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The EN-Survival Game: An Environmental game for Residential Accommodation

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Abstract

The significance of using games for educational purposes is well documented in the literature. It has been argued that serious games can draw more engagement and user attention to topics when compared to conventional web or print media, including concepts around energy education. The smarter household project has deployed an energy indoor health monitoring system in 19 UK social housing units, utilizing internet technologies to connect the end-user through tablet devices to multiple interventions (dashboard visualization, application of gamification and serious game). The serious game aimed to help residents understand their energy consumption whilst stimulating energy efficient behaviors towards managing indoor conditions via in-game decisions. This chapter presents our preliminary findings relating to the serious game as an intervention across the 19 households. The game demonstrates potential value to trial participant in terms of how to apply the lessons learned from the in-game scenarios to their everyday activities.

Keywords: *Serious Games, Game Based Learning, Environmental Games, Energy*

1. Introduction

Addressing climate change may require behavior change at the individual level. Such change is typically more important than technological solutions, as changing people's behavior and attitudes towards energy consumption will be able to generate long term reductions (Minx, Callaghan, Lamb, Garard, & Edenhofer, 2017). Behavior change programs can be effective in encouraging people to use less under some circumstances (Nauges & Wheeler, 2017) . For example, evidence suggests that provision of comparative usage information to end users can lead people to change their behavior. Serious gaming is one intervention which can be used for influencing user behavior (Gugerell & Zuidema, 2017). We investigated an experimental co-design process to collaboratively design a serious game called the 'EN-Survival Game'. The game was part of the EPSRC Smarter household project and was focused on was focused on researching into the application of games as a mean to reduce energy demand, meet UK Government CO2 reduction targets, and reduce domestic reliance on fossil fuels, offering protection from price risks and fuel poverty as well as providing more affordable and comfortable domestic environments

(Shukla et al., 2019; Wood et al., 2019). Low-income households may be limited in the benefits they can reap from such systems because they already living within a tight budget, and suggestions for further energy-related cost savings may be detrimental to their health and wellbeing. This makes it important that the impact of actions taken to save energy is well communicated. In order to assist those household occupants we have created the 'EN-Survival Game'(Shukla et al., 2019). The purpose of the game was not only to reduce energy consumption, but rather to allow people to optimize their consumption by understanding the relationship between that and indoor environmental conditions, and to give some suggestions as to how energy might be conserved and how to improve their wellbeing. . During the past decade, serious games have grown considerably more popular in their application as educational tools. Commonly cited purposes of these games are (i) to be educational; classically employing pedagogies around abstraction, problem-based learning, or social learning and, (ii) to be fun and engaging, through concepts such as "flow" or self-efficacy theory (Bellotti, Kapralos, Lee, Ger, & Berta, 2013; Bourgonjon, Valcke, Soetaert, & Schellens, 2010). It has been reported that in comparison to conventional methods, serious games can draw more engagement and user attention to a topic. In our view, there are five elements of a serious game: (i) story (ii) gamification (iii) individual feedback (iv) simulation and (v) the goal to learn (elearningindustry, 2017). Jans et al. (De Jans, Van Geit, Cauberghe, Hudders, & De Veirman, 2017) investigated the design of serious games to raise awareness. They reported that serious games are promising tool to raise awareness for two main reasons - motivation and enhancement of player's interest on a selected topic. We have previously (De Jans et al., 2017) highlighted the usefulness of informant design when developing serious games. Influencing the end user knowledge is one of the main focus of serious games and core of the more pedagogically-centered game based learning (Kato, Cole, Bradlyn, & Pollock, 2008; Lieberman, 2001). These games can be played by single or multiple users or in group settings. The main aim is to assist the participants in decision making, learning or influencing their attitude/behavior. Khaled and Vasalou (Khaled & Vasalou, 2014) reported that serious games often have more impact or use if the simulations are close to the real life experience of the participants. This can be achieved by collaborative design with the participants where engagement activities with the end users provide valuable knowledge for the design of serious game.

In the specific area of the environment and energy conservation, an array of similar principles applies to those behind public health issues. In both cases, a need exists to stimulate a change in the immediate behaviors of audiences, which may struggle to perceive the long-term benefits. Games may provide a useful platform for creating the levels of sustained engagement and motivation, and this hypothesis has been explored through a range of projects aimed an energy awareness for households: for example, the Energy Life project (Bjorkskog et al., 2010) focused on the use of pervasive devices for monitoring consumption, forming a game around usage. The ASPIS project is focusing on the improvement of urban planning and design practices to the benefit of urban sustainability, with emphasis on sustainable public open spaces [34]. Other environmental concerns have been tackled through social media; for example the i-Seed serious game (Petridis et al., 2011) sought to create a game within the Facebook platform to promote positive attitudes towards the environment. Other approaches have equally embraced mobile platforms and other emerging technologies to reach audiences with an environmental message (Gustafsson, Katzeff, & Bang, 2010).

