Developing Gamified Elements to Influence Positive Behavioural Change towards Organisational Energy Efficiency

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Abstract: Demands for energy within public sector buildings, such as administrative offices, cultural heritage sites, and museums, represent a significant financial and environmental burden. With issues relating to climate change now more prominent than ever, energy efficiency is an important aspect for consideration at both organisational and occupant levels in public buildings. Occupant behaviour plays a key role in the process of saving energy, with the major areas of wastage being directly linked to the use of heating, lighting and electrical devices. Automating these devices can provide a partial, if costly, solution; however, the influence of personal preferences on comfort levels and productivity must also be considered. Strategies may thus seek to enhance organisational energy efficiency in the public sector by promoting positive behavioural changes amongst occupants or visitors. However, such strategies must be informed by knowledge of related behaviours, business processes and best practices for saving energy within specific workplace contexts. To encourage and support participants in adopting energy-conscious behaviours, the incorporation of serious games and gamification offers potential to bring about positive behavioural change. This paper presents the OrbEEt Behavioural Change Framework and its application through the development of a gamified ecosystem consisting of three interfaces; a smartphone game, an intranet portal, and an in-office display. This involves the incorporation of behavioural triggers through an infrastructure of high granularity sensor data, the identification of which are informed by the results of a questionnaire targeting 28 participants across four European pilot sites, representing a diverse range of cultural, climatic, and operational settings for public sector buildings. The work herein represents the pre-intervention stage of the ongoing 3-year OrbEEt research project, with the potential application of these behavioural triggers and interfaces extending to various organisations that are looking to improve overall energy efficiency, while maintaining business productivity and ensuring best practices.

Keywords: Serious Games, Gamification, Energy Efficiency, Office Environment, Behavioural Change

1. Introduction

The increasing amount of global energy consumption has presented real-world problems in terms of the environment, through factors such as climate change, global warming and ozone layer depletion. As such, there is a push towards addressing energy efficiency through a range of potential solutions, improvements and changes. For example, at high-level, the utilisation of renewable or alternative energy sources is becoming more prominent, whereas at low-level, some seek to improve the energy awareness of individuals to facilitate the efficient use of electrical equipment. Within developed countries, commercial and residential buildings can account for up to 40% of the overall consumption, which can exceed other sectors such as industrial and transport (Pérez-Lombard et al., 2008). Indeed, energy demands within public sector buildings, including administrative offices, archives, research institutes, hospitals, cultural heritage sites and museums, represent a substantial public sector cost and environmental concern. Energy consumed by the various business processes that take place while working within public sector buildings contribute to global warming to a significant degree (Orland et al., 2014). The energy performance in these buildings can be attributed to factors such as heating, lighting and electrical device use (Vidako, 2017), as well as the occupants and their behaviour (Zhao & Magoulès, 2012), however by considering the potential for energy consumption measurement, it is possible to facilitate behavioural change through the consideration of work patterns to foster accountability (Jakobi & Stevens, 2015) and make a positive impact on emissions.

This paper presents the pre-intervention stage of the ongoing 3-year OrbEEt research project, which aims to address the issues of organisational energy efficiency within public sector buildings through the incorporation of gamified elements to facilitate positive behavioural change for occupants. To this end the OrbEEt Behavioural Change Framework (OBCF) is outlined, purposing the available technical aspects of the OrbEEt platform towards positive behavioural change by the definition and application of key behavioural stages and transitions, linked fundamentally with the development of a gamified ecosystem consisting of an in-office display, intranet portal and smartphone game. The OrbEEt platform itself consists of an infrastructure of sensor networks collecting energy data within four European pilot sites that represent a diverse range of cultural, climatic, and operational settings for public sector buildings. This high-grain energy data is communicated, processed and made available through the Systemic Enterprise Operational Rating (SEOR) engine, which provides a multitude of web services for accessing Key Performance Indictors (KPIs) at current or historical timeframes, including energy indictors, business indictors, environmental indictors and comfort indictors, all at granularities including device, room, business process and pilot site levels. These KPIs are utilised through a process of behavioural triggering, a core facet of OrbEEt that provides the foundation for positive behavioural change along with the OBCF and gamification. A behavioural trigger is a form of directed and tailored feedback presented within the gamified ecosystem as a method of informing occupants, providing realistic goals and fostering a sense of competition and achievement. The identification of these behavioural triggers is informed by the results of a questionnaire targeting 28 participants across the pilot sites to establish behavioural baselines. The focus of this paper is in presenting the OBCF, behavioural triggers and gamified ecosystem, to outline the basis for OrbEEt and its ongoing work towards addressing organisational energy efficiency.

