between males and females in the use of a computer. A Mann-Whitney U Test revealed significant differences in the duration the computer was active during the first week for males (Mdn = 3224 mins, n = 11), and for females (Mdn = 2219 mins, n = 12) $U = 32$, $z = –2.1$, $p < 0.03$, $r = –0.30$, with males being more active. A similar significant trend appeared during the second week, in the duration the computer was active for males (Mdn = 3869 mins, n = 11), and for females (Mdn = 1871.4 mins, n = 12), $U = 16$, z = -3.1, $p < 0.00$, $r = –0.45$. The same test revealed no significant differences in the third week for males (Mdn = 2433.5 mins, n = 11) and females (Mdn = 2305.4 mins, n = 12), $U = 50$, z = -1, $p < 0.32$, $r = –0.14$. Figure 7.9 shows the distribution of the duration of computer active time between males and females throughout the study. For more detail on gender-related statistical analysis, see Table A.2.

The source of the difference in the total duration of computer use between males and females might be arise from PC requirements on courses that males and females attend, with courses females attend possibly being less demanding on PC usage. Another reason might be the lifestyle young males and females have. An example might be males playing PC games for longer hours. Another reason might be the type of computer young males and females prefer. In this study, only the males had desktop computers.

By comparing the active time of all participants from both groups (game and individual, N = 23), it can be seen that the majority of laptop computers were less active compared with desktop computers throughout the study. This trend is clearly visible in Figure 7.10. The difference was statistically significant only for the second week. The test revealed a significant difference in the duration the computer was active during the second week between desktops (Mdn = 4109.1 mins, n = 5), and laptops (Mdn = 2064.9 mins, n = 18) $U = 9$, $z = –2.7$, $p < 0.00$, $r = –0.39$. The same trend also existed in the game group where, throughout the study, laptop computers were less active compared with desktop computers. In particular, a Mann-Whitney U Test showed a significant difference for the game group for the computer being active in the second week between desktop (Mdn = 3989.5 mins, n = 4), and laptops (Mdn = 2185.6 mins, n = 16) $U = 9$, $z = –2.2$, $p < 0.02$, $r = –0.34$.

For all participants, the test revealed no significant difference in the duration the computer was active during the first and third week. The statistics for the first week are:

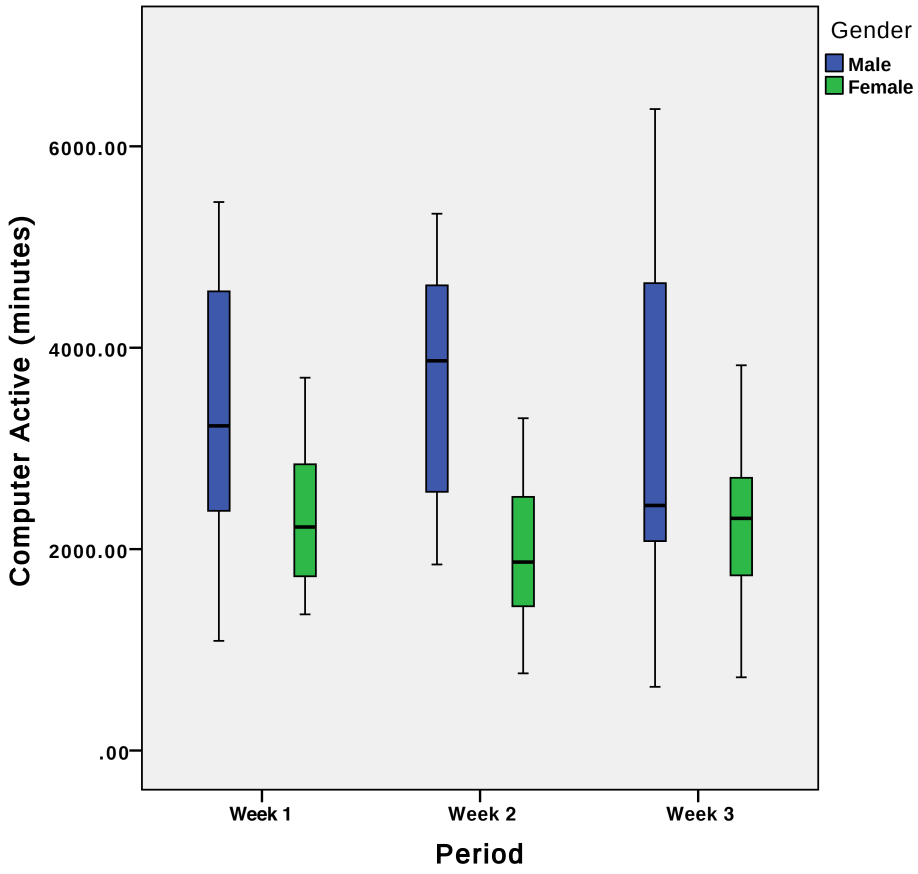


Figure 7.9: Distribution of the duration the computer being active among males and females throughout the study

desktops (Mdn = 2597.6 mins, n = 5), laptops (Mdn = 2319.3 mins, n = 18), U = 27, z = –1.3, p = 0.17, r = –0.19, and for the third week are: desktop (Mdn = 3386.2 mins, n = 5), and laptops (Mdn = 2305.4 mins, n = 18) U = 27, z = –1.3, $p < 0.17$, r = –0.19. Similarly, the game group showed no significant differences in the computer being active for the first and third week. More specifically, the statistics for the first week are reported in Table A.4. Note that the number of desktop computers is quite small (n = 5) in comparison to the laptop computers, and all desktop users were males. Therefore it is not clear if these results are directly related to the type of computer or is gender-related.

7.3.2.3 Correlations

These results show a correlation between engagement with the Web site and waste reduction. To understand how these variables correlate with each other, a Spearman's Bivariate correlation test was performed on: the type of computer, the number of views on the leader board for the game group, "catching activity", "catch a computer", the

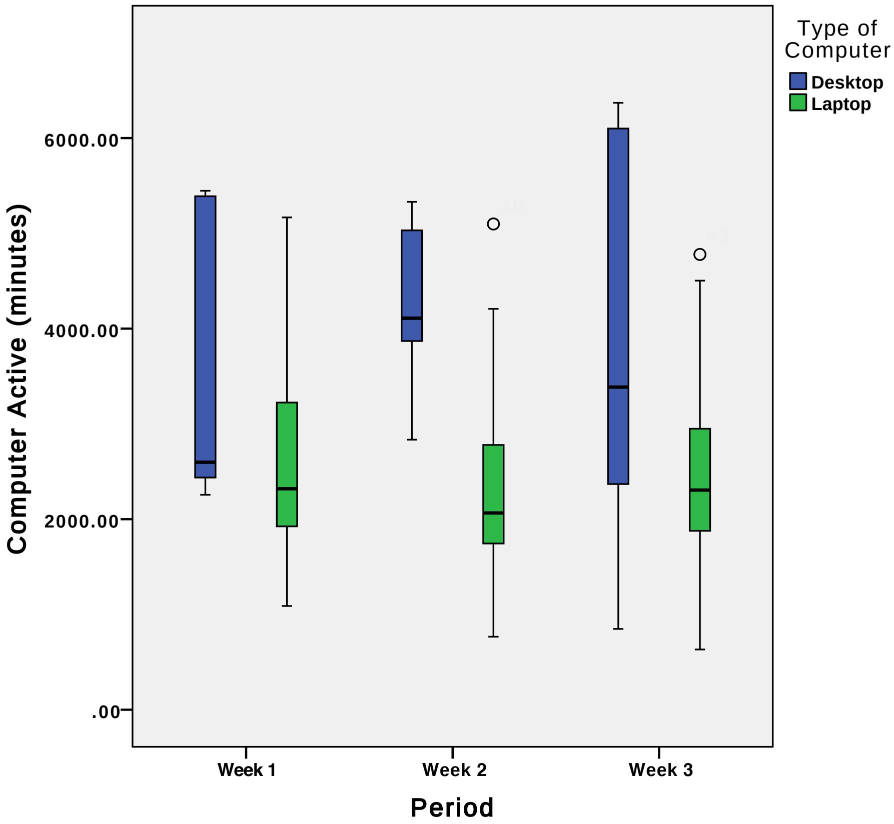


Figure 7.10: Distribution of the duration the computer was active among desktop and laptop computers throughout the study, the diagram includes participants of both groups game and individual N = 23

number of friended participants, and the number of computers caught. Only statistically significant results having large correlation coefficients (> 0.7) will be addressed.

