Saving Energy at Work: The Design of a Pervasive Game for Office Spaces

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ABSTRACT

Decreasing the energy consumption is an important goal for individuals and public or industrial institutions. Pervasive games have been used to teach people to save energy in private households. We present *Climate Race*, a pervasive game addressing office workers. In the user-centered design process, three main requirements were identified: unobtrusiveness, cooperative gameplay and privacy. The implemented prototype monitors energy consumption and relates it to the activities of the player by measuring corresponding behavior. It provides feedback through a game application. Participants in a pilot study judged the game to be generally appropriate for the workplace, and changes in motivation were reported. Explicitly requesting feedback was preferred over immediate notifications. Sensor measurements showed that energy-saving situations occurred more often during the study.

Keywords

Energy Efficiency, Pervasive Games, Designing for the Workplace

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces

General Terms

Human Factors; Design

1. INTRODUCTION

In the context of climate change, reducing the energy consumption has become a hot societal and political topic. A wide landscape of systems have been designed to support sustainability in HCI research (cf. [2, 9]) and industry. Besides *smart meters* and similar feedback systems, the idea of using games to motivate sustainable behavior in private households (cf. [7, 6, 13] has also been successfully implemented and evaluated.

However, few examples exist for office spaces. *CSK (Cambridge Sensor Kit) Energy* [17], a system for energy measurement and feedback in households and office environments, monitors electricity consumption in office buildings at floor level. While a savings potential is identified, Taherian et al. also have difficulties with such coarse data and see the need of including additional sources of information in order to relate the consumption data to the activities of users. Harris & Cahill [8] use this kind of user-level data, specifically information on presence and current computer usage and different user profiles derived from this information, to control the power status of computers. While this approach allows them to get close to the optimal policy, it also carries the risk of annoying users by powering off their machines.

Like in this study, energy efficiency in office environments has generally concentrated on building automation (e.g., [3, 1]) rather than on the possibility to reduce energy consumption through behavior change. However, in a study by Siero et al. [16] feedback on energy consumption led to a reduced energy consumption at the workplace—in this case, industrial production units. More specifically, workers had to set goals saving energy, and one of two groups was able to compare their performance to the other group, leading to increased energy savings. These mechanisms are similar to typical game design patterns. Foster et al. [5] present design implications for energy interventions in organizations, and game-like elements are also part of their results.

Meanwhile, our approach to motivate office workers to save energy is explicitly game-based. The presented game is an example of *persuasive technology*, i.e., the use of technology—in particular computer technology—for persuasion (cf. [4]) and *pervasive games*, as it expands temporally and (a bit less) socially beyond the "magic circle" (cf. [11]).

2. DESIGN

The design of a pervasive game targeting the workplace needs to take into account the context of its users, as the work environment puts specific constraints on the design. Therefore, we involved users from the beginning in an iterative user-centered design process. Participants of the workshops and the pilot study were research fellows at the same research institute as the authors, with a scientific background in computer science or computational linguistics.

Throughout the process, two questions were explored. *Is the concept of a persuasive pervasive game appropriate for office spaces?* and *Does the game motivate players to save energy?*

In the first user workshop, a storyboard sketch (see Figure 1) representing the initial idea was shown and explained to five users. During one hour, participants were invited to reflect on the general concept, brainstorm for ideas on the game design, and gather requirements pertaining to the imagined game played at their work-

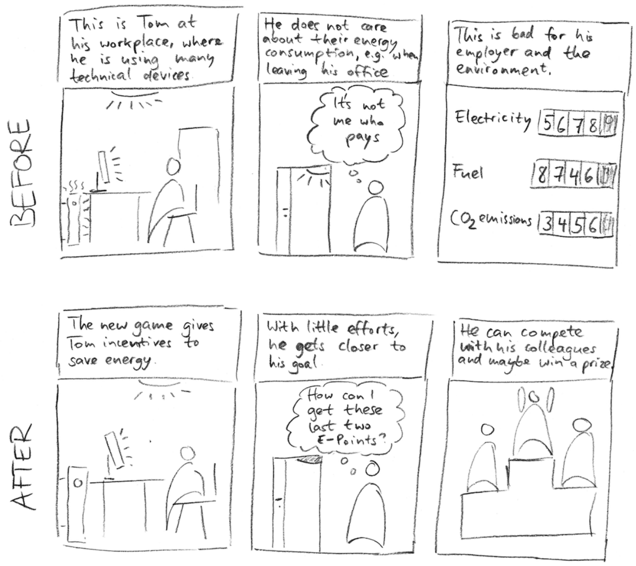


Figure 1: The storyboard presented to participants of the brainstorming workshop. It shows the idea of the energy-saving game and conveys the concept of a competition among colleagues.