The paper is structured as follows: Section 2 explores related work on gamification for behavioural change and Section 3 outlines the OBCF, along with behavioural theories that form its foundation. The results of the pre-intervention questionnaires are presented in Section 4 and Section 5 discusses the behavioural triggers and their application within the developed gamified ecosystem. Finally, the conclusions and future of the OrbEEt project are provided in Section 6.

2. Related Work

The use of gamification to improve the energy efficiency of users and support positive behavioural change is well documented through the implementation of serious games and various systems. Work by presented Orland et al. (2014) sees a virtual pet game deployed within a mid-size commercial office, with the aim to save energy by reducing plug-loads. The game mechanics utilise energy consumption data for specific devices that results in chickens gaining or declining in health based on the performance, with players earning virtual rewards daily. The intervention demonstrated a reduction in 42 participants' plug-loads by 13%. This work shows that the application of gamification, in this case through gamifying device energy consumption, can be effective within a field setting. It also shows that gamification is an effective form of learning, with 69% of the 42 participants indicating that they were helped by the game to become more energy conscious. Similar work outlined by Börner et al. (2013) discusses a related topic with the use of pervasive interventions within a workplace to stimulate environmental awareness and learning through displays with gamified elements and personalised feedback. The parallels highlight the importance of awareness, but also show that other aspects governed by a range of internal and external factors are required for achieving change.

SimGreen (Zhang & Zwolinski, 2015) is an example of a game that faces players with immediate challenges using fictional contexts and situations to encourage reflection and changes in day-to-day practices. As has been shown with similar interventions, the social components are placed at the forefront with players assuming roles and teams. This is an important aspect as it fosters an air of both cooperation and competition, which provides an important element of motivation and engagement towards behavioural change. Other examples of gamification and serious games show success in this area, with Tolias & Costanza's (2015) IdleWars game raising awareness for energy conservation, Bourazeri et al. (2012) with SmartGrid enabling long-term user engagement through incorporating SmartMeter data and Brewer et al. (2015) using the ShareBuddy casual mobile game to increase understanding of the shift concept. Additional considerations are highlighted in work by Jakobi & Stevens (2015), which examines the potential value of energy measurements in office environments. The work suggests that energy metrics can be a powerful tool with the potential for energy consumption to be reduced by between 5% and 12% through behavioural change. The benefits from

the utilisation of energy data is considered as part of the behavioural triggering and shows the relevance of setting obtainable goals, most importantly with clear and directed feedback.

All these examples of related work highlight that gamification is a useful tool with respect to energy efficiency and can support the process of positive behavioural change, however it can also be seen that gamification must consider many different aspects to be successful. Whether it is the factors of awareness and learning, the social contexts for cooperation and competition or the setting of goals and giving timely feedback, a gamified system must address these elements to achieve its purpose. For OrbEEt, this is present within the gamified ecosystem due to the application of the OBCF, which applies behavioural theories to gamification to stimulate intrinsic motivation to reduce consumption, support engagement with the platform, and scaffold behavioural change through gamified feedback.

3. OrbEEt Behavioural Change Framework

The OBCF is informed by behavioural theories and gamification mechanics that have shown to achieve and sustain long-lasting human behavioural change. The principal theories employed to design the OBCF include The Transtheoretical Model (TTM) (Prochaska & Velicer, 1997), Self-Efficacy Theory (Bandura, 1977) and Work on Expert Tutors (Lepper et al., 1997). As suggested by TTM, success typically depends on a person's readiness to change, however often is the case that this readiness only applies to a small minority of people. As such, the stages of change outlined in TTM are an important consideration for any framework, as it treats behavioural change as a process over time, building to lasting and maintained change. To support this, the Self-Efficacy Theory purports that a person who has a strong belief in their ability to perform a specific behaviour will be more like to perform it and maintain in that behaviour until they reach some form of success. Indeed, a key facet of this theory is social learning that outlines people not only learn from information, but also from watching others and being supported emotionally by others. This social aspect interacts well with the "INSPIRE" acronym, which summarises the approach that expert tutors use to engage individual learners. These behavioural theories when combined with elements of gamification form the foundation of the OBCF, as can be seen in Figure 1.

