Saving is Fun: Designing a Persuasive Game for Power Conservation

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ABSTRACT

EnergyLife is a mobile game application that aims at increasing energy awareness and saving in the household; it centers around a feedback system with detailed, historical and real time information that is based on wireless power sensors data. The challenge is to provide through feedback knowledge and motivation for sustainable saving. A three-month field test in eight households was organized for EnergyLife. The test involved the automatic collection of access data to the application, and the administration of satisfaction questionnaires, interviews, and usability tasks in the tested families. The paper describes the results of the test and the ensuing re-design strategy, centered on better tailoring the application to the players' actions. The lessons learned can be useful to other persuasive games, since a good fit to the actions of the user is a precondition of effectiveness of any persuasive application.

Categories and Subject Descriptors

H.5.2. User Interfaces

General Terms

Design, Human Factors

Keywords

Energy awareness, persuasive technology, feedback, pervasive mobile games

1. INTRODUCTION

Research in the field of HCI on energy awareness in households has recently started to address energy awareness applications [[11]]. Technical solutions are provided [[25], [23]] on the one side; on the other, households consumption habits prior to [[6]] or after [[13], [24]] the adoption of a feedback system are investigated via several methods including contextual interviews [[8], [9], [16], [20]]. Findings suggest carefully designing the affordance of the technology to prevent unwanted implications of the information displayed to the user [[20], [21], [24]]. In fact, according to Froehlich et al. [[10]], the design attributes of feedback have yet to be fully investigated. Systematic tests of design of eco-feedback technology, i.e., "technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact," are rare [[10]: 1999].

The present work is a contribution to better test the design characteristics of a feedback system [[14]]. It focuses on EnergyLife, a household game application that aims at increasing consumers' awareness about energy conservation. In the disguise of a game, this application offers services that are state-of-the-art in eco-feedback technology and incorporate the findings of decades of research on environmental feedback (for a longer explanation of the EnergyLife concept based on feedback literature, see [[23]]). Two field tests of EnergyLife were planned: a first field test focused on the usability and acceptance of the prototype in a real context, and a second field test a few months later tested the effectiveness of the persuasive game in increasing energy conservation.

This paper describes the usability field test to highlight the design aspects that proved critical in the field and the redesign strategy adopted. First, it outlines the technical system underlying EnergyLife and the feedback system implemented in the application. Then it describes the game rationale and interface. Then it explains which the data collection techniques were used during the field test (questionnaires, task series, and interviews), and what strengths and weaknesses emerged as a result. The strategy adopted to address these weaknesses is then described, centering on better tailoring the game to the players' actions.

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2. ENERGYLIFE

2.1 System structure

In addition to systems providing simple feedback of energy usage [[21]] (e.g., "Energy Detective," "Power-Cost Monitor," "Kill-A-Watt" [[18]]), or feedback improved with colors and graphics (e.g., "Wattson," "Energy Orb," and "Energy Joule"), persuasive games with energy and environmental goals are appearing (e.g., EcoIsland [[18]], PowerHouse [[11]]). While these games rely on self-reporting or aggregate measures, EnergyLife is a persuasive game that collects real consumption data that is automatically fed into the system by a sensing layer.

EnergyLife relies on a client-server system that is pervasive in the household and – through its mobile interface – able to follow the user everywhere (Figure 1).

