Power Explorer – a casual game style for encouraging long term behavior change among teenagers

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ABSTRACT
When it comes to motivating teenagers towards energy awareness, new approaches need to be considered. One such is the use of pervasive games connected to the players own energy consumption. Earlier work has confirmed this to be a highly effective approach. The question however remains if post game effects on behavior can be achieved. In this paper we try to answer this by trying out a slightly different design compared to previous work. The hypothesis is that a more casual game play and a richer learning interaction enabled by building the game on a real time sensor system could stimulate more lasting effects. Electric consumption data after the 7 days evaluation on a test group of 15 players shows tentative indications for a persistent post game effect compared to the control group of 20 households. Findings also show a statistically significant positive change in the players' attitude towards saving energy compared to the same group. Findings, at the same time, also indicate a negative effect on the player's attitude toward environmental questions in general.

Categories and Subject Descriptors
H.5.2 User Interfaces

General Terms
Design, Human Factors.

Keywords
Pervasive games, serious games, persuasive games, advergames, energy conservation, behavior change.

1. INTRODUCTION
The recent UN reports [1] on climate change set new demands on our society. It is clear that much needs to be achieved on all levels of society in order to reach the new targets towards sustainable living. One part of the challenge is the reduction of our energy consumption. Studies of home electricity consumption have shown that people's behavior plays an important role when it comes to excessive energy usage [2]. The savings potential – by changing energy usage behaviors in the home – is estimated to lie between 10-30% [2][3][5]. Engaging people in making these - often small – behavior changes to reduce electricity consumption and emissions of CO_2 is therefore crucial.

Energy in our homes however (in terms of heat or electricity at least) is often visually concealed to us. Underlying electric functionality is for example many times hidden away by product manufacturers for reasons of safety or esthetics. Knowing what constitutes everyday saving behavior and what matters is therefore difficult**.** When targeting teenagers, this problem description is particularly true since the knowledge level regarding energy conservation in this group is generally low [6]. This group is also often less cost-motivated since they rarely pay for their own use of electricity.

In earlier work, we have shown that a mobile pervasive game connected to the players' energy meters can be used as a powerful tool in order to both **motivate** and **educate** teenagers and their families towards energy conservation in the home [4][5]. This game used consumption data that was updated every 24h from automatic meter systems employed by energy utility companies. Two teams of teenagers competed to save energy in the evenings and received results the following morning. The evaluation [5] of this concept named Power Agent, with teenagers and families playing the game for a period of 10 days showed a remarkable reduction in energy consumption (both heat and electricity were measured). However, the study was not able to show any persistent long-term energy conserving effects on the participants as energy consumption basically returned to normal within a few days after the game trial had ended.

In this paper, we contribute to the discussion on design of pervasive learning games to encompass **long-term sustained learning and behavior changes**. This work applies mainly to pervasive learning games in the area of energy efficiency but results should also be transferable to areas where one aims at developing learning games to change long term behaviors such as lifestyle-induced health problems and psychotherapy. We report on the evaluation of a newly developed pervasive mobile game called Power Explorer [7]. This prototype builds on the previous research of Power Agent but takes an alternative design approach in order to investigate how to successfully design for long-term effects in regard to electric energy conservation.

This prototype employs a real-time sensing system capable of providing ***instant feedback*** to the player. This means that the player – when turning on and off electrical appliances in the home – can directly receive feedback on their actions. The approach also provides a more ***casual*** and laidback game play**.** Our hypothesis is that this will stimulate a stronger post-game effect on players' behavior by building stronger associations with specific appliances (instant feedback) and encouraging players to adopt long term, rather than radical short term strategies (casual game play).

The article is organized as follows: at the onset we discuss fundamental aspects of pervasive games that make them particularly suitable for learning and behavioral change. Moreover, we report on related work within the field of persuasive technology and computer-supported learning. After presenting our game – Power Explorer – we present the findings from an evaluation study with 15 teenagers and families that played the game one week in the spring of 2008. In the remainder of the article, we discuss how one can design games to prolong learning and reinforce behavior changes over time.

2. BACKGROUND

The use of computer games for the tasks of educating and motivating people on various topics is common today. The effectiveness of games as carriers for learning and persuasion has however also been questioned [8] as players tend to learn the medium and not the message and have difficulties in applying knowledge learnt from these games into real life contexts. In the following sections, we will argue that pervasive games, in this regard, are better suited for motivational and educational purposes compared to traditional forms of computer games.