There was a strong, positive correlation between the leader board views and catching activity views ($r_s = 0.85$, $n = 18$, $p < 0.00$). Squaring the correlation coefficients indicates that these two variables share 73.2% of their variance. A scatterplot is shown in Figure 7.11. The n is 18, and not the total in the game group, because two cases were eliminated as outliers (having a high number of page views on both Web pages).

A similar positive correlation appears between the views of the leader board and "catch a computer" ($r_s = 0.80$, $n = 18$, $p < 0.00$). Squaring the correlation coefficients indicates that the two variable share 64.8% of their variance. A scatterplot is shown in Figure 7.12.

The catch a computer Web page is also positively correlated with the number of computers a participant caught ($r_s = 0.75$, $n = 18$, $p < 0.00$). Squaring the correlation coefficients indicates that the two variables share 56.6% of their variance. This is a relatively obvious correlation because catching a computer has the prerequisite of going to "catch a computer" Web page. The more often they visit the page the higher the chance of catching a computer. A scatterplot is shown in Figure 7.13. All the aforementioned correlational results show that people who caught a computer engaged with both leader board and "catch a computer" Web pages.

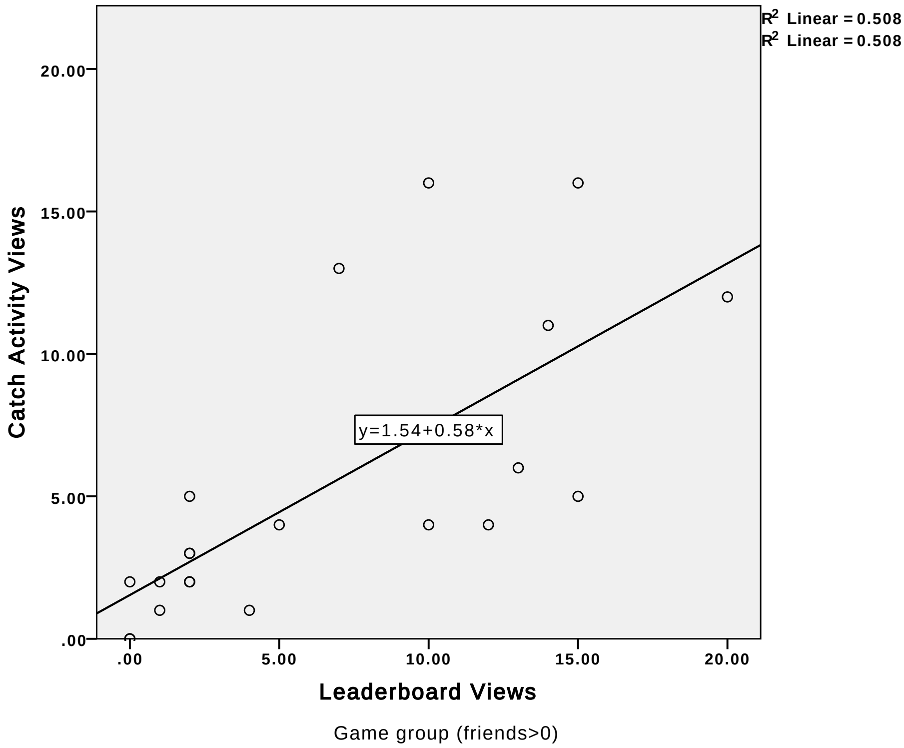


Figure 7.11: Correlations between "catch activity page views" and "leader board page views"

7.3.3 Qualitative Analysis

26 participants took part in the interviews. The remaining 10, even though invited to participate, did not respond. Participants in the interviews included those from both game and individual groups, and those for whom either the software stopped working (2 had installation issues), or for whom there were other issues (8 had installation procedure issues) resulting in missing data.

These latter 10 participants were excluded from the quantitative analysis due to insufficient data. The analysis of the one-to-one semi-structured interviews used an approach inspired by thematic analysis. The analysis started by categorising the material at the sentence level. The focus is on themes (Braun and Clarke, 2006) related to the evaluation of the EcoScreenCatcher system and participants and their perceptions of waste.

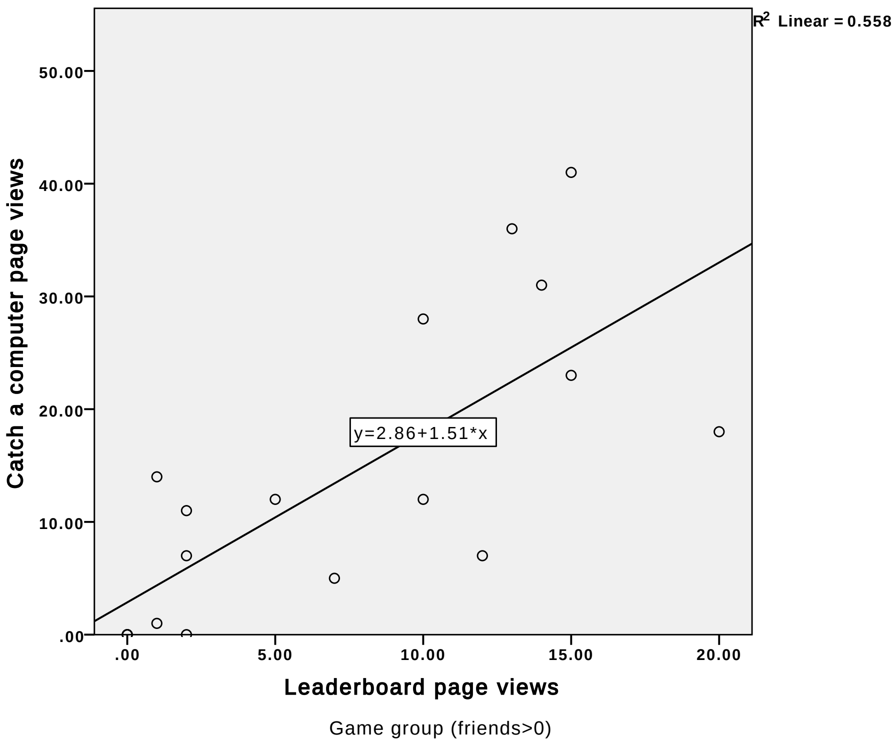


Figure 7.12: Correlations between "catch a computer page views" and "leaderboard page views"

7.3.3.1 Incentives to Save Energy

EcoScreenCatcher game is considered as an incentive mechanism for sustainable behaviour. Some of the laptop users reported that the lack of access to a power source acted as an incentive to change the laptop's power settings to more energy-saving ones in order to maximise the use of time on the laptop. Some participants reported dimming their monitors; changing their power plan to an energy-saving one; using only necessary applications; and closing unused ones when working on the move. "*Yes, well firstly you have the power setting which is low battery power setting and then after I would kind of close applications such as Skype and, well others I would try to resume kind of what I would be doing. And the practice would be quite low probably. So yes.*" [P9, friends: 8, computer type: laptop, catches: 1]. Participants also reported closing the lid when the laptop was not in use. "*When I am finished what I am doing, I put it on sleep rather than leaving it on because you want to get the maximum battery life out of getting one charge.*" [P24, friends: 8, computer type: laptop, catches: 1].

