Gaming at work to save energy - Supporting behavioural change of occupants through cooperative games

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ABSTRAKT

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Commercial buildings are one of the main contributors to energy consumption while both energy management and occupants’ consumption behaviour play crucial roles in how energy is consumed. This study explored the energy awareness of occupants in a commercial building with the goal to investigate how increased awareness could support behaviour change. For this purpose, a cooperative gamified visualization of energy consumption data, “EnerSpace”, is designed, implemented and evaluated. 8 occupants participated in this study who experienced a one-week baseline period and a one-week “EnerSpace” game period. In EnerSpace, the participants were divided into two teams and powered a spaceship with their energy saving respectively on a resource exploitation trip to Mars. Each participant had an avatar in the spaceship who introduced the participant’s personal consumption data. The energy conservation of the participants affects the moving speed of the spaceship and the living condition of their avatars. Participants were rewarded by a postcard sent by the avatars when reaching a destination. The results showed that the participants 1) decreased their energy consumption, 2) reported a fun and engaging experience with EnerSpace, and 3) felt motivated for energy conservation by different motives. This study indicated a potential for energy saving in a commercial building using a cooperative game.

Author Keywords
Persuasive technology; gamification; visualization; energy consumption; energy awareness; behaviour change; HCI.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

1. INTRODUCTION
The rapid growth of energy consumption has raised increasing concerns over the decades. Data gathered by the International Energy Agency showed a dramatic increase in primary energy by 49% and CO2 emission by 43% from 1984 to 2004 [30]. Moreover, energy consumption is estimated to keep rising due to the growth of economy and population [30]. Among the contributors to energy consumption, buildings are admittedly a significant one. For instance, the U.S. Energy Information Administration has reported that the building sector consumes 20% of the worldwide energy [1]. It has similarly been found that around 40% of energy was consumed by buildings in Europe in 2015 [2]. Those numbers proved the urgency to cut down energy consumption and increase energy efficiency in buildings, which calls for the attention of both organizations and individuals.

Several studies have proved that there was a gap between estimated energy consumption and actual energy consumption of buildings [16, 25]. The actual consumption could be up to 3 times larger than the estimated consumption. One of the causes for this gap is that energy simulation did not take occupants’ behaviour into consideration, which stresses the importance of occupants’ role in how energy is consumed. Therefore, occupants’ awareness of energy consumption and their behaviour becomes an interesting topic to look into, which lays the foundation for designing persuasive visualizations.

Researchers have introduced gamification and social networks into eco-visualizations in order to engage users through competition and interpersonal relations [15, 24, 33]. Studies have focused on providing energy education [23] and gamified energy feedback [20, 26]. Overall, the studies have focused on using both individual and cooperative approaches to energy conservation. As an example, project Nuage Vert introduced a collective eco-visualization that projected the energy consumption of citizens in Helsinki to the sky [22], which invoked a sense of community and contribution. Researchers have also worked on designing gamified missions, competitions and cooperation to motivate energy conservation [17, 18]. For instance, Power Agent was a persuasive game designed to encourage energy conservation of a family by team competition [18].

However, there are mainly two gaps within current studies. One is about the long-lasting effects of the visualization. Studies have proved that users stopped paying attention to the eco-feedback system after about 4 weeks and that the effects of presenting a new visualization did not last more than one week [27]. The other gap is that current studies tend to either focus on individual feedback or group competition. There lacks a combination of both where users could feel their contribution to the group while also getting personal feedback and motivation. Due to the time limitation of this study, the second gap was the main focus.
of interest while the long-lasting effects of the visualization were not fully evaluated due to the short time period.

This thesis aims to explore the energy awareness of the occupants in a commercial building and how a cooperative game could support behaviour change. The following research questions are investigated:

- What is the level and type of energy consumption awareness of occupants in a commercial building?
- What are the effects of a cooperative game with both group and individual elements on promoting energy-saving behaviour of occupants in a commercial building?

In this paper, we present the design, implementation and evaluation of a cooperative game that we call EnerSpace, which was designed to motivate occupants to reduce electricity consumption in a commercial office setting.