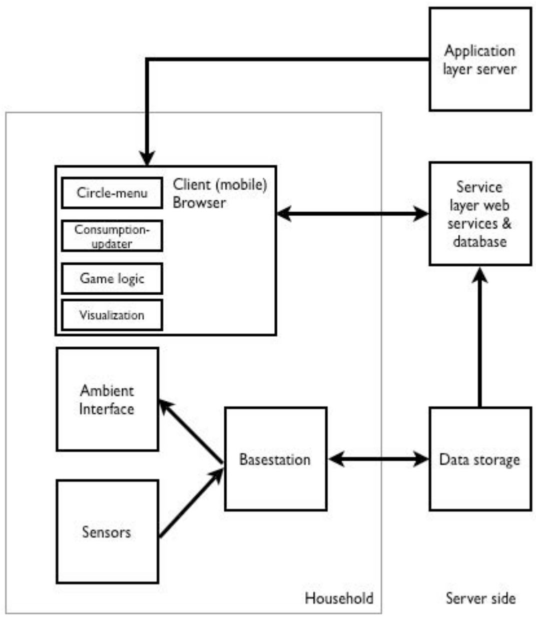

Figure 1: Overall system diagram

It utilizes wireless sensors that are easily inserted between appliance plugs and sockets, which measure in real time the consumption of the appliances. A base station located in the house collects the data locally and sends them to a cloud service that communicates with the smartphones, where the EnergyLife application runs. Any Linux/Unix-based computer can act as a base station, but as it needs to be turned on (and preferably online) all the time, a dedicated low-consumption machine was preferred. Different setups were tested; currently, VIA Artigo runs a Debian Linux consuming 15W. The system is designed to interface with third-party products as easily as possible. For instance, it also uses Plugwise sensors as an alternative to its own BeAware sensors, and SchellCount 1- and 3-phase meters as an alternative to main meters.

The application client is a Web application adapted for touch screen-enabled mobile devices. The current platforms are iPhone and iPod Touch, since they support the new Web standards (HTML5, CSS3 with 3D manipulation) used in the application. The application could also work in new releases of WebKit rendering engine browsers, but without the multi-touch functionalities. The client-side JavaScript running in the client Web browser builds the user interface and communicates with the Web services provided by a server-side engine called the service layer. The system is also non-intrusive, energy efficient, and protected from possible privacy risks.

2.2 Two pillars: Action and knowledge

The core component of EnergyLife is the provision of consumption feedback. Some preliminary investigation with stakeholders alerted us that the actual consumers' knowledge about electricity conservation is poor and fragmented (see also [[21]]. Similar results were returned by an online survey with 498 respondents (197 women, 301 men, aged 39.74 years on average, SD=11.484) from North Europe (98 respondents living in Sweden and Finland) and South Europe (400 respondents living in Italy). Respondents were asked what percentage of electricity can be saved by using fluorescent bulbs; they could answer by selecting from a drop-down menu a multiple of 10 between 10 and 100%. The correct answer (80%) was selected by 26.3% respondents; 32.7% of the sample selected a figure that differed 20% from the correct one; 41% of the respondents provided a value higher or lower than 20% with respect to the correct one. Also, respondents were given a list of 24 electric devices with labels and pictures. The list differed in the two versions of the questionnaire directed to North and South Europe (including sauna in the latter, for instance). Participants were asked to select the four devices that consumed more electricity, time of usage being equal. The correct answers were 36.56% of those provided by the Italian sub-sample, 54.33% of those provided by the Scandinavian sub-sample.

Since showing consumption data would be ineffective and discouraging if the players did not know how to reach the goal [[15]], it was decided to add some other features in addition to consumption feedback, to improve the players' knowledge about sustainable consumption practices. These features were tips, quizzes, and a community area; they were activated gradually as a reward to the players' achievements.

2.3 Game rationale and interface

The main interface on the application consists of a three-dimensional carousel (Figure 2; for usage scenarios, please refer to www.energyawareness.eu); the user interacts with it by touching the screen of the mobile devices.

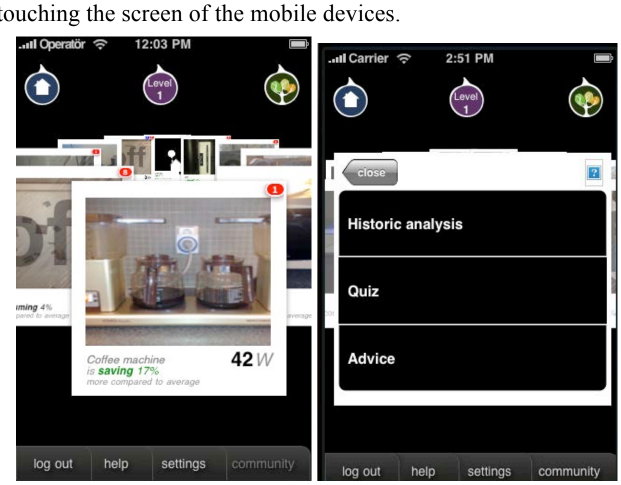

Figure 2: Measured appliances are represented as cards in a carousel showing their consumption and saving with respect to a baseline (left). Tapping a card flips it around and provides further details (right). Icons on top of the screen allow access to level info and saving breakdown

Each card in the carousel represents an electric appliance, the consumption of which is monitored by sensors; an additional household card represents the consumption and saving of the whole household. Tapping the cards flips them around to offer additional information and functionalities.

