Encouraging energy conservation in office environments through group feedback and individual comparison feedback

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Abstract

Sustainable behavior is fundamentally a group phenomenon. This implication is essential, especially, because the impact of a single individual is rather small, and a true change depends on the aggregate actions of a significant amount of people. Therefore, energy conservation is determined by the joint performance of a group of individuals. Furthermore, the sustainable behavior of an individual is interdependent with the interactions and relations to other subjects and an effective change may be influenced by each others actions. The current demands require innovative forms to motivate and to effectively engage people into a behavioral change.

Previous research showed that providing feedback about the energy consumption of specific behaviors made individuals to reduce their energy waste. Additionally, the literature suggested that providing rewards, information, and different types of feedback - individual feedback and comparative feedback- had an effect on the energy consumption levels of similar sets of households. However, it is not clear if providing comparative feedback to individuals might be helpful for promoting energy conservation. In a previous study, Midden, Ham and Kleppe (2011) tested the effectiveness of two kinds of feedback - group feedback and individual comparison feedback. Their results revealed that group feedback was more effective in a collectivist culture (Japan) and, individual comparison had a positive effect in an individualistic culture (The Netherlands). However, in the study of Midden et al. (2011), participants were arranged through small group paradigm and they had to make decisions through brief interactions. A question that raises in the current study is whether the same effect would be present in settings where individuals might have stronger interdependencies, since they have to interact with other individuals on a daily basis through longer periods of time.

The current thesis approaches energy conservation as a group phenomenon and it extends the work from the previous study of Midden et al. (2011) into a field experiment. During the field experiment, the electrical consumption of 72 doctorate students was continuously recorded for 5 weeks. The individuals were assigned in groups and those groups were divided into the two experimental conditions - individual comparison feedback and group feedback- and a control condition. The evaluation of the feedback strategies was done by measuring the individual power consumption of each participant. The current work makes a bridge between the topic of persuasive technology and its application to the real world by implementing a behavioral intervention in a group of offices in the Potentiaal building of the Electrical Engineering Department.

This project was done in collaboration with the HTI department and the ACTLab (Activity and Context recognition Technologies) from the Electrical Engineering Department, and it was funded by the GreenerBuildings European project.
1. Introduction

1.1. Theoretical framework.

Environmental degradation (i.e. the alteration of the environment through the transformation and depletion of resources as a result of the interaction between the human and its surroundings; Stern, Young, & Druckman, 1992; ) has left the modern society in an urgent predicament: we must change into more sustainable behaviors. The constantly increasing demands for resources and energy use, which have led to more production of waste, are the most important issues driving this environmental catastrophe. More than 30 billion tonnes of waste are produced every year in the European Union (EUR, 2010). Ninety five million tonnes of waste are generated solely by activities related to water supply and energy production. Furthermore, it is expected that the amount of waste will continue to rise up to 45 percent compared to the amount of waste produced two decades ago (EUR, 2010). Global energy supply generates more than one quarter of the total greenhouse gas (GHG, e.g. CO2) emissions in the world (IPCC, 2007).

Sustainable energy production and consumption is one of the main concerns addressed in the road-maps of the governments’ growing strategies for the following decades (EUR, 2011; EUR, 2012). Since the over-dependence on limited natural resources (e.g, oil, gas and coal) for the generation of energy is one of the key issues in climate change (IPCC, 2007), several measures to increase the use of renewable energy sources are continuously pushed by policy makers. Additionally, new consumption strategies promote sustainable consumption in order to reduce the demand and production of energy. It is acknowledged that the whole society should actively commit to more sustainable energy behaviors to effectively fight climate change. The current demands require innovative forms to motivate and to effectively engage people into a behavioral change (Foht et al., 2011). How can we promote and achieve effective behavioral change, and how can we make individuals further commit to the goals of sustainable behavior?

The main challenge that any successful behavioral intervention faces is the inherently social nature of sustainability (e.g., Biel and Thø gersen, 2007; Fielding et al., 2008; Van Vugt, 2009). The support and adoption of a new behavior of consumption depends directly on the individual’s decisions and consequent actions. However, those decisions and actions are affected by the social dynamics that surround the individual. As previous research has suggested, participation and engagement into new behaviors are not only influenced by personal factors (Stern, 1992). According
to previous work from Midden, Ham and Kleppe (2011) and earlier work from Earley (1999), energy conservation is also influenced by the individual’s relationship with additional factors such as nature, culture, technology and finally, but not less important, other people. A person’s behavior is shaped by the continual interaction between the person and other individuals surrounding him (Kenrick et al., 2009). For example, in a shared working space, energy consumption might vary from person to person, but everyday group interactions affect the adoption of the appropriate sustainable behavior. Interventions on sustainable behavior should focus on how to influence the person by considering him or her not as an isolated target but as part of a defined set of individuals, name it: community, neighborhood, office, or family.

Sustainable behavior is fundamentally a group phenomenon. This implication is essential, especially, because the impact of a single individual is rather small, and a true change depends on the aggregate actions of a significant amount of people (Stern, 2000). Therefore, energy conservation is determined by the joint performance of a group of individuals. Furthermore, their performance may be influenced by each other's actions: whether an individual does or does not adopt a sustainable behavior is interdependent with the interactions and relations to other subjects within the context in which he or she is embedded. The more his or her goals and actions depend on others behavior, the more difficulties the person encounters to achieve the goal. This difficulties often lead into conflict of interest with other people. The individual has to choose between the fulfillment of an individual goal or interest, or the fulfillment of a common goal (Lindenberg, 1997). Because of these conflicts, energy conservation is commonly treated as a social dilemma (Van Vugt, 2009). In social dilemmas, the person has to decide whether or not to act in pursuit of his- or her self-interests, and therefore negatively affect the fellow individuals. The person could decide to cooperate with his fellow group members but social uncertainty develops as the persons is not confident if his fellow group members will cooperate as well. Uncertainty about the possible decisions of fellow affected individuals or about the conflict itself increases the probability of defection and opportunistic behavior (Dijk, Cremer, Mulder, & Stouten, 2008). Another example: when individuals have unlimited access to a finite common resource, each person consumes as much as he or she wants. Reckless consumption of the common resources will eventually lead to overharvesting. Being aware of the size of the resources and the level of individual use might eliminate careless consumption (Dijk et al., 2004). Creating mechanisms and tools to reduce this uncertainty will allow people to make more intelligent decisions and to commit to sustainable behaviors.

Technology provides means for reducing that uncertainty and promoting sustainable behavior. For instance, persuasive technology can increase the awareness of a problem and persuade the individual to change by providing feedback about the consequences of that specific behavior (Midden, Kaiser, Florian & McCalley, 2007; Fogg, 2003). Furthermore, technology provides new leverage for persuasion such as delivering persistent, anonymous and personalized messages through multiple modalities of interaction (Fogg, 2003). These advantages make new behaviors eas-
1.1 Theoretical framework.

Persuasive technology can track and provide tailored information feedback about the performance and raise people awareness about a particular behavior and help them to change or reinforce it (Fogg, 2003; Cees Midden). Previous research has proved that providing data about the energy consumption reduced their energy waste (McCalley & Midden 2002). Persuasive technology enables us to monitor our energy consumption in real time and make people actively aware and more energy efficient. New technologies and their ubiquitous capabilities have opened an opportunity to intervene during the right situation and motivate the person to stop the undesired activity (Fogg, 2003).

Midden, Ham and Kleppe (2011) implemented an intervention using persuasive technology in which they approached energy conservation as a group phenomenon. Their results revealed that the cultural background and the influence of the actions of other group members enabled the participation or even conflict with the sustainable behavior. As part of the intervention, Midden et al. (2011) presented two kinds of feedback: group feedback and individual comparison feedback. They compared the effect of individual versus group feedback in motivating people to save energy across two different types of cultures: collectivist - Japan - versus individualistic - The Netherlands. The feedback intervention consisted of a computer game where participants were associated to a digital avatar. The digital avatars of all participants were placed in an island type scenario. The island type scenario was based on a previous intervention implemented by Takayama, Lehdonvirta, Shiraishi, Washio, Kimura and Nakajima (2009). Participants were given a questionnaire regarding to several options of energy saving actions in which they should choose the most appealing option while always trying to save energy. The feedback varied according to their preferences. Individual comparison feedback differentiated - by the color of the clothes of the avatars - between the participant who had the highest energy saving score - green color - and the one who had the worst energy saving score - red color. Group feedback consisted of varying the level of the water displayed in the island scenario. The less energy saved, the higher the level of the water, resulting in the risk on sinking the island and thus the participants’ avatars. Their results showed mixed results dependent on cultural differences. They found that in a collectivist culture (Japan), group feedback was more effective and, individual comparison did not have an effect on the behavior. On the other hand, they also showed that in a more individualistic culture (The Netherlands), group feedback did not have significant results but individual comparison had a positive effect. The results also showed that participants in The Netherlands with group feedback but not individual comparison used the highest amount of energy.

Looking at Midden’s results (2011), providing participants with feedback has proven to be able to change their energy consumption significantly. However, Midden et al. (2011) mainly focused on differentiating the effect that the type of feedback had on different cultural settings. Additionally, in the study participants were arranged through small group paradigm and they had to make decisions through brief interactions. An interesting question is if the same effect would be present in real group
settings involving long term interactions. Individuals might have stronger interdependencies since they have to interact and relate to other individuals on a daily basis through longer periods of time, for example at home or at the office. One possible difference is that in short term interactions, such as brief and one-shot interactions, individuals tend to behave in a selfish way because there is little risk and little chance of being punished and no need to meet further expectations (Blau, 1964). This could explain why group feedback was not effective for Dutch participants in the study. In long term interactions, individuals might feel a bigger sense of social control (Blau, 1964; Clark and Mils, 1993; Yamagishi et al., 1998) and therefore a higher need to meet group expectations. In this sense, group feedback might be also effective for long term interactions.

In the case of individual comparison feedback, participants from the Netherlands had a better performance and reduced their energy consumption effectively. The individual comparison feedback provided information that might enable the individuals to identify their own performance and thus reduced their energy consumption. Therefore, we expected that this type of feedback should have similar results in long term interactions: the individual comparison feedback might still reduce social uncertainty and increase the commitment to the goal of saving energy.

The current thesis extends the previous study of Midden et al. (2011) into a field experiment over long term interactions.

1.2. The current study

This section explains in detail the way in which the current study explores the role of pervasive and persuasive technology in promoting sustainable behavior in a real setting.