2. BACKGROUND

2.1 Theoretical Model of Behavioural Change

In order to design for behaviour change, the first step is to understand how occupants’ current behaviour is shaped and influenced by multiple factors. Psychologists have raised several theories to build up behaviour models. One of the most well-known theories is the Theory of Reasoned Action [15] that was introduced by Fishbein and Ajzen in 1975. They believed that individuals’ intention to perform a certain behaviour led to the actual behaviour and the behavioural intention was determined by the attitude towards behaviour and subjective norm. Subjective norm is the social pressure that individuals perceive for a certain

To further the understanding of occupants’ behaviour, a large number of studies have looked into how different factors affect occupants’ behaviour. As mentioned in the Theory of Planned behaviour, social factors played a crucial role in influencing occupants’ behaviour. Social comparison serves as a trigger for motivating sustainable behaviour. Also, comparing with someone who is slightly better can have a positive effect on an individual’s performance [19]. What this finding suggests is the importance to make sure that there is always a chance for each side to win in a competition, otherwise, people lose their competitiveness. Besides, a building facility also plays an important role in promoting an energy conservation culture by organizing relevant events and workshops, which was proved to be related to the energy-saving behaviour of occupants in the building [3]. Moreover, another study revealed that public recognition of one’s energy-saving behaviour led to a higher decrease in energy consumption than solely self-monitoring behaviour [6].

Attitudinal factors such as personality traits and lifestyle have been proved to lead to a significant difference in consumption behaviour [32, 35]. For instance, researchers analyzed the impact of personality traits on four types of behavioural patterns (clothing adjustment, window opening, blind closing and interaction with a ceiling fan) and two kinds of thermal perception (sensation and preference) [35]. They found that all personality traits led to significantly different behavioural patterns. Extraversion had a significant influence on thermal sensation and neuroticism had a significant influence on thermal preference. These results contribute to the possibility of using attitudinal factors to anticipate or simulate the behavioural patterns of the occupants in the building.

Cost reduction has also been reported to be a motivation to save energy at offices [3], but the actual effects depended on the personal sensitivity to price [37]. In addition, psychologist Richard Katzef and his team found that commitment to conserve resources is more influential for occupants’ behaviour than monetary incentives [26]. This might suggest that intrinsic motivation is stronger than extrinsic motivation. However, a survey with 229 students on campus showed that the majority of participants agreed on the importance of energy conservation, but they reported that they lack clear motivations [3]. Contextual factors, such as perceived behavioural control, have been found to partly explain this low level of motivations [3]. In an office building, the energy consumption is mainly influenced by energy planning and management, which results in occupants’ low sense of control and insufficient engagement in energy conservation.

In summary, social factors, attitudinal factors, economic factors and contextual factors all have a great impact on occupants’ energy saving behaviour. Firstly, these findings point out what potential motives that might appeal to the occupants in a commercial building, which directed the

Figure 1. The structure of the Theory of Planned Behaviour.
field study in the visualization design process. Besides, it could be useful to think about how to include influential motives into eco-visualization.

2.2 Persuasive Technology
Persuasive technology aims at using technology to achieve behaviour change without coercion [10]. BJ. Fogg has introduced his behaviour model that stressed three elements of persuasive technology: motivation, ability and trigger [11]. Motivation is why a person conducts a certain behaviour. Ability indicates if the person has the required ability to complete a behaviour. A trigger means a reminder, deadline or other things that invoke the person to perform a behaviour. Those three elements are of necessity to achieve the persuasion of a certain behaviour. The relationship of the model can be expressed in the equation: B (behaviour) =M (motivation) * A (ability) * T (trigger). A study that followed this model has achieved their energy saving goal [34], which suggests that taking those three elements into consideration could be beneficial.

Many studies have worked on applying gamification to eco-visualization in order to provide energy education and feedback on energy consumption [8, 20, 24, 28]. A study introduced a game called EnerCities to promote energy education by asking users to run a sustainable city [23]. The results showed that the experimental group who played the game had better knowledge of their consumption behaviours’ impact than the control group [23]. Regarding providing gamified feedback, Energy Chicken is a game that relates the energy consumption of each device in the office environment to an object in a virtual farm [28]. The size and condition of the chicken in the virtual farm are influenced by the users’ energy consumption. The researcher conducted a 12-week evaluation with 49 occupants after collecting the consumption baseline for 4 weeks. Their results proved the persuasiveness of Energy Chicken as the energy consumption was reduced by 13% [28]. Another game called Coralog also visualized users’ energy-related behaviour as the simultaneous health status of a coral reef, whose size and colour changed accordingly [24]. While users were motivated to change energy-related behaviour by Coralog, they also expressed their wishes to see the data of daily energy consumption besides the more abstract representation of the coral reef. This interesting finding highlights the importance to keep the balance between abstract representation and factual data in a persuasive system.