2.1 Pervasive games as motivators and educators

Pervasive games are often referred to as games that extend beyond the traditional interface into the real world [9]. Montola et al [10] have further more suggested that one can view this reality expansion in terms of a *spatial, temporal and social expansion*. Whilst traditional learning games typically struggle with achieving transfer [11] between game simulation and real world tasks, pervasive games have the potential to directly incorporate reality, providing a **situated learning experience**. In classic learning theory, transfer refers to the situation where the learner must generalize and use abstract knowledge (i.e., learnt from a book) and applies this knowledge to real world problems and requirements. An inclusion of reality will obviously minimize this contextual gap.

In the case of Power Agent and Power Explorer the reality expansion emerges as the game utilizes a sensor network connected to the energy consumption in the home. In this way the entire home and its electrical appliances are transformed into a game interface. We will refer to this method as a *subject-specific reality expansion*. By interacting with the appliances the game provides feedback on actions in relation to the goal of saving energy. The critique regarding, players of learning games, learning the medium and not the message here becomes somewhat obsolete. In the case of Power Agent and Power Explorer being successful in the game also means being successful at saving energy, hence, the **medium and the message are merged [12]**. The quality of having a game with a common goal of game and message also lets game designers focus on the concept and content of the game instead of balancing game experience with for example learning goals which often have been seen as a difficulty in many serious or educational games [13][8].

Moreover, interesting from a learning and motivation perspective is also the way pervasive games **include non-players** such as family and friends in the game experience (e.g., social expansion). The *social expansion* of pervasive games arises from the fact that the physical stage (the street, the home etc.) of the game is shared. The social interaction emerging from this – which could be seen in Power Agent [5] – seems to generate a more **natural platform for shared reflections, experiences and interpretations of events**.

2.2 Post game effects

Although a *subject-specific reality expansion* of a persuasive learning game brings the player closer to a reality context there still exists a gap between game situation and the post game situation. As the motivation to change behaviors comes from winning the game and not from the benefits from adopting the behavior there is always a risk that the participants will fall back into their old behavior when the game ends. This is true unless some kind of shift of motivation from the game to the task in general occurs (implying a change in attitude among the players). Within the field of psychology there are a number of theories that formulates that such a shift of motivation is likely to occur as the players engage in real-life game-tasks regarding a subject (such as saving energy). One of these is the Self-Perception Theory [14] which asserts that we form our attitudes by observing our own behavior; another is the Cognitive Dissonance Theory [15] which deals with the human need of resolving internal conflicts between behavior and belief. Yet another is classical conditioning [16] which can be seen as a form of low-level associative learning.

In the previous Power Agent trial [5] the participants did indeed demonstrate a shift in attitude towards energy conservation. After the game, participants claimed that they were still motivated and committed to continue to save energy. Despite this measured energy consumption levels returned to pregame levels as soon as the game trial ended. We could here also see that many of the extreme measures performed by the participants during the game – such as turning everything off, or skipping dinner – was short term strategies not continued after the game. A key problem with these kinds of interventions is therefore to explore how to successfully design for long-term behavioral change.

In Power Explorer, we suggest the use of a real-time sensor system for measuring electricity consumption which would provide continuous updates on consumption. The use of real-time sensor system implies a richer learning environment. By visualizing changes in consumption, we enable the user to map power events to the current tasks performed and in doing so are able to better provide support for associative learning. The use of real-time sensor system furthermore enables a game that could be played in a more casual game style (i.e. less committing, faster rewarding and also less immersive) which would endorse more long term strategies by players as the extreme measures seem to have been a result of the very focused and committed game style of Power Agent that in turn was a necessity of the slow feedback loop.

3. RELATED WORK

Consumption feedback: Feedback on one's personal energy consumption can play an important role in helping people adopt new energy consumption patterns in their homes. The Twin River Investigation in the seventies by Socolow [2] is probably the opening work on energy consumption feedback in the domestic environment. In this study, home-owners were given feedback in terms of notes with consumption figures (i.e., trend data) placed outside their kitchen windows. This feedback enabled them to decrease their total consumption about 10-15 percent. Since then, a lot of research has been carried out in a similar vein [3] of investigation with varying approaches and means to provide the feedback. Lately, these studies focus on using modern communications and digital means to convey the feedback. Most studies however fail to, in depth address the design aspect of the feedback as well as whether the effects could be maintained in a long term perspective [3].

Pervasive learning games and advergames: The prototypes Savannah [17], Rexplorer [13] and Frequency 1550 [18] all represents the few examples of pervasive learning games, that currently exists. All of them are location based. Savannah is played on a predefined open field and aims to educate school children about the life of the savannah. The other two examples teach about local history in Regensburg and Amsterdam respectively through a story driven game play. Conqwest [19] is an example of a pervasive location-based advergame. It is a treasure-hunt-game designed to promote a mobile operator (Qwest), where the players collect points by photographing semacodes or capture other teams' bases.