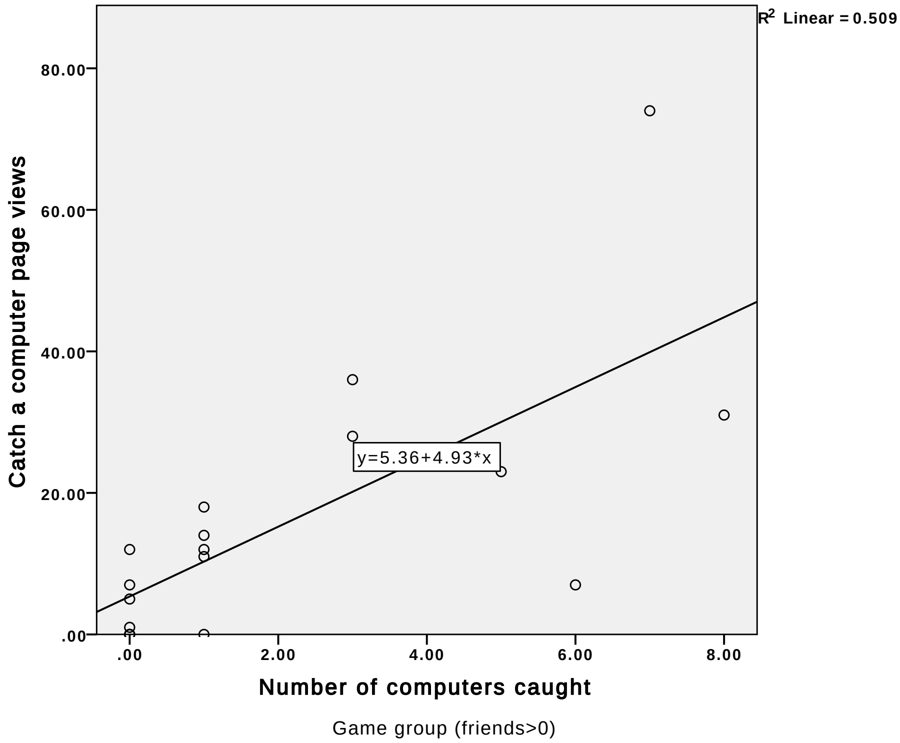


Figure 7.13: Correlation between "catch a computer page views" and "Number of computers caught"

7.3.3.2 Awareness

Qualitative analysis showed that the system (in both game and individual groups) raised awareness related to computer energy waste. More specifically, "*... It [the game] really made me more aware when I wasn't using my computer and it was still on and therefore using energy.*" [P6, friends: 1, computer type: laptop, catches:0]. Another participant reported similarly "*It's really good, I liked it a lot. [It] definitely made me more aware of how much energy I waste.*" [P3, friends:14, computer type: laptop, catches: 3]. There were also reports of raising awareness on computer usage in general, where participants tried to reduce the number of hours they used their computer "*... But I was more conscious of it. I thought, every time I put my laptop 'When I go over' If I come back home, get my laptop out, I think, do I actually need to turn it on right now? Am I actually going to turn it on and do my assignment or am I just going to turn it on, play some music and just wander off somewhere? So, it kind of did stop me for a bit and made me use my laptop slightly a bit less.*" [P15, friends: 0, computer type: laptop, catches: 0]. Given that this quotation comes from someone in the individual group, it can be inferred that prompts and daily feedback are capable of raising awareness. Similar findings, where persuasive prompts were successful in not only raising awareness but also in reducing device usage (in this case mobile phones), has been reported by Hiniker et al. (2016).

7.3.3.3 Change in attitudes

Participants also reported a change in attitudes towards sleeping/hibernating and shutting down their computer more often. One participant reported an attitude change when they stopped using their computer to engage in other activities (e.g. cooking), something that did not happen before the study, "*I am more aware of wasting energy now, so instead of say, when I cook, I'll just close the lid now.*" [P3, friends:14, computer type: laptop, catches: 3].

After playing the game, P16 expressed interest in keeping that behaviour even after the study, "*... Before that,[...] it's just a computer telling at me that how many times I've been left my computer idle. But now, I have the incentive to keep it more efficiently use of electric? Yes. ... I tend to keep that good habit.*" [P16, friends: 10, computer type: laptop, catches: 7]. Similar to the IdleWars study, some participants had the ingrained habit of only switching off the monitors when they leave their desk. However, EcoScreenCatcher was different from IdleWars, since the timer was still ticking even when the monitor was off and therefore making them lose points, and this incentivised them to sleep the computer. "*Well, before I installed it, I always just used to leave my computer on with the monitors just turned off. I'd just turn the monitor off and leave it, I did not really think much of it. But then I installed the game, I realised wait, that will actually just still tick the timer down, so even now, after I've uninstalled it, I just put it to sleep instead. And I, I kind of did not realise how easy it is to sleep and unsleep it, so I guess in that sense it did work, because I always put it to sleep now.*" [P20, friends: 17, computer type: desktop, catches: 6]. Changes in attitude were also reported in terms of switching the computer off at the end of the day instead of putting it to sleep: "*... I started turning my computer off at night because I used to just put it to sleep or just close the lid. But now I turn it off.*" [P25, friends: 0, computer type: laptop, catches: 0]. "*I was doing it during the study as well, yes. [It] kind of started about halfway through.*" [P25, friends: 0, computer type: laptop, catches: 0].

A change in attitude has been reported from a participant with regards to her 6 friends[2] playing the game, reporting that towards the end of the study, the idle time of her friends was less, making it difficult for her to catch them "*Yes, I was constantly trying to catch people. I only had five friends playing it. So there weren't that many people but yes, I would always try and catch people. I think it was the second week when the game was actually active that I actually caught people and the third week I think I only caught one person. I'm not too sure but towards the end, I think people started getting smarter and were less idle but in the beginning, I was catching. I think I caught quite a few people. Maybe three times.*" [P10, friends: 6, computer type: laptop, catches: 5].

[2]This participant forgot one friend, as the log file indicates that she has 6 and not 5 friends.

7.3.3.4 Spill over effect

The game triggered energy-saving behaviour not only with computers but other devices as well. P22 reported a spill over from computers to lights, "*In my house, I have the cooker-hood which has a light on it. Before I would just leave it on when I was cooking, even when I was away, and now I try to switch it off because that is more energy-saving. Switching off lights when you are not in the bedroom, in the toilet.*" [P22, friends: 14, computer type: 2, catches: 8]. Similar behaviour was adopted with regard to other resources like water, "*... I used to take quite long showers, in the past month or so, because of the game as well. I think I've been more aware and I've been trying to take normally five minutes a shower.*" [P3, friends:14, computer type: laptop, catches: 3]. A participant living in a shared house reported that his housemates adopted a sustainable behaviour towards computers. The discussion triggered because of the screen saver prompt appeared on the computer screen, "*I spoke to my housemates about it [the study] and I told them that it was basically to raise awareness about computer usage and electrical inefficiency. In fact, it was quite funny because they then started to be more careful about their computer usage. Even I noticed my friend normally studies on the dining table and he leaves his laptop on for about one hour. But every time he went out of the room he would turn it to sleep immediately. So that was a habit that I was quite surprised at.*" [P24, friends: 8, computer type: laptop, catches: 1]. Others expressed interest: "*I told my girlfriend. [...] She was interested what it was because I left it at her house once and she asked "why is your laptop saying you have been wasting energy for a minute"... [I] told her it was part of a study [...] I explained to her what it was. She was just interested in what it was really, why my laptop had been saying something and counting time.*" [P6, friends: 1, computer type: 2, catches: 0].

7.3.3.5 Waste perception

When asked what household activities they perceive as wasteful, participants reported appliances being on and not in use. The majority of them said lights, "*People who leave lights on? Typically, in my flat it is censored but the bathroom light there is a pull switch, one that is left on sometimes from my girlfriend that annoys me sometimes.*" [P11, friends: 1, computer type: laptop, catches: 3]. As well as other appliances such as: the oven, TV being on standby and leaving the phone, or laptop to charge, even though the battery is already charged, "*When people leave their phone charging on overnight. That's another one. It's unnecessary waste. Because even when your phone fully charges, you see a blue light that comes on your phone. It shows that there is some current flowing through the circuit and that wastes electricity.*" [P6, friends: 1, computer type: 2, catches: 0]. Others reported overcharging as waste in general, "*I try not to overcharge stuff. As soon as it is 100% battery I take it off.*" [P26, friends: 2, computer type: laptop, catches: 0].