2. Literature review

Given that a significant component of the energy consumption challenge is linked directly to end-user behavior, current research on game based learning is increasingly exploring the application of innovative technologies and behavioral messaging techniques(Lameras et al., 2017; Philippe, 2020). From a theoretical perspective, techniques are often underpinned by an understanding of challenges around self-efficacy and social cognition (Bandura, 1986), in particular the limited ability of the individual to perceive a meaningful contribution to issues such as climate change through their individual actions, and the weak link between stated intention to act and measurable actions. Subsequent interventions have sought to address these challenges by targeting groups rather than individuals (Bedwell et al., 2014), providing extrinsic rewards (Wiersma, 1992), or seeking to adjust social norms(Smeaton & Doherty, 2013). Evidence shows promising impact when presenting consumption information to end-users (Borner, Storm, Kalz, & Specht, 2012), though success is neither universal nor guaranteed, with group-level intervention shown to have negative effect in a small scale (n=16) study (D. Foster, Linehan, & Lawson, 2014). Other studies have sought to understand this negative effect, with suggestions that “freeriding”, conflict, or differing social norms, may be explanatory factors (Bedwell et al., 2014). More recent behavioral theories seeking to serve more directly as a design basis for interventions have sought to identify pragmatic considerations in effective behavioral intervention design, either by consolidating known factors though statistical approaches (Grob, 1995), or aligning the theory to the stages of change of a participant (Prochaska & Norcross, 2001).

Many of the factors posited by current theory as mediating behavior change, including self-efficacy, social norms, immediacy, engagement and reward, are relevant to game-based interventions. Games are gaining interest as a means of behavioral intervention, due in part to the increased availability of hardware and rising digital literacy amongst end users, and their ability to engage end-users, which may serve to aid in translating intention to act to measurable action. Games and play also provide means to abstract problems or behaviors, or communicate concepts in a novel manner, making them relevant to situations where knowledge has been acquired but is not being translated to action due to issues around self-efficacy, social norms, or translating intent to action. The methodologies used to evaluate game-based intervention in the home energy space are diverse, with limited large-scale empirical data available; studies typically seek to provide design-level input through mixed-method or grounded theory approaches (Derek Foster, Lawson, Wardman, Blythe, & Linehan, 2012). Primary design-level evidence suggested by the literature base includes a likely limited impact of points, badges and leaderboards when introduced without an understanding of social context and how participants construct value around rewards (Wiersma, 1992); providing asynchronous feedback, avoiding ‘push’ notifications (Simon J., Jahn M., & Al-Akkad, 2012); and that challenge may be a stronger motivator than real or virtual incentives (Kalz, Börner, Ternier, & Specht, 2015). In an evaluation of a workplace game for energy consumption, implementing a leaderboard (Tolias E., Costanza E., Rogers A., Bedwell B., & N., 2015), users were observed to cheat, artificially altering their consumption data. On the one hand, this illustrates the risk of relying on technology to ascertain user behavior in a context where the user is motivated to 'game' the system, yet on the other that users were sufficiently engaged and motivated to cheat is a positive observation.

In general, the evidence base surrounding the design of games for behavioral intervention is difficult to consolidate into generalizable findings, as noted by existing metareviews (Connolly, 2012). In part, as suggested by Connolly et al. (Connolly, 2012), this is due to a paucity of large-scale empirical evaluations, such as randomized control trials. Yet even those that exist typically illustrate a particular game as 'working' for a particular challenge, and given the limited ability to understand causality present in such trials, this evidence is often more useful for the exploitation of a specific intervention than to inform future design. This is further compounded by the nature of the design of persuasive digital games as crossing the space between artistry, psychology and technology, and the associated challenges in reconciling differing perspectives on priorities, expertise and methodologies. Commonalities in methodology include advocating participatory, iterative design (Connolly, 2012), yet this is challenging to enact meaningfully in practice due to high cost and time overheads. Furthermore, the general case with behavioral intervention is that a 'one-size fits all' approach to a single intervention, which seeks to be taken up and used by the majority of a given demographic is unlikely to succeed (Prochaska J. J. & Prochaska J. O., 2011). Therefore, evaluation and consideration of user feedback or participatory design input needs to acknowledge the likelihood that for a significant proportion of end-users, a single intervention is unlikely to be meaningful.