The game starts by displaying information about electricity consumption. This information is provided both as kW/h (instantaneous consumption), and as saving percentage, by comparing the current period consumption (e.g., week) to the average consumption during a reference period (Figure 2).

The application also offers a breakdown of the previous week's consumption along with the relative contribution of each device (Figure 3a) and an historical description of the consumption by device (Figure 3b).

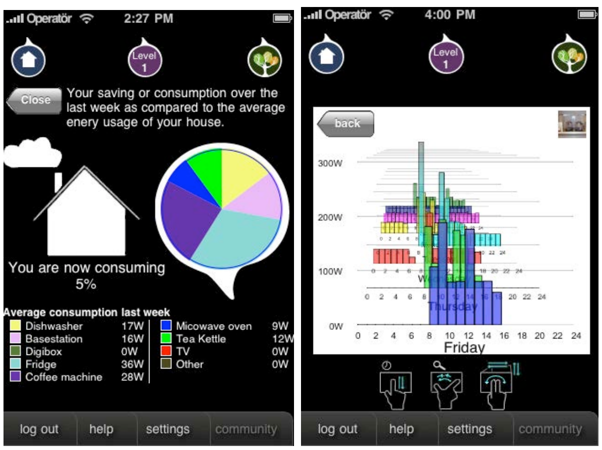

Figure 3: a) An example of the Saving Breakdown page; b) an example of a Historical Analysis page in which each row represents one day and each column represents the consumption during one hour

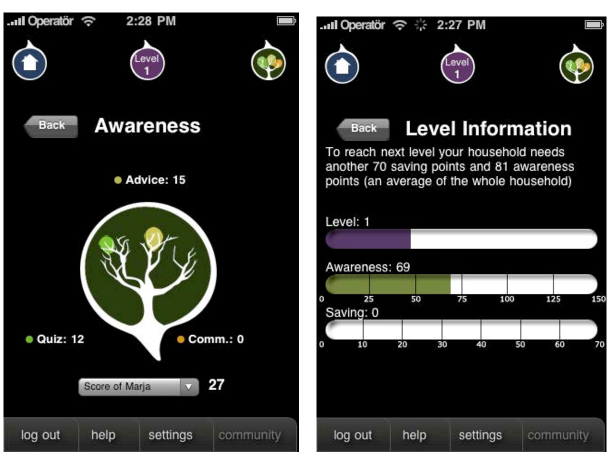

Figure 4: Left, the Awareness page shows the user's scores as in reading tips, answering quiz. Right, the Levels page, in which users can see how many points need to be reached in "awareness" and saving to reach the next level.

Several features are then added progressively. After a period of experience with consumption feedback, the players enter the second level and receive tips and quiz. Tips are meant to provide the necessary information on the way in which the consumer can conserve electricity in the household and with the monitored devices; the quiz verifies the acquisition of such knowledge in a playful way. Finally, to maintain involvement, an in-game community is activated with a Twitter-like interface. Community facilitates the sharing of experience and practical wisdom among EnergyLife users, which is found to encourage change in habits [[24]] and keeps the awareness on energy conservation high. Users can see their own score as well as the scores of other family members.

In the field test version of the prototype, both aspects (consumption and knowledge) were translated into scores, i.e., saving scores and awareness scores. Saving scores depended on the saving achieved, and awareness scores derived from reading tips, answering quizzes correctly, and exchanging messages in the community.

3. LONGITUDINAL FIELD TEST

Playing a game is an experience that does not exhaust itself in a few hours and needs to be followed during its evolution [[1]], especially if the game is supposed to indefinitely accompany users' everyday lives, first as a motivator and then as a reminder of the new habits acquired [[18]]. EnergyLife is meant to engage users on the long run and to progressively activate different features based on the users' performance. Therefore, even though EnergyLife underwent a series of preliminary laboratory tests to improve its usability, a field test of three months was organized to test its usability and acceptance.[1]

3.1 Participants

Participants were 24, 11 men and 13 women, aged 34.87 on average (SD = 14.62). The field test took place in Northern and Southern Europe (Finland and Italy). Four households per country participated, all but one composed of three to four members living in urban areas (Catania and Helsinki) and owning the house where they lived. This type of household was selected because they have a high saving potential and are widely present in both European regions. None of the households included people working on the project. An agreement defined mutual expectations between the research team and households, and all household members signed a general informed consent to participate.