Even though most of the participants reported as waste appliances being on and not in use, there is no universal agreement on the threshold of how long the device needs to be on to be considered waste. As the primary aim of the study is computers, the following comments focus solely on that. The interviews demonstrate that convenience is a major factor that shapes how participants perceive waste. P18 justified computer-related waste based on the time it takes to do frequent activities such as going to the bathroom and making tea, "*In my opinion it should be slightly more [than five minutes] because for example I live on the second floor of the house and if I go to the kitchen to have a cup or water, I always waste around four minutes, and if I see someone in the corridor we will chat for one minute, and so it is already five minutes. Not really more, but around seven minutes? Because I waste probably two minutes in the bathroom when I go.*" [P18, friends: 13, computer type: laptop, catches: 1]. A similar perception was reported by P21, "*Sometimes the small tasks that you do in the house like to get the washing out, or hang it up, or wash the dishes really quickly, that's going to be 10 minute intervals. But it shouldn't [be] half an hour because then there is almost no point in having it as there aren't even that many 'half an hours' in the day.*" [P21, friends: 1, computer type: desktop, catches: 0].

There was a similar perception, of using a resource but not utilising it fully, reported for other resources such as water and food. Again, the perception of depleting a resource when not in use persists in the context of water having the tap on when not in use "*... I knew someone that purposefully leaves the tap on when she is brushing her teeth, and I consider that to be wasteful. She was not the type of person that just brushes for 10 seconds. She does it for a full two minutes... She actually leaves the tap on, brushes for two minutes and the tap goes on and on for two minutes.*" [P4, friends: 13, computer type: laptop, catches: 0, no data for first week due to installation issues], as well as "*... opening the tap fully when you just need a little bit.*" [P22, friends: 14, computer type: 2, catches: 8].

Another important factor is how fast and easy, and therefore convenient, it is to activate the computer again, "*I think five minutes is alright, five minutes is fair enough. Especially if it's easier to reconnect once you've got back. Because on my laptop I just have a password and I go in, I put it that way. But if I did not have to do it, then it would be even more practical if you just had to click on your mouse and then, you know, the screen, there it is.*" [P3, friends:14, computer type: laptop, catches: 3]. Some participants considered 3 hours of inactivity to be wasteful: "*Eight hours [of inactivity] is very wasteful. About three hours - if I was going to leave the house for that, I will turn the laptop and the lights off.*" [P12, friends: 10, computer type: laptop, catches: 12].

Comfort was sought, and therefore wasted on tasks on the computer side, where waste perception was influenced by the work they were doing on their computer, "*I think it sort of depends on what you're doing. So like at the moment I'm doing a sort of coursework* *piece on a magnetic plunger, so it's a lot of watching simulation run and putting stuff into Excel and sort of analysing it, so looking at data a bit. So there five minutes was kind of a bit short, but if you're just browsing the internet and then getting distracted and then doing something else, then it's fine. So it, it just depends entirely. I think I had mine set to about 15 minutes.*" [P2, friends: 0, computer type: desktop, catches: 0].

Throwing away food leftovers is considered wasteful, "*... but what is just generally wasteful is when people don't eat all their food and just throw it in the bin.*" [P21, friends: 1, computer type: desktop, catches: 0]. Waste is also considered the improper management of food resulting in it going bad, "*... or maybe we buy a lot of food without noticing the expiry date, and we don't, like, manage well on the food. So we have to throw it away.*" [P16, friends: 10, computer type: laptop, catches: 7]. Food waste was reported by half of the participants (n = 13) making it the second most popular option after electricity. One of them justified its popularity due to its tangible aspect and the costs associated with it: "*[I picked food because,] when you are at the store, you are trying to pick [on] price [but] you are really focusing on what you are looking at, and when you purchase it is almost like a tangible... it is more tangible than the price. When you see it expire, [it] is no longer good and it actually hurts.*" [P11, friends: 1, computer type: laptop, catches: 3]. "*You literally see yourself throwing money in the garbage.*" [P11, friends: 1, computer type: laptop, catches: 3].

Throwing food is also considered waste because it is nurtured from parents to their children and from culture: "*... I think it was the monks that produced, like they had the farms so they were the ones who produced the rice and everything. So, they're the ones who provided the food for everyone so I think it was ingrained in that era that we shouldn't waste the food that they've actually made for us. So that every time we have some meal we'll say this word called* ***Itadakimasu*** *just as, it kind of means thank you very much for the food and just to be grateful. So I think it might be culture that's kind of ingrained, thinking that wasting food is bad, like that's kind of ungrateful. I think that's why.*" [P15, friends: 0, computer type: laptop, catches: 0].

Excessive use of resources is also perceived as waste by the participants. For house temperature, heating the house beyond an individual's comfort level is considered wasteful, "*People having places a little too hot I don't like because it is considered wasteful as well also because I like my place typically a little bit cooler. In England, people have 60° F (15.5° C) in the house which is way too cold for me.*" [P11, friends: 1, computer type: laptop, catches: 3]. Excessive use of water is also reported being wasteful: "*I waste water as well because, when I go from the bathroom, normal people have a shower for 5 minutes and I take half an hour. So I waste quite an amount of water. And people in the third world, don't have water at all and I don't feel good about it.*" [P18, friends: 13, computer type: laptop, catches: 1].

Participants perceived as waste having an appliance consuming resources towards an outcome (e.g. heating the room) and performing an action that causes the opposite effect (e.g. opening a door or window), "*Heating with the windows open for example, that's very [wasteful] even though it's very comfortable.*" [P4, friends: 13, computer type: laptop, catches: 0, no data for first week due to installation issues].

7.3.3.6 Human element of feedback

If we consider catching a computer as a feedback mechanism coming from a human, such a mechanism triggered peer pressure towards adopting a sustainable behaviour. More specifically, P1 mentioned: "*I think right at the start I wouldn't think anything about waste, whereas now, I believe "oh, no what if the screen comes up to say you have been wasting energy for this long, and this guy catches me again and I can't". I think I definitely tried more than I did than before.*" [P1, friends: 6, computer type: laptop, catches: 0]. Computer-based feedback is considered less motivating compared with human-based feedback: "*Back to the scenario of the machine telling you, it's not healthy interaction, and I think it's less motivation for us too.*" [P16, friends: 10, computer type: laptop, catches: 7]. *"So you feel more mobilised to reduce your idle time if a person tells you rather than a machine tells you?" [INT]*
"Yes." [P16, friends: 10, computer type: laptop, catches: 7].

Similarly, this time focusing on feedback originating from a friend is also considered more influential compared with a machine: "*It's just because your friend is reminding you. If it's a machine, the machine is kind of like, an everyday thing. From calendars to alarms, it's really kind of like, normal. But if a friend catches you it's, like, you're reminding me of my bad habits, yes.*" [P14, friends:1, computer type: laptop, catches: 1].

7.4 Discussion

The questionnaires revealed that both the game and the feedback mechanisms, educated recipients about computer-related power settings. Even though there was a decrease in the frequency of sleep and hibernation actions during the day, it is not clear whether this is because participants are losing interest or they started shutting down their computers more often. Participants reported a changed attitude towards shutting down the computer instead of sleeping it, even though this action did not have benefit to the participants other than eliminating consumption. The log file analysis showed that the game triggered sustainable behaviour for players with four or more friendships. Participants who engaged with the site through page views (on the leader board, catch a computer, or catch activity page), showed idle time reduction in the second week compared with the first week. The log file analysis showed males being more active than females during the first week and second week. The post-study semi-structured interviews showed spill over effects to other appliances, to resources other than electricity (e.g. water), and to people who do not participate (e.g. housemates). Moreover, the feedback mechanism (existing in both game and individual groups) raised awareness and, combined with the game, triggered sustainable attitudes. Finally, the semi-structured interviews showed that the game was successful as a motivational mechanism. The interviews also revealed in the majority of participants considering as waste appliances being on and not in use.

7.4.1 Human involvement and behaviour change

Catching a computer (a feature used by the game elements group) or the "fear" of being caught was reported from the questionnaire as the favourite feature of the game. Catching was the only difference between the first, the second and third weeks (for the game group), showing significant reduction of computer idle time during the second week for members of the game group with four or more friends. The study started at the beginning of a semester. P2 stated during her interview that she started her coursework during the last weeks of the study, and five minutes was considered good as a part of a game, but not during periods when she had deadlines. The lack of significant results between the first and third weeks might be because some students started working on their coursework requiring simulations to be run. Such a condition is considered wasteful in the current version of EcoScreenCatcher. Having four or more friends created adequate peer pressure to change behaviour. Another reason might be that participants with more than one friends were more committed than the one who did not.