The goal of the current research was to execute a field experiment by deploying an energy measurement infrastructure and monitor the patterns of energy consumption in a group of offices of the Eindhoven University of Technology (TU/e). This project was embedded into a larger research framework on ICT systems for building adaptivity pertained to comfort and energy saving. In this effort, a first living-lab installation for pilot tests and a second major intervention were foreseen in the building of the Faculty of Electrical Engineering (Potentiaal building) of the Eindhoven University of Technology.

The current study tests whether strategies that display the effects of individual contributions are more effective than strategies that only display the effects of group contribution in a field experiment. In particular, the current research investigates the differences in effectiveness between providing individual comparison feedback and providing group feedback in order to reduce energy consumption.

As part of the manipulation, feedback is expected to reduce social uncertainty and increase engagement and commitment into sustainable behaviors. Thus, it is ex-
pected that groups that received feedback (individual comparison and group feedback) would decrease their energy consumption compared to the group that did not have feedback. In consistency with previous research we expect that individual comparison feedback would be more effective than group feedback. Our argument is that individual comparison will have a better effect in motivating people to perform well and save energy since it is easier for participants to identify their own performance. Based on this, we formulated the following hypothesis:

**Hypothesis 1. Individual comparison feedback will be more effective than no feedback condition.** Individual comparison feedback should reduce energy consumption.

**Hypothesis 2. Group feedback will be more effective than no feedback condition.** Group feedback should reduce the energy consumption.

**Hypothesis 3. Individual comparison feedback will be more effective than group feedback.** Individual comparison feedback should reduce energy consumption more effectively than group feedback.

The evaluation of the effectiveness of these feedback strategies, and thus the hypotheses above stated, included sensor-based behavior-change measurements, behavior observation, and questionnaire assessments which will be discussed in the Methodology chapter.
2. Methodology

2.1. Design

The experiment consisted of a field experiment comparing two experimental conditions (individual comparison feedback and group feedback) with a control group (no feedback) in a repeated measures design. The experiment lasted for 5 weeks and it was done within a group of offices in a building - Potentiaal - of Electrical Engineering Department of the Eindhoven Technical University. The experiment was executed during the period November 2012 - December 2012, including one week of data collection to create a baseline measure, followed 3 weeks of experimental manipulation, and a last week of post-experimental measurements.

2.2. Participants

Participants were 62 men and 10 women from 22 to 38 years old (M= 27.75, SD= 3.11), all postgraduate students with different international backgrounds. Most representative backgrounds were from Netherlands (16), China (12), and Italy (8). Participants were continuously recorded 24 hours a day, for 32 days (including weekends), divided in 5 weeks between November and December 2012. The participants were located across 6 floors of the building from the Electrical Engineering Department at the Eindhoven University of Technology. Participants were distributed in offices which vary in size and occupants. In some cases, participants from the experiment shared the same office. All the participants were randomly assigned into groups of 4, accounting for 18 groups in total. The groups were divided randomly across the 2 experimental conditions and the control condition.

2.3. Energy Measurements

Electrical consumption, expressed in terms of power, was measured for each participant. Each power recording was measured in watts and represented the rate at which an individual consumed energy at a given moment of time. Power simplifies the comparison between individual’s energy consumption during work related
office activities. This approach simplifies the detection of simple variations of en-
ergy consumption triggered by specific actions or activities, for example, setting the
computer into stand-by or switching it off.

A recorded value included the power consumption of the personal computer, the
attached screens and a desktop lamp, if existing. The instant power values of each
sensor were recorded in a frequency of a minute during the 32 days of the experiment.
During the first week, recordings were done without providing any feedback, in
order to obtain a baseline record that helped to normalize the data recordings of
the consumption of each participant.

Daily energy consumption ($e_{\text{day}}$) values were calculated from the average of the
instant power ($e_{\text{instant}}$) values recorded during each day. Formula Equation 2.1 shows
how daily energy consumption was calculated, where $N_{\text{records}}$ corresponds to the total
amount of instant power records registered during that day.

$$
e_{\text{day}} = \sum \frac{e_{\text{instant}}}{N_{\text{records}}} \quad (2.1)
$$

From the first week (baseline week) daily values were compared and, arbitrarily, the
day with second highest value was selected as baseline. Some participants (n=2)
were only in the office for one day of the week, thus they only have a single valid
value for determining the baseline.

2.4. Technical Implementation

For the purpose of this field experiment, an energy measurement infrastructure
was developed and deployed. The system consisted of 72 Plugwise devices, twelve
computers acting as gateways and a central database server, an application server
as back-end and a web server in charge of the front-end channel.

The recordings of consumption were done using the Plugwise devices (i.e. ZIGBEE
enabled sensor for measuring electrical consumption; Zigbee). A single Plugwise
device was deployed per participant. An ubiquitous computing middle-ware (Con-
text Recognition Network Toolbox - CRNT: Bannach et al., 2008 ) was in charge of
collecting the records every minute from each Plugwise device via a wireless com-
munication protocol. An extra module for the CRNT was developed to manage the
wireless communication protocol used by Plugwise devices. The 12 computers were
deployed through all the building in the floors where the offices of the participants
were located. The CRNT was installed on each computer in order to collect the data
from each Plugwise device. The computers acted as gateways collecting the data
and transferring them to a centralized database server where the data recordings
were later processed by the web application.
2.5 Feedback

The web application was in charge of doing the calculations and comparisons required for presenting the specific feedback to the participants through its web interface. The web application was developed in HTML5, PHP, Java and JavaScript following the technical standards to support the most common web navigators (Safari, Chrome, Opera, Firefox and Internet Explorer).

The diagram contained in the image shows how the above mentioned technology was deployed during the experiment. The Plugwise device was connected to all the electrical devices from the participants and it was connected via a wireless communication protocol to the gateway computer where the CRNT was running. The CRNT collected the data and sent it through HTTP requests over the Internet to the central server where the data was stored in the database (MongoDB). The web application consisted of a back-end module developed in Java was and it deployed on an Apache Tomcat application server. The front-end module was developed in PHP, HTML and JavaScript and it was deployed on an Apache web server. The web application made the calculations and comparisons, and created the adequate feedback screens for the participants.

Figure 2.1.: Deployment of the technology used during the experiment.

2.5. Feedback

Feedback was presented in two different ways depending on the day of the week. Every Monday, weekly feedback was generated from the accumulated energy values recorded during the previous week, including the weekend. Daily feedback was presented during the rest of the days of the week and it was based on the energy...
consumption of the previous day. The main reason to present two different types of feedback - weekly feedback and daily feedback - was to integrate the energy measurements done during the weekend. We expected that the participants would be mainly in the office during regular working days, however energy could be consumed during the weekend. Participants might leave the computer on during the weekend or they could even be in the office. Thus, weekly feedback included the energy consumed during the weekend.

The feedback was provided through a web interface and it consisted of a virtual animated island containing 4 avatars which were associated to each participant of a specific team (see Figure 2.2). The idea of the animated island was inspired in the concept of the EcoIsland, a work done previously by Takayama et al. (2009).

The way the feedback was presented differed depending on the experimental condition. In the group condition, the feedback was represented by the water level around the island which could rise or fall according to the overall consumption of the group. In the individual comparison condition, a crown was assigned to the person who consumed the lowest amount of energy of the group and a pair of donkey ears was assigned to the person who consumed the highest amount of energy of the group. The crown represented a positive performance compared to the performance of other members from the group. The donkey ears indicated a bad performance in comparison to the performance of other group members. Participants in the control group could only see their avatars and the avatars of the other team members.

**Feedback calculation.**

The feedback was calculated based on the ratio of change of the daily energy consumption compared to the baseline. The main problem was that participants could
not be compared directly given that every individual not only differed in the type of electrical appliances but in their working schedules. In this sense, hours of presence in the office had to be taken into account. Therefore, some transformations were done over the daily energy consumption.

First, every participant was asked to indicate the amount of hours they expected to spend in the office during each experimental week. An indicator of daily working hours was defined by dividing the indicated amount of week hours by the amount of regular working days in the week. Afterwards, the daily energy consumption values of regular working days were divided by the daily working hours in order to create a normalized daily energy measure. The formula Equation 2.2 shows how the normalized daily energy measure is calculated by dividing the average power consumed during the day by the indicator of daily working hours.

\[
e_{\text{normalized}}(t) = \frac{e_{\text{day}}}{\text{hours}_{\text{day}}} \quad (2.2)
\]

Additionally, energy consumed during the weekend was treated differently than energy consumed during regular working days. The power consumed during the weekend days should have a higher impact on the feedback indicator than the energy consumed in a regular day, in order make more significant actions like leaving the computers on during the weekend. Therefore, energy consumed during the weekend was not normalized, in other words, it was not divided by the daily working hours. This gave a higher weight to the energy consumed during Saturday and Sunday, compared to a regular working day at the moment of calculating the feedback.

Finally, in order to provide a standard measure to compare the individual’s performance, it was calculated the ratio \(\alpha_{\text{energy}}\) of the normalized daily energy consumption compared to the normalized baseline. This indicator was calculated by dividing each normalized daily energy measure by the normalized version of the baseline measure (i.e. baseline divided by the calculated daily hours from the baseline week) as seen in formula Equation 2.3:

\[
\alpha_{\text{energy}} = \frac{e_{\text{day}}(t)}{e_{\text{baseline}}(t)} \quad (2.3)
\]

Using this indicator of the ratio of change \(\alpha_{\text{energy}}\), it was possible to compare each individual’s performance and generate an appropriate feedback. In the case of the group feedback, the level of the water was calculated as the average of ratio indicators \(\alpha_{\text{energy}}\) of all the team members (see formula Equation 2.4). If the total mean of the team members increased, the level of the water increased as shown in Figure 2.3. If the total mean of the team members decreased, the level of the water decreased as well, see Figure 2.4. The level of the water could decrease until disappearing from
the image or it could increase until covering the avatars completely. The interval in pixels between the two extremes consisted of 225 pixels. A middle point at was defined in this interval corresponding to a value of 1 in the total mean of the $\alpha_{\text{energy}}$ values. If the mean was higher than 1, meaning that they consumed more than the mean baseline, the level increased above the mid-point. The maximum level of water corresponding of 225 pixels in the image was reached when the mean presented values higher than 2, meaning that they consumed more than the double of the energy they consumed during the baseline.

$$water_{\text{level}} = \frac{\sum \alpha_i}{n_{\text{members}}}$$  \hspace{1cm} (2.4)

Figure 2.3.: Example of Group Feedback with water level rising.
Individual comparison feedback was obtained by comparing the ratio indicators \( (\alpha_{\text{energy}}) \) of each of the members of the team and extracting the members with the lowest and highest consumption values. The member with the lowest ratio indicator received the crown (see formula Equation 2.5).

\[
\alpha_{\text{lowest}} = \text{MIN} [\alpha_0, \alpha_1, \ldots, \alpha_n] \tag{2.5}
\]

The member with the highest ratio indicator \( (\alpha_{\text{energy}}) \) received the donkey ears (see formula Equation 2.6).

\[
\alpha_{\text{highest}} = \text{MAX} [\alpha_0, \alpha_1, \ldots, \alpha_n] \tag{2.6}
\]

Figure 2.5 shows an example of the feedback displayed for the individual comparison condition. The animated island contains the 4 avatars of the team members, and one of them has the crown and the other one has the donkey ears.
Figure 2.5.: Example of individual comparison feedback. Members have the crown or the donkey ears depending on their personal performance.