In addition to providing energy consumption feedback on an individual level, researchers have introduced social network, competition and cooperation on a group level in order to achieve better user engagement through interpersonal relationships and the sense of belongingness [12, 17, 18, 22, 33]. Art project Nuage Vert was a city-scale light installation in Helsinki that lasted for a week [22]. The artist illuminated vapour emission with a lime-hued laser animation that visualized the real-time electricity consumption of citizens in Helsinki. This collective visualization invoked a sense of community and contribution. Boork and her colleagues introduced a collective prototype called Super Graph that employees in the office crafted together [5]. The Super Graph was hung in the lunchroom and moved vertically according to the collective energy consumption. This served as a symbol that represented the employees’ efforts and created the sense that every employee was a part of something bigger. The idea of competition and cooperation also fits into the office environment. Climate Race is a persuasive game that was co-designed by workers in the office, whose goal was to reach a team goal of 1000000 points and the points were collected by energy saving and by completing missions [33]. While Climate Race achieved the change of workers’ motivation, it also revealed a provoking finding that workers preferred explicitly requesting feedback over immediate notifications. This finding is especially crucial for how to provide feedback in a non-intrusive way.

Although previous studies have achieved energy conservation using different approaches, the reason why a specific strategy was picked for designing the persuasive system was unclear. Only one research designed their system on the basis of a psychological survey that gathered users’ energy consumption habits on three dimensions: information frames, emotional sentiment and interpersonal relationships [8]. Their survey revealed what was appealing to the users, and the system was therefore designed to provide group energy consumption feedback in an animal-related environment that created an emotional arousal. Since the consumption feedback was exhibited in a laboratory, peer effect also appeared to motivate the users to conserve energy. Although the design was based on user study, their system only provided energy consumption feedback as a group. This is similar to many cooperative persuasive technology setups, where an individual level consumption feedback is generally missing in cooperative approaches. Therefore, the main intention of this study was to tackle the lack of a combination of both group level and individual level, which could make the users feel their contribution to the group while also getting personal feedback and experiencing game elements.

2.3 Persuasive Strategies
As mentioned before, less attention has been paid on how to choose the right persuasive strategy to design persuasive technology. A study did an investigation on how personality traits influence the perceived persuasiveness of several persuasion strategies [29]. The strategies were summarized from the previous studies, which included competition, simulation, self-monitoring and feedback, goal setting and suggestion, customization, reward, comparison, cooperation, personalization and punishment. The results showed that personalization and simulation appealed to users with all kinds of personality traits, since it presented the direct outcome of users’ behaviour. Besides, goal setting and suggestions provide great motivation to
extroverted and conscientious individuals with no negative effect on others. However, researchers also found that users mostly perceived personalization, simulation, goal setting and suggestions as “boring” and “not engaging”, which they suggest it could be counteracted by incentive-oriented strategies, such as rewards, competition and comparison. According to this study, simulation and personalization could serve as appropriate persuasive strategies for occupants with diverse personality in the building. Additionally, goal setting and suggestion, competition and cooperation could be used to increase occupants’ engagement.

As a simulation helps people to build up the linkage between their behaviour and corresponding outcome by providing feedback, there exist diverse approaches to presenting the feedback, such as game status, appointments, leaderboards and so on. Psychologists summarized The Media Equation from numerous psychological studies that people react to computer and media as real-life people [31]. As similarity was proved to be an influential factor for persuasion, research has also shown that people are easier to be persuade by people with higher similarity [6]. This suggests that computers could persuade people by adopting social roles [31]. For instance, ELIZA was a software program created by MIT that adapted a social role as a psychotherapist and was designed to replicate the counselling process between a real therapist and patient [12]. It gave a response in text when a user typed a question such as “I have a problem”. The results showed that the users treated ELIZA as a human therapist despite the fact that they knew it was a software. Moreover, another finding indicated that the persuasiveness of social feedback (e.g.: compliment) given by a robot was stronger than interactive factual feedback (e.g.: energy meter) [23]. Based on those findings, one of the core gamification mechanics of this thesis was a gamified simulation where a computer played a social role in order to provide social feedback.