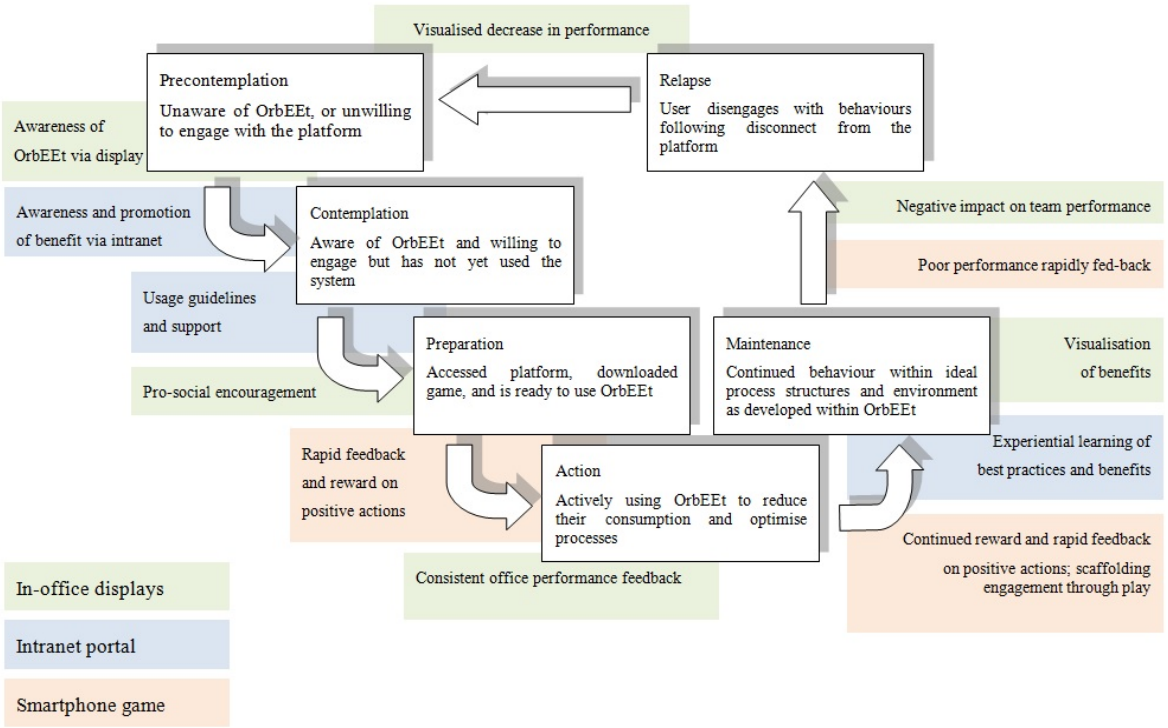

Figure 1: A summary of the OBCF stages and their transitions. Each stage incorporates elements of gamification linked to the interfaces present within the gamified ecosystem.

The OBCF stages and transitions are intended for application within a gamified ecosystem consisting of three distinct user interfaces, each of which allow for specific supporting actions through the key features presented

in Table 1. As was highlighted in Section 2, the successful utilisation of gamification for behavioural change requires certain aspects to be considered including awareness, learning, social context, goals and targeted feedback. As can be seen with the OBCF, these elements are incorporated within the guidelines for developing interface features and are intrinsically linked to the outlined behavioural theories. Indeed, the utilisation of the three interfaces provides additional advantages through individual options and a combined synergy that is not found in typical serious game interventions. In-office displays for example can be powerful tools for communicating with participants, whereas the serious game being smartphone-based provides an aspect of pervasiveness, while the intranet portal supplies a means for facilitating learning and personalised metrics. The interface features presented in the OBCF are guidelines for gamified ecosystem development, however these features are also supported at low-level through energy KPIs and behavioural triggers, which are detailed in Section 5.

