Enhancing Energy Conservation by a Household Energy Game

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Abstract. This paper presents the results of a study, comparing a game versus a dashboard with respect to energy conservation in the household. In a pretest-posttest design, an empirical study tested whether change in attitude, knowledge, engagement and behaviour with respect to energy conservation in the household was different for participants playing *Powersaver Game* compared to a control condition where participants used an energy dashboard with the same content, but excluding game features. The aim of this game (developed using an iterative user-centered game design methodology) is to influence household energy consumption by means of electricity and gas usage in the long-term. The intervention time was at least 5 weeks and pre and post measures based on 21 days intervals. All energy conservation activities that the application provides (e.g. washing clothes on low temperatures) take place in the real world and feedback is based on real time energy consumption. This inverse gamification principle aims to optimize the transfer between the game world and the real world. Energy consumption significantly changed in the game condition compared to the control condition, and the difference between both conditions is more than 33% after the intervention. In the game condition, knowledge about energy conservation was significantly increased, although no significant differences in increase of attitude and engagement were found. We conclude that *Powersaver Game* is effective in transfer of energy conservation knowledge, which leads to energy saving behaviour on the long term. It cannot be concluded that playing the game leads to a greater change in attitude, however, attitude scores of the participants were high from the start.

Keywords: Gamification · Energy conservation · Persuasive games · Behaviour change

1 Introduction

Gamification by incorporation of game features can be a valuable strategy for making non-game products, services, or applications, more motivating, and/or for engaging the user [6]. We expect that a persuasive application that aims to stimulate energy conservation is more effective when game features like missions, quizzes, narrative,

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competition and rewards are implemented. Additionally, besides game features, the inclusion of reality by using reversed gamification principles in a persuasive application can be an outstanding effective means to change people's energy conservation behaviour [8]. Gamification research has shown that the integration of serious games into real life could have positive effects on attitude and behaviour [3, 4, 10, 11, 16, 20]. In a normal gamification process, game features are implemented in real world processes to stimulate desirable behaviour. In this research project, a different and novel approach is chosen. It takes the opposite approach by implementing real world processes like household energy activities into the game design itself. The aim of this approach is to optimize the transfer between the game world and the real world. When the transfer is optimized, the game is expected to be more effective in change of behaviour and attitude [13]. Implementing real world processes in a game design is still an emerging principle in gamification research [8]. When people are highly engaged, they are apt to adopt the attitude that is promoted in the application [17]. This can lead to a higher awareness of relevant factors involved in, for instance, energy conservation. In effect, attitude may positively change, and subsequently trigger a change in energy saving behaviour on the long term. The assumed chain of events that higher awareness (more accessible knowledge) leads to attitude change, which leads to behaviour change, is what persuasive games try to accomplish [2, 5, 19].

The persuasive application *Powersaver Game* is developed in an iterative user-centered design approach [8, 9] and is used as a tool in a larger research project that examines the influence of playing in the real world on attitudes towards energy conservation, and on energy conservation behaviour in the long term. The focus is specifically on energy consumption in households by means of electricity and gas usage. The aim is to contribute to the stimulation of individual sustainable behaviour by studying how gamification can be a positive incentive for people to change their behaviour regarding energy use at home. It also aims to study whether transfer from game play to real life behaviour has a long-term character. It is conducted over a longer period of time, measures changes in knowledge, attitude, engagement and behaviour also after delay, and includes an adequate control condition. Families have played *Powersaver Game* or used in the control condition the *Powersaver Energy Dashboard* version which contains no game features.

The research question is if there are changes in knowledge transfer, attitude towards energy conservation, engagement and energy conservation between the game and control condition. This is, basically, the effectiveness of a game focused on energy conservation. We hypothesize that knowledge, attitude, engagement and energy conservation of participants playing the game will increase more than that of participants in the dashboard control condition.

In the next section the research design is presented, with special attention to game design. In the third section the outcomes of the empirical data are discussed. Finally, we draw conclusions and discuss how we will continue our research with *Powersaver Game*.