2.6. Questionnaires

2.6.1. Competition and cooperation.

In order to get a better understanding about the differences in motivations and engagement triggered by the type of feedback, participants were asked about how cooperative or competitive they perceived the other members of their group. One item measured the overall perception about other group members in a scale ranging from very competitive to very cooperative. The second and third items measured specifically the self-reported motivation to compete against and to cooperate with other members during the task.

2.6.2. User experience.

For determining how engaging was the feedback provided by the web interface and how it affected the interaction, 18 items were defined. Six items originally from the QUIS (Questionnaire for User Interaction Satisfaction, Chin et al. 1988) scale were used for measuring the overall experience of the game (wonderful, easy, satisfying, adequate, stimulating and flexible experience). Nine items were defined to rate the feedback effectiveness, feedback consistency and feedback understanding (e.g. “How much control did you feel that you had over the changes in the interface?”, “The system understood the changes of my energy consumptions”, “The feedback provided was a consequence of my actions”). Three additional items were used to
measure usability, learn-ability and satisfaction of the interface. For more details refer to Appendix C.

2.6.3. Personal differences.

**Environmental attitudes**  The attitudes towards the environment were measured with the revised New Environmental Paradigm scale (NEP; Dunlap et al., 2000). The NEP is a self reported measure consisting of 15 items employed to examine the relationship of specific environmental attitudes, beliefs, and behaviors with ecological world views.

**Pro-social behavior**  The 9-item triple dominance measure, developed by Van Lange et al. (1997), is a simple and concrete scale to measure interpersonal orientation attitudes. Individuals have to select different choices consistent to social value orientation and according to those results, respondents are classified as cooperators, individualists, or competitors. Individualistic and competitors can be classified as pro-self behaviors, while cooperators are classified as pro-social.

**Self-efficacy**  Self-efficacy is the perceived ability to achieve goals and task performance (Locke et al., 1986). It is considered to affect behavior and since it supports the individual to set goals and to cope with adversity. For measuring the self-efficacy, the General Self-Efficacy Scale (GSE) was used. The GSE scale consists of 10 items and it was developed by Schwarzer and Jerusalem (1995). The General Self-efficacy scale had high reliability with Cronbach’s $\alpha = .775$.

2.6.4. Perceived social uncertainty and group identity.

Participants were asked to report whether they contributions influenced the contributions of their team members. They were also asked to indicate how important they perceived they contributions compared to the others and to what extent they felt identified with their group members.

2.6.5. Social structure and communication patterns.

Participants were asked to report whether they knew their group members, how well they knew them, and how often they discussed with them about the game. Participants were also asked to indicate how often they talked with other participants about the game. Even though, the web interface did not provide with means for communicating within group members, it was expected that group members would keep contact and would discuss about the experiment. Discussions about the game
might be oriented towards the goal of improving their performance, either personal or group. Communication might help to reduce the existing social uncertainty and to improve coordination within team members. Participants were asked to indicate an estimate of hours spent in the office per week.

Five items were defined for exploring the extent to which participants felt the prevalence of a social norm during the experiment. Two items measured the perceived normative pressure from other participants, and the existence of a perceived dominant attitude from other participants towards the game. Perceived benefits or sanctions such as disapproval from other members, could determine whether the individual engages in the specific behavior. Hence, one question measured the perceived social approval (e.g. “How favorably do others in general view your contributions?”) and the last two items asked about how beneficial, in terms of joy, the game was for the participant and for others.

2.7. Study Procedure

Participants were personally invited to take part the experiment. A letter introducing and explaining the experiment was given to each participant. In the letter, the field experiment was explained as an interactive online game application which would track their energy consumption, and would challenge them to adopt sustainable behaviors (see appendix Introduction letter). Subsequently, participants signed an informed consent form. A power strip was used to create a single point of measurement connecting all the available electrical appliances (e.g. computer, external screens, desktop lamp) to a single electrical source. The Plugwise devices were attached between energy socket and the power strip. Participants were informed that the game would start a week after the installation and that the duration of the game would be of only 3 weeks, even though, energy measures were done during 32 days, 24 hours a day, including weekends. During the first week energy consumption was recorded to create a baseline measurement for normalization and further comparison. At the beginning of the second week, participants received an email announcing the start of the game. The email contained a web link to the first questionnaire and the link to the web interface with the specific login details (user and password) for the game. The first questionnaire contained general demographics, personal computer usage, environmental attitudes and self-efficacy measures. Users were indicated to log into the game every morning for three weeks. When logging for the first time at the beginning of each week, participants were asked to fill in the amount of hours that they would spent in their offices during that week. Afterwards, a web page with the instructions was displayed explaining the goal and the expected interaction (feedback). The goal was the same for all participants across the three feedback conditions: to make their personal energy consumption as low as possible. Every condition received a different explanation for the expected feedback interaction. Participants in the group condition were explained that the level of the
2.7 Study Procedure

Figure 2.6.: Diagram of the experimental procedure.

water surrounding the virtual island would rise or fall according to the overall consumption of the group. In the individual comparison condition, participants were explained that a crown would be given to the person who consumed the least energy of the group and a pair of donkey ears would be given to the person who consumed the most energy of the group. For the control group, it was only explained that the interface displayed all the members of their group. An image illustrating an example of the expected feedback was displayed next to the instructions.

Weekly feedback was presented every Monday based on the accumulated energy consumptions of the previous week. Daily feedback was presented every other day and it was generated based on the energy consumption details of the previous day. Participants received two weekly email reminders (every Monday and Wednesday) during the game period (three weeks). This procedure was repeated during three weeks.

During the Monday of the fourth week, as every Monday of the experimental procedure, participants entered the website, indicated the amount of hours of presence and consulted the feedback value of the previous week. At the evening of the Monday, participants received an email stating the end of the experiment and asking them to fill in the post experimental questionnaire containing manipulation check, user experience and social measures. evening of the Monday of Energy recordings continued during the rest of the fourth week but no feedback was provided any more. The entire procedure of login into the game and consulting the feedback took about 3 minutes per person. Questionnaires took less than ten minutes each. Participants received 10 Euros as compensation for their participation in the experiment. The diagram on Figure 2.6 displays the procedure as a the sequence of actions were executed during the experiment.
3. Results

3.1. Feedback Strategies

In this section, the results of the feedback strategies used during the experiment will be presented and their effectiveness will be compared and analyzed.

3.1.1. Energy Consumption

An exploratory analysis was conducted over the daily consumption values collected for the 72 participants during the 32 days that the experiment lasted. Figure 3.2 illustrates the average daily power consumed during the field experiment. In the baseline week, values of consumption were smaller (M = 13.32, SD = 17.04) across all conditions, compared to all the other recordings collected during the experiment. This could be explained as the Hawthorne effect, in other words, individuals became aware that they were being measured, and tried to reduce their energy consumption. During the following week, the feedback is introduced but the consumption rates were higher than the baseline week (M = 15.15, SD = 15.89), with an interesting drop of energy consumption at the end of the week. In the second week of the manipulation, the general consumption increased (M = 15.82, SD = 15.29) compared to the experimental week 1, but the change is only noticeable if groups are analyzed separately. For instance, subjects in the individual comparison feedback consumed on average 0.36 watts less (M = 19.18, SD = 21.29) than the previous week (M = 19.54, SD = 21.58). Consistent to the expected change, subjects in the group condition reduced their overall consumption 0.31 watts (M = 13.86, SD = 10.46) compared to the previous week (M = 14.17, SD = 14.33). The consumption of the group feedback condition continued to decrease during the third experimental week (M = 11.89, SD = 14.45). In contrast, the average of the individual comparison condition slightly increased during the third experimental week (M = 19.54, SD = 21.58). Figure 3.1 displays the mean scores of the power consumption of the three conditions for each week of the experiment. In the last week of measurements, the feedback is not present anymore and the consumption increased (M = 18.90, SD = 20.32) in all conditions. The power consumption of the subjects that received individual comparison feedback did not present variations during the experiment and remained constant despite the feedback manipulation. The consumption of the individuals in the group feedback had a reduction trend.
during the experimental manipulation and it increased in the last week when the feedback was not present. The control group increased its consumption during the experiment. The high values of the standard deviations of each week indicate that daily rate of energy consumption presented a lot variation, specially when including the energy consumed during the weekend. In the Figure 3.2, the variation between days can be noticed. For example, days at the end of the week - Thursdays and Fridays - present less power being consumed compared to days at the beginning of the week - Mondays, Tuesdays and Wednesdays.

After data exploration, some corrections were done over the recordings of several participants. Two day values from one individual which presented extreme values, suggested a possible error with the measurement device or a rare condition in which the participant might have used an extra electrical device that consumed instant power of 1000 watts. These two day values were transformed into values equivalent to 3 standard deviations of the overall consumption of that individual. Due to incomplete recordings, 10 of the participants who presented frequent problems in the measuring device (Plugwise) were not included in the analysis. Five additional participants who quited the experiment were also excluded. The final analysis included only data of 57 participants: 21 in the control condition, 20 in the individual comparison feedback and 16 in the group feedback.

![Figure 3.1: Mean scores of the energy consumption of the experimental conditions and control group during the manipulation.](image-url)
3.1 Feedback Strategies

In order to test the difference between type of feedback strategy, the consumption data was submitted into a repeated measures ANOVA (“days” as within subjects factor vs “feedback type”, as between subjects factor). Twenty two levels were defined for the factor “days”, corresponding to the duration in days of the experimental manipulation. The daily power consumption records for each individual were assigned to the 22 levels. The type of feedback was used as between subject factor, and the 3 conditions of feedback (no feedback, individual comparison and group feedback) were included. The baseline was considered as a covariate (f(1)=60.908, p<.000). Assumptions of normality and homogeneity of variances were satisfied. The results for the main effect of days (days(21) = 1.988, p < .01) suggested a violation on the assumption of sphericity (χ²(230 = 873.068), leading to consider the Huynh-Feldt correction and adjusting the degrees of freedom to 10.469 (p < .05, ω²= .008) as detailed in Table 3.1.