"Catching a computer" can be considered a feedback mechanism originating from a person (rather than e.g. from a sensor). The study shows that such feedback originating from humans was effective and likable, even though sporadic. This result has potential for future eco-feedback systems combined with sustainability enthusiasts to guide people towards a goal (e.g. Environment Champions for the work environment, Team facilitators for the home environment). Environment Champions are professionals or volunteers highly knowledgeable and enthusiastic about energy conservation in the work environment, whilst Team Facilitators support neighbourhoods on environmental issues (Nye and Hargreaves, 2010). Their main responsibility is to carry out inspection on buildings and provide guidance, and advice, and support on energy conservation best practice. Eco-feedback systems are persistent and useful "persuasion" tools but they lack knowledge on how people perform activities and what resources they use from their environment to achieve comfort (Pink et al., 2008), as well as practices they perform to achieve a certain level of comfort and convenience. Human involvement is important to prevent consequences on the well-being of vulnerable populations (Buchanan et al., 2015). An Energy Champion can assess the environment as well as resources used and suggest ways to reduce environmental impact whilst keeping the desired levels of comfort, convenience and well-being.

A human being as a communicator is essential for any system designed for providing information (and other actions such as *ad hoc* messaging) around sustainability because it adds trustworthiness and can activate social norms. A trustworthy system is one with high persuasion capabilities (Fogg, 2002). A human Energy Champion increases the credibility of the overall system by working as a gatekeeper for the fairness of the information provided (for the given environment). The data show that the minutes it is acceptable for the computer to be considered idle is influenced by the size of the household and the time it takes to perform a frequent task and return to the screen. An Energy Champion also provides depth-based learning on green actions (beyond the obvious switching off appliances when not in use) tailored to different environments (Woodruff et al., 2008). In the EcoScreenCatcher, information is provided on ways to save energy and understand the different computer power setting modes. A good example of depth-based learning is a study showing that energy-saving tips helped participants to save more energy (Geelen et al., 2012). An expert can also provide encouragement, more specifically, a person is more likely to adopt a particular behaviour when encouraged by others (Cialdini, 2003). This work has shown how the game group, via the catching action, worked as an injunctive norm and incentivised people to reduce their computer idle time in the short term.

7.4.2 Competition beyond comparative feedback

Most studies on household-oriented games that utilise competition use mainly comparative feedback, where people can compare their performance with others (Geelen et al., 2012; Kimura and Nakajima, 2011; Kaufman, 2009). Competition is a powerful motivation and one way to trigger it is through comparative feedback (Malone and Lepper, 1987). The drawback of comparative feedback is that people at the bottom of the ranking have a tendency to lose motivation (Brandon and Lewis, 1999). This work uses comparative feedback, but it lasts for only a week, giving a fresh start every Monday and motivation to players featuring at the bottom of the leader board. In addition, the focus is on a different aspect of competitiveness where participants interact by expressing mild disapproval in the gamified form of catching a computer. The questionnaire showed that catching a computer was the favoured feature of the system. This result, combined with significant reduction in computer idle time for the first and second week for participants from the game group with four or more friendships, suggests that the catching action provided an additional incentive to engage with the system.

The Fogg Behaviour Model identifies three factors that must occur at the same time for the required behaviour to happen (Fogg, 2009): Motivation, Ability, and Trigger.

Figure 7.14 shows a visualisation of the model, where the vertical axis indicates the motivation and the horizontal the ability, while the star represents the target behaviour. The higher the motivation and ability the more likely the target behaviour is to occur. This study used a minute counter on the computer screen to act as a trigger. Technology can contribute towards facilitating ability by making a certain action easier to perform. Throughout the study, the trigger and the ability did not change. Therefore, we argue that "catching/fear of being caught" act as a behaviour change motivator, being realised with the involvement of a human rather than being caught by a machine.

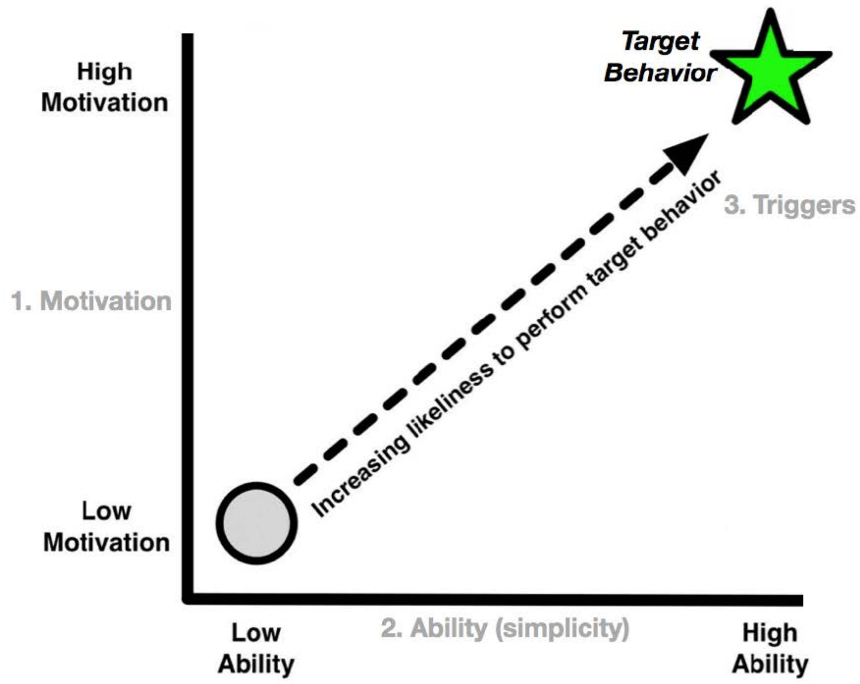


Figure 7.14: The Fogg Behaviour Model (Fogg, 2009)

7.4.3 Using prompts to trigger spill over effects

The screen saver was designed to work as a prompting mechanism (trigger), drawing attention to energy waste and inviting the participant to sleep, hibernate or shut down her computer. Studies have shown that prompts can encourage pro-environmental behaviours like recycling (Austin et al., 1993), but this has been criticised for performing successfully only in the short-term (Schultz et al., 1995). The interviews showed that prompts triggered pro-environmental spill over effects, not only to other appliances (e.g. switching off lights to save energy), and resources (e.g. water, by taking shorter showers), but also to other household residents exposed to it (e.g. housemates started switching off their PCs after being exposed to the prompt). The idea of the lights not being left on is a direct extension of the game idea, whereas the idea of shorter showers is quite different, because it reduces comfort. The interviews also showed that participants from the individual group became more aware of the environmental issues around energy waste and also reported an attitude change, but this impact could not be quantitatively evaluated. This finding could be explained by the way the study was designed (limited number of participants in the individual group).

7.4.4 Eco-feedback systems as a mechanism of learning and challenging peoples' perception of waste individually

Eco-feedback systems focused on waste, combined with nudging mechanisms such as a game, have the potential to change behaviour. The qualitative analysis showed that waste is influenced by people's perceptions of comfort and convenience. Therefore, feedback systems must be tailored to individuals or targeted groups. Several products focus on understanding people's comfort levels, such as the Nest thermostat[3] which detects people's comfort levels based on their input when they don't feel comfortable. Future eco-feedback systems need to focus on understanding the individual's comfort levels based on factors such as habits and environment, and provide waste oriented feedback that gradually challenges their comfort levels.

Convenience also plays a major role in influencing the perception of waste. Eco-feedback systems need to facilitate sustainable activities by making them easier to perform. The computer usage log files (see Figure 7.7) showed there was a reduction of computer idle time for laptop computers (during the second week), while the questionnaire showed laptop participants sleep or hibernate their computer by closing the lid quite often. This suggests that the laptop computers delivered better results due to the convenience of closing the lid. This finding is compatible with Fogg's Behaviour Model (Fogg, 2009) wh,ere the lid of the laptop increased the ability to deactivate the laptop.