2 Method

Media comparison research examines differences in learning the same content of a game – or as similar as possible - with conventional media, answering the research question: "Do people learn better with games or conventional media [15]?" Inspired by this approach, our focus is comparing a persuasive game (*Powersaver Game*) and control condition (*Powersaver Energy Dashboard*) within a computer-based medium. This prevents us for problems of possible media differences. In *Powersaver Game* several gamification features are incorporated and is a persuasive game that can be expected to stimulate energy conservation. *Powersaver Energy Dashboard* is a learning application that provides instruction and feedback on energy conservation. In both conditions every 2 days families receive the same information about energy conservation about a specific theme, e.g. washing clothes, and receive feedback. Besides knowledge transfer, i.e. learning results, we also measure attitude, engagement and behaviour, i.e. energy consumption.

2.1 Participants

In this study 21 households including 49 participants older than 12 years participated on a voluntary basis in this experiment. 6 Households dropped out during the intervention. The loss is 17 participants. From the remaining 32 participants who finished the application only 15 from 7 households in the game condition filled in all questionnaires.

2.2 Design

Powersaver Game is a web-based application and is played in households whereof the whole family is involved. The navigation by the player of *Powersaver Game* is done by point and click in the Internet browser. It is an Eco-feedback, Multiplayer, Roleplaying and Point & Click Adventure game [1] and has been designed in an iterative process [9]. A real time connection between the household energy meter and game server is accomplished by dataloggers with an Internet connection. The data of energy consumption is sent to a database of a server at Utrecht University.

Avatars of family members are the central characters of *Powersaver Game*. The family composition in the game is customized to the household. The game starts with an introduction of the story. A storyline in a game can be engaging because it can stimulate our emotions [7, 18]. A family arrives at a dilapidated country house where a professor had caused a failed experiment. The family enters the main hall of the house that contains several doors (Fig. 1). Behind each door a room is situated where a game character in the form of a confused electrical device is placed. A cat (former pet of the professor) called Kyoto guides the family in the game. In every mission session the family is asked to enter a preselected room. Before the door opens a quiz has to be played. A quiz contains questions about energy conservation that will prepare player's knowledge for the missions that are occurring in that specific room. When the family enters the room a character in the form of a device that is in a confused state is shown (Fig. 2). The family has to accomplish missions, which contain energy conservation

knowledge, to help the device to return to a normal state. All missions (e.g. washing clothes on low temperatures) take place in the real world; this represents our inverse gamification principle. The total period of playing the game is at least 5 weeks if players end missions and start new ones in the given time. It takes approximately 2 days to complete a mission. The game has 13 missions, 8 quizzes and an end-battle/scene. The end condition is reached when all devices and the professor are brought out of their confused state. The player is getting feedback on energy use and savings during playing, which is based on average energy consumption in the 21 days before the intervention started. The results of the quizzes are shown and achievement of a completed mission is displayed with a badge. A household is in competition, another game feature, with 7 virtual households, but assumes to play against real households. Competition is simulated to stimulate households to achieve high scores and it was technically not feasible to implement a real and fair competition.