3. METHODS

3.1 Participants and Procedure

The study was done at ABB Corporate Research building in Västerås. In the study, 8 participants who work in ABB Corporate Research Center as engineers participated in a cooperative gamified visualization experiment. The age distribution was 50% between 31-40 years old, 25% between 41-50 years old, 12.5% between 20-30 years old and 12.5% above 51-year-old. The gender balance was 75% males and 25% females. All the participants volunteered to join the study and signed an informed consent.

At the beginning of the study, an energy meter was installed in each participant’s office. All the devices in the office, including lights, monitor and other peripherals were connected to the energy meter. For the first 7 days, an average hourly consumption (Wh) of each participant was collected as a consumption baseline. This was categorized for working hours (7:00-19:00) and non-working hours (19:00-7:00 and weekends). On the first day of the baseline period, the participants were asked to fill in a pre-evaluation questionnaire about their energy awareness. After the baseline period, participants engaged in the active play of the cooperative game EnerSpace for 7 days. The participants were divided randomly into two teams (team red and team blue) who competed with each other. At the end of the evaluation period, participants were also asked to complete a post-evaluation questionnaire about their energy awareness and user engagement. This was followed by a 20-min interview with each participant concerning their experiences with EnerSpace. During the baseline and evaluation period, the participants were asked to log the time when they came and left the desk, which was later used for data analysis.

3.2 Data Analysis

This study collected qualitative data from the interview and quantitative data from the questionnaires as well as the experiment. As for qualitative data, I used thematic content analysis for analyzing the transcripts from the interview [7]. The process of the thematic content analysis was generating the codes from the transcripts, defining themes and interpreting the results. As for the questionnaire, both pre-questionnaire and post-questionnaire included questions of “Do you know how much energy you consumed yesterday?”. Participants could choose from three answers that vary from knowing exact amount to have no idea. The answers to the pre-questionnaire and post-questionnaire were compared to see if the cooperative game has increased the energy awareness of occupants. Also, participants responded to the statements such as “I was more aware of my consumption due to the game” in 5-point Likert scale.

As for the energy meter data collected in the experiment, I used Paired-Samples T-test to analyze the consumption data. Firstly, the average hourly consumption (Wh) before and during the game was compared. Afterwards, the average hourly consumption from three periods of time was compared between before and during the game respectively. These three periods of time were defined as the working hours, non-working hours in a weekday and weekends according to the participants’ personal logs. 75% of the participants logged their exact time of arrival and leaving while 25% of them provided a timetable of their daily routine. The energy meter collected 5-6 data points per minute, however, the data frequency varied from 5-6 times per minute to once several hours during nighttime, which was due to a less stable data transfer of the energy meter. To cope with this instability, I modified the formula for calculating the average hourly consumption only from the hours with constant data.

4. GAMIFIED VISUALIZATION: ENERSPACE

4.1 The Design of EnerSpace

The design of EnerSpace went through the stages of field study, defining personas and scenarios, design iteration and developing a working high-fidelity prototype. The field
The study included an observation of energy consumption behaviour in ABB Corporate Research building and an interview with 15 occupants who work in the building. The finding from the field study suggested that occupants in the building did not have enough awareness and knowledge of their energy consumption due to low engagement in energy conservation. Occupants generally considered themselves motivated for energy conservation, but did not take actions to save energy actively or monitor their energy consumption. The main user scenarios related to energy consumption and located in the building were around the office desk and “Fika” room (Fika is a Swedish concept of drinking coffee and socializing), which were the two most frequently used places at ABB. Therefore, it was concluded that the Fika room is the commonplace where co-workers have a coffee break and chat. Comparing a Fika room with an office desk, the occupants get more spare time when waiting for a coffee, which assumingly makes the Fika room a less obtrusive place to display the visualization.

On the basis of the field study, I generated 8 ideas and organized a brainstorming section with 2 UX designers to converge the ideas to a competition between departments in a space trip context. By showing storyboards with different prototypes to the end-users, I found out that the occupants still wanted to access their personal consumption data in spite of the cooperative game setting, which further highlighted the importance of visualizing both individual and group data. In order to select what kind of consumption data to show, I designed a prototype that contained six types of consumption data, including a current average hourly consumption (Wh), in-team ranking, line chart, badge and so on. Six occupants in the building were asked to rank those data presentations from 1 (the most interesting) to 6 (the least interesting). The results showed that the top three data presentations that 83% of the participants agreed were their current consumption, their saving and how far it was to the destination. The data presentation that all participants were the least interested in was the line chart that showed how their energy consumption changed over time. On the basis of this, I chose to show the occupants’ current consumption, saving and estimated time of arrival in the final design. However, displaying the individual data in a public setting such as a Fika room would be sensitive and require the protection of participants’ privacy, which means only the participants could access their own data. With the alternative solutions such as login using a username and password, face recognition was chosen in this study in order to ease the login process and save the participants’ efforts. Eventually, I specified the gamification mechanics of EnerSpace and implemented a high-fidelity prototype with the core functions to test with the occupants in ABB Corporate Research building.