Table 1: The relationship between the OBCF's stages of change and their transitional triggers. Each stage and its transitions informs the development of specific interface features and gamified elements focused towards supporting positive behavioural change.

Stages of Change	Transitions	Interface Features
Precontemplation	Awareness of OrbEEt and promotion of its benefits.	**In-Office Display:** Messages promoting OrbEEt and its purpose. **Intranet Portal:** Wiki content to inform users about the OrbEEt platform and provide any other required information.
Contemplation	Usage guidelines, support and pre-social encouragement.	**In-Office Display:** Presentation of leaderboards based on group performance. Messages showcasing feedback to promote engagement. **Intranet Portal:** User manuals, forums and targeted metrics to provide support to the end users.
Preparation	Rapid feedback and reward on positive actions. Consistent office level performance feedback.	**In-Office Display:** Messages providing targeted feedback based on performance for lighting, heating and office devices. **Smartphone Game:** Bonus energy currency awarded based on group efficiency performance.
Action	Continued reward and rapid feedback on positive actions, which scaffolds engagement through play and experiential learning of best practises.	**Smartphone Game:** If overall group performance increases, the amount of bonus energy provided to players increases respectively. **Intranet Portal:** An incorporated quiz game to support learning and self-efficacy.
Maintenance	Visualisation of benefits, poor performance feedback and negative impact on team performance.	**In-Office Display:** Messages providing feedback showing positive reinforcement for successful performance and highlighting benefits and rewards. Leaderboards showcase overall performance in a social and competitive context. **Smartphone Game:** If overall group performance decreases, the amount of bonus energy provided to players decreases respectively.
Relapse	Visualised decrease in performance.	**In-Office Display:** Supporting messages and visualisations shown of energy consumption.

4. Pre-Intervention Questionnaire

To identify further areas for development and inform behavioural triggering, discussed in Section 5, a pre-intervention questionnaire was distributed amongst the four OrbEEt pilot sites; Imperial Palace of Innsbruck

(Austria), centre of Health Technology Assessment and Public Health (Germany), Town hall of Asparenna (Spain) and Pernik Municipality (Bulgaria). In addition, the establishment of behavioural baselines and an initial assessment of the participant readiness to engage with OrbEEt platform are crucial for future validation efforts. The questionnaire targeted 28 participants and the Likert Scale responses towards the ten behaviour orientated questions are presented in Figure 2.