Of these four examples Rexplorer with its aim to get people to move about the city and Conqwest with a goal of among other things display technical features (such as the use of semacodes) supported by the mobile operator, can be said to be closest to Power Explorer (in terms of a *subject-specific reality expansion, and a merging of message and medium*). None of these however addresses the issue of long term effects of the games.

4. POWER EXPLORER

Power Explorer is a mobile phone game played on a HSDPA and java enabled handset (e.g. SonyEricsson K660i). The game client lies dormant in the background when not in use and can in this way push messages about exceedingly high consumption, received challenges or act as an ambient interface by making electric sounds as consumption rises to regularly pull the player back into the game. The client is connected to a game server which in turn is connected to WiFi equipped current sensors[1] installed in the central electric distribution box of each player's home.

4.1 Game play and interface

Power Explorer is played through an avatar – a "monster blob" – that is individual to all players. The monster blob can visit four different environments that have different modes of interaction; the pile, the habitat, and two duels. The game is designed to balancing the two opposing goals of saving energy (habitat and pile) versus engaging players in using and learning about appliances (the duels). The two existing duels in the current version of the game are the rainforest duel and the polar dual. Playing the duels offer an engaging real-time player-to-player competition while playing in the habitat is a quite low key explorative task.

Fig. 1. The main view of Power Explorer (the habitat).

[1] The sensor module was in this case custom made. Affordable wireless energy sensors are however becoming readily available in different energy monitoring products in the market.

The habitat: In the habitat, the avatar lives within a virtual climate environment. The objective here is to keep the monster blob healthy. The data for controlling the climate comes directly from energy usage in the player's home. The current electrical power level is visualized by the bar on the left of the screen. Power events such as turning something on, is visualized by weed growing up around the monster blob while turning something off results in flowers growing. The size of a power event occurring translates proportionally into the size of the plant appearing. These plants serve as food for the monster blob and will therefore be eaten one by one. While flowers will have positive effects on the monster blobs health too much weed will make it sick.

A grey cloud in the sky represents the levels of CO_2. At the beginning, players will by default have a cloud the size of 500 units (a scale from 0 to 1000). CO_2 will over time slowly evaporate from this cloud causing it to shrink. If you use electricity in your home however, your "monster blob" will start emitting small clouds of CO_2 gas in response to eating too much weed. Each of these small gas clouds represents a fixed amount of energy having been used in the household. The gas emitted by the avatar will rise and join the big cloud causing it so grow.

This means that use of small amounts of electricity will make the cloud shrink while excessive use will cause it to grow until it eventually fills the entire screen with further consequences for you avatars health. Hence, in order to keep your monster happy and healthy you must keep electricity consumption down. The equation is set so that the level where the cloud goes from increasing to decreasing is 85% of the participants' normal household consumption in reference to the weeks prior to the game.

The pile: In the second view, monsters of all of the participating players are stacked in a pile. The position of your avatar in the pile corresponds to your current ranking in the game in a King of the hill fashion (see Figure 2 left). The red ring in indicates the players own blob. The green sleeping monster with a golden scarf is the one who won the last duel. The monsters with closed eyes are players currently offline. By pointing at one of the other players' monster you can see its current CO_2 level. Ranking in the game is based on the size of the CO_2 cloud. To reach the top you will therefore need to keep the consumption down as long as possible to clear off all the CO_2. Since some activities each day inevitably will use a lot of electricity it is important to perform these activities quickly and efficiently to avoid buildups of CO_2.

The Rainforest duel: The idea when designing the Duel in the rainforest was to bring learning about the amount of energy different devices consume when in continuous use i.e. this duel focuses on energy. The duel set the player's two avatars running side by side on a racetrack in the middle of a rain forest (Fig. 2 middle). To win, the player has to get to the end of the track before the competing player and avoid various tricky and dangerous obstacles along the way. The obstacles move or appear periodically throughout the duel. Some obstacles can be avoided by pressing the "jump button" however most obstacles must be avoided by timing their periodical movements. That means setting the right speed on your monster. The speed is adjusted by manipulating the electricity consumption of your home.

Hence, to win this duel, the player needs to have an understanding of the amount of electricity different domestic appliances consumes, to be able to quickly set the right speed. Increasing the electricity consumption, in order to increase running speed, also increases the precipitation in the rainforest that will lead to a build-up of rainwater making both players drown (Fig. 2 middle). Consequently, the task of the players´ is to carefully maintain a balance between gaining enough speed to make it through the obstacle without flooding the forest. Running in to an obstacle will make you bounce back and loose health. If the water level is high this might mean bouncing back into the water loosing even more health.