### 4.2 Gamification Mechanics

In the gamification, EnerSpace, the narrative is that two spaceships are sent to the universe for a resource exploitation to cope with the resource shortage on Earth (see Figure 2). Users are divided into several teams (e.g.: team red) and each team owns a spaceship whose color corresponds to its team color (see Figure 3). The spaceships are powered by the energy that the team members save in the office. Energy conservation is defined as comparing the team’s current hourly average consumption (Wh) to that from the baseline period on working hours and non-working hours respectively. The energy conservation was visualized in a gamified way by the moving speed of the spaceship and rotating speed of the flame behind it (see Figure 3). The more the team members save, the faster the spaceships moved and the flame rotates. If the energy consumption exceeds the baseline, both elements stop. A dotted line shows the route of a spaceship with a number indicating the distance (see Figure 2). The dotted line of the spaceship in the first place in the competition is presented slightly clearer than the other in order to show the ranking in a subtle way. The spaceship who first arrives at the planet have the priority to start the exploitation while the
other spaceships that arrive later could only exploit what is left. How many resources each team has collected is shown on a ranking list at the top-right corner of the interface (see Figure 2). When the resources on one planet is depleted, all the spaceships will move on to the next destination.

**Figure 3. The colour of the spaceship matches the team colour.**

Besides the main view, an individual view is shown when a participant’s face is recognized. On the individual view, the participant’s consumption data is visualized as the living condition of an avatar and also displayed on a control panel on the interface. Each user has an avatar on the spaceship who serves as a concierge to introduce the user’s personal consumption data in an animation. In this animation, the avatar will first give a greeting, then talk about the user’s personal consumption data and the estimated time of arrival to the destination (see Figure 4(a)). The consumption data shown on the control panel include an average hourly consumption (Wh), a percentage of saving compared to the user’s baseline and a ranking within the team (see Figure 4(a)). When the spaceship arrives at a destination, the avatar will send a postcard or souvenir to the user as a reward (see Figure 4(b)).

**Gamified Feedback**

The energy consumption of the whole team will also influence the living condition of their avatars. When the consumption of a team exceeds the baseline, there are three levels of power failures inside the spaceship that move from running out of coffee to shutting down the heating system (see Figure 5).

**Increasing Gamification Engagement**

Special events are triggered when specific conditions occur to increase gamification engagement. When a team keeps saving energy for 5 consecutive days, the spaceship accumulates enough energy for a space jump that shortens the distance between the destination and the spaceship (see Figure 6). Other events may also occur in order to award the team that is in the lead and, as well as, encourage the team that is behind.

**Situation-based Saving Tips**

The avatar gives situation-based saving tips occasionally. For instance, the avatar suggests “I heard the weather in Västerås is great. Why not turn off the lights if it is bright outside?”. Those tips provide users with approaches to increase energy efficiency. The content is based on current situations including but not limited to weather and place.

**4.3 Implementation**

The EnerSpace was set up with a 1080p monitor and a Logitech C920 HD Pro Webcam in the Fika room in ABB Corporate Research building. The energy consumption of each participant was measured using a FIBARO Wall Plug.
The data was collected by a VeraPlus Advanced Home Controller via Z-wave protocol and then sent to a server. The software of EnerSpace was developed in Python Flask, HTML5 and JavaScript. The animation and 3D model in EnerSpace were made in Cinema 4D, Adobe Fuse CC, Adobe Mixamo and Adobe Premiere CC.

5. RESULTS

5.1 Consumption Data
Participants’ baseline average hourly consumption (Wh) varied from 16.99 Wh to 58.45 Wh ($M = 34.33$, $SD = 15.17$). The average hourly consumption decreased by 21% during the game ($M = 27.26$, $SD = 9.14$), although the difference was not significant ($t(7) = 1.33$, $p = .226$).