Results for the main effect of the feedback condition (Table 3.2) were significant (feedback(2) = 4.229, p < .05), suggesting that there was an evident variation of the general power consumption between the experimental conditions.
Table 3.1.: Tests of Within-Subjects Effects of the experimental manipulation.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>4562.694</td>
<td>21</td>
<td>217.271</td>
<td>1.988</td>
<td>.005</td>
<td>.036</td>
<td>.991</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>4562.694</td>
<td>8.253</td>
<td>552.819</td>
<td>1.988</td>
<td>.044</td>
<td>.036</td>
<td>.828</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>4562.694</td>
<td>10.469</td>
<td>435.831</td>
<td>1.988</td>
<td>.030</td>
<td>.036</td>
<td>.893</td>
</tr>
<tr>
<td>days * baseline</td>
<td>3849.068</td>
<td>21</td>
<td>183.289</td>
<td>1.677</td>
<td>.029</td>
<td>.031</td>
<td>.971</td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>3849.068</td>
<td>8.253</td>
<td>466.356</td>
<td>1.677</td>
<td>.099</td>
<td>.031</td>
<td>.744</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>3849.068</td>
<td>10.469</td>
<td>367.665</td>
<td>1.677</td>
<td>.079</td>
<td>.031</td>
<td>.821</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>3849.068</td>
<td>16.507</td>
<td>232.638</td>
<td>.836</td>
<td>.762</td>
<td>.031</td>
<td>.896</td>
</tr>
<tr>
<td>days * feedback</td>
<td>3840.151</td>
<td>42</td>
<td>91.432</td>
<td>.836</td>
<td>.762</td>
<td>.031</td>
<td>.896</td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>3840.151</td>
<td>16.507</td>
<td>232.638</td>
<td>.836</td>
<td>.647</td>
<td>.031</td>
<td>.591</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>3840.151</td>
<td>20.938</td>
<td>183.407</td>
<td>.836</td>
<td>.675</td>
<td>.031</td>
<td>.673</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>3840.151</td>
<td>1113</td>
<td>109.312</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>error (days)</td>
<td>121664.247</td>
<td>53</td>
<td>2001.449</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>121664.247</td>
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<td>278.131</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>121664.247</td>
<td>554.855</td>
<td>219.272</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2.: Tests of Between-Subjects Effects of the experimental manipulation.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>160.918</td>
<td>1</td>
<td>160.918</td>
<td>.080</td>
<td>.778</td>
<td>.002</td>
<td>.059</td>
</tr>
<tr>
<td>baseline</td>
<td>121903.472</td>
<td>1</td>
<td>121903.472</td>
<td>60.908</td>
<td>.000</td>
<td>.535</td>
<td>1.000</td>
</tr>
<tr>
<td>feedback</td>
<td>16928.510</td>
<td>2</td>
<td>8464.255</td>
<td>4.229</td>
<td>.020</td>
<td>.138</td>
<td>.717</td>
</tr>
<tr>
<td>error</td>
<td>106076.795</td>
<td>53</td>
<td>2001.449</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overall difference on consumption.

As an effect was encountered, planned contrast comparisons were used to understand what were the differences in energy consumption between the experimental conditions (no feedback, individual comparison and group feedback). Table 3.3 shows in detail the results from this test.

The first planned contrast comparisons revealed a marginal significant difference between subjects that received no feedback and subjects that received individual comparison feedback, \( t(21) = 1.48, p = .07 \) (1-tailed). Contrary to hypothesis 1, subjects that received individual comparison feedback consumed in average more energy compared to individuals who did not receive feedback. A marginal significance difference was found between subjects with no feedback and subjects with group feedback \( t(21) = 1.327, p = .06 \) (1-tailed). This result provides support for hypothesis 2 in which it was expected that the group feedback condition would reduce the energy consumption compared to the no feedback condition.

**Table 3.3.:** Planned contrasts comparison for overall power consumption

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( -\frac{1}{2} )</td>
<td>( -\frac{1}{2} )</td>
<td>0</td>
<td>.265</td>
<td>2.649</td>
<td>.921</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>-4.420</td>
<td>2.984</td>
<td>.144</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>4.951</td>
<td>3.215</td>
<td>.130</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>9.371</td>
<td>3.226</td>
<td>.005</td>
</tr>
</tbody>
</table>

A significant difference - \( t(21) = 2.90, p < .01 \) - in the total energy consumed was found between subjects in the individual comparison condition compared to subjects in the group condition. This difference provides evidence against Hypothesis 3, suggesting that the group feedback condition reduced their consumption compared to the individual comparison feedback group. Still, these comparisons only tested the differences in the overall consumption and do not consider changes over time, which could give a more precise explanation for the encountered effects.

Trends over consumption.

Previous results only revealed partial evidence on the difference between the overall consumptions of the control and experimental groups. A second procedure of planned contrast comparison over the linear trends was executed to clarify the relationship between the perceived change of consumption and the experimental manipulation. Linear trends show the measure of how the Dependent Variable - power
consumption - changes as the Independent Variable - feedback condition - changes while holding constant all covariates - the baseline. Table 3.4 displays the results of the planned comparisons of the linear trends. First test (no feedback vs feedback) revealed a significant difference, $t(21) = 1.923$, $p < .05$ (1-tailed), between the linear trends of the two groups. This result suggests that the feedback effectively decreased energy consumption over time.

Table 3.4.: Planned contrasts comparison for trends in power consumption

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1/2</td>
<td>-1/2</td>
<td>0</td>
<td>526.548</td>
<td>273.798</td>
<td>.060</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>409.291</td>
<td>308.365</td>
<td>.190</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>643.805</td>
<td>332.304</td>
<td>.058</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>234.514</td>
<td>333.418</td>
<td>.485</td>
</tr>
</tbody>
</table>

The difference between the linear trends was marginally significant, $t(21) = 1.397$, $p = .095$ (1-tailed), when comparing the control group with the individual comparison feedback condition. Participants in the individual comparison feedback presented a marginal trend to reduce their energy during the experimental weeks, but their consumption was higher than the baseline. The difference encountered in the linear trends between subjects in the control condition and subjects in the group feedback condition was significant, $t(21) = 1.937$, $p < .05$ (1-tailed). This provides support for hypothesis 2 in which group feedback was expected to reduce energy consumption compared to no feedback at all.

The comparison between the linear trends of the individual comparison feedback condition and group feedback condition showed that the slope of the linear trend was higher for the group feedback condition than for the individual comparison feedback condition. Individuals in the group feedback condition reduced more effectively their energy consumption over time. This result - however not significant, $t(21) = 0.703$, $p = .48$ (2-tailed) - contradicts Hypothesis 3.

Figure 3.3 shows the linear trends presented during the manipulation weeks. Both individual comparison feedback and group feedback show decreasing linear trends while the no feedback group slightly increased.
3.1 Feedback Strategies

3.1.1.2. Week days and weekends comparisons.

Week days comparison.

The 16 week days corresponding to the regular working days were submitted to a repeated measures ANOVA (“days” as within subjects factor vs “feedback type”, as between subjects factor). This analysis was similar to the one done before, but in this case, all the weekend values were extracted to reduce the variance of power encountered during the week. The results from the analysis (Table 3.5) - with Huynh-Feldt correction- revealed that the effect of days was not present anymore $F(8.043) = 1.377, p = .204$. This suggests that energy savings achieved during the weekends possibly had an effect on the measured consumption. Later in the next subsection, the effect will be tested by only comparing consumption during the weekends. The effect of feedback was significant, $F(2) = 4.168, p < .05$. as detailed in Table 3.6.

Contrast comparisons revealed that individual comparison feedback was not more effective than no feedback, $t(15) = 1.45, p = .152$. Group feedback was marginally significant compared to no feedback, $t(15) = 1.55, p = .06$ (1-tailed). Individual comparison feedback condition consumed more energy compared to group feedback condition, $t(15) = 2.88 , p < .01$. See Table 3.7.

The trend analysis detailed in Table 3.8 only revealed a significant difference between no feedback and group feedback, $t(15) = 2.11, p < .05$. 

Figure 3.3.: Trend lines of the power the consumption during the experiment.
Table 3.5.: Tests of Within-Subjects Effects during only week days.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td>2484.725</td>
<td>15</td>
<td>165.648</td>
<td>1.377</td>
<td>.152</td>
<td>.025</td>
<td>.838</td>
</tr>
<tr>
<td>days * baseline</td>
<td>1297.886</td>
<td>15</td>
<td>86.526</td>
<td>.719</td>
<td>.766</td>
<td>.013</td>
<td>.489</td>
</tr>
<tr>
<td>days * feedback</td>
<td>3172.863</td>
<td>30</td>
<td>105.762</td>
<td>.879</td>
<td>.654</td>
<td>.032</td>
<td>.824</td>
</tr>
<tr>
<td>error (days)</td>
<td>95627.759</td>
<td>795</td>
<td>120.286</td>
<td>.720</td>
<td>.400</td>
<td>.002</td>
<td>.133</td>
</tr>
</tbody>
</table>

Table 3.6.: Tests of Between-Subjects Effects during week days.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1073.750</td>
<td>1</td>
<td>1073.750</td>
<td>.720</td>
<td>.400</td>
<td>.002</td>
<td>.133</td>
</tr>
<tr>
<td>baseline</td>
<td>104795.098</td>
<td>1</td>
<td>104795.098</td>
<td>70.265</td>
<td>.000</td>
<td>.535</td>
<td>1.000</td>
</tr>
<tr>
<td>feedback</td>
<td>12432.110</td>
<td>2</td>
<td>6216.055</td>
<td>4.168</td>
<td>.021</td>
<td>.138</td>
<td>.710</td>
</tr>
<tr>
<td>error</td>
<td>79046.147</td>
<td>53</td>
<td>1491.437</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1 Feedback Strategies

Table 3.7.: Planned contrasts comparison for overall power consumption during the week days

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1/2</td>
<td>-1/2</td>
<td>0</td>
<td>.319</td>
<td>2.682</td>
<td>.906</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>-4.420</td>
<td>2.984</td>
<td>.152</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>4.951</td>
<td>3.215</td>
<td>.128</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>9.371</td>
<td>3.226</td>
<td>.006</td>
</tr>
</tbody>
</table>

Table 3.8.: Planned contrasts comparison for trends in power consumption during the week days

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1/2</td>
<td>-1/2</td>
<td>0</td>
<td>322.718</td>
<td>159.460</td>
<td>.048</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>236.737</td>
<td>179.591</td>
<td>.193</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>408.699</td>
<td>193.533</td>
<td>.039</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>171.962</td>
<td>194.182</td>
<td>.380</td>
</tr>
</tbody>
</table>

Weekends comparison.