place. The results were three main user requirements:

The game is *unobtrusive*. As one participant noted, *"saving energy has to be justifiable in proportion to the effect on work productivity"*. Interference of the game with the work that the player has to do has to be kept to a little; the primary responsibility of the player is to fulfill her job as an employee. As consuming energy is also part of the job, it is important to distinguish between necessary and unnecessary use (wastage) of energy, thus relating the energy consumption to the activities of the player. One participant said, *"It is difficult to define what it means to save energy: One colleague has got a coffee maker in his office, or a paper is being written late at night."*

The game is *cooperative*. Workshop participants explicitly requested to make the game a group effort rather than an individual one by saying, *"The group is measured"*, or, *"saving—yes, but within the group"*.

***Privacy* is respected.** While they also discussed sharing their energy consumption with colleagues (*"My colleagues can see it on Facebook, or they get a text message"*), participants emphasized that privacy is an important issue for the game. One participant said, *"Avoid the Big Brother effect!"*. Players must not be forced to share data about themselves that they do not want to share.

Besides the user requirements, a first version of the design resulted from the workshop. A paper prototype of the main aspects of the intended mobile game was drawn and subsequently shown to a total of nine users in three workshops in order to review the design. The initial concept was then modified according to the results in order to produce the final concept of the *Climate Race* game, consisting of the game design with goals and rules as well as of the interaction design.

2.1 Game Design

The game design relies on few elements. This simple design is intended to keep the game unobtrusive. The game takes place in real time and is based on score points. The *goal* is set to 1,000,000 points for the entire group to be achieved together. This *cooperative principle*—one of the user requirements and also the basis of a privacy-respecting implementation—, in which the actions of all players account for one single score, allows players to compensate for colleagues who might not be able to intensively participate in the game, due to work demands. The points are collected during the *game duration of 10 days*. Giving a concrete goal with a target score and a deadline is meant to give an initial motivation.

Points result from *events for saving or wasting energy* (positive or negative points for reaching goals or failing to reach them are reflected in the score). While the feedback would ideally be given immediately after one of these respective actions is detected from the sensor data, a reliable recognition result can only be assumed after some time. Therefore, most events occur after a five-minute timeout, with another event occurring if the situation remains unchanged for 60 minutes. These events directly represent the rules that define energy-aware behavior for the game, and they allow players to learn what is considered energy wastage. They include switching off lights when leaving the office vs. leaving them on ($\pm$2,500 and $\pm$27,500 points after 5 and 60 minutes, respectively), not using electric lights while in the office (+30,000 points after 60 minutes), switching off electrical devices when leaving the office ($\pm$1,250 and $\pm$13,750 points) or leaving them in standby (+1,000 and $-$1,500 points), and leaving on the radiator while opening the window ($-$5,000 points after 5 minutes).[1] In order to balance the game and to make cheating difficult, the same event can only occur again for the same player after a defined pause. Events that occur five minutes after the action can only occur once every 60 minutes. Events that occur after the situation stayed unchanged for 60 minutes can only occur once every four hours.

Additional points are awarded for *solved quests*. Quests are tasks that are presented to all players at some time and need to be fulfilled before a deadline to earn the promised number of points, and are based on penalizing energy wastage (represented by negative points), electric lights, standby, or even any energy consumption at a specified date or during a period. Some quests can only successfully be solved if all players cooperate on the tasks, other quests are analyzed on a per-player basis. These tasks allow players to find out about additional ways to save energy and offer bonus points in return.

To keep up the game tension, *random events* can add or deduct points, and the *level of difficulty* increases while the game progresses by multiplying negative points for wasted energy and by decreasing positive points for saved energy. This goes along with assumed improvements of players' performance in the course of the game.

2.2 Interaction Design

The input to the game is based on implicit interaction (cf. [15]) through the energy consumption behavior of the players, measured through smart plugs and sensors for lighting status, radiator status, presence, and window status. Implicit interaction is less intrusive than explicit interaction, which makes the input fulfill the requirement of *unobtrusiveness*.