The polar duel: The other duel is a fighting match on an iceberg at the North Pole (see Figure 2 left). In this game, the aim is to knock the opponent off the icecap into the water by throwing various objects. Small objects like snowballs, fish and seals have little impact on the opponent but can be thrown much longer while polar bears and whales have a major impact on the rival but can only be used if the opponent is close. Some objects like seals will also slide on the surface of the ice while others, like the whale will go through the ice on impact and leave a hole. To avoid objects the opponent has reposition his or her monster and when sliding objects are used the monster has to jump to avoid trouble.

The player gets access to the objects by changing the electricity consumption in the home. For example, to get a powerful whale the player has to understand that the task is to turn on a major electricity-consuming device such as an electric radiator, for a second or two. For a smaller snowball a lamp might be sufficient. In this way the thought is that this duel will forces the player to explorer the power (rather than the energy) aspect of electric appliances in the home. Once an object is retrieved the player has to make sure his monster is facing the opponent's monster before pressing the throw button. The players combined consumption rate will affect the sun over the polar landscape. A hot sun corresponds to a high consumption and will melt the ice cap more quickly.

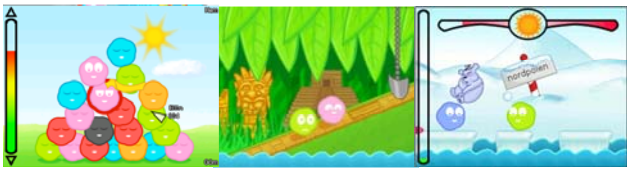

Fig. 2. The pile (l), the rainforest- (m) and the polar- duel (r).

5. METHOD

Both quantitative and qualitative methods were employed in this study. Quantitative data consists of game server logs, electric consumption data, temperature logs for the area and forms filled out by the participants before and after the game. Qualitative data consists of interviews with the participants after the evaluation was completed and in-game observations made by the participating researchers.

The trial was carried out during one week's time during the late spring of 2008. The game was played by 15 test participants in the age of 12 to 14 years old together with five researchers acting incognito as players. Moreover, a reference group of teenagers living in the same area was used. Both the reference and the test participants participated on a voluntary basis (permit from parents was required). Special care was taken to make sure the composition of types of heating systems concurred in the two groups to eliminate effects by weather.

A questionnaire with general questions about energy and electricity was filled in by test participants and reference persons alike, once before the game and once after. Another form with specific questions regarding the game was only submitted to the test participants after the game trial. Six of the participants were also interviewed after the game. The semi-structured interviews were recorded, transcribed and categorized.

Electric consumption data was logged for all households before, during and after the game test. Data from each house was normalized in relation to a reference period four weeks prior to the game trial. An average of the relative change in consumption was calculated for the game period as well as the following weeks for each house. These two values were then compared to estimate the savings made. In addition a T-test was carried out on the two groups to establish the statistical significance of the readings. The estimated savings were also tested for correlation to temperature readings as a second precaution to verify that the reference group and the test group were similarly affected by temperature shifts.

6. RESULTS

The observations in this study have been sorted into the categories; energy saving strategies, attitude changes, learning and a more general game design category. In this section, examples from each of these categories will be presented. First, however, we will present the overall consumption figures followed by a short presentation of the six interviewees and their individual achievements.

6.1 Overall consumption change

The observations based on the AMR data shows that consumption for both groups follow the temperature synchronized during the weeks prior to the game (Fig. 3). The black line (Fig 3) is the average of the relative energy consumption for the players and the grey line corresponding data for the reference group, also plotted as a dotted line is the outside temperature. The red dashed line shows the results of T-tests (the P-value) between the two groups. The blue area indicates the week of the game trial.

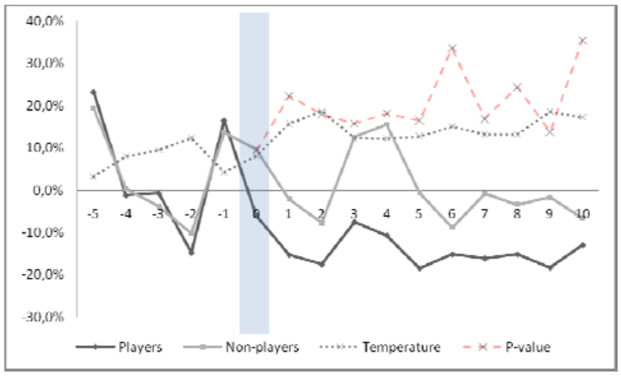

Fig. 3. The relative consumption change (x-axis in weeks).