At last, the consumption during the 6 weekend days of the experimental weeks were compared using a repeated measures ANOVA (“days” as within subjects factor vs “feedback type”, as between subjects factor). This analysis tried to reveal differences in energy consumption during the weekend, since the experiment focused on motivation energy saving actions like turning off the computer when not using it, specially in the weekends, when normally people are not in their offices. The results did not reveal any difference in the weekends consumption within the subjects - $f(2.838) = 1.293$, $p = .279$ -, but the comparison between the feedback groups revealed a marginal significant effect of feedback, $f(2) = 2.958$ $p = .061$. Table 3.11 and Table 3.12 show in detail the results of the planned contrasts.

The results of the weekdays and weekends comparisons did not reveal any additional information than the results obtained from the analyzing the whole days of the experimental phase.
Table 3.9.: Tests of Within-Subjects Effects during the weekends.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td>311.359</td>
<td>5</td>
<td>62.272</td>
<td>1.293</td>
<td>.267</td>
<td>.024</td>
<td>.456</td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>311.359</td>
<td>5</td>
<td>62.272</td>
<td>1.293</td>
<td>.267</td>
<td>.024</td>
<td>.456</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>311.359</td>
<td>2.547</td>
<td>122.235</td>
<td>1.293</td>
<td>.280</td>
<td>.024</td>
<td>.312</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>311.359</td>
<td>2.838</td>
<td>109.706</td>
<td>1.293</td>
<td>.279</td>
<td>.024</td>
<td>.330</td>
</tr>
<tr>
<td>days * baseline</td>
<td>78.739</td>
<td>5</td>
<td>86.526</td>
<td>.327</td>
<td>.896</td>
<td>.006</td>
<td>.133</td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>78.739</td>
<td>5</td>
<td>86.526</td>
<td>.327</td>
<td>.896</td>
<td>.006</td>
<td>.133</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>78.739</td>
<td>2.547</td>
<td>197.107</td>
<td>.327</td>
<td>.773</td>
<td>.006</td>
<td>.108</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>78.739</td>
<td>2.838</td>
<td>161.364</td>
<td>.327</td>
<td>.795</td>
<td>.006</td>
<td>.111</td>
</tr>
<tr>
<td>days * feedback</td>
<td>664.176</td>
<td>10</td>
<td>105.762</td>
<td>1.379</td>
<td>.190</td>
<td>.049</td>
<td>.697</td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>664.176</td>
<td>10</td>
<td>105.762</td>
<td>1.379</td>
<td>.190</td>
<td>.049</td>
<td>.697</td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>664.176</td>
<td>5.094</td>
<td>240.927</td>
<td>1.379</td>
<td>.235</td>
<td>.049</td>
<td>.480</td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>664.176</td>
<td>5.676</td>
<td>197.239</td>
<td>1.379</td>
<td>.229</td>
<td>.049</td>
<td>.511</td>
</tr>
<tr>
<td>error (days)</td>
<td>12760.033</td>
<td>265</td>
<td>48.151</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sphericity Assumed</td>
<td>12760.033</td>
<td>265</td>
<td>48.151</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greenhouse-Geisser</td>
<td>12760.033</td>
<td>135.003</td>
<td>94.517</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huynh-Feldt</td>
<td>12760.033</td>
<td>150.421</td>
<td>84.829</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.10.: Tests of Between-Subjects Effects during the weekends.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1073.750</td>
<td>1</td>
<td>1073.750</td>
<td>.720</td>
<td>.400</td>
<td>.002</td>
<td>.133</td>
</tr>
<tr>
<td>baseline</td>
<td>104795.098</td>
<td>1</td>
<td>104795.098</td>
<td>70.265</td>
<td>.000</td>
<td>.535</td>
<td>1.000</td>
</tr>
<tr>
<td>feedback</td>
<td>12432.110</td>
<td>2</td>
<td>6216.055</td>
<td>4.168</td>
<td>.021</td>
<td>.138</td>
<td>.710</td>
</tr>
<tr>
<td>error</td>
<td>79046.147</td>
<td>53</td>
<td>1491.437</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.11.: Planned contrasts comparison for overall power consumption during weekends.

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$-\frac{1}{2}$</td>
<td>$-\frac{1}{2}$</td>
<td>0</td>
<td>.124</td>
<td>3.127</td>
<td>.969</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>-4.497</td>
<td>3.522</td>
<td>.207</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>4.744</td>
<td>3.795</td>
<td>.217</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>9.242</td>
<td>3.808</td>
<td>.019</td>
</tr>
</tbody>
</table>

### Table 3.12.: Planned contrasts comparison for trends in power consumption during the weekends.

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Individual Comparison Feedback</th>
<th>Group Feedback</th>
<th>Hypothesized Value</th>
<th>Contrast Estimate</th>
<th>Std. Error</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$-\frac{1}{2}$</td>
<td>$-\frac{1}{2}$</td>
<td>0</td>
<td>26.6</td>
<td>22.363</td>
<td>.24</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>25.444</td>
<td>25.186</td>
<td>.317</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>27.756</td>
<td>27.141</td>
<td>.311</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>2.311</td>
<td>27.232</td>
<td>.933</td>
</tr>
</tbody>
</table>
3.1.1.3. General results.

The results showed that participants in the individual comparison feedback condition consumed in average more energy than the control condition. However, the difference in consumption was marginally significant. The trend analysis revealed that the individual comparison feedback presented a reduction in their energy consumption. This reduction was not large enough to be significant. Thus, the results do not fully support Hypothesis 1. and than the group feedback condition.

In the case of Hypothesis 2, the difference in the average consumption between individuals that received group feedback and individuals that did not receive feedback was marginally significant. Additionally, the comparison in trends showed that the difference between the group feedback condition and the control condition was significant. Thus, we can conclude that there is support for Hypothesis 2.

The results related to Hypothesis 3 suggested that subjects in the individual comparison feedback group consumed more energy than subjects in the group feedback condition. The results from the linear trend comparisons showed that the group feedback condition tended to reduce more their consumption over time than the individual comparison feedback, however, this result was not significant. If we consider the overall consumption, the individual comparison feedback group reduced more energy in average, therefore, we can support Hypothesis 3.

3.1.2. Cooperative vs Competitive

The overall impression of the feedback condition in terms of competitive and cooperative was tested. The item measuring the perceived competition or cooperation of the other members in the team was recoded into two variables: values above the 4 points of the 9 point likert scale were recoded into perceived cooperation and values below the 5 points of the scale were recoded into perceived competition. The means of the two items measuring the perceived competition or cooperation, and the two items measuring the participant’s willingness to cooperate and compete among members of the group were compared using a Oneway ANOVA. There was a significant relation between type of feedback and perceived competition (feedback(2)= 3.629, p<0.05). Further analysis through comparison of planned contrasts revealed a marginal effect - t (29) = 1.840 p (2-tailed) = .076 - indicating that participants in the individual comparison condition perceived their team members as more competitive than the participants in the other 2 conditions. Degrees of freedom were adjusted because of violation to the assumption of homogeneity of variance, t (11.104) = 2.030, p (two-tailed) =.067. Participants in the individual comparison feedback were more motivated to compete against other team members - t(29) = 1.750, p (2-tailed) = .091 - than participants in the group feedback and in the control group. A marginal effect was revealed, indicating that participants in the group condition perceived their members as less cooperative than participants in
the no feedback condition - \( t (29) = -1.671, p \text{ (2-tailed)} = .10 \). No difference was found between the group condition and individual comparison condition on their willingness to cooperate nor in their perceived cooperation of other team members.

### 3.2. User experience

Twelve items from the user experience measure were selected after correlation analysis and were explored using Principal component analysis (PCA) with orthogonal rotation (varimax). Barlet test of sphericity \( \chi^2(66) = 360.55, p < .001 \) revealed a sufficient large correlation between items. The Kaiser-Meyer-Olkin measure supported the adequacy of the sample KMO = .76. As a result of the analysis, three factors presented eigen values over Kaiser’s criterion of 1 and, combined, explained 77.28% of the total variance. Table 3.13 displays the factor loading after oblique rotation. The items clustered at each of the extracted factors suggested the following sub-scales: (1) engagement, (2) usability and (3) feedback consistency. Sub-scales of engagement and feedback consistency had high reliability with Cronbach’s \( \alpha = .92 \) and \( \alpha = .75 \) respectively, while sub-scale of usability had relatively low reliability with Cronbach’s \( \alpha = .51 \).

Further analysis indicated a marginally significant effect on the engagement factor on the type of feedback received (no feedback, individual comparison, and group feedback), \( F(2, 29) = 3.28, p = .52, \omega = .35 \). Planned contrasts revealed a significant increase in engagement for feedback condition over no feedback condition \( t(29) = 1.89, p < .05 \text{ (1-tailed)}, r = .33 \). Furthermore, individual comparison feedback increased engagement compared to group feedback, \( t(29) = 1.73, p < .05 \text{ (1-tailed)}, r = .31 \). For the factor of feedback consistency, a marginal effect was found \( F (2,29) = 2.25, p = .124, \omega = .27 \) on the type of feedback (no feedback, individual comparison, and group feedback). Contrast comparison showed that people who had individual comparison feedback reported the feedback to be more consistent compared to people in the group feedback condition, \( t(29) = 2.09, p < .05 \text{ (2-tailed)}, r = .36 \). The factor usability did not show any significant differences among all types of feedback.

### 3.3. Personal Differences

In this section, the self reported measures covering the personal differences between subjects across conditions will be explored in order to see if these differences could have an effect over the differences in power consumption.