7.4.5 EcoScreenCatcher vs IdleWars

Although the number of participants in the EcoScreenCatcher study and the IdleWars study is roughly the same, a big difference was seen in catching activities for both first week (19 bust actions) and second week (9 bust actions) of the game. The EcoScreen-Catcher study experienced 51 and 31 catch actions during the second and third weeks respectively. This could be attributed to the nature of the environments; in the work environment participants are exposed to the game for a limited period only, whereas in the home environment people can catch a computer any time they want. Moreover, busting a computer in IdleWars requires more effort (walking towards the idle computer and scanning the QR code) compared with catching in the EcoScreenCatcher (clicking a button on their computer). In both studies, there is a reduction of catching/bust actions

[3] https://nest.com/

in the last week suggesting a novelty effect, as expected. In the EcoScreenCatcher study, the reduction was less (it dropped by 39%, while in IdleWars it dropped by 53%).

As in the IdleWars study, the EcoScreenCatcher game also triggered behaviour change spill over effects to household residents who did not participate in the study. In this study, the source of making the gameplay visible was the screensaver prompt whereas in the IdleWars study the main reason was the exposure of the worker to the participants of the game. Another interesting difference is how the work environment facilitated better communication compared with the home environment. Qualitative analysis of both studies found that the IdleWars game triggered more discussion among workers compared with EcoScreenCatcher, even though the latter aimed at facilitating communication (e.g. Facebook comment plugin, messaging the opponent after a catch action). The work environment has an effective means of communication such as email lists and face-to-face communication. This helped people share knowledge on computer power settings and teach those who did not know.

7.5 Conclusion

This Chapter presented an evaluation of EcoScreenCatcher, a competition-oriented serious software game designed to eliminate computer energy waste in the home environment. It showed that the involvement of the human element in eco-feedback designs, as a feedback and behaviour observation mechanism, triggered attitude change and to some extent behaviour change. A game, with prompts and feedback, is capable of raising awareness of PC energy consumption and influence attitudes towards PC energy reduction. As in the IdleWars study, the EcoScreenCatcher game also triggered behaviour change spill over effects to household residents who did not participate in the game. In this study, the source of making the gameplay visible was the screensaver prompt, whereas in the IdleWars study the main reason was the exposure of the worker to the participants of the game.

It was also seen that waste was influenced by an individual's perceptions of convenience and comfort, and is also influenced by the environment. Waste perception is important because of the aversion humans have to waste (Arkes, 1996). This shows the potential for future eco-feedback designs aiming at waste instead of consumption. Both software and humans can contribute to the identification of waste at the individual level, either by identifying comfort or making the required behaviour change action easier to perform.

Chapter 8

Future Work

This dissertation presented eco-feedback systems oriented around energy waste. Two games were developed based on PC-based energy consumption, in both the home and work environment. Both systems were evaluated qualitatively and quantitatively. In addition, to identify perceptions of waste in household appliances, FigureEnergy interviews were analysed[1]. These interviews (of consumption-oriented feedback) gave the opportunity for participants to discuss energy-related waste for the household, beyond computer equipment. This chapter focuses on potential future studies to pursue for both work and home environments. More specifically, four interesting research directions were revealed: how people perceive waste, how web site engagement correlates with behaviour change, other ways of using peers in eco-interventions, and to what extent exposure to eco-friendly behaviours of others influences non-participants.

This work investigated how people perceive waste in the home environment with the use of the FigureEnergy system. Future directions could consider investigating how workers perceive waste in the work environment. More specifically, a system that tracks electricity consumption, room occupancy and temperature could be used. This system could produce reports on workers' routines, energy consumption, and comfort. Focus groups could be conducted to allow workers to reflect on the reports and talk about how their behaviour has an impact on energy consumption, as well as what behaviour they consider wasteful.

The deployment of EcoScreenCatcher showed that engagement in the Web site page views positively correlated with behaviour change. This hypothesis could be tested in both the home and work environments. The test could potentially take into account page engagement based on the type of content each Web page provides (e.g. normative feedback, information, a game) and the impact it has on behaviour change. Pre- and post-study questionnaires could provide insights on causation of engagement and behaviour change.

[1]The development and deployment of the FigureEnergy system is not addressed in this work.

Even though human involvement in feedback was successful in engaging participants in both studies, this could be investigated further. This work investigated human involvement as part of a game intervention, physical in the work environment, remotely in the home environment. In an important design approach, human involvement was less authoritarian, i.e. arising from peers or friends. Future work could investigate other ways of human involvement such as having a weekly designated person for a household or a small group of employees responsible for mentoring consumption behaviour.

Finally, this work showed that both IdleWars and EcoScreenCatcher raised awareness of consumption to non-participants. This creates a rich opportunity to investigate spill over effects when people are exposed to feedback or other behaviour change interventions. Spill over effects could influence other environments. For example, could a worker exposed to an intervention in the work environment save energy at home, and *vice versa*.

Chapter 9

Conclusion

The general contributions of this dissertation is the introduction of a game-based waste-oriented feedback, the human involvement in feedback provision and the impact it has on work (see Chapter 3) and home environments (see Chapter 6). More specifically, the deployments conducted on both environments focused on computer-based energy oriented feedback and evaluated both quantitatively and quantitatively showing that both deployments raised awareness on energy conservation. Furthermore, in order to understand how people perceive energy waste in a household (beyond just computers) we analysed the Figure Energy (FE) interviews focusing on energy waste (see Chapter 5).

Research contribution included:

- A game intervention combined with waste oriented feedback was successful in raising awareness in both work and home environments.
- The gameplay visibility occurred in the workplace revealed the potential of behaviour spillover effect to workers not playing the game.
- From the EcoScreenCatcher study and the Figure Energy interviews we saw that waste is influenced by individual's perceptions of convenience and comfort and it is also influenced by the environment (e.g. house size).
- Similar to IdleWars, EcoScreenCatcher triggered behaviour spillover effects to household residents who did not participate in the study.
- In the home environment the involvement of the human element as a feedback mechanism in eco-feedback designs triggered attitude and short term behaviour change.

To understand how people interact on waste oriented game in the work environment, the IdleWars game was introduced to a small medium enterprise. The IdleWars study showed that the physical interaction and competition elements of the game engaged participants to play the game with participants developing tactics on how to find the idle computer (who gets up from the desk, who is in the kitchen). The gameplay visibility occurred in the workplace also showed the potential of behaviour spillover effect to workers not playing the game. Moreover, the social environment in the workplace triggered a discussion on different computer power management options. The deployment also revealed some design limitations. Firstly limitation is the leaderboard and the scoring mechanism. Having multiple scores made participants focus only on numbers they busted a computer. Secondly, the implementation enabled the person who busts to bust a computer, make it active and bust again resulting in an increased score in the busting leaderboard. Thirdly, the requirement of having the monitor active to bust the computer for participants having the ingrained habit of switching off the monitor (and not the computer) when leaving their desk. The focus group interview helped identify the aforementioned limitations and inform the design for the EcoScreenCatcher game.

For better understanding the perception of waste beyond computers, the FE interviews were analysed focusing on waste. Similarly with the EcoScreenCatcher study the majority of participants reported as waste appliances being on and not in use. They were also perceptions of waste that were not universally agreed, the EcoScreenCatcher identified convenience and comfort whereas FE identified cleanliness, culture and age. Both software and humans can contribute to the identification of waste at the individual level by identifying comfort or make the required behaviour change action easier to perform as well as taking into account attributes like culture and age. From the literature, we saw that waste oriented feedback is important because of the aversion humans have on waste (Arkes, 1996). This aversion reveals a potential for future eco-feedback designs aiming at waste instead of consumption.

To understand how people interact with a waste oriented game in the home environment, the EcoScreenCatcher game was introduced. The results showed that the involvement of the human element as a feedback and behaviour observation mechanism in eco-feedback designs triggered attitude and to some extend behaviour change. A game, prompts and feedback are capable of raising awareness on PC energy consumption and influence attitudes on PC energy reduction. The use of prompts as part of the gameplay made energy waste visible to non-participants causing in this way spillover effects. In this study, the source of making the gameplay visible was the screensaver prompt whereas in the IdleWars study the main reason was the exposure of the worker to the participants of the game. Finally, from the interviews we saw that there is no clear definition of waste and it is highly influenced from personal perceptions of convenience and comfort.