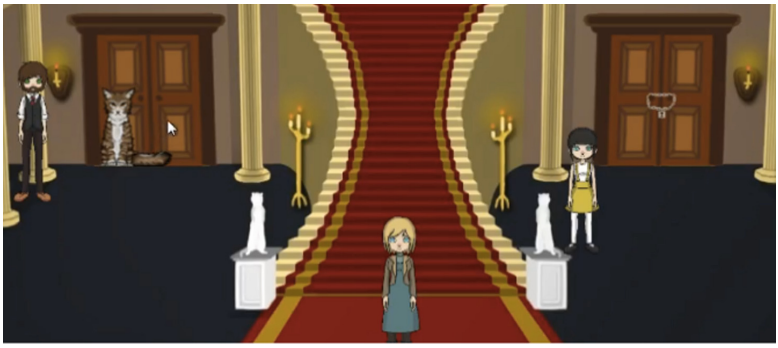

Fig. 1. Part of the main hall

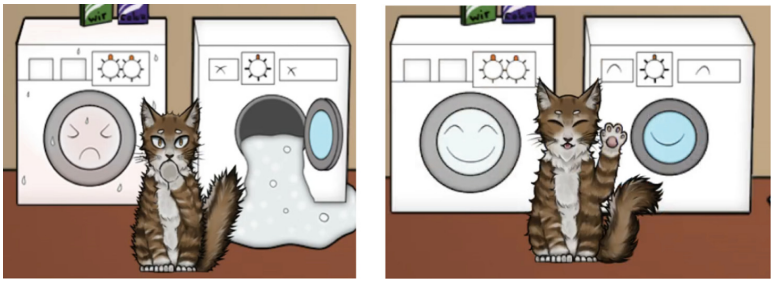

Fig. 2. Scenes laundry; Bad State (on the left) and Normal State (on the right).

Control Condition

For our approach families used *Powersaver Energy Dashboard* in the control condition. The energy dashboard has an identical design style as the menu page of the game. It contains a screen where energy conservation recommendations and a timer are presented, and to give feedback two screens with energy consumption charts and energy

conservation results are presented. The form, timing and content of the information the control condition receives are highly similar as in the game condition, but excluded game features such as missions, quizzes, narrative, competition and rewards [19].

2.3 Measurements

Participants completed an online pretest as well as an online posttest questionnaire to assess their attitude towards sustainable energy consumption related topics and knowledge level towards household energy conservation. For attitude measures both questionnaires included 30 statements rated on a 7 point Likert-scale ranging from strongly disagree to strongly agree. Different statements on the same topics are used in pretest and posttest. 15 Statements are regarding micro-level attitude topics (about sustainable energy consumption in a household) as well as 15 statements regarding macro-level attitude topics (10 statements about sustainable energy and 5 statements about sustainability). Macro-measures were composed partly based on previous research on attitudes toward sustainability [19]. With this approach we measure specific hierarchical attributes of the object of sustainable energy attitude [22]. Krosnick and Petty [14] describe that strength-related attributes of attitudes are categorized in affective, cognitive and behaviour intention components. In our questionnaire we only used statements from affective and cognitive categories, because behaviour intention to save energy in the household was already high by voluntary registration to participate in this experiment. For knowledge measures 12 multiple-choice questions including 4 answer options per question are used. The questions are related to the content about energy conservation from both applications. The same questions are used in the pretest and posttest.

Engagement measures were composed based on previous research on engagement in serious games [21]. To monitor engagement participants completed an online questionnaire in the second week and the last week of the intervention. Both questionnaires included the same 7 statements rated on a 7 point Likert-scale ranging from strongly disagree to strongly agree.

Behaviour, in the form of energy consumption, is monitored during 21 days before the intervention to set a good baseline of average energy consumption. In both applications the user is getting feedback (on energy use and savings) during the intervention. And after the intervention the energy consumption is monitored for 21 days to examine the impact of the intervention.

2.4 Procedure

Participants have been recruited using different methods and communication channels like social media, direct mail, digital newsletters and public lectures. Participants registered at the beginning of 2017 using an online form. They could participate when the technical situation of their energy supply (e.g. presence of smart energy meter) was adequate. In spring 2017, 49 participants from 21 households filled in the online pretest. To monitor real energy consumption in this period also hardware was installed in the households. It took at least 21 days of monitoring to set a firm baseline. All participants above 12 years replied to the pretest questionnaire about attitude and

knowledge measurements and the first engagement questionnaire in the second week of the intervention. Participants were randomly assigned to conditions, however we took care that there was a global matching between conditions on the composition of the household (adults and children), attitude towards energy conservation (higher or lower than average compared to other participants) and energy consumption (higher or lower than average of the same type of households in The Netherlands). Knowledge scores are not used in this assignment process because all participants scored very low. All household types are equally represented in each condition. 11 Households are assigned to the game condition and 10 households are assigned to the control condition. The intervention started in June and ended in July 2017. Some households ended later due to delay in starting new sessions. From the 11 households that started in the game condition 6 households finished on schedule (Mean 5,5 weeks) and 4 households finished later (Mean 18 weeks). 1 Household did not finish the game. From the 10 households that started in the control condition 5 finished in mean 13 weeks and the other 5 households stopped halfway after 4 weeks.