3.2 Equipment

The research team installed sensors (on the refrigerator, TV, washing machine, microwave, PC, and on two more devices freely chosen by the user) and basestation in all households; the team provided mobile phones and configured EnergyLife application on them. After installation, the application and its functionalities were explained to all household members.

3.3 Data

3.3.1 System data

Access to the application was recorded continuously for the three months of the field test and stored separately from the information on the users' identity in compliance with the project's confidentiality policy. Additional data was collected in two subsequent visits to the households. At each visit, participants were given a specific informed consent, explaining the kind of data collection planned for that visit.

[1]The length of the field test depends on the length of the reference period against which the saving percentage is calculated ("baseline"). In most studies [[8]], the field test lasts as much as the reference period or longer, ranging from twice to five times as long. Since the baseline in our prototype was one month, the field test should last at least one month. We decided to run the field test for three months.

3.3.2 Usability tasks

Two series of tasks with EnergyLife were performed by all family members during two separate visits. The first series included 11 tasks testing the users' ability to acquire all the different kinds of information directly or indirectly available in the application. A series of eight tasks was then administered in a subsequent visit aimed at going deeper into some usability aspects that proved problematic in the prior visit or to test features that were not active yet during the first visit. The task execution was video-recorded and analyzed later to determine whether tasks were completed successfully.

3.3.3 Satisfaction questionnaire

Each participant was required to complete a questionnaire of 51 items evaluating his/her experience with EnergyLife along common usability dimensions (navigation, comprehensibility, pleasantness, learnability, consistency, user control, utility). The items were statements with which the users could express their level of agreement on a six-degree Likert scale. Some items were inspired by Satisfaction Usability Scale [[4]] and QUIS 5.0 (Questionnaire for User Satisfaction [[7]]), but the majority were especially formulated to test the specific features of EnergyLife. For each item, scores lower than four (or higher than three, when statements were phrased negatively) were considered to be revealing a problem with the application. The questionnaire also included a comprehension check about tricky aspects of the game; answers were in multiple-choice format and were coded as correct or wrong. The questionnaire was administered twice, once in the middle and once at the end of the field test.

3.3.4 Group interview

At the end of the last visit, all family members were grouped together and interviewed about their experience with EnergyLife. The interviews followed a protocol, and regarded the moment in which EnergyLife was mostly used, preferred functionalities, attempts to test the reliability of EnergyLife, any perceived change in attitude due to EnergyLife, and any technical problem experienced. The interviews were video-recorded, transcribed, and organized by collating information regarding the same issue. Answers recurring across individuals and families were then singled out.

3.4 Results

3.4.1 General acceptance and usability

The participants seemed to like EnergyLife and appreciated its rationale and goal, according to the answers collected through the satisfaction questionnaire. All together, an average positive score was obtained in items measuring pleasantness (M=4.25; SD= 0.46) and utility (M=4.24; SD=0.46). More specifically, users agreed that the interface was enjoyable (design, language, integration in the environment), and that the application was useful in the management and awareness of electricity consumption and effective in changing consumption habits. They agreed that the quizzes were fun and the tips were translatable into real actions. Respondents agreed that energy saving was an important and shared goal and were generally satisfied with EnergyLife. Regarding navigation (i.e., effectiveness in locating information, recognizability of application areas, possibility to go one step back), EnergyLife received a good assessment (M= 4.52, SD= 0.46), and so did user control (M= 3.77, SD= 0.46), related to the possibility of repairing an undesired operation, and get (quick) responses to the input. Consistency was also positively rated, except for the regularity of the information provision that was actually poor due to technical problems (M= 3.52; SD= 0.46). These evaluations did not differ significantly from the first to the second administration of the questionnaire, showing that the positive scores were not a novelty effect.