As expected, at the point of the game trial (week 0), the two groups diverge. This diversion persists during the entire post game period measured. Significance of difference between the two groups however decreased shortly after the game trial ends (P-value increases), indicating a greater overlap between the two groups. Consumption during the 10 weeks following the game trial was on average 14% lower in the player group compared to the reference group (P-value=0.16 for the same weeks). Of the 15 participants 12 showed some level of decrease in the use of electricity. Only three of the participants increased or showed no changes in their consumption during the game trial.

6.2 Background interviewees

The following section aims to provide us with an understanding of the range in preconditions as well as the difference in how the game was embraced and played by different players. The players interviewed have therefore actively been selected to represent extremes within the player group.

Willem is a 13 year old boy he lives in an apartment heated by remote heating (i.e. not effecting electric consumption). During the game trial he played 85 duels and was actively interacting with the game about 7h and 26 min each day. This makes him the **most engaged player.** Despite this he only ended up on a 9th place among the 15 participants. Willem had a malfunctioning meter during the first couple of days which might have affected his game results. The energy log from Willem's apartment (not affected by this fault), shows that he still managed a reduction in electricity consumption by 18% during the game trial and a 14% reduction in the weeks following the game.

Maja is a 12 year old girl living in a house with remote heating. During the game trial she only played 11 duels and was only actively interacting with the game for about 2½ minutes each day. This makes her **the least involved player** in this game trial. Maja finished 2nd last in the game. Energy logs from Maja's house shows an increase in consumption by 8% during the game trial but surprisingly a decrease in consumption the 10 weeks following the game by 27%.

Sara is a 13 year old girl who lives in a house heated by wood pellets. During the game trial she played 26 duels and was on average active 17 minutes a day. In terms of savings, Sara was **the worst example** among all players. Energy logs from Sara's house show an increase in electric consumption during the game trial by 71% and an increase by 65% the weeks after the game.

Vincent is a 12 year old boy who lives in an old house which is heated partly by electricity and partly by two tile stoves and a wood boiler in the basement. He describes himself as somewhat of a game fanatic and explains that he really enjoyed the game. After having held the top position for more than half the time during the trial, Vincent **finished first** in the game. During the game trial however he only played a moderate 25 duels. He spent about 2h 11min each day actively interacting with the game. Energy logs from his house show a reduction in use of electricity by 51% during the game and 23% after the game. Vincent's older sister had earlier been participating in the Power Agent trial. He was therefore well acquainted with the earlier game concept which gave him an advantage.

Adam is a 13 year old boy who lives in a house that is heated by an air-source heat pump. During the game trial he played 23 challenges of which he won 17. With a success rate of 74% this makes him **the most skilled player** in the trial when it comes to the duels. Adam spent about 2h and 43min each day actively interacting with the game. In terms of savings however, Adam did not do so well. Out of the 15 players he only ended up as number 13 and was never able to gain the top position on the pile, even for a short time. Energy log from his house shows an unchanged consumption level during the game. The ten weeks after the game however the log shows a reduction of electric use by 22%.

Maria is a 14 year old girl living in a house that is heated by remote heating as well as an open fireplace. During the game Maria engaged in 71 duels and actively played for about 2h and 2 min each day. Maria **finished 2nd** of the 15 participants and held the top position for 21% of the game time. In terms of energy savings, the log in her case indicates a reduction by 20% during the game week but only a reduction by 7% during the following 10 weeks.

6.3 Energy saving strategies

On the question of what they did differently during the game most participants mentions turning off lamps, TVs and computers. Many express it as turning of things that were unnecessary or that you didn't use indicating rather non-extreme measures being performed.

Table 1. Change before vs. after.

Q13: Do you usually check out how much appliances consume?			
	Players	Non-players	P-value
Change	12,1%	0,7%	0.1

In Marias case the whole family seams to continuously have discussed which devices they could turn off. Marias mom: "*We turned off the computer during nights, before we were a bit sloppy in that regard. But now it was like that... the computer was turned off and in fact it still is now as well, even though it's over (the game)"* (ex. 1). This is a clear example of a non-extreme, sustainable, long term strategy.

In a few cases the participants talk about energy saving measures that would directly infringe on comfort levels. In Marias case they express it as that they wanted to make a commitment for the game, but that particular evening there was a big TV event that they had planned watching. Unable to turn the TV off and be - as they express it - cheated on the evenings TV festival, they made a compromise by turning off the surround sound system connected to the TV set. In the game they could see that this actually made a whole lot of difference which made them satisfied with their decision. This measure was however, as they expressed it, *"done for the game"* and would fit as a typical example of a short term strategy not likely to be continued after the game.