I hope this work opened up opportunities for future HCI research to design future systems related to sustainability and more specifically how people perceive waste in both work end home environments. Waste oriented feedback can be beneficial to future eco-feedback designs and games designed for sustainability. For this to be fully validated longitudinal *"in the wild"* studies need to be conducted. I also hope this work inspired sustainability designers to provide interventions that do not add excessive embodied greenhouse gas emissions for example by introducing new hardware to their designs.

Appendix A

EcoScreenCatcher

In this appendix has two sections, the first section presents all the statistical tests (statistically significant and not statistically significant) performed for the EcoScreenCatcher study is presented. A.1 shows the within-group test between the three weeks of the study. A.2 presents a between-group test with regards to the gender of participants. A.3 portray a between group test on the type of computer (desktop vs laptop). Finally A.4 display the within groups test between laptops being plugged-in and unplugged. The second section shows the semi-structured interview questions for the EcoScreenCatcher study.

A.1 Statistics

Table A.1: Within group test per week

Variables	M (SD)			z	p (2-tailed)	N	r	Filter
	Week 1	Week 2	Week 3					
CI (minutes)	**133.41 (307.02)**	**87.21 (239.07)**	**-**	**-1.96**	**0.04***	**12**	**-0.40**	**friends>3**
CI (minutes)	-	87.21 (239.07)	89.60 (173.66)	-0.39	0.69	12	-0.08	friends>3
CI (minutes)	133.41	-	89.60 (173.66)	-0.94	0.34	12	-0.19	friends>3
CI (percentage 100% = CA + CI)	4.34 (7.21)	2.771219 (6.82)	-	-1.49	0.13	12	-0.30	friends>3
CI (percentage)	-	2.771219 (6.82)	2.37 (7.52)	-0.54	0.58	12	-0.11	friends>3
CI (percentage)	4.34 (7.21)	-	2.37 (7.52)	-1.33	0.18	12	-0.27	friends>3
CA (minutes)	2721.92 (1021.96)	2627.45 (1238.91)	-	-0.39	0.69	12	-0.08	friends>3
CA (minutes)	-	2627.45 (1238.91)	2437.86 (1265.05)	-0.31	0.75	12	-0.06	friends>3
CA (minutes)	2721.92 (1021.96)	-	2437.86 (1265.05)	-0.78	0.43	12	-0.16	friends>3
CI (minutes)	**2846.30 (1033.08)**	**3281.08 (1377.20)**	**-**	**-2.07**	**0.03***	**9**	**-0.48**	**friends>8**
CI (minutes)	-	3281.08 (1377.20)	2433.46 (1415.54)	-0.05	0.95	9	-0.01	friends>8
CI (minutes)	2846.30 (1033.08)	-	2433.46 (1415.54)	-0.77	0.44	9	-0.18	friends>8
CI (percentage)	2.52 (3.90)	2.57 (2.78)	-	-1.59	-1.59	9	-0.37	friends>8
CI (percentage)	-	2.57 (2.78)	2.03 (7.78)	-0.17	0.85	9	-0.04	friends>8
CI (percentage)	2.52 (3.90)	-	2.03 (7.78)	-0.53	0.59	9	-0.12	friends>8
CA (minutes)	2846.30 (1033.08)	3281.08 (1377.20)	-	-0.53	0.59	9	-0.12	friends>8
CA (minutes)	-	3281.08 (1377.20)	2433.46 (1415.54)	-1.36	0.17	9	-0.32	friends>8
CA (minutes)	2846.30 (1033.08)	-	2433.46 (1415.54)	-1.59	0.10	9	-0.37	friends>8
CI (minutes)	**137.24 (177.91)**	**87.21 (70.81)**	**-**	**-2.52**	**0.01***	**8**	**-0.63**	**Computers Caught >1**
CI (minutes)	-	87.21 (70.81)	130.51 (147.29)	-0.70	0.48	8	-0.17	Computers Caught >1
CI (minutes)	137.24 (177.91)	-	130.51 (147.29)	-0.42	0.67	8	-0.10	Computers Caught >1
CI (percentage)	**4.34 (4.51)**	**2.63 (3.30)**	**-**	**-2.10**	**0.03***	**8**	**-0.52**	**Computers Caught >1**
CI (percentage)	-	2.63 (3.30)	3.66 (8.20)	-0.42	0.67	8	-0.10	Computers Caught >1
CI (percentage)	4.34 (4.51)	-	3.66 (8.20)	-0.56	0.57	8	-0.14	Computers Caught >1
CA (minutes)	3186.35 (1066.38)	2878.48 (1381.41)	-	-0.56	0.57	8	-0.14	Computers Caught >1
CA (minutes)	-	2878.48 (1381.41)	2437.86 (1535.40)	-0.42	0.67	8	-0.10	Computers Caught >1
CA (minutes)	3186.35 (1066.38)	-	2437.86 (1535.40)	-1.26	0.20	8	-0.31	Computers Caught >1

Table A.2: Between group test Male vs Female

	Male Mdn (n)	Female Mdn (n)	N	U	z	p	r	Filter
CA (Week 1, minutes)	**3224 (11)**	**2219.6 (12)**	**23**	**32**	**-2.09**	**0.03**	**-0.30**	**-**
CA (Week 2, minutes)	**3869.98 (11)**	**1871.38 (12)**	**23**	**16**	**-3.07**	**0.00**	**-0.45**	**-**
CA (Week 3, minutes)	2433.46 (11)	2305.43 (12)	23	50	-0.98	0.32	-0.14	-
CI (Week 1, minutes)	123.03 (11)	173.48 (12)	23	53	-0.80	0.44	-0.11	-
CI (Week 2, minutes)	77.16 (11)	87.07 (12)	23	66	0.00	1	0	-
CI (Week 3, minutes)	121.00 (11)	82.63 (12)	23	55	-0.67	0.52	0.10	-
CI (Week 1, percentage)	2.529067 (11)	7.75(12)	23	40	-1.60	0.11	-0.33	-
CI (Week 2, percentage)	2.19 (11)	5.13 (12)	23	50	-0.98	0.34	-0.20	-
CI (Week 3, percentage)	2.03 (11)	3.28 (12)	23	65	-0.06	0.97	-0.01	-
CA (Week 1, minutes)	2910.77 (10)	2292.30 (10)	20	30	-1.51	0.14	-0.33	friends >0
CA (Week 2, minutes)	**3575.53 (10)**	**1871.38 (10)**	**20**	**15**	**-2.64**	**0.00***	**-0.59**	**friends >0**
CA (Week 3, minutes	2401.05 (10)	2370.41 (10)	20	44	-0.45	0.68	-0.10	friends >0
CI (Week 1, minutes)	127.19 (10)	117.60 (10)	20	44	-0.45	0.68	-0.10	friends >0
CI (Week 2, minutes)	80.45 (10)	87.07 (10)	20	49	-0.07	0.97	-0.01	friends >0
CI (Week 3, minutes)	107.61 (10)	77.65 (10)	20	39	-0.83	0.43	-0.18	friends >0
CI (Week 1, percentage)	3.08 (10)	5.80 (10)	20	37	-0.98	0.35	-0.21	friends >0
CI (Week 2, percentage)	2.38 (10)	5.13 (10)	20	37	-0.98	0.35	-0.21	friends >0
CI (Week 3, percentage)	2.37 (10)	2.82 (10)	20	43	-0.52	0.63	-0.11	friends >0