3.4.2 Usage purpose

The interviews collected at the end of the field test show that users had both generic goals, such as navigating EnergyLife during lunch breaks or while watching TV at night, and specific goals, such as checking the refrigerator's consumption or the instantaneous consumption of the household while several appliances are on simultaneously, to avoid blackouts.[2] Users even carried out some deliberate tests of the system: They checked the instantaneous consumption reported by EnergyLife when no electricity was used in the house, or checked the consistency between the historical consumption graph and the actual usage of a certain device during the day. In case of specific goals, the visit to the application can be very short and focused: users checked if they forgot a device at home, if the consumption changed after purchasing new appliances, if there was any "saving" message in the cards, if the family's habits with a device followed a commonly agreed plan, if any new tip or quiz had arrived. The average number of interactions with the devices per login (M=4.53; SD=1.75) suggests that these last kind of visits prevailed: most participants seem to access the application to undertake a specific action.

The other remark from the interviews is that EnergyLife worked as a magnifier, making "leaks" visible and providing otherwise missing feedback on conservation actions. EnergyLife highlighted the consequences of some actions that would otherwise appear negligible to the user, such as keeping devices on stand-by mode, or turning the TV on as a mere background to other activities. The interviews show that users started chasing bad habits and were eager to see the effects in the game. The refrigerator, computer, and dishwasher were the devices attracting the more interest. In parallel, they regularly checked the arrival of quiz and tips, developing a habit of turning on the application when they expected this feature to get updated.

In synthesis, after a while, users know the application and how to extract useful information with respect to their consumption habits. At this point, all the feasible changes in their consumption habits had already happened ("negotiable practices" [[20], [24]]), compatible with the infrastructural, cultural, and social constraints of their daily lives. At this stage, visits to the application become very specific, serving to maintain new habits. This provides the basis for long-term engagement.

3.4.3 Areas of improvement

During the last period of the field test, there was a significant decrease in the frequency of access to EnergyLife. The Mann-Kendall test for monotonic trend shows a reduction of the accesses during the field test (τ =-0.414, p<0.001). This can be explained by the fact that visits became more specific, but also by some events that occurred in the last part of the test period.

- Some technical bugs made the arrival of quizzes and tips erratic, and in fact, the evaluation of the regularity of advice tips decreased significantly from June [M= 3.75] to September [M=1.48; $t_{(22)}$= 7.92; p< .000].

[2]These families have a contract with the energy provider to purchase a limited amount of instantaneous kW/h; if this amount is exceeded for several minutes, the electricity provision stops.

- Usability tasks (Figure 4) revealed that saving calculations, differences between individual and household scores, and time references for the consumption/saving calculation needed to be simplified. This was confirmed by the comprehension check in the satisfaction questionnaire.

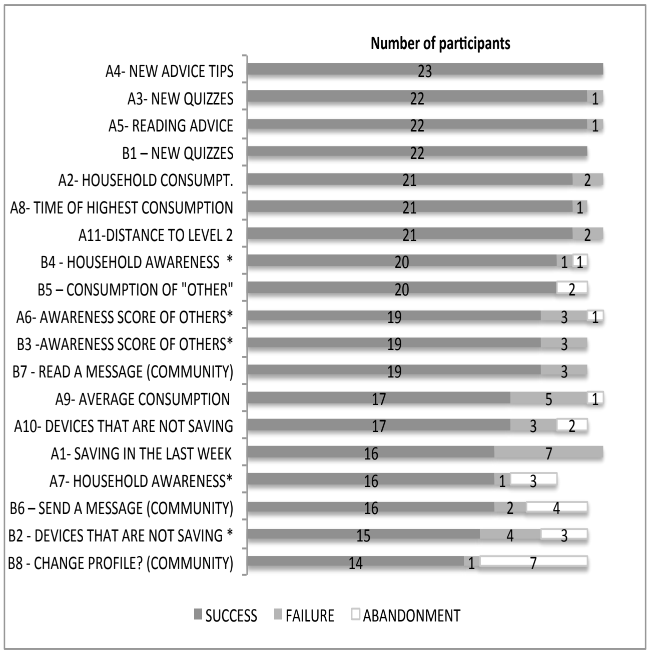

Figure 4. Task results ordered by the number of people completing a task successfully. Tasks administered in the second and third visit are identified with A and B respectively. Tasks repeated in both visits are identified with an asterisk.

Of interest here is the second class of issues, namely the fact that users – unexpectedly - found the game (and some aspects of the game interface) complicated to understand. Since playing the game was the pretext to have the users act so as to gradually improve their conservation behavior and knowledge, any inability to understand the big picture – i.e., how to progress in the game and which action returned which score – was detrimental to the final goal. The final section of this paper describes the strategy followed to improve the comprehensibility of the game.