Maja (the seemingly least involved player) tells us she: *"… kind of told mom that she should turn off the radio and other unnecessary things… and not to do too much laundry"* **(**ex. 2**).** She however later added that she also tried to remember to turn off the TV after she was done with it (something she had not always done in the past). Vincent (the winner) on the other hand employed a strategy that he learned from his sister playing the earlier Power Agent game. That is, he employed a – not more than two devices at the time – principle and made fires in the tile stoves to save on electric heating. In this case classifying measures as long-term or short-term is not entirely straightforward. Vincent however reflects that they to a larger extent – as he expresses it – *"kept it up"* after the game this time than they did after previously playing the Power Agent game. He attributes this to the fact that Power Explorer in his opinion was more fun to play.

6.4 Attitude changes

In Table 2 (Q1), we can see an attitude change toward saving energy before versus after the game.

Table 2. Change of rating before vs. after the game trial.

PLAYERS	NON-PLAYERS	P-VALUE
Q1: How important is it to save energy?		
6.1%	-5.3%	0.04
Q2: I usually encourage my friends to save energy!		
8,8%	-4,3%	0.08
Q3: How important do you feel, questions about the environment are?		
-7,1%	0,8%	0.16

On average the player group felt more positive about saving energy after the game while the reference group became slightly more negative (a statistically significant difference). We can also see that participants also saw themselves as more prone to promote energy conservation to their surroundings, indicating a change in self perception.

Players also perceived appliances to consume more electricity after the game compared to before. A learning test in the questionnaire, showed that devices were on average rated 4.6% higher in term of experienced electricity consumption by the player group when asked after the game compared to before (1.4% by the reference group, p-value = 0.25). In Table 2, Question 3, we can also see that the game did not appear to have any positive effect on the players' attitude towards the environment in general. In fact, results rather indicated a more negative attitude in this regard.

Of our interviewees, Sara (our "worst example", who increased the consumption both during the and after the game) also displayed the least enthusiastic attitude. On the question of what she thought about the subject of saving energy, she answered that she didn't have an opinion. On the question if she thinks about the subject often (after the game) she answered that she didn't. She then however reflected that she probably thought of it a bit more often than before.

While Willem (our "most engaged" player) shows a more split opinion on the subject. ***Willem:*** *"Well… you don't have to use it unnecessary. I don't feel that it is that important but… You can't just use… nothing. You have to use some"* **(**ex. 3**)**. Adam (our "most skilled" player) on the other hand clearly felt that not using too much electricity was rather important. **Interviewer:** *"Is this something you have always thought?"* **Adam:** *"Well…It was probably when I started playing this game that I started getting an opinion of it"*. ***Interviewer:*** *"Opinion of what?"* ***Adam:*** *"Of that it is good to save electricity because it costs very much and so… it is not good"* **(**ex. 4**)**. In this example, for Adam, the private economy seems to be the primary reason for saving energy.

Adam furthermore explains that it felt good to turn things off. Another of the interviewees, Maria, similarly explains that she now after the game reacts more and gets annoyed by things "*just being on for no god reason*". Our top contender, Vincent also talks (and at the same time laughs) about the fact that he now (after the game) feels "huge pressure" from seeing for example the washing machine being on which he knows consumes a lot of electricity.

6.5 Learning

Two of the questions in the 2 x 2 questionnaire aimed at finding out if the participants gained explicit knowledge about electrical appliances from the real-time feedback mechanisms in the game. These two questions were constructed so that the respondents had to rate a number of tasks or appliances in regard to electrical consumption. The first question focused on power (i.e., the rate of consumption) for different appliances while the other focused on energy used for different tasks. The results from these questions were transformed into points by comparing how the rated the different tasks or amongst each other. The points before and after was then compared.

Table 3. The change in scores after versus before the trial.

PLAYERS	NON-PLAYERS	P-VALUE
Power test		
0.6%	-0.9%	0.4
Energy test		
-3,5%	2,4%	0.17

The results from the power test are weak in terms of statistical significance. The indication is that the increase in explicit knowledge in regard to power rating on appliances is marginal. The results from the energy test, is on the other hand somewhat stronger. This test indicated that the players were actually worse at determining the amount energy used for different tasks after the game.

The results are in some regard contradictive to findings from the interviews as we here could find a lot of examples where the participants had gained detailed knowledge regarding specific appliances from playing the game (in terms of power). One example of this could for example be the use of the surround sound system by Maria and her family (ex.1). Many of the players also mention the washing machine or the dishwasher as large consumers.