Table A.3: Between group test Desktop vs Laptop

	Desktop Mdn (n)	Laptop Mdn (n)	N	U	z	p	r	Filter
CA (Week 1, minutes)	2597.55 (5)	2319.250000 (18)	23	27	-1.341641	0.198936	-0.27	-
CA (Week 2, minutes)	**4109.06 (5)**	**2064.933333 (18)**	**23**	**9**	**-2.683282**	**0.004933**	**-0.55**	**-**
CA (Week 3, minutes)	3386.18 (5)	2305.433334 (18)	23	27	-1.341641	0.198936	-0.27	-
CI (Week 1, minutes)	123.03 (5)	135.06 (18)	23	39	-0.447214	0.691135	-0.09	-
CI (Week 2, minutes)	49 (5)	87.21 (18)	23	41	-0.298142	0.800618	-0.06	-
CI (Week 3, minutes)	121(5)	84.13 (18)	23	29	-1.192570	0.257066	-0.24	-
CI (Week 1, percentage)	2.209035 (5)	4.690914 (18)	23	31	-1.043498	0.325181	-0.21	-
CI (Week 2, percentage)	1.179224 (5)	3.046786 (18)	23	29	-1.192570	0.257066	-0.24	-
CI (Week 3, percentage)	1.945046 (5)	2.800992 (18)	23	41	-0.298142	0.800618	-0.06	-
CA (Week 1, minutes)	2517.19 (4)	2581.21 (16)	20	27	-0.472456	0.681940	-0.10	Friends>0
CA (Week 2, minutes)	**3989.52 (4)**	**2185.64 (16)**	**20**	**9**	**-2.173296**	**0.029309**	**-0.48**	**Friends>0**
CA (Week 3, minutes)	2877.41 (4)	2366.01 (16)	20	25	-0.661438	0.553560	-0.14	Friends>0
CI (Week 1, minutes)	93.016667 (4)	127.841667 (16)	20	29	-0.283473	0.819814	-0.06	Friends>0
CI (Week 2, minutes)	63.100000 (4)	87.216667 (16)	20	32	0.0	1.000000	0	Friends>0
CI (Week 3, minutes)	189.141667 (4)	84.133333 (16)	20	18	-1.322876	0.211352	-0.29	Friends>0
CI (Week 1, percentage)	3.41 (4)	3.73 (16)	20	27	-0.472456	0.681940	-0.10	Friends>0
CI (Week 2, percentage)	1.34 (4)	3.04 (16)	20	22	-0.944911	0.384727	-0.21	Friends>0
CI (Week 3, percentage)	10.01 (4)	2.37 (16)	20	24	-0.755929	0.494118	-0.16	Friends>0

Table A.4: Within groups test between laptops being plugged-in and unplugged

Variables (% of the total CA and CI time)	M (SD)		z	p (2-tailed)	N	r	Filter
	AC	AD					
CI (Week 1)	4.86 (5.37)	4.23 (30.74)	-1.06	0.28	18	-0.25	type of computer = laptop
CA (Week 1)	95.13 (5.37)	95.76 (30.74)	-1.06	0.28	18	-0.25	type of computer = laptop
CI (Week 2)	4.90 (9.09)	6.37 (36.28)	-1.20	0.22	18	-0.28	type of computer = laptop
CA (Week 2)	60.35 (27.37)	93.62 (36.28)	-1.32	0.18	18	-0.31	type of computer = laptop
CI (Week 3)	4.74 (6.62)	7.75 (32.17)	-1.49	0.13	18	-0.35	type of computer = laptop
CA (Week 3)	95.25 (6.62)	92.24 (32.17)	-1.49	0.13	18	-0.35	type of computer = laptop
CI (Week 1)	4.39 (4.17)	2.70 (31.80	-0.96	0.33	16	-0.24	type of computer = laptop & friends >0
CA (Week 1)	95.60 (4.17)	97.29 (31.80)	-0.96	0.33	16	-0.24	type of computer = laptop & friends >0
CI (Week 2)	4.60 (9.46)	4.96 (38.30)	-1.19	0.23	16	-0.29	type of computer = laptop & friends >0
CA (Week 2)	56.66 (24.27)	95.03 (38.30)	-0.73	0.46	16	-0.18	type of computer = laptop & friends >0
CI (Week 3)	4.72 (6.16)	7.75 (7.75)	-1.53	0.12	16	-0.38	type of computer = laptop & friends >0
CA (Week 3)	95.27 (6.16)	6.16 (33.97)	-1.53	0.12	16	-0.38	type of computer = laptop & friends >0

Table A.5: Between group test friends <2 vs friends >1

	friends <2 Mdn (n)	friends >1 Mdn (n)	N	U	z	p (2-tailed)	r
pre_CA_minutes	2270.11 (9)	2842.36 (14)	23	43	-1.25	0.20	-0.18
during_CA_minutes	2561.71 (9)	2389.94 (14)	23	61	-0.12	0.89	-0.01
during_CA_minutes_2	2368.65(9)	2366.01 (14)	23	59	-0.25	0.80	-0.03
pre_CI_minutes	136.06 (9)	127.19 (14)	23	60	-0.18	0.85	-0.02
during_CI_minutes	47.03 (9)	87.21 (14)	23	57	-0.37	0.70	-0.05
during_CI_minutes_2	117.73 (9)	87.21 (14)	23	58	-0.31	0.75	-0.04
pre_CI_percentage	5.55 (9)	3.73 (14)	23	52	-0.69	0.75	-0.10
during_CI_percentage	2.19 (9)	2.77 (14)	23	61	-0.12	0.89	-0.01
during_CI_percentage_2	2.88 (9)	2.37 (14)	23	58	-0.31	0.75	-0.04

Table A.6: Between group test friends <3 vs friends >2

	friends <3 Mdn (n)	friends >2 Mdn (n)	N	U	z	p (2-tailed)	r
pre_CA_minutes	2292.30 (10)	2846.3 (13)	23	47	-1.11	0.26	-0.16
during_CA_minutes	2312.15 (10)	2475.88 (13)	23	58	-0.43	0.66	-0.06
during_CA_minutes_2	2340.47 (10)	2433.46 (13)	23	61	-0.24	0.80	-0.03
pre_CI_minutes	129.55 (10)	132.76 (13)	23	57	-0.49	0.61	-0.07
during_CI_minutes	46 (10)	90.7 (13)	23	48	-1.05	0.29	-0.15
during_CI_minutes_2	103.54 (10)	125.88 (13)	23	59	-0.37	0.70	-0.05
pre_CI_percentage	4 (10)	3.82 (13)	23	65	0	1	0
during_CI_percentage	1.85 (10)	2.85 (13)	23	53	-0.74	0.45	-0.10
during_CI_percentage_2	2.42 (10)	2.71 (13)	23	60	-0.31	0.75	-0.04

A.2 EcoScreenCatcher Interview Questions

A.2.1 General questions

- Can you tell me about yourself?
- What you do? Your age?
- How familiar you are with computers?
- How long do you have the computer?
- What kind of computer it is (desktop, laptop)?
- And so lets just start by generally asking how did you get on with the system?
- What was the most valuable feature of the system and why?

A.2.2 Specific questions

- Did you had a look at the leaderboard?
- Were you consider yourself featuring at the top of the leaderboard?
- What was more important for you the number of computers caught or the leaderboard?
- Did you have a look at your catching activity?
- When it comes to computer usage, what do you consider wasteful?
- Do you think that five minutes of inactivity is ok as a threshold to define wasteful behaviour?
- Did you talk with your friends about the study? If yes, what did you tell them?
- Did you read the daily email send to you? Do you have any comments about it? Did you apply any of
- suggestions mentioned there?
- When you work, or you are on the campus do you have the same behaviour with regards to leaving the computer on or off? Is it different? Why is different?
- Have you ever changed your computer's power settings before the study (e.g. hibernate, sleep,)? What about after the study?
- Have you tried to catch a computer? Why?
- How did you feel being caught?

- Did you develop a strategy to win the game?
- Can you describe an ordinary day of you playing the game?
- Did you use the program or the game for other purposes that it was supposed to?
- What about privacy? How do you feel with regards to the privacy aspect of it (e.g., the fact that you friends can see whether you are on your computer or not)?
- Did you ever switch off the program? if yes why?
- (if you have a laptop) Can you describe your day with your laptop when it is plugged and unplugged from the mains?
- Do you consider yourself as wasteful?
- Can you describe some incidents that you left (or forgot) your computer ON?
- What it is preferable to you automatically sleeping your computer or doing it manually and why?

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