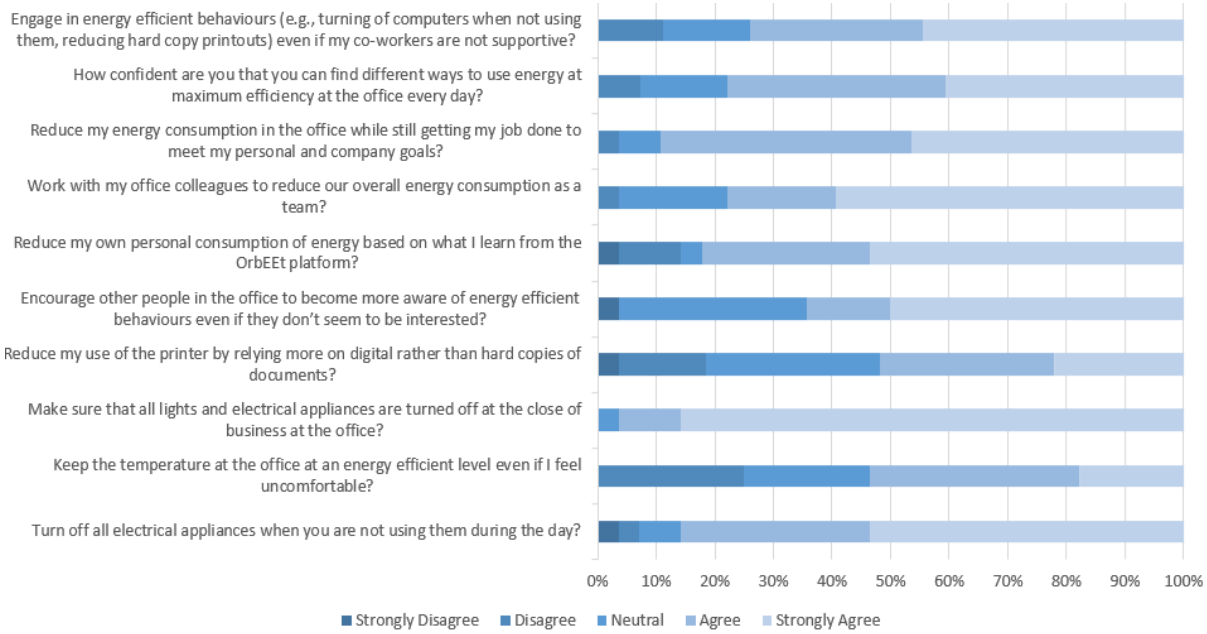

Figure 2: Diverging stacks bar chart highlighting the Likert scale questionnaire responses.

The responses suggest that participants have a positive attitude towards reducing their energy consumption and in adopting the interfaces into their working environment. Indeed, a total of 78% agreed, 41% strongly, that they are confident to find alternative ways of using energy at maximum efficiency, indicating that they are open to new ideas and approaches. 82% agreed, 54% strongly, that they are willing to reduce their own personal energy consumption and learn from OrbEEt, which supports adoption of the platform. 89% believe, 46% strongly, that they will be able to reduce their consumption while keeping to company goals and business processes and finally, 74% agree, 44% strongly, that they will be able to engage with OrbEEt even if co-workers are not supportive.

For questions regarding the energy types and surrounding behaviours, 86% agreed, 54% strongly, that they turned off all electrical appliances when not using them during the day. Similarly, 96% of participants responded they agree, 86% strongly, that they make sure that all lights and electrical appliances are turned off at the close of the business. These are highly important considerations for the behavioural triggers and help to shape the criteria, identifying areas where potential energy savings can be found. One area that shows potential for positive behavioural change is pushing towards using digital documentation over printing hardcopies, with only 52% of participants agreeing that they carry out this practice. Similarly, the participant responses towards the question regarding keeping the temperature energy efficient even if uncomfortable were mixed, with only 54% agreeing. Overall, while the results are highly positive, especially in terms of practices regarding lighting and electrical devices, there is still the potential to save energy through the application of focused behavioural triggers. The responses have highlighted that considerations need to be made for the context in which behavioural triggers occur, namely for elements of comfort, environment and business processes, so that triggers can be effective as a means of setting goals and providing feedback, which are important considerations within the OBCF.

Another question shows that 64% of participants agreed, 50% strongly, that they are willing to encourage other people in the office to reduce their energy consumption, even if they don't seem interested. This links back to the OBCF and outlines the potential impact that OrbEEt can have on energy efficiency through social engagement and competition (Vine & Jones, 2016). Indeed, participants showed that they are positive to the idea of working together as a team, with 78% agreeing, 59% strongly. This suggests that participants are open

to varying levels of granularity with respect to behavioural triggers and an important element when considering trigger design.

5. Behavioural Triggering

The act of behavioural triggering is closely linked to the OBCF, as discussed in Section 3, and utilises the energy KPIs provided by the SEOR engine through the sensor infrastructures installed within the pilot sites. A behavioural trigger is essentially a form of gamified feedback based upon energy performance at various granularities. The purpose of a behavioural trigger is to support the essential transitions between the stages of change, as shown in Figure 1, which incorporate the elements of precontemplation, contemplation, preparation, action, maintenance and finally relapse. A behavioural trigger is presented through the gamified ecosystem and typically takes the form of a message with a format first outlining current performance, then the next goal and finally advice on how to achieve that goal. Depending on performance, a trigger can either be a reinforcement type if consumption is below baseline or an improvement type if consumption is above baseline. In this manner, it targets multiple elements of the OBCF and gamification guidelines, by not only provided rapid feedback and rewards, but also conveying new tasks and directing them in context to promote self-efficacy. The in-office display interface is primarily utilised for the communication of these messages as a non-interactive application, pictured in Figure 3, designed to be running on tablets situated around the office or in relevant spaces.