This study divided the whole experiment into three periods of time, which were the working hours, non-working hours in a workday and weekends. When comparing the average hourly consumption between before and during the game for three time periods respectively, all the participants consumed less while playing the game except for the non-working hours in a workday (see Figure 7). For the non-working hours in a workday, the average hourly consumption increased by 48% during the gameplay week ($M = 7.32$, $SD = 8.08$) than before ($M = 4.96$, $SD = 6.29$). Conversely, results indicated a large decrease of 81% in energy consumption during the game ($M = 1.73$, $SD = 2.15$) than before ($M = 9.18$, $SD = 13.93$) during the weekend ($t(7) = 1.72$, $p = .130$). Even though both periods are off-duty hours for the participants, the different results might suggest a different behaviour pattern for the weekend and non-working hours in a workday. Besides, the average hourly consumption during working hours was reduced by 23% during the gameplay week ($M = 56.80$, $SD = 21.29$) than before ($M = 74.13$, $SD = 36.57$). However, the difference was not significant ($t(7) = 1.59$, $p = .155$). These results showed a general tendency of reduction in energy consumption during the gameplay week with different degrees of decrease for the three periods of time.

Figure 7. The line chart shows how the average hourly consumption changed after the game.

5.2 Questionnaire results

Pre-questionnaire
The participants were asked to fill a pre-questionnaire about their energy awareness and consumption behaviour at the beginning of the baseline period. The results indicated that 87.5% of the participants did not know how much energy they consumed with the rest only having a general idea of the amount. All the participants showed interest in knowing energy consumption data and 87.5% of them felt motivated for energy conservation. All the participants took actions to save energy either intentionally or by habits. Turning off the lights was mentioned by all the participants as an action to save energy, while only 25% of the participants turned off the computer or made it sleep when not in use.

Post-questionnaire
To investigate participants’ energy awareness and user experience after the game, a post-questionnaire was given after the game. Results about energy awareness showed that 25% of the participants knew the amount of their energy consumption while 25% of the participants had a general idea of the amount. Also, 75% of the participants thought they were more aware of their energy consumption after the game. Besides, all participants thought it was fun to play the game and reported being engaged with EnerSpace. They were interested in knowing how the competition and space trip goes and 87.5% of them stated that they thought of the game in their spare time. 60% of the participants felt more motivated by the game while 50% of them thought they saved more energy due to it. As regards if they thought that they saved more energy during the game, the responses were neutral, which was followed up for how the participants viewed their energy conservation during the game in the interview. As many as 75% of participants would like to keep playing the game. In summary, EnerSpace appears to have helped to increase the participants’ awareness and knowledge towards energy to some degree, and the participants had a positive experience with it.

5.3 Post-experiment interviews

Impact of EnerSpace
The results about the impact of EnerSpace were in-line with the post-questionnaire. All the participants thought they gained a better understanding of their consumption after playing the EnerSpace. Although there has been an ABB company goal for energy reduction for a long time, they generally felt more motivation and engagement as an individual because of the game. Some participants reported that they sometimes thought about the game before they left the office and that this reminded them to shut down the computer and turn off the lights. However, even though they were motivated for saving energy, they mentioned that some of their regular work tasks (e.g. running simulations) took time to run and that they had to keep those simulations running during the day. Therefore, they tried to save on the occasions that they could, but were aware that some energy had to be consumed in order to do their job.

Gamification Mechanics
The mechanics of EnerSpace was a competitive competition with visualized energy consumption data on both group and
individual level. As for the mechanics, all the participants agreed that it was fun to play and the competition motivated them to save energy to different extents. Some participants felt motivated by the sense of competing with another team, while others were mostly attracted by the comparison between their current consumption and the corresponding baseline. Knowing their consumption data and how much they saved already provided sufficient motivation for them. These participants appeared to consider energy saving as a competition for themselves although the competition still added some additional value, as a participant said: “what motivates me is the energy saving itself, and the between-team competition is like some spices on top of it”.

As for the cooperation, some participants liked the idea of competing as a team because of the sense of community. They had in-team discussions around it, such as “I talked with some of them and we went to the computer and saw how the spaceship was going together”. Also, the team created social pressure for one to behave, as a participant mentioned: “knowing the team then I kind of feel bad if I am not contributing”. However, one participant also mentioned a shortcoming that they did not experience a process of making up a team, which resulted in a weaker sense of cooperation and belongingness.