4. SIMPLIFYING BY TAILORING

After the field test – in addition to solving the technical bugs – a general simplification of the application is executed. First, the interface is simplified. The card carousel remains the only navigation metaphor. The three icons at the top of the screen, which link to score pages and saving breakdown, are removed; access to score pages and saving breakdown is allowed from the back of the house card in the carousel. Second, we single out three aspects of the players' activity that were not well represented in the game feedback and consequently undermined its comprehensibility: the users' different stages in the awareness process; the parallel existence of both an individual and a collective agency, responsible for different aspects of the game outcome; and the separation between two feedback types, i.e., saving and awareness. In the rest of this section, we explain how the game can be better tailored to the users' actions to amend these inconsistencies.

4.1 Users' awareness stage

Players' awareness increases as they play not only quantitatively but also qualitatively; first, they make a commitment and take actions to change their behaviors [[18]], and then they achieve a maintenance phase in which saving is maintained but not improved [[11], [12]]. Tailoring means not only personalizing the content of the game, or keeping track of the users' profile. It also means taking into account the users' gradual increase of awareness. Based on recent work that points out how feedback should take into account different stages and motivational aspects of the user (precontemplation, contemplation, preparation, action, maintenance) [[10], [18]], we identified four phases: goal setting, knowledge acquisition, knowledge check, and maintenance. The game levels were then re-designed to better support these stages (Figure 5).

At the *first* level, only saving feedback is provided, showing the consequences of consuming electricity. This represents the goal-setting stage, when the user needs to know the extent to which the consequences of his/her actions differ from the desired ones. At the *second* level, the user starts receiving tips on possible conservation strategies; at the *third* level, once the user has acquired sufficient knowledge, quizzes are provided.

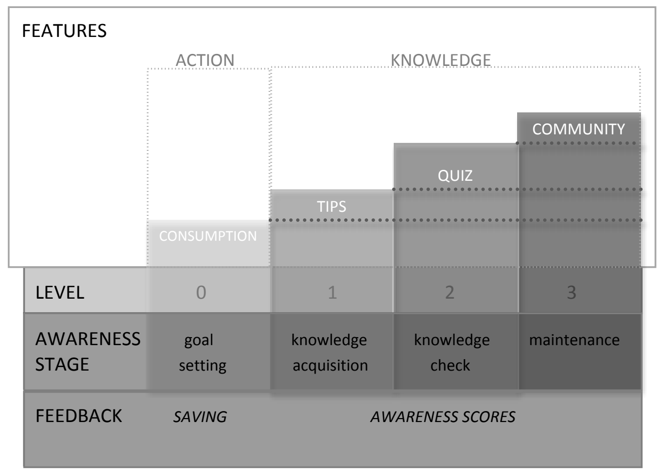

Figure 5. Representation of the different features implementing saving and awareness feedback and regarding players' action and knowledge; of the level of the game at which the features were activated, and of the corresponding stages in the players' process of increased awareness.

The *fourth* level provides some tools to address the maintenance stage, at which the game must be able to stay attractive to the users who can no longer increase their saving but nonetheless should not be allowed to decrease it. At this stage, the game offers the feedback that becomes a natural part of their daily life and through the community area keeps electricity conservation alive by exhanging messages with people in the same program [[12]]. Its new features, which included a ranking of the individual users and of the households, provide a source of novelty that keeps the game attractive, and introduces a social comparison across households (while during feedback, intervention comparative feedback across households could be counterproductive [[19], [22]]) that encourages them to maintain the saving standards achieved.

4.2 Individual and collective agency

The game has two kinds of outcome, conserving electricity and acquiring knowledge. The former is necessarily collective since it depends on electricity usage in the house. The latter, instead, is an achievement of individuals. Therefore, it was decided to separate the two agencies more clearly: saving feedback is provided only via saving percentage, consumption data and saving breakdown, but not by scores. Scores are gained by reading the tips, answering the quiz questions correctly, and receiving messages. In this way the system takes into account more coherently the aspects that relate to the household as a whole and those pertaining to the individual player, acknowledging that in energy saving there are both individual and collective agencies in the house [[6]].