The game application provides feedback to the users in a mobile and a stationary variant. Both have advantages and disadvantages: Putting the game on the desktop computer promises an extremely tight integration with normal work, while a mobile application can

[1] The points values were calculated to be roughly proportional to the amount of energy that is considered to be saved or wasted by the respective action, and so that the events that were expected during the game period according to previously measured test data would altogether generate points that get close to the goal of 1,000,000 points.

also notify the player while she is not in the office.

The game application shows the overall score, a countdown timer, and allows players to access a list of the quests as well as their descriptions (see Figure 2(a-b)). Players receive immediate notifications about game events concerning them: Each player is notified of saved or wasted energy events caused by her behavior, and all players are notified of new quests and their success after they have ended, as well as of random events. An important idea behind the notifications is that players learn about the game mechanics in the course of the game. By noticing the situations in which they are deducted or awarded points they can adapt their behavior to perform better in the game.

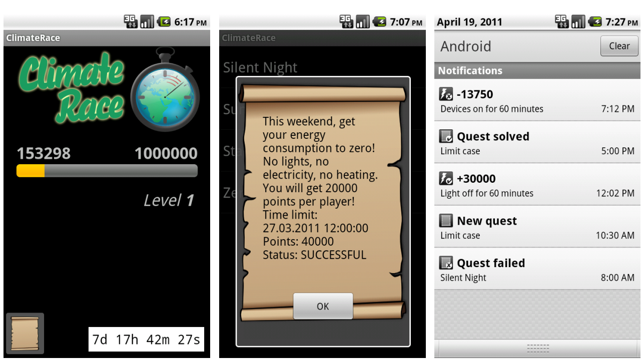
Players are notified in different ways by the mobile application and the desktop application: On the smartphone, the system's notification mechanism is used (see Figure 2(c)). Besides a visual notification, this includes sound and vibration. Notifications are also displayed when the application is not running. These default settings may be changed through the application preferences. On the desktop computer, the notification is displayed by an additional icon in the system tray and a pop-up message, accompanied by sound. Notifications are only displayed when the application is running. Modifying a configuration file allows the players to disable notifications.

3. STUDY

To conduct a pilot study, a game system prototype was implemented. As a sensor platform, we use the *EnergyPULSE* system [10]. Each room was equipped with an off-the-shelf smart power plug, as well as several electronic sensors based on the *Arduino* platform.

In order to fulfill the requirement of *respecting the privacy* of players, the system was designed so that it does not persistently store data about the energy consumption of individual players. Once the notifications have been displayed, they can be erased. However, during the evaluation this information was kept so that it could be analyzed subsequently.

As the system requires a certain amount of hardware to be deployed in the participants' offices, the size of the study was limited to one group of five participants. Participants' offices were equipped with the sensors and all sensor data regarding energy consumption and corresponding behavior was recorded. During a first phase of three months, comparison data was collected. In a second phase of two weeks, the game was evaluated. Before the game started, participants received an e-mail introducing them to the game scenario.



(a) (b) (c)

Figure 2: Screenshots from the mobile game client: The main screen (a) gives an overview of the current state of the game and provides access to the list of quests, quest details (b) show task, time limit, points and status, and individual notifications (c) immediately inform players when game events occur.

Sensor data acquired during the two phases was analyzed to determine the frequency of the different events according to the game rules. Post-evaluation questionnaires were used to gather feedback regarding all of the questions. The results served as the basis of semi-structured interviews.

3.1 Results and Discussion

The sensor data showed that during the game, electrical devices were less frequently left powered on before leaving for five minutes (72.8% of the population before the game, 60.2% during the game), but rather put in standby (23.6% vs. 34.5 %) or even switched off (3.6% vs. 5.3%). Similarly, electric lights were switched off more often before leaving the room (55.0% vs. 69.6%).

The effect of the game was mainly credited to the cooperative concept, as stated by a player, *"There was incentive due to the game and that the others would also be affected."*. Quests also gave more concrete motivation through their smaller goals compared to the global goal, as one participant said, *"Because it was the task to do it"*. One player mentioned discussions with other participants, *"When we were given the tasks, we talked about it: 'Remember tonight to pull all the plugs!'"*.