<table>
<thead>
<tr>
<th>Items</th>
<th>Pattern</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate your overall experience over the game: wonderful</td>
<td>.89</td>
<td>.89</td>
</tr>
<tr>
<td>Rate your overall experience over the game: satisfying</td>
<td>.81</td>
<td>.87</td>
</tr>
<tr>
<td>Rate your overall experience over the game: adequate</td>
<td>.91</td>
<td>.90</td>
</tr>
<tr>
<td>Rate your overall experience over the game: stimulating</td>
<td>.86</td>
<td>.85</td>
</tr>
<tr>
<td>How much control did you feel that you had over the changes in the interface?</td>
<td>.47</td>
<td>-.43</td>
</tr>
<tr>
<td>Did you feel as if your motivation towards saving energy increased over the experiment?</td>
<td>.94</td>
<td>.89</td>
</tr>
<tr>
<td>What was your experience of the interaction? Easy to learn</td>
<td>.88</td>
<td>.91</td>
</tr>
<tr>
<td>What was your experience of the interaction? Easy to use</td>
<td>.91</td>
<td>.92</td>
</tr>
<tr>
<td>What was your experience of the interaction? Satisfying</td>
<td>.67</td>
<td>.76</td>
</tr>
<tr>
<td>The system understood the changes of my energy consumptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The system gave the correct feedback.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The feedback provided was a consequence of my actions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3 Personal Differences

3.3.1. Environmental attitudes

The results of the New Environmental Paradigm (NEP) scale were explored using Principal Component Analysis. Five factors with eigen values above 1 were revealed by the analysis. Based on previous research (Dunlap et al., 2000), it was decided that considering 5 factors was an inconvenient approach and a new analysis was done, specifying the number of factors to be extracted into only 3. The 3 extracted components were treated in a similar way to the ones obtained by Kempton, Boster, and Hartley (1995) in a previous study. The factors were defined as: (1) Nature is a limited resource upon which humans rely, (2) Nature is balanced, highly interdependent and complex, and therefore susceptible to human interference and (3) Materialism and lack of contact with nature have led our society to devalue nature. The factors presented Kaiser-Meyer-Olkin (KMO) of .61 and explained the 57.40% of the total variance. The factor loading is shown in Table 3.14. Four of the original items of the NEP scale were not considered because they did not present loads above .4 and they had very small correlation. Table

After one way ANOVA (NEP factors vs feedback condition) a marginally significant effect ($\chi^2(2, 27.913) = 2.547, p = .096$) was found on factor number 1: Nature is a limited resource upon which humans rely. Planned comparison revealed that individuals in group feedback scored less for factor 1, compared to subjects in the individual comparison and to subjects in the control group. This meant that individuals had a weaker attitude towards nature as a limited resource. Even though, participants in the group feedback condition had a weaker attitude towards environmental problems, they still reduced their energy consumption. The three factors were later tested as a covariate in the energy consumption analysis and the effect of the factors resulted in non significant at all, suggesting that they did not have any effect over the energy consumption.

3.3.2. Self-efficacy

For analyzing the General Self-efficacy scale, a single factor was determined by adding the values of each of the items. The factor presented a mean of 29.98 (SD = 3.61). Subjects in the control group reported the lowest self-efficacy ($M = 28.73$, $SD = 3.85$), subjects in the individual comparison feedback which reported the highest self-efficacy ($M = 30.75$, $SD = 3.642$) and subjects in the group feedback condition ($M = 30.14$, $SD = 3.88$). The differences of the means was tested and it resulted in a non significant effect ($f(2,46) = 1.304 \, p = .281$) indicating that self-efficacy was the same in all conditions.

3.3.3. Pro-Social behavior

To calculate the self-reported Triple Dominance Measure (TDM) scale, answers selected by participants were summed up according to three classifications: pro-self,
**Table 3.14.** Component matrix for NEP scale. Extraction method: Principal Component Analysis.

<table>
<thead>
<tr>
<th>Items</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>If things continue on their present course, we will soon experience a major ecological catastrophe</td>
<td>.78</td>
</tr>
<tr>
<td>The earth is like a spaceship with very limited room and resources</td>
<td>.75</td>
</tr>
<tr>
<td>The so-called ecological crisis facing humankind has been greatly exaggerated</td>
<td>-.67</td>
</tr>
<tr>
<td>Plants and animals have as much right as humans to exist</td>
<td>.56</td>
</tr>
<tr>
<td>The balance of nature is very delicate and easily upset</td>
<td>.52 -.47</td>
</tr>
<tr>
<td>Human ingenuity will insure that we do NOT make the earth unlivable</td>
<td>.70 .43</td>
</tr>
<tr>
<td>Humans have the right to modify the natural environment to suit their needs</td>
<td>-.40 .56 .51</td>
</tr>
<tr>
<td>We are approaching the limit of the number of people the earth can support</td>
<td>.50 .56</td>
</tr>
<tr>
<td>The earth has plenty of natural resources if we just learn how to develop them</td>
<td>-.40</td>
</tr>
<tr>
<td>Humans were meant to rule over the rest of nature</td>
<td>.60</td>
</tr>
<tr>
<td>When humans interfere with nature it often produces disastrous consequences</td>
<td>.44 .53</td>
</tr>
</tbody>
</table>
3.3 Personal Differences

individualistic and competitive. Since the questionnaire was realized after participants finished the experiment, it is interesting to note that all the participants who answered the correctly this questionnaire and belonging to the group condition, scored higher in pro-social scale than the other conditions. It is possible that individuals were primed by the group feedback presented to them, because individuals in the group feedback depended more on group dynamics like coordination and cooperation. Figure 3.4 shows the percentage of participants according to their social orientation.

![Interpersonal Orientation Chart](image)

**Figure 3.4.:** Pro-social, individualistic and competitive attributes measured by the TDM scale.
4. General Discussion

In the present study, we tried to replicate the previous study of Midden et al. (2011) and extend it through a field experiment. We investigated energy conservation as a group effect and we tested the possible effects that two different types of group feedback could have over the energy consumption of a group of people in the Eindhoven University of Technology. More specifically, we tested the differences in effectiveness between providing participants with individual comparison feedback and providing them with group feedback in order to reduce energy consumption.

4.1. Main Findings

It was expected that the individuals that received feedback about their energy consumption would reduce their consumption compared to the individuals that did not receive feedback. However, the results of the study presented here showed that different types feedback lead to different effects on individual behavior. We found clear differences between our results and the results of the study of Midden et al. (2011).

Firstly, the individuals that received the group feedback reduced their energy consumption more effectively compared to individuals that did not receive feedback. This result supported our hypothesis and provided new evidence about the way individuals might react to different types of settings regarding to their sustainable behavior. According to the results of the previous study (Midden et al., 2011), group feedback was only effective for subjects that came from a collectivist culture (Japan), while subjects that came from an individualistic culture (The Netherlands) group feedback was not motivating them enough to save energy. In the case of our study, we found evidence that group feedback was effective in changing the behavior of the individuals, when consumption was monitored in a context that occurred through a longer period of time.

Secondly, individuals that received individual comparison feedback also presented a tendency to reduce their energy consumption. However, they consumed more energy in average compared to individuals that did not receive feedback. This result might not support our first hypothesis, nevertheless, as figure Figure 3.3 shows, there is a tendency to reduce their energy which might suggest that the feedback had a positive effect on the energy conservation behavior. The feedback motivated the individual to save energy but it might not have reduced the uncertainty that surrounded the goal of saving energy completely.
The energy conservation behavior is regulated by comparing the obtained feedback with the current goal. And also by adjusting this behavior to the perceived difference between their personal performance and the standard of comparison. Individuals adjust their behavior to what they consider their point of reference. The point of reference for the individual comparison feedback are the people who consumed the most or the least energy. Therefore, the subject has to reduce his personal energy consumption enough to match the reference point, without considering the overall consumption of the group. The individual comparison feedback only clarifies the individual performance while it does not give information about the state of the resources. Following this line, in figure Figure 3.1 it can be appreciated that participants in the individual comparison feedback incremented their consumption in the first experimental week compared to their consumption during the baseline week. This difference might be explained by the same fact that individuals did not have information about the overall energy consumption of the group. Without a reference point about the general state of the resources, the individual might only reduce his personal consumption in comparison to the team members, but the individual’s consumption might still be above the standards of what could be considered as effective energy reduction.

Our results give evidence that providing feedback to individuals within a group triggers their commitment to sustainable behaviors. However, in order to effectively achieve improvements in the performance, the type of provided feedback should be adapted based on the extent in which the individual depends on shorter or larger timespan interactions.

In addition, we explored the participants’ motivation to cooperate and compete with other group members. In the previous study, individuals in the comparison feedback said in their comments to the researchers that they were actively motivated to compete and they really wanted to win during the intervention. This triggered us to try to get better insights about people’s motivation and the activation of a competitive or a cooperative mindset regarding the type of feedback as a way to motivate engagement. While no difference was found between the group condition and the individual comparison condition on their willingness to cooperate, the results suggested that subjects in the individual comparison feedback reported higher motivation to compete and perceived their fellow members as more competitive. This suggests that the individual comparison feedback triggers competition among individuals.

The results from this study show the potential of feedback on group settings to motivate energy conservation.

### 4.2. Limitations

There were a couple of limitations to these results. First, participants were assigned randomly into groups. The groups did not represent a natural setting of group
4.2 Limitations

formation in an typical office environment. In our experiment, members of a group were distributed across a building, sometimes divided through several floors and participants might not interact with their other group members on a regular basis. The groups would have been more representative if the room of occupancy was considered as the grouping criteria. However, most of the offices in the building where the experiment was executed did not have a regular number of occupants. In most of the cases, offices were occupied by 2 or 3 persons per office, while in several cases, offices were only used by a single individual. In some cases an office could contain 5 or more individuals. Our new criteria of grouping facilitated the comparisons among groups, but it reduced its ecological validity. A possible way to solve this issue, could be to consider groups with a more regular number of occupancy, for example, groups per floor.

A second limitation was that, to calculate the feedback, we considered the hours of the participant’s presence during the week. The time of presence was the best indicator we had to generate feedback during the experiment. The feedback was generated based on the energy spent during that day and it would be adjusted to hours of presence. In this sense, the feedback was expected to change behaviors that considerably affect energy conservation: leaving the computer on while it is not being used, for example, during the nights, lunch breaks, and weekends. Participants indicated the amount of hours of their presence but this indicator might not be an exact measure of presence. If the subject indicated that she would spend 8 hours in the office, we expected that the energy consumed should be equivalent for those 8 hours. However, the person might spend more time in the office, and therefore, the feedback might not be correct.