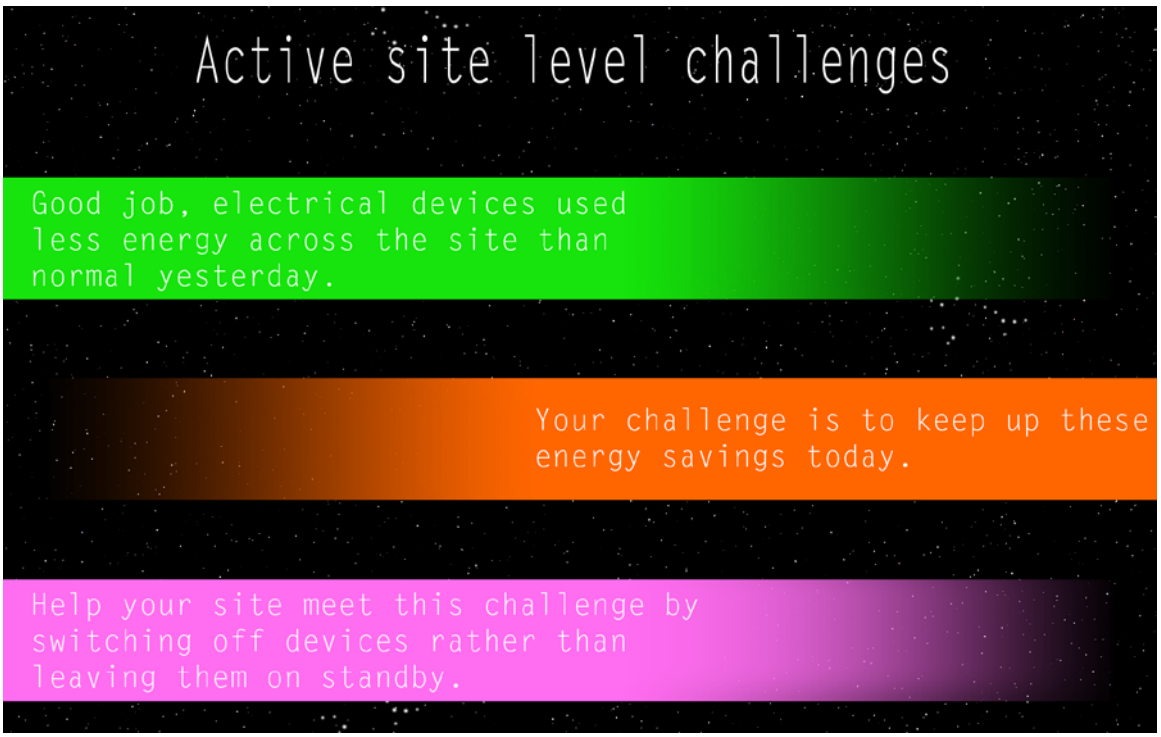

Figure 3: An example in-office display behavioural trigger. In this instance, it is a reinforcement trigger as can be seen from the first component of the message. This is coloured green to represent success, where as an improvement trigger would be coloured red to represent a task failed.

The strength and novelty behind these behavioural triggers comes from the fine-grained energy KPIs provided by the SEOR engine with which to judge various areas for efficiency performance at current and historical timeframes. In addition to energy indictors, SEOR also provides several other elements important for the triggers and identified through the pre-intervention questionnaire, outlined in Section 4, including comfort indictors, environmental indictors and business indictors. These indictors can be retrieved at several different levels of granularity including site-level, operation-level, room-level and device-level. The energy indictors provide KPIs for the three major areas of potential energy savings within the office setting, namely lighting, heating and electrical devices (Vidako, 2017). As can be seen, the level of detail provided through this retrievable data allows for behavioural triggers to be rapid and highly relevant to the occupants. Table 2 presents the OrbEEt behavioural triggers, which are informed by the OBCF and pre-intervention questionnaire results.