4.3 Contextualized tips

Users are eager for specific information and tips. Thus, we used the consumption data collected by the sensors to customize the content of the tips provided by the application. In this way, the tips were more specific, and the user felt that knowledge and awareness are not segregated in the system. A new feature was then designed, which we called "smart advice." The content and generation of smart advice tips are highly contextualized. The content integrates information from the electricity sensors and is tailored to the local consumption in the house, e.g., “28 trees had to absorb the CO2 produced by your PC this week: try to reduce its usage by turning it off when you don't use it.” The generation of smart advice tips is triggered by specific consumption values registered in the house: for instance, if EnergyLife detects that the stereo was on stand-by mode longer than 10 cumulative hours on a specific day, the household members receives a tip such as the following: “On Tuesday, your stereo was left in stand-by mode for 11 hours. By switching it off completely, you could save electricity.” The system now relies on a database of over 100 advice tips with related triggering rules.

In Table 1, we summarize the redesign of EnergyLife after the field test.

Table 1. Redesign after field test

	EnergyLife in the first field test	Implications for new version
Player	Awareness and saving scores; individual scores are visible to other household members	Awareness scores only; scores are gained by individuals (individual ranking list) and households (household ranking list)
Feedback	Saving information and random advice tips	Addition of Smart Advice tips, triggered by energy consumption behavior
Levels	Three game levels, two broad outcomes (saving and knowledge), individual log-in; upgrading based on saving and on advice tips/quiz	Four game levels, two broad outcomes (saving and knowledge), individual progression in the game; upgrading based on advice tips/quiz only
User interface	Icons to access additional info	Info moved from icons to card carousel

5. CONCLUSIONS

The three-month field test of EnergyLife allowed us to test acceptance and usability of an eco-game in everyday life, since users can go through subsequent levels of the game and develop usage routines intertwined with their energy consumption habits. The essence of the re-design based on the test results was to better tailor the application to the actual nature of the users’ actions. Tailoring is recommended both by a user-centered approach in design and by the principles of feedback intervention [[23], [2], [17]]. In the improved version of EnergyLife designed after the field tests, tailoring was achieved by better following the users’ awareness stage; by better mapping the game rationale onto the individual and collective agency responsible for the game outcome; and by further contextualizing the tips provided, exploiting the application's ability to detect actual consumption in the house. Thus, users were considered not only as individual players, but also as individuals who change over time while playing the game and who act within a family.

In conclusion, based on the experience with EnergyLife revealed by the first field tests, some general recommendations can be provided for the design of a serious game that targets lay users in everyday life and involves feedback to users’ real life behavior.

Table 2. Recommendations for feedback-based serious games

Components and features	Description	EnergyLife
Competition	The way in which players compete	Define “players” by taking into account actual agency
Chance	Some chance elements that can change the position of the players	Contextualize random components of the game to the actual users’ behavior
Simulation	Presence of real-world activities and role playing	Base feedback on real data based on the targeted users’ behavior
Session, levels rules, goals	This determines what is a game and a play session	Ensure a proper progression of challenges and learning
Events, actions, conditions	Conditions and events that give temporal unfolding to the game	Foresee tools to support both action and knowledge directing it
Elements, and interface	Additional features, interfaces, and artifacts	While common games can have very complex interfaces, serious games should be simple and clear.

The main game components to be designed are competition, chance, and simulation [[3]]. Regarding competition, it is important that players engage in the game both as individuals and as members of the larger unit that is relevant to the game, e.g., the family in the case of energy saving at home. Competition is then to be planned within and between households. Regarding chance elements that can change the position of the players, such as the one included in advice tips and quizzes in EnergyLife, they need to be contextualized to the actions of the users that are monitored by the application. In this way, users will better benefit from the information provided and can use it to direct action. Users expect that all feedback provided by the application relies on the fine-grained data it collects and that all feedback information are at the same level of sophistication. Finally, in serious games implementing feedback, simulation should not replace real data but should enrich it with aspects that real data could not have. Thus, although some energy awareness games rely on self-reported data, real-world activities need not to be just simulated, but should be automatically included in the application if timely and effective feedback needs to be provided.

If we take into account the game features [[5]], the design should define what a game and a play session are by setting levels rules and goals. It is then recommended to model the users’ awareness stage and have the game levels fit it properly. Regarding conditions and events that give temporal unfolding to the game, we recommend basing it on two pillars, action and knowledge, and backing up action with proper knowledge directing it. Finally, while common games can have very complex interfaces, serious games should be as simple and clear as possible to fit lay users.

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