A risk emerged when considering the hours of presence for calculating and generating the feedback measure: all members had to indicate their amount of hours before the feedback could be generated. Individuals were asked to indicate their time presence at the beginning of the week but the possibility that a member of the team would not indicate their time presence in time - before the first feedback of the week was generated - was existent. For example, a participant’s working week could start on Tuesday, rather than Monday, thus she will not indicate her number of hours until she arrived to her office on Tuesday morning. By that moment, other members of the team would have already consulted the interface and expected to see the feedback. But the feedback would not be displayed until the last member had filled in the required hours of office presence. To reduce this risk, the feedback algorithm was modified to automatically adapt to the number of members that have already indicated their time presence. Thus, in the case of group feedback, the algorithm calculated the average consumption based on the available members. In the case of individual comparison, the algorithm needed at least two members available to compare and extract the members with the highest and the lowest consumption. The feedback changed as soon other members’ hours became available. This modification to the algorithm reduced the problem but it did not solve it entirely since there was no other possible way to control that all members would indicate their time presence.
in a synchronized way.

Additionally, we should consider the differences in equipment between the participants. The differences in equipment could lead to less or more energy consumption. Furthermore, participants also might have different possibilities to change their behavior. For example, a specific type of computer may allow to set the computer into the hibernate option while another type of computer might not have that possibility. In this reasoning, the effort for changing behavior for each participant differs according to the type of equipment.

4.2.1. Towards application and future.

Meet Caroline, Take 1: an example of the social perspective of sustainability.

Caroline works as a researcher at a well known company that creates health-care products. She has been working for this company for five months. Caroline considers herself as a pro-environmental person. When she started working at the company, she was surprised by the amount of energy that her colleagues wasted. Computers were left on during the night and sometimes even during the weekends. Since her job duties mainly consist of computer related tasks, Caroline spends most of the day working with her computer which makes it more difficult to save energy. She tries to make a difference by turning off her computer when she is not using it. She also turns the lights off whenever she leaves her office. However, saving energy is not always possible because she shares her office with other 2 colleagues, and she cannot turn off the lights if they are still present. Several times in the morning, she has found that the lights of her office were left on during the night. She tries several times to convince them to waste less energy, but the situation does not improve. Instead, she is criticized by her colleagues and this leads to several discussions. Caroline does not desire any more conflicts with her colleagues and she decides to care less about her own energy savings.

Meet Caroline, Take 2: an example of a successful behavioral intervention.

Last week, the company where Caroline works, implemented a system which measures the energy consumption of each room. The system is an initiative to save energy and reduce costs. A screen located in the hallway displays the information about the energy consumption of each of the rooms including Caroline’s office. The screen also displays information about the money costs equivalent to the energy spent by each room. Additionally, the system includes a computer game functionality: a ranking system that displays which room has saved the most energy during the week. At the end of each month, the system praises the employees with the most energy effective office. The system has encouraged many of the employees, including Caroline, to save more energy than they had been saving. For instance, Caroline
sets her computer into sleep mode every time she goes for lunch or for her regular coffee break. Her colleagues do not leave their computers on during the night anymore and they are always careful of turning off the lights when they leave the room. The game concept implemented by the system has changed the patterns of behavior of the employees radically. The management department of the company wants to achieve more reduction and promises a prize, given to the room that reduces its energy consumption the most.

The current thesis has pointed out the opportunity of providing feedback in a group level as a strategy to promote energy conservation. However, the effectiveness of the strategy depended on providing the proper feedback. Additionally, the feedback should also be relevant to the behavior that is expected to be affected. In the case of our experiment which included long term intervention, participants suggested that they would like to see how they performed during the time that the experiment lasted. Providing historical information might also affect the performance. Our results gave us insights about the different kinds of motivations that the specific type of feedback could trigger in a group, for example, competition, or cooperation among team members. By adjusting the goal and the type of feedback, we could increase engagement to sustainable behavior. More research should be done on identifying the role that individual and interpersonal motivations plays in engagement.

Further work should focus on recognizing the actions that have a bigger impact on energy wasting. In the case of our study, power consumption was monitored every minute, but we only considered the daily average consumption as energy measure. Further work could focus on studying the patterns during shorter periods of time. The data we collected showed every minute when a person was executing a resource consuming task in the computer or even when the computer was just left on without executing any task, and all of that in precise detail. Analysis of the energy consumption over shorter periods of time might possibly identify the moments in which the person is really using the computer (Jaramillo Garcia and Amft, 2013). This might lead to more accurate feedback which could influence the person to turn off the screen when she is not working.

In the example provided by the case, Caroline might reduce her energy consumption to the optimal point without affecting her daily activities. She cannot turn off her computer and stop working in order to save energy. She still needs to use the computer during her work; therefore, the biggest opportunities to save energy lie in reducing the moments in which the energy is not effectively used, in other words, the moments of energy waste. An individual with low energy waste, like the case of Caroline, might find it difficult to reduce her personal energy consumption even more. More focus should be given to trying to change behaviors that affect energy waste directly. In the case of our research, energy conservation could be achieved by turning off the electronic appliances when they are not being used in that exact moment. For instance, similar to the example of Caroline’s colleagues, a person
could save energy by not leaving on the computer during the weekends and during the nights. But even saving energy during work breaks might also make a difference. It might be possible that small actions like turning off the computer or setting it on standby during lunch and coffee breaks could make a huge difference on saving energy.
A. Appendix: Introduction letter and Consent Form

This appendix contains the letter that was given to each participant containing the instructions and explanation about the experiment and the consent form that every participant signed.

A.0.2. Introduction letter

Energy-Saver Game: Encouraging energy preservation in office environments. We invite you to participate in a study called Energy-Saver Game. With Energy-Saver Game, we investigate an innovative form to promote energy saving. Energy-Saver Game is an interactive online application, which keeps track of the energy consumption, and challenges you to adopt new behaviors. This application includes game factors of challenge, fantasy, cooperation and competition to improve gaming experience and enhance participation.

Advantages and disadvantages of participation As an advantage from participating in this study, you will learn more about your energy efficiency at work and how to optimize it. Moreover, you will receive information of your performance in comparison to other participants. We hope you can benefit from your participation and that you participate because you find the study useful, however, we appreciate your participation and therefore we will offer you a reward of €10 if you complete the study. Your participation is extremely useful to us.

Moreover, this study tries to be pleasant and effortless, and it requires your attention for only about 3 minutes every morning and we will ask you to fill in a questionnaire at the beginning and at the end of the experiment.

There are no risks for health, safety, or privacy involved in participating in this research study.

Informed consent For the success of this experiment your participation is essential. If you agree to participate in this research study, please sign the participant consent form and return it to us (see contact information at the end).
Study Protocol  Before the study commences, you will be assigned to a group. Each specific group has a goal to save energy. The experiment will consist of approximately 1 month (October 2012) of data collection. Energy plugs which measure the electrical consumption of electrical appliances will be installed in your office. We will only measure the energy consumption of the devices which are directly related to your daily work activities: your personal computer, its attached display and a desk lamp (if available). Each energy meter is placed between the socket and the electrical appliances. The online game application will provide feedback about energy consumption on a daily basis. You will be provided with a web link where you can consult the online application.

Questionnaire and feedback  To identify energy consumption patterns and improve gaming experience, you will be asked to provide information about your average working time at the beginning of each week. You will also be asked to fill in a questionnaire with about computer usage (e.g., applications you use) demographics and gaming experience at the beginning and at the end of the experiment.

Privacy and data analysis  The information from the energy meter and questionnaires will be anonymized before storing and further processing. Anonymization is done by assigning random identifiers to participants and groups. The collected data will be analyzed to identify the differences and trends in behavior patterns in anonymized form.

For the quality of the results of the data results it is important that participants are independent in their responses. Therefore, please do not comment or discuss about the game with other participants during the research. Information about the results After the data and responses have been analyzed you will be informed about the study outcome.

Exiting from the study prematurely  Of course we hope that you will complete the experiment. However, in case you would decide to stop the study, you are free to do so at any moment. There is no personal disadvantage related to exiting from the study. Please inform us immediately if you decide to leave prior to study completion.

Link to the Energy-Saver Game

http://www.actlab.ele.tue.nl/~jmunoz/energysaver/

Contact information

If you have any question about the study and also during the study or you cannot further participate for any reasons please contact:

Jesus Muñoz Alcantara, email: j.munoz.alcantara@student.tue.nl

Thank you very much for your participation!
A.0.3. Consent Form

Please carefully read this form. Please ask if you do not understand some aspect or you have questions. I hereby declare the following: The experimenter has informed me verbally and in writing about the nature, goal and protocol of this research study. I have been informed about the expected effects, potential advantages/disadvantages, as well as risks.

I have read the participant information sheet related to this study and understood it. All of my questions have been answered to my satisfaction. I can keep the participant information sheet and will receive a copy of the signed consent form.

I had enough time to decide. I freely participate in this study.

I am aware that my personal data will be used anonymously and for research purposes only. I agree that my data may be analyzed under these conditions.

I do / do not (cross out what does not apply) want to be informed about the final results of this study.

I can withdraw my consent and participation at any time during this research, without reason or consequence.
B. Appendix: Procedure

This section contains the emails that were sent to the participants as part of the communication procedure of the experiment. The section B.1 contains the introduction email containing the link of the web interface and the link of the first questionnaire. Section B.2 contains the email reminders sent to each of the participants twice a week, and section B.3 contains the email sent at the end of the experiment to thank all participants and it also contained the link to the second questionnaire.

B.1. Introduction Email

Dear «Participant’s name»:

Thank you for participating in the Energy-Saver Game. With this study, we investigate an innovative form to promote energy saving.

Your participation is extremely useful to us. We appreciate your participation and therefore we will offer you a reward of €10 if you complete the study. The experiment will last until the 17th of December, 2012.

In order to start, you have to fill in the following questionnaire which will help us to create a better image of your profile towards energy consumption. This questionnaire will not require more than 10 minutes of your attention.

Please fill in the first questionnaire: Link to Questionnaire «personalized link of questionnaire»

For the success of this experiment your participation is essential. Attached you will find your login details (user and password) and we ask you for your commitment to enter into the site every morning just after you start your computer. This study tries to be pleasant and effortless, therefore, it will require your attention for only about 3 minutes every morning. It might be convenient to create a daily alert on your agenda or Outlook to remind you to enter the website every morning.

Login Details to Energy-Saver Game http://www.actlab.ele.tue.nl/~jimunoz/energysaver/

User: «user»
Password: «password»
Exiting from the study prematurely  Of course we hope that you will complete the experiment. However, in case you would decide to stop the study, you are free to do so at any moment. There is no personal disadvantage related to exiting from the study. Please inform us immediately if you decide to leave prior to study completion.