In the questionnaire, participants reported no negative impact on work productivity (*median* = "No, hardly" for all questions)[2]. Some participants thought that the game was too simple and asked for the game to be more proactive, in particular to develop a more elaborate game narrative, *"That it is accompanied by a kind of storyline"*.

The individual elements of the game concept received varied feedback from participants. When asked how suitable they found each of them, *"Energy saved" events*, *quests*, and the *common goal* were seen as more appropriate (*median* = "Rather suitable" for all of them) than *"energy wasted" events* (*median* = "Somewhat unsuitable, somewhat suitable"). Regarding the interaction design, requesting information was seen as a more suitable concept (*median* = "Suitable" for both the mobile and the stationary application) than notifications (*median* = "Rather unsuitable" for acoustic notification on mobile phone, *median* = "Rather suitable" or *median* = "Somewhat unsuitable, somewhat suitable" for all other notifications styles—visual, acoustic, vibration). This shows a general preference of the pull-based communication paradigm (information is requested by the players) to pushed notifications. One participant explicitly stated that notifications disrupted her work routine, *"When the phone vibrated and I was immersed in something else, that was unpleasant."*

Therefore, the interaction paradigms need to be reconsidered to fully meet the goal of unobtrusiveness. Despite the persuasive effect of immediate notifications—engaging players through constant feedback—players should be given the choice when to dedicate attention to the game, like the principle of implicit interaction does for the game input. Effectively, pushed notifications seem to be more intrusive than requiring the attention of players for a certain time. In combination, these points suggest that more emphasis should be put on quests than on the "energy saved" and "energy wasted" events, as they left the players more freedom to organize their participation, along with more short-term goals instead or in addition of the global goal, and other styles of feedback than immediate notifications.

[2] All of the following questions were rated on a five-level ordinal Likert-style scale.

Privacy issues are mainly addressed by the game design adapting a cooperative principle, leaving personal information undisclosed. This satisfied all participants except one who complained that *"[the data] is collected somewhere"* during the evaluation. However, participants demanded that personal information be dealt with sensitively, even though they might disclose it to co-workers, *"Personally, I don't see a problem in this workplace, but I figure that this will be the opposite in industry, because this is personal data and nobody else's business."*

Participants generally confirmed the suitability of the cooperative concept. In the interviews, a competition between single players was again criticized, *"The game might work better if we played against each other in a closed group, but this option can't be seriously considered for ethical and social reasons."*. However, a competition among groups would be appreciated by all participants, which would allow to leverage the psychological effect of comparative feedback (cf. [16]).

A clear tendency towards the mobile or the stationary version of the game cannot be identified, as all participants also stated that they generally consider both variants as suitable. In the interviews, some participants said that in general, they would prefer the desktop variant, *"In general, I think the desktop is simpler, because you're looking at it anyways."*. On the other hand, it was acknowledged that *"in an environment where the game comprises several rooms the mobile phone would probably have been better"*.

According to the questionnaire results, the ideal game duration would be between two and four weeks. However, one participant proposed to repeat the game from time to time, *"come back to the game every now and then"*. As suggested, the game might also be applied repeatedly or combined with other feedback systems, e.g. possibilities to access historical data or to see and compare individual contributions, for a longer lasting effect.

4. CONCLUSION AND FUTURE WORK

We presented the design, development and evaluation of *Climate Race*, a persuasive pervasive game to motivate energy-saving behavior in office spaces. The pervasive game-based concept represents a novel approach to this domain.

The results of the pilot study, showing that energy wastage was reduced during the evaluation period, demonstrate the potential of the game-based approach. While the quantitative analysis does not allow us to determine what led to the behavior change—the game elements, the mere fact that feedback was provided, or just the awareness of being observed (cf. [12])—and the number of participants was limited due to the required resources (hardware and time), the interviews of participants that experienced the game in a real work environment help to better understand the background. However, the pilot study took place in an environment and with participants that are open towards innovation as well as towards their colleagues. The conclusions can thus not be generalized to all office employees, and the interviews show that corporate culture plays an important role in the attitude towards the game (cf. [14]).

In the future, it will also be possible to include additional aspects of sustainable behavior in the game, e.g., printer usage or the amount of waste. We are also currently planning a larger evaluation in the field where we will include a control group in order to be able to assess the impact of the game elements.

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