3. System Architecture for the EN-Survival Game

Drawing from the current literature on theory and design of game-based approaches, we adopted a rapid prototyping methodology for the development of the game, with the first iteration, evaluated in this article, being developed in a timespan of 3 months. The prototype drew on several concepts related to the design of serious games, explored by other studies. Firstly, the game sought to provide a compelling narrative, shown to be a key engagement factor in digital games (Marsh T. et al., 2011). It also sought to use and scaffold analogy as a means to facilitate challenge and problem-solving, without compromising the overall narrative. Similar approaches to analogy within serious game design have shown such ability to allow users to engage with a problem, whilst understanding its real-world connection (Dunwell I. et al., 2014). A primary benefit of the use of analogy, rather than simulation, is to the designer in allowing more direct design for 'flow', a balance between challenge and user ability (Csikszentmihályi M., 1990), which is often not inherently present in a more direct simulation. More concretely in this case, the common household tasks of controlling humidity, room temperature, and carbon dioxide levels in an energy-efficient manner were translated to the abstract situation of a survivor in an arctic shelter, where controlling these variables is essential for survival.

The game was developed and deployed to Android and Windows x86 using Unity 5.4.2. A 3D environment, with player control via touch allowing them to move their character by tapping the ground and interact with objects by tapping them directly, as shown in Figure

1. Once interacted with, camera transition allows the player to directly manipulate a range of environmental controls: a hob, refrigerator, cooker, microwave, thermostat, windows and the overall layout of the environment. Each of these links to an underlying simulation of temperature, humidity and CO2 levels, informed by target learning outcomes: heating water on the hob rapidly raises humidity, using the conventional oven over the microwave results in a higher energy consumption rate, and keeping the windows closed, whilst helping to preserve room temperature, also results in rising CO2 and humidity levels. These all pose a risk to the player's health; visualized as shown in Figure 2. Health is depleted by sub-optimal environmental conditions and replenished by cooking or purifying (boiling) water to drink, placing a demand on the player to consume energy as efficiently as possible. The failure condition is met with the option to continue immediately with health replenished and a lower final score, or to repeat the game from the start. The goal here is to motivate both casual players seeking to complete the narrative and more engaged gamers seeking to achieve the highest score, measured in total kWh consumed at the end of a play-through, plus any restart penalties.

***Figure 1**: Gameplay environment. Health (top left) is influenced by temperature, humidity and CO2 levels. Multi-layered objectives (top-right) relate to both the environmental control and puzzle-solving. Objects can be tapped on to initiate interaction.*

***Figure 2**: Player health. The ideal comfort levels for temperature, humidity, and CO2 are derived from the literature and learning objectives. Eating and drinking (left) replenishes health, but requires the player to expend energy to cook frozen food or purify water*

Another affordance for flow was the incorporation of non-serious puzzles within the environment, derived from common gaming generics: hacking a computer, solving a chess puzzle, accessing a locker code, searching for fuel and finding a lost survivor. In incorporating these, further effort was made to synergize simulation and gameplay. This was done in a non-linear fashion, based on the observed importance of player choice and freedom in game design (Adams E., 2013). The player is tasked with simultaneously operating control panels to modify environmental parameters (Figure 3), to keep the environment safe for puzzle-solving under an ‘escape room’ paradigm.

Figure 3:Example mini-game puzzle. In this game, the user can rearrange the furniture in the shelter. Actions such as unblocking the radiator, and separating heat sources from the refrigerator, have benefits to energy consumption.

The simulation at the core of the shelter gameplay was designed based on target learning outcomes, informed rather than driven directly by real-world cause and consequence. Total energy use, and energy remaining, is shown to the player on a generator control panel in the shelter, seeking to create a sense of pressure for efficient energy use as levels tick down. An overall play-through of the game was designed to be accomplished in 45 minutes to an hour, with the opportunity to repeat the game for a higher score incorporated but, under pragmatic expectation of user engagement, not designed to be required for learning outcomes to be achieved.

4. Results for the EN-Survival Game

Participants were asked to fill in a survey about their experience of the game. This was completed by 13 of our 17 trial participants. Some participants filled in an additional section which asked for the views of anyone else in the household who had played the game (19 in total). In addition to our 17, 19 trial participants were asked about their views on and experience of the game in the follow-up interview (this was an added bonus because the game was played by other people living in the household).