When a household finished all the sessions they were asked to fill in the online posttest. Only 15 participants, a third of total, respond to the second questionnaire about engagement before the last week of the intervention and the posttest questionnaire about attitude and knowledge measurement after the intervention. These 15 participants that responded to all questionnaires are from 7 households in only the game condition.

The hardware was disconnected after at least 21 days from the end of the intervention.

3 Results

The effects on energy conservation and knowledge, engagement, and attitude measures are presented below. Energy conservation between the game and control condition is based on 6 households from the game condition that have finished on schedule (mean 5,5 weeks) and 5 households from the control condition that have finished (mean 13 weeks). 4 Households that finished the game later (mean 18 weeks) did not provide data on energy consumption within the time constraints for our study. Unfortunately the post-measurements fell in the heating season.

Only knowledge, engagement, and attitude measures from the game condition are discussed due to lack of sufficient observations in the control condition on the questionnaires.

3.1 Energy Conservation Measures

The results in energy conservation between households in the game and control condition are presented in Table 1. The average energy consumption per day from 21 days after the intervention is compared to the consumption over 21 days before the intervention. The difference in percentage change of total energy consumption (%Δ kWh electricity + %Δ m^3 gas/2) is presented as well as the percentage change in consumption

in kWh electricity and m^3 gas. An independent-samples t-test on the gain scores is performed to test if differences in percentages of change between the game and control condition are significant.

Table 1. Energy conservation: mean changes, standard deviations, t-statistic and significance levels of difference.

Energy conservation	Game		Control		Diff	*t*	*p*
	M	SD	M	SD	M		
Total	21,4%	7,7	−12,2%	18,5	33,6%	−4,081	<0,005
kWh Electricity	12,9%	7,9	−1,7%	16,6	14,5%	−1,915	<0,05*
M^3 Gas	30%	12,1	−22,7%	38,3	52,7%	−3,211	<0,05

* one-tailed test

There is a significant major difference of 33,6% in total change in energy conservation between both conditions: t (9) = −4,081, p < 0,005: while the game condition consumes 21,4% less energy than before the intervention, the control condition consume 12,2% more energy. When we look specifically at conservation of kWh electricity there is a significant difference of 14,5% between groups: t (9) = −1,915, p < 0,05 (one-tailed test). The game condition consumes almost 13% less kWh electricity than before, while the control condition consumption is almost the same as before the intervention. The largest significant difference between the groups is 52,7% m^3 gas consumption: t (9) = −3,211, p < 0,05. Notable is that in general the standard deviation of the control condition is high.

3.2 Knowledge, Engagement and Attitude Measures

The results in knowledge, engagement and attitude measures of participants are presented in Table 2. These fifteen participants who filled out all questionnaires (thirty percent of all participants), as explained above, are only from the game condition. A paired-samples t-test is executed to conclude if differences between the pretest and posttest are significant.

Table 2. Knowledge, engagement & attitude in the game condition: means, standard deviations, t-statistic and significance levels of difference.

	Pretest		Posttest		Post - Pre		*t*	*p*
	M	SD	M	SD	M	SD		
Knowledge*	4,27	1,62	5,8	1,93	1,53	1,81	−3,29	0,005
Engagement	5,35	0,94	5,29	0,75	−0,06	0,45	0,54	ns
Attitude								
Total	5,38	0,85	5,34	0,74	−0,04	0,4	0,391	ns
Micro-level	5,35	0,88	5,43	0,75	0,09	0,51	−0,662	ns
Macro-level	5,41	0,92	5,25	0,81	−0,17	0,4	1,609	ns

* Maximum score = 12, ns - not significant at 0,05 level

The average score on knowledge increased from 4,27 to 5,8 points. Although the average score in the posttest is not high (the maximum score possible is 12 points), knowledge about energy conservation increased significant: $t\ (14) = -3{,}29$, $p < 0{,}05$.