The question of what appliances that consume much electricity, we can however also see a tendency to include things that are not big consumers in terms of power but that waste energy as well. ***Interviewer:*** *"What consumes much electricity then?"* ***Willem:*** *"The vacuum cleaner, the stand-by mode on the TV and things like that… the computer and…"* **(**ex. 5**).** Several participants also used the visualizations in the game to refer to the consumption of devices. Moa refers to lamps as making small flowers and the TV as making larger ones while Vincent refers to the objects in the duel as to how much things consumed (snowballs etc.).

On the question of what time of the day the player's house used most as well as the least amount of energy, 10 out of the 15 players gave a very accurate and seemingly correct answer in both questionnaire and interviews. ***Maria:****"Well it changes. Like in the evenings for example it was pretty high and then in the mornings it was lower since not everything was on as much and then it wasn't as much lamps and so, since it was much lighter then."* **(**ex. 6**).**

Finally, it seems the knowledge regarding different appliances was also widely shared and discussed among players in story like fashion. ***Vincent:*** ***"****I played against my second cousin and he put on his coffee machine and then… an ice block can disappear in an instant. Washing also consumes a lot of electricity I've noticed and well coffee is… well you probably get that to"* **(**ex. 7**)**.

7. Game design

During the seven day game trial, the average participant engaged in about 14 hours of play and 35 duels. The reviews from most interviewees were positive. ***Moa:*** *"It was between average and good."* ***Interviewer:****"Between average and good?"* ***Moa:*** *"Yes… It was quite fun!"* **(**ex. 8**).** The most appreciated feature of the game was the polar duel. Many also explained that it was fun to find out how much electricity you used although not everyone appreciated learning about appliances. ***Maria:****"It wasn't that fun to check the appliances at home but..."* ***Interviewee:****"But it was fun? What was it that was fun?"* ***Maria:*** *"Well to see how much electricity you use!"* **(**ex. 9**).** When offered to play again in a future test all interviewees except Moa were positive. Moa explained that she had, had little time to play the game and were unsure of whether to participate again.

Understanding: The players were also asked to explain 8 different features of the game both in the questionnaires and in during the interviews. The features asked about were, the CO_2 cloud, the CO_2 level counter, the "monster blob" (The avatar), the power bar, the weed, the flowers, the control of the avatar in the rainforest challenge and the controls of the polare challenge. Findings show that most features were very accuratly understood by players. Most uncertainties were however, found around the exact interpretation of the CO_2 level counter and the controls of the two duels.

Feedback: A few technical issus were encountered during the trial. Williems meter showed a constant high consumption during the first day of the game. There were also multiple instances where duels were interupted due to problems with mobile network coverage. During the real time duels there could also sometimes arise problems with delays in data transmissions. The same applied to the power bar and the plants, where the feedback sometimes got delayed a second or two causing confusion among players. The interviewees however report that feedback most of the time was percieved as accurate and that they felt a clear connection between their actions and the feedback. ***Adam:*** *"I was moved up and down sometimes... the more electricity I used."* ***Interviewer:*** *"Did you feel that it was correct then?"* ***Adam: "****Yes it corresponded quite good i think!"* ***Interviewer:*** *"It was like that... when you did something at home then..."* ***Adam: "****Yes when I put on the computer then maybe... you would start losing... and get more on the this meter."* ***Interviewer:*** *"And did something happen in the pile then?"* ***Adam:*** *"Yes... someone else perhaps saved some energy and then it changed place with me."* **(**ex. 10**).**

Game strategies: In terms of strategy some of the players claimed to occasionally having used a second phone in parallel with the game in order to talk to their opponent while playing in duels. Players in the top region of the pile also seem to have avoided challenges from those in the bottom of the pile since these players often had nothing to lose in terms of ranking and therefore could use as much energy as needed to knock down the opponent. On the question on how many devices they used in combination with the game most answered between 1-5, two persons answered "many" and 7 players answered that they didn't know. In the questionnaire most players, 10 of the 15, noted that they sometimes did and sometimes did not look at the visualizations at the same time as they maneuvered electric appliances when exploring the home. Three of the players did often use the application in this synchronized fashion, one player claimed to rarely having used the device in a synchronized way and one other player that he/she never employed synchronized usage

8. DISCUSSION

A persistent effect of 14% reduction can be measured during the whole period monitored after the game had ended (Fig 3). Although these findings are not statistically significant, it gives a tentative indication that a post game behavior change was achieved. We can also see that in this trial the participants do not report on extreme measures as in the Power Agent trial. They rather defend the necessary everyday use (ex. 3) at the same time as new habits regarding wasteful use of electricity is formed (ex. 1). These findings together support the idea that a casual game play would promote more long term sustainable energy conservation strategies thus achieving post game behavior change. We can also see how stories and reflections regarding particular appliances are shared between players (ex. 7) indicating how the immediate feedback aided in creating associative experiences. The two top contenders (Vincent and Maria) also express how they were emotionally affected by seeing appliances being on that they knew consumed a lot of energy which could be interpreted as cases of classical conditioning.