Table 2: A list of the OrbEEt behavioural triggers. The trigger code represents a trigger's type (**H**eating, **L**ighting or **E**lectrical devices), granularity (**S**ite, **O**peration, **R**oom or **D**evice) and number within the series.

Trigger Code	Target Behaviour	Measurement Duration	Trigger Duration	Conditions	OBCF Category	Elements
HS1	Heating usage inefficiency	1 Day	1 Day	Heating Energy Use > Baseline	Action > Maintenance	Time Space
HR1	Heating on when comfort level is high	1 Hour	1 Hour (9am-5pm)	Therma Comfort > Correct Level & Heating Energy Use > 0	Contemplation > Action	Time Space Environment
HD1	Heating left on overnight	8 Hours (9pm-5am)	3 Hours (4-7pm)	Heating Energy Use > Overnight Baseline	Action > Maintenance	Time Device
HO1	Heating on during operation or business process when comfort level is high.	3 Hours (10am-1pm)	3 Hours (1pm-4pm)	Operation Heating Energy Use > 0 & Room Therma Comfort > Correct Level	Contemplation > Action	Time Business Environment
LR1	Lights on when comfort level is high	1 Hour	1 Hour (9am-5pm)	Visual Comfort > Correct Level & Lighting Energy Use > 0	Contemplation > Action	Time Space Device Environment
LD1	Lights left on overnight	8 Hours (9pm-5am)	3 Hours (4-7pm)	Lighting Energy Use > Overnight Baseline	Action > Maintenance	Time Device
LO1	Lights on during operation or business process when comfort level is high.	3 Hours (10am-1pm)	3 Hours (1pm-4pm)	Operation Lighting Energy Use > 0 & Room Visual Comfort > Correct Level	Contemplation > Action	Time Device Business Environment
ES1	Electrical usage inefficiency	1 Day	1 Day	Device Energy Use > Baseline	Action > Maintenance	Time Space
ER1	Computer usage inefficiency	1 Hour	1 Hour (9am-5pm)	Device Energy Use > Baseline	Contemplation > Action	Time Space Device
ED1	Computers left on overnight	8 Hours (9pm-5am)	3 Hours (4-7pm)	Device Energy Use >	Action > Maintenance	Time Device

				Overnight Baseline		
ED2	Printers or copiers left on overnight	8 Hours (9pm-5am)	3 Hours (4-7pm)	Device Energy Use > Overnight Baseline	Action > Maintenance	Time Device
ED3	Printers or copiers left on when not in use	1 Hour	1 Hour (9am-5pm)	Device Energy Use > 0 & Device Not in Use	Action > Maintenance	Time Device
EO1	Equipment inefficiency during operations or business processes	3 Hours (10am-1pm)	3 Hours (1pm-4pm)	Operation Energy Use > Peak Baseline	Action > Maintenance	Time Business

The intranet portal incorporates aspects of behavioural triggering to work in synergy with the in-office display, by provided a more directed form of feedback. Each OrbEEt user who logs in in can access their own energy profile page linked to their primary workspace, which displays relevant current and historical statistics with respect to energy, business processes and comfort. In addition, the relevant room-level trigger messages are provided here as well, to offer directed performance feedback and further objectives to the user. This incorporates aspects of the OBCF, providing a further avenue for occupants engage with the platform and transition to positive behavioural change.

The smartphone game utilises behavioural triggering in its own unique way with a bonus energy mechanic. As outlined in the OBCF, this serious game provides a form of feedback and reward for players who perform well at the tasks set within the in-office display and portal. It also helps to foster competition (Vine & Jones, 2016), by pushing scores to a social leaderboard situated within the intranet portal. This completes the gamified ecosystem, with each of the three interfaces linking to the OBCF, behavioural triggers and communicating between each other to provide a platform with the specific features to support behavioural change.

Figure 4: An example of the virtual environment and gameplay within the OrbEEt planet escape game. The astronaut in this scene is gathering resources for the goal of blasting off and returning home.