The engagement is high and constant during the intervention. There is no significance difference in engagement at the beginning and end of the intervention: $t\ (13) = 0{,}54$, $p > 0{,}05$.

All attitude scores are already high from the beginning and the intervention did not lead to a significant attitude change: Attitude total: $t\ (14) = 0{,}391$, $p > 0{,}05$; Attitude at micro-level: $t\ (14) = -0{,}662$, $p > 0{,}05$; Attitude at macro-level: $t\ (14) = 1{,}609$, $p > 0.05$.

4 Conclusion and Discussion

Based on the results of this study we conclude that there are differences in learning the same content of a persuasive energy conservation game, developed by using an iterative user-centered game design methodology, compared to a dashboard control condition. Furthermore, and most importantly, we conclude that energy consumption changed significantly on the long term. A persuasive game that includes reality by using reversed gamification principles is, thus, effective in learning people to save energy in the household and to actually do that for the long term, while an energy dashboard does not change that behaviour at all. Similar studies [e.g. 3; 4; 10; 11; 16; 20] also presented positive results but had some shortcomings; the lack of a control condition, the intervention time was short, no real consumption measurements are used, implementation of gamification could be better, limited number of variables is measured and/or the lack of pre-measurements & post-measurements [9], which altogether could explain that the positive effect on energy conservation in our study is higher than in previous studies.

From the beginning of the intervention, participants in the dashboard control condition had delay in starting missions (mean 13 weeks to finish while 5 weeks is possible), did not carry out missions (no energy conservation) or quit (50% in 4 weeks). Unfortunately, these participants in the control condition were not motivated to respond to questionnaires, so the resulting number of questionnaires is too small for meaningfully analyzing the data. It is possible that some participants are disappointed in that they are not assigned to the game condition and therefore less motivated. But there are also participants from the control condition who stated after the intervention that they did not prefer to be assigned to the game condition. In the game condition energy consumption (behaviour) changed and knowledge about saving energy at home increased. Also in this condition, despite of the long intervention time, engagement remained high during the whole intervention. These results align with the earlier mentioned chain of events that higher awareness (more accessible knowledge) for a longer period leads to increased knowledge, which leads to behaviour change on the long term. The attitude scores on micro-level and macro-level are extremely high, both nearly the same and the intervention did not change it. Because of this a ceiling effect regarding attitude could be the case, resulting in no-gain in attitude but still a positive change in energy conservation behaviour.

Krosnick and Petty [14] mention that the more extreme an attitude is, the more an individual likes the object of the attitude, and should be more likely to guide behaviour. It is surprising that during the intervention a substantial number of participants in the control condition, thus with an extreme attitude score, dropped out. It is possible that behaviour intention within the attitude diminished [14]. In future research questionnaires have to be modified to study this phenomenon. These results can have considerable implications for policymakers and companies in the field of smart energy meters. Now in practice only dashboard designs are used to give feedback on energy consumption (e.g. Nest) and our data seem to indicate that these designs are probably not effective on the long term [12].

Constraints in this study are that only from participants in the game condition all dependent variables (knowledge, attitude, engagement and behaviour) could be analyzed and that there is not sufficient data to look closely at the control condition. Independent of the preceding, the results also showed in the control condition no positive change was attained in the long run. Another constraint is the limited number of households participating in this study. This limitation also occurs in related studies [3, 4, 10, 16, 20]. Although the number of households was limited, still significant differences are found. There is a possibility to scale up the number of participants if the smart energy meter can be monitored without additional hardware and a large(r) campaign to recruit households is launched.

To bring the research field on energy reduction games a step further, the research question would be useful "Which persuasive features of a persuasive game exactly promote lasting changes in knowledge, attitude and behaviour regarding sustainable energy use of households?". For that purpose we will in a next phase of research apply a "value added" approach [15]. Here we examine the effects of the persuasive features personal relevance (by means of customized avatars) and social interaction (by means of competition) – separately and combined - on participants' knowledge, attitude and behaviour with respect to sustainable energy consumption with *Powersaver Game*.

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