The first part of the game survey consisted of statements based on the QUIS methodology (Questionnaire for User Interface Satisfaction) (Chin J., Dieh, & Norman K.L., 1988) in order to assess initial reactions, ease of getting started, and time taken to learn the game. Responses to these questions tended to be negative, with the 8 out of 9 statements having a mean response of 4 or below (on a scale of 1 to 9, 9 being the most positive option). Additional exploration into these views was carried out in the interviews.

Usability

Players were asked in the survey about the furthest point they reached in the game (Figure 4, n= 17). The majority of players (65%) made it to the second stage, where they were solving puzzles inside the shelter. No statistically significant relationship could be seen between age of participant and progress in the game, or progress and gender.

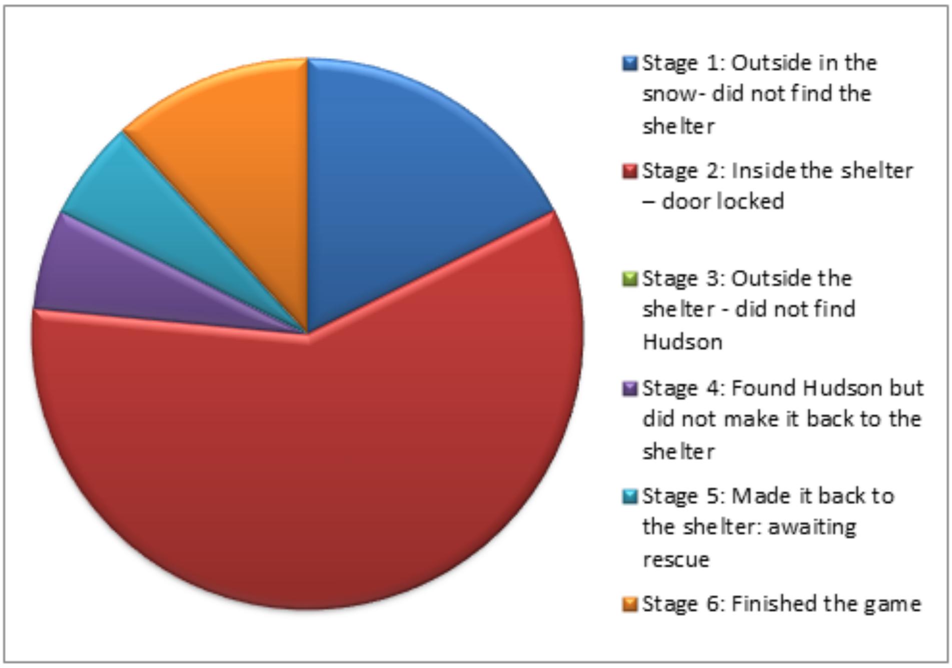

Figure 4: Progress players made in the game (information captured via survey)

It is worth noting that by the point of the follow-up interview, 4-8 weeks later, everyone who had tried that game had at least made it into the shelter (Stage 2 of the game).

Game play support was provided by means of a walkthrough video and a user guide. The majority of feedback from players related to navigation and controls, with several players noting that their struggle to move around the game environment made the experience frustrating, e.g. "I knew what to do, but it's actually doing it. I didn't know how to do it and that's what was the frustrating part" (Darren). This kind of comment was typical of the players, along with limited time available before the character 'dies', and a feeling that "…I was juggling so many balls in the air…" (Daphne).

11 out of 17 trial participants mentioned that they do not regularly play games or described themselves as 'not a gamer'. This may have contributed to players' difficulty in managing the multiple demands of the game.

Learning from the game

Less than positive feedback relating to usability and navigation is not uncommon for a research prototype game, and it was noticeable that feedback on learning was much more positive. Notably, this reported learning from the game took place after most of the players had been using the Energy Dashboard app for several months, and so the game could be seen to provide additional learning potential on top of the app.

A positive result was that most respondents agreed or strongly agreed with the statements around learning:

• I feel more knowledgeable about CO2 after playing the game (58% agree or strongly agree)

• I feel more knowledgeable about humidity after playing the game (58% agree or strongly agree)

50% of players also agreed or strongly agreed with the statement ‘Playing the game has made me more aware of things I can do to save energy or make my indoor environment healthier/more comfortable’. Positive learnings were noted around the arrangement of furniture and appliances (for circulation of heat and not compromising ability of refrigerators to cool food), and the impact of opening windows on the indoor environment.

However, the implication of usability difficulties is that those who made limited progression in the game would not have as great a chance to learn as those who reached the final stages of the game or completed it.