Contact information  If you have any question about the study and also during the study or you cannot further participate for any reasons please contact:
Jesus Muñoz-Alcantara, email: j.munoz.alcantara@student.tue.nl
Thank you very much for your participation!

B.2. Email reminder:

Dear «Participant’s name»:
For the success of this experiment your participation is essential. Please remember to enter the website every morning when you start your computer. It only takes 3 minutes of your time. If possible, please create a daily alert on your agenda or Outlook to remind you to enter the website every morning.

Contact information  If you have any question about the study and also during the study or you cannot further participate for any reasons please contact:
Jesus Muñoz-Alcantara, email: j.munoz.alcantara@student.tue.nl
Thank you very much for your participation!

B.3. Final email.

Dear «Participant’s name»:
The Energy-Saver Game has come to an end. Thank you for your participation. It was extremely useful to us.
We really appreciated your participation and therefore we will reward you with €10.
Finally, please fill in the following questionnaire about your perception of the game and the interface. This questionnaire does not require more than 10 minutes of your attention. This will help us to improve our prototype and any further comments are very welcome.
Please fill in the first questionnaire:
Link to Questionnaire
Thank you very much!
Contact information  If you have any question about the study please contact:
Jesus Muñoz-Alcantara, email: j.munoz.alcantara@student.tue.nl phone: +31634232351
C. Questionnaires

This section contains the two questionnaires included during the experimental phase. The first questionnaire was delivered on the first day of the experiment and the second questionnaire was applied in the last day of the experimental condition.

C.1. Questionnaire 1 (pre-experimental)

C.1.1. Part 1. Demographics and computer usage

1. What is your age? __________
2. What is your gender? Male ( ) Female ( )
3. What is your country of origin? __________
4. How many hours do you use the Web every week during work?
   _______ None
   _______ Less than 5
   _______ 5 to 10
   _______ 10 to 20
   _______ 20 to 40
   _______ 40 +
5. What kind of Operating System do you use most frequently for your daily work activities?
   _______ Windows
   _______ Mac OS
   _______ Linux / Unix
   _______ Other, please specify: __________
6. How many external screens do you have?
   _______ None
   _______ 1
Acknowledgments

7. For what kind of activities do you use your computer at work? Order from 1 to 5 in order of recurrence, where 1 is the most recurrent, and 5 the least recurrent.

- Mathematic Calculations, Simulations and Tests
- Video & Audio Analysis and Simulations
- Programming, and software tests
- Graphic Design,
- Reading documents, articles, Presentations
- Writing documents, spreadsheets, presentations
- Email
- Other on-line activities (on-line search, news, IM, social media)
- Other, please specify: ____________

8. List the top 5 software programs or applications that you use most frequently at your work.

9. Which of the following actions / measures do you actually use to save energy on your office?

- Dim the screen,
- Turn off the screen when you go to lunch,
- Turn off, hibernate, set to stand by your computer when you go to lunch
- Turn off, hibernate, set to stand by your computer when you are not using it
- Turn off the computer when you leave the office
- Turn off the lights of your office when you do not need them
- Turn off the lights of your office when you leave the office
- Set up a stand by timer of inactivity for the monitor
- Set up a stand by timer of inactivity for your computer
- Use the laptop on battery power
- Other, please specify: __________________

10. Which of the following actions / measures would you be willing to actually implement in order to save energy on your office?

Choose five measures and number them in order of importance, where 1 is the most important, and 5 the least important
C.1.2. Part 2. Environmental Attitudes: (New NEP Scale)

Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you STRONGLY AGREE, MILDLY AGREE, are UNSURE, MILDLY DISAGREE or STRONGLY DISAGREE with it.

11. We are approaching the limit of the number of people the earth can support.
12. Humans have the right to modify the natural environment to suit their needs
13. When humans interfere with nature it often produces disastrous consequences
14. Human ingenuity will insure that we do NOT make the earth unlivable
15. Humans are severely abusing the environment
16. The earth has plenty of natural resources if we just learn how to develop them
17. Plants and animals have as much right as humans to exist
18. The balance of nature is strong enough to cope with the impacts of modern industrial nations
19. Despite our special abilities humans are still subject to the laws of nature
20. The so-called “ecological crisis” facing humankind has been greatly exaggerated
21. The earth is like a spaceship with very limited room and resources
22. Humans were meant to rule over the rest of nature
23. The balance of nature is very delicate and easily upset
24. Humans will eventually learn enough about how nature works to be able to control it

25. If things continue on their present course, we will soon experience a major ecological catastrophe

C.1.3. Part 3. Self-efficacy (General Self-efficacy scale)

Please indicate to what extent the following applies to you: (Not at all true / Hardly true / Moderately true / Exactly true )

26. I can always manage to solve difficult problems if I try hard enough.

27. If someone opposes me, I can find the means and ways to get what I want.

28. It is easy for me to stick to my aims and accomplish my goals.

29. I am confident that I could deal efficiently with unexpected events.

30. Thanks to my resourcefulness, I know how to handle unforeseen situations.

31. I can solve most problems if I invest the necessary effort.

32. I can remain calm when facing difficulties because I can rely on my coping abilities.

33. When I am confronted with a problem, I can usually find several solutions.

34. If I am in trouble, I can usually think of a solution.

35. I can usually handle whatever comes my way.

C.2. Questionnaire 2 (post-experimental)

C.2.1. Part 1: Usability (Quis Scale)

For each of the following questions, fill in 0-9 or leave blank if question is not applicable.

1. Rate your overall experience over the game:
   a) terrible wonderful / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
   b) difficult easy / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
   c) frustrating satisfying / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
   d) inadequate adequate / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
   e) dull stimulating / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
   f) rigid flexible / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 /
7. How much control did you feel that you had over the changes in the interface?  
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

8. To what degree did you feel you were (not) causing the changes in the interface?  
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

9. Did you feel an increase or a decrease of your consumption over the time?  
Decrease / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Increase

10. Did you feel as if your motivation towards saving energy increased over the experiment?  
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

11. What was your experience of the interaction?  
a) Very easy to learn / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very difficult to learn  
b) Very easy to use / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very difficult to use  
c) Not at all satisfying / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very satisfying

14. The system understood the changes of my energy consumptions.  
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

15. The system gave wrong feedback.  
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

16. The feedback provided was a consequence of my actions.  
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

17. How difficult/easy was to change your energy consumption values?  
Difficult / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Easy

18. How difficult/easy was comparing attributes of the feedback provided to you?  
Difficult / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Easy


19. To what extent did you feel that the members of your team were competing against / cooperating with you in your goal of saving energy?  
Very competitive / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very cooperative

20. To what extent were you motivated to compete against / cooperate with the other members of your team in order to save energy.  
Not at all motivated / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very motivated

21. To what extent did you feel identified with your group?
22. To what degree do you think that your group members were motivated to save energy?
Not at all motivated / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very motivated

23. How hard do you think that the other members of your group were trying to contribute with the goal of game?
Very hard / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

24. How important were your contributions to the goal of the game of saving energy?
Very important / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

25. While playing the game, did you notice that the changes in your energy consumption had an influence on other members' behavior?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

26. The more I contributed to the game, the more the other members contributed as well, and the less I cared about my contributions, the less the others will contribute. Does this apply?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

27. How similar are your group members to you in their orientation towards saving energy?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all


28. Please indicate to what extent you know your team members:
(Do not know Know who (s)he is / Acquaintance / Friend / Close Friend )

Member 1
Member 2
Member 3

29. How often did you speak to them about the game? (Daily / Twice a week /Weekly /Less often than weekly / Not at all)

Member 1
Member 2
Member 3

30. How much did your energy consumption habits change during the game?
Not at all / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Very much

33. Which of the following actions / measures did you actually implement to save energy during the experiment?

- Dim the screen,
- Turn off the screen when going to lunch,
- Turn off, hibernate, set to stand by the computer when going to lunch
- Turn off, hibernate, set to stand by the computer when not using it
- Turn off the computer when leaving the office
- Turn off the lights of the office when they were not needed
- Turn off the lights of the office when leaving the office
- Set up a stand by timer of inactivity for the monitor
- Set up a stand by timer of inactivity for the computer
- Use the laptop on battery power
- Other, please specify: ____________

31. To what degree will you recommend this kind of applications to your colleagues in order to motivate them to save energy?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

32. How much pressure to contribute to the game did you feel from other people participating in the game?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

33. Do participants in this game have a dominant attitude towards saving energy?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

34. How favorably do others in general view your contributions?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

35. How enjoyable do you think others find this game?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

36. How much did you enjoy participating in the game?
Very much / 0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / Not at all

37. What percentage do you think that participants reduced their general energy consumption during the game?
/ 0% / 0 to 4% / 4% to 8% / 8 to 12% / more than 12% /

38. In general, how often did you discuss with other people about the game?
/ Daily / Twice a week / Weekly / Less often than weekly / Not at all /
C.2.5. Part 6. Social Orientation. (TDM)

For each of the nine choice situations, circle A, B, or C, depending on which column you prefer most:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>You get 480, Other gets 80</td>
<td>You get 540, Other gets 280</td>
<td>You get 480, Other gets 480</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>You get 560, Other gets 300</td>
<td>You get 500, Other gets 500</td>
<td>You get 500, Other gets 100</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>You get 520, Other gets 520</td>
<td>You get 520, Other gets 120</td>
<td>You get 580, Other gets 320</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>You get 500, Other gets 100</td>
<td>You get 560, Other gets 300</td>
<td>You get 490, Other gets 490</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>You get 560, Other gets 300</td>
<td>You get 500, Other gets 500</td>
<td>You get 490, Other gets 90</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>You get 500, Other gets 500</td>
<td>You get 500, Other gets 100</td>
<td>You get 570, Other gets 300</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>You get 510, Other gets 510</td>
<td>You get 560, Other gets 300</td>
<td>You get 510, Other gets 110</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>You get 550, Other gets 300</td>
<td>You get 500, Other gets 100</td>
<td>You get 500, Other gets 500</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>You get 480, Other gets 100</td>
<td>You get 490, Other gets 390</td>
<td>You get 540, Other gets 300</td>
<td></td>
</tr>
</tbody>
</table>
Bibliography.


Jaramillo Garcia, P. and Amft, O. (2013). Improving energy efficiency through activity-aware control of office appliances using proximity sensing - a real-life study. Proceedings of the 5th International Workshop on Smart Environments and Ambient Intelligence, IEEE.