As expected, savings during the game are on average lower in Power Explorer compared to Power Agent (an effect of less extreme measures, and the duels). Savings in Power Agent are on average 22% for the game period with peaks of up to 75% savings during certain game sessions, savings with Power Explorer averaged on 16% during the game period. This should be put in relation to that the goal of the game can be said to be set to 15% of savings since this is the point where players were starting to get positive feedback from the game. The conflicting design of on one hand wasting energy during duels and on the other hand saving energy in between seems to have contributed positively to the dynamics of the game (se game strategies previous section). While some players like for example Adam choose a strategy of focusing on the dueling, others like Vincent choose a strategy of focusing on saving energy. As we can see by the segregation of players in regard to dueling these choices were also recognized among the players. Interestingly Adams's and Vincent's post game results despite the different strategies are both very similar.

In terms of game experience we can from extensive engagement by the participants and positive reviews from interviewees conclude that interacting with electricity in this way was a fun and rewarding experience. Although the concept seems to have appealed more to some than others, a genuine (perhaps underestimated) interest in *"how much you used"* (ex. 9), could be seen. The context of this statement, implying a rating on a social scale, rather than in kilowatts.

We can in this user test also see a significant positive attitude change towards energy savings among the player group (table 2). Participants also seem to be more positive about promoting topic of energy conservation to others. But even though the esthetics in Power Explorer conveys the environmental aspects of saving energy (the CO_2 cloud for example), some players still seem to have interpreted the task of saving energy first of all as an economical task (ex. 4). A quite peculiar result is also that the players, at the same time as having become more positive towards energy saving, appear to have become more negative towards questions about the environment in general. This could possibly be interpreted as a case of cognitive dissonance [15]. Since the esthetics of the game, would have communicated the bad impact on environment, from daily use of electricity that many times were inevitable, the players might instead of changing behavior, resorted to changing their attitude to match their behavior.

When it comes to learning similar conflicting results can also be found. The results show that players gained a specific understanding of what time of the day they consumed electricity they also claim to have seen a connection between for example their computer and the position in the pile (ex. 10) and also showed specific knowledge regarding devices (ex. 1). The power test on appliance level taken by the respondents on the other hand implied only a very weak indication of learning and the test aimed at energy consumption of tasks even show a decrease in points among the players. One explanation to this is that the participants learned only about devices relevant to them i.e. things that they frequently used, such as lamps, the TV, computer, stereo and so on.

As we could see in excerpt 5 there is also a tendency to include things that constitutes wasteful use energy on the question of "What consumes much electricity?" There is however also a problem of keeping the two concepts of energy and power apart. Although Power Explorer had the ambition to address this issue we can see that it in this regard is not entirely successful. While a microwave oven for example consumes quite a lot of power, it still is very energy efficient since it typically heats food very quickly. Including wasteful use of energy, as in excerpt 5 would imply a one-dimensional view of electric appliances, by the participant. In other words, an appliance is either good or bad on a scale. A power consuming device as the microwave oven might therefore mistakenly be labeled as bad in terms of energy consumption.

9. CONCLUSIONS

Findings from Power Explorer show tentative indications for a persistent post game effect on consumption, a significantly positive attitude change towards energy savings, the forming of what appears as long term energy saving strategies in forms of new habits as well as a lower degree of extreme energy saving measures being performed by players compared to the previous work of Power Agent. This supports the notion that, in order to achieve long term effects, a casual game play, with small investments by players and fast and frequent rewards in terms of feedback is preferable compared to a highly immersive game with extensive investments by players and a slow reward mechanism. Findings furthermore show, examples of device specific learning, and detailed experience sharing among players. This indicates that the direct feedback of the game also works towards enriching the learning environment as well as enabling appliance level associative learning.

In the Power Explorer trial we can also see indications for a more negative attitude change regarding environmental questions in general, an effect that we attribute to the occurrence of cognitive dissonance induced by the esthetic message of the game. Nevertheless based on the findings so far we conclude that pervasive games, with a *subject related reality expansion*, employing a casual game play and a real time feedback loop appears to be an effective tool in order to encourage teenagers towards both short term as well a long term behavior changes.

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