In some cases, the learning reported by participants from the Energy Dashboard app, the Energy Game, or simply taking part in the trial, carried forward to affect their everyday behaviors in terms of energy use or indoor environmental conditions. The most reported behavioral change at the second interview was to laundry activities (washing or drying clothes), mentioned by 57% of trial participants. In most cases this was either reducing the number of washing loads carried out in a week or using the tumble dryer less. These behavioral changes were attributed by the participants to reading the hints and tips on the Energy Dashboard, seeing peaks in electricity usage on the app when doing laundry, or general trial participation. For example, Kay said:

“I do actually think about what is in the machine. I went to put it on Saturday night, and I said to myself no, that can wait until another night, which I did. So yes, I do think I’ll put it on tonight but when I see how much actually is in there, I think it can go on another day. So that has made me think as well.”

The other key change made by participants was around ventilation of the property. 43% of trial participants mentioned a change in ‘airing’ or window-opening behaviors, for example that described by Becky: “…before I probably wouldn’t have even cared, I wouldn't have even thought about it. Especially like I said about cooking and opening the windows, or just opening the windows when I had washing and stuff in here. I just wouldn't have been bothered probably before."

In a few cases this change was specifically attributed to learning from the game. Kate noted that "…that comes down to the game more than the app…I suppose I did know that if you open the window it reduces the humidity, but the CO2 thing I didn't realize existed really, or had an effect on an environment." Another participant reported that after playing the game they started opening a window in the lounge. This was a property that suffered from mold issues and where ventilation had not previously been regularly carried out, so this was a positive impact. The release of the game was the final activity of the trial, and therefore it is likely that some participants had already learned about how to maintain healthy indoor environmental conditions and manage energy efficiently from the app and other earlier trial activities. However, it is still a positive outcome that some participants made changes to their routines following playing the game. 58% of survey respondents agreed that they were able to connect the game activities to their real-life energy use, and/or managing the indoor environment in their home, demonstrating that despite the extreme environment in which the game was set, most players could still make a connection between it and their everyday lives.

Some participants reported difficulties in actually applying what they had learned from the app or the game. In several cases, this was due to long-term health conditions, or disagreements with other family members:

Daphne: "…quite often I would come down, I'd say, "Have you seen this? It's going in the red," and what do we do? I said, "Open the window." He said, "It's too damned cold to open the window." So, sometimes, it's been a battle. Not from the project, but trying to do things to see how it would affect the pointer".
This is to be expected in multi-occupant properties, where changes in behaviors that affect all residents must be negotiated.

The game shows clear potential for making it clearer to the trial participants how to apply what they learned through the Energy Dashboard app. The Hints and Tips function of the app made behavioral changes (like those made to laundry habits) clear, but the app did not make it clear how to make the indoor environment healthier. This was the key role of the game: demonstrating how to use ventilation to manage carbon dioxide and relative humidity levels. Learning findings from this small trial of the game and the app were positive. Usability issues are likely to have hindered some people's learning from the game, as most participants did not reach the later stages.

Due to the game being tested after the app had already been provided, it is possible that changes to behavior had already been enacted by the time the game was trialed. Going forward, it could be useful to test both the app and the game in a large-scale randomized controlled trial. However, it is positive that 58% of participants felt more knowledgeable about carbon dioxide and humidity after playing the game. This demonstrates the potential role of a serious game about energy to embed learning and impart further information about aspects that had been less well understood previously in the trial (in this case, indoor environmental conditions and actions that can be taken in the home environment to rectify unhealthy situations). However, the reality of everyday living in multi-occupant homes is that changes cannot always be made when these impact upon the comfort of others. To tackle this, more research is needed into how to get whole households involved and invested in these kinds of trials.

5. Conclusions and future work

Serious Games offer a range of benefits such as making users feel responsible for success according to their actions, match high-quality content and high engagement, turn mistakes into learning elements avoiding the message that an error is something that cannot be recovered, allow problem based learning, situated learning and make users feel more comfortable with the exercise. SGs offer the ability to participants to assume an active role in a situated and experiential learning process that potentially can alter their behavior. It is also widely accepted that educational games can increase the attractiveness of learning, giving a powerful tool in the effort against de-motivation and dropouts, two issues largely affecting academic performance and behavior. Moreover, Serious Games may help to connect specific contents and skills in a friendly, error-free environment, where the student or the user is able to play, probe, make mistakes, and learn. In the case of Smarter Household serious game, the evidence that we have collected demonstrated that the residents made the connections between the game and the real life. However, in order to verify that statement we need to evaluate the game using a larger sample .

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