The game itself, named OrbEEt Planet Escape, is an interactive people and resource management simulation that incorporates aspects of energy efficiency within its gameplay to provide an environment of learning within the context of OrbEEt. Players see themselves stranded on a strange planet at a crash site, where their goal is fix the spaceship and accumulate enough key resources to escape the planet as fast as possible, pictured in Figure 4. To accomplish this, players control a team of astronauts, each with their own personality, strengths and weaknesses. Players build structures within the crash site and assign astronauts to work them to collect periodic resources. Each astronaut however, is good in some areas but not others, so managing the team is of great important to gain a high score. Players can even directly engage and complete minigames themselves to earn resources. As time progresses, enough resources are collected to upgrade structures and begin working on the goal of escape directly. How players choose to spend these resources will directly affect their level of success and final score.

In terms of gameplay, the bonus energy mechanic provides a multiplier to specific resources gained throughout the progression of the game. To activate this mechanic, player's login using their OrbEEt intranet portal account, which provides the player's spatial information and allows high scores to be pushed to the leaderboard. The multiplier is then calculated daily at room-level by comparing the previous day's lighting, heating and electrical device consumption to established baselines and the users own previous performance. The multiplier can be up to 2x base rate at the highest level due to positive player performance, however the typical rate is 1.5x base for average OrbEEt performance. Embedding this type of energy information within entertaining games has shown it can produce significant changes in energy behaviour (Reeves et al., 2015).

6. Conclusion and Future Work

In this paper, a selection of the issues present with respect to energy efficiency at both the organisational and occupant levels have been highlighted. Indeed, with the demands for energy within public sector buildings rising, it has been shown that reducing energy consumption is a substantial task with many different variables. However, potential energy savings can be made by positively changing the behaviour of building occupants and moreover how they address their high-level responsibilities within the office, such as tackling the various business processes required for their job role. In addition, by focusing on personal aspects such as comfort and unidentified habits causing ghost loads etc., it is possible to leverage this potential. It can be seen from previous work that gamification can be utilised as a force for extending learning and providing an arena for engagement and competition, which have been shown as effective tools for aiding in behavioural change. As such, herein, the OrbEEt project has been presented through the OBCF, behavioural triggers and gamified ecosystem, informed by the results of a pre-intervention questionnaire aimed at providing behavioural baselines for targeted development and refinement.

The OrbEEt project is ongoing and the work presented here marks the pre-intervention stage in the overall life cycle. The next stage of the project is intervention, wherein a period of nine-month validation is planned at the four outlined pilot sites to empirically evaluate the interfaces and behavioural triggers. A mixed-methods approach is to be adopted that considers both the efficiency savings of the developed platform from sensor metrics, and the end-user perspective via self-report. A growing emphasis of research into the use of games and gamification is the application of methodologies and methods which provide transferrable findings into best design practices, principles, and discrete mechanics or systems (Callaghan et al., 2016; Khaled et al., 2014). As such, a primary focus of OrbEEt's research method and methodology is to ascertain the behavioural cues which work most or least effectively within, and between-groups across pilot sites, relating this to both their stage within the OBCF, content, presentation style, and motivating influence of the smartphone game. The fine-grained nature of data capture allows energy information, and a wide range of other office metrics, to be monitored over time within groups. This also allows for comparison to baselines established over time, and the capacity to detect individual or group behaviours in response to a behavioural trigger. An overall goal of this planned evaluation is to contribute to an understanding of how triggers can be best designed and implemented to result in behaviours, and furthermore, how the use of gamification elements such as rewards for accomplished triggers, can be ideally applied.

The applications for OrbEEt are numerous given the elements of consideration with respect to business processes, high granularity sensor data and the personal preferences of the occupants. By employing a clearly defined behavioural framework that is tied closely to specific aspects gamification, OrbEEt can be purposed

towards many different environments and scenarios. This is further aided by the modularity of the behavioural triggers, whereby new triggers can be added, old triggers removed and refinements made easily within the gamified ecosystem and overall infrastructure. In this manner, the OBCF, behavioural triggers and gamified ecosystem have primary applications within organisations that are looking to improve overall energy efficiency, while maintaining business productivity and ensuring best practices. In addition, the components of OrbEEt such as the behavioural triggering, can be applied for various other purposes that seek for positive behavioural change as a fundamental factor.

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