Gamified Data Visualization

The gamified visualization included presenting the energy consumption data with game elements and displaying those data on the individual page. As for the game elements, most participants liked how the movement and position of the spaceship represented their energy conservation since they could easily see what changes their behaviour brought. In terms of having an avatar as a partner who introduced the progress of the space trip, they thought it was fun and made the game more interactive. Although the participants agreed that they cared the most about the consumption data, they would prefer to have both the data and the avatar, which felt more interesting and engaging than solely factual data, such as a participant said about the avatar “it felt more like I was in a competition instead of only reading facts on the screen. So it was presenting the same thing but in another way. I was attracted by all the animations”. As for the saving tips the avatar provided, some participants felt persuaded by it as “Someone talked to me and said this, I was like, okay, why not?”. Also, the participants experienced a sense of prouness when receiving a compliment and postcard from the avatar.

When talking about the consumption data displayed on the control panel (see Figure 4(a)), all participants thought it gave them an idea of how much they consumed and saved. However, some participants found that only one number of their current consumption was not enough and it was hard for them to get a general idea of their consumption from it. They wanted to access more data, which was in conflict with the results from voting on the data presentation of interest during the design process. All participants wished to add a line chart of how the energy consumption changed over time, from which they could be aware of how their consumption changed at a different time period of a day and compare the consumption between weeks. Additionally, some participants mentioned it would be fun to know how much each device consumes and their total consumption instead of an hourly average consumption. A monetary indicator was suggested to provide a stronger motivation for some participants who preferred to know how much money they saved from the energy conservation.

Another complaint about the current data was that the participants did not know how much their personal baseline was and how the personal saving was calculated, which indicated that a more detailed explanation was needed in the beginning. Also, some participants wanted a clearer representation of the connection between their energy conservation and game, since they wondered how their saving influenced the speed of the spaceship. Another data displayed on the individual page was the in-team ranking. Since it was a group game, most participants reported that they did not care much about it. However, some participants found themselves thinking about what they did wrong and compared themselves with other teammates when they were at the bottom of the ranking. This indicated that the in-team ranking could serve as a reminder for the users who might over-consume energy.

Fika room as the context

All the participants liked the idea of using the Fika room as the context for EnerSpace. One main reason was that setting up the game in the Fika room raised more awareness of not only the participants but also other occupants in the ABB Corporate Research building. The participants were asked about what was going on frequently and it created a topic around energy conservation. The other reason was that the participants came to the Fika room in their spare time and were expecting some “interruptions” for work. The setup in the Fika room appears to have met the demand of being less obtrusive. Nevertheless, some participants mentioned they would like to have the game both in the Fika room and in the office. The advantage mentioned of having it in the office was that they could check their consumption frequently and understand the real-time effects of their behaviour. Also, the Fika room could be hard to reach for some participants who spend most of the time on meetings or in the laboratory. The different preference for the contexts of the EnerSpace was likely to result from the different ideal data-checking frequency for each participant. 50% of the participants said that they would like to check their consumption data once per day while 25% of them thought 2-3 times a week was enough and the rest wanted it hourly to get instant feedback of their behaviour. According to the self-report of the participants, the participants followed their idea data-checking frequency to use the EnerSpace since there was no instructed requirement on the frequency of use. 75% of them logged in it once or twice a day while the rest logged 2-3 times per week.
Future Improvements
In addition to the suggestions mentioned above, other desired features were proposed by the participants. One future improvement was to expand the scale of the game and included more equipments into the game, such as the heating system. Since the heating system is one of the main contributors of energy consumption, some participants thought they would be more motivated for saving a larger amount of energy. Another possible improvement was to add the game to a desktop or mobile platform, which made it possible to play with it whenever the participant wanted.

6. DISCUSSION

6.1 Impact of EnerSpace
Combining the results from the data analysis, interview and questionnaire, the EnerSpace could help increase energy awareness and support consumption behaviour change. The energy awareness was reflected in being aware of one’s energy consumption and reminding oneself of energy conservation consciously. After the EnerSpace, 75% of the participants thought they were more aware of energy consumption while 37.5% of the participants who did not know the amount of energy they consumed before had an idea of it now. This proved that the participants acquired more knowledge of their consumption data. Results from the interview explained three influential motives that drove the participants to energy conservation. The first and main motive was the competition where the participants tried to behave in a more environmental-friendly way in order to occupy a better place in the competition. Also, the social pressure and responsibility of being a team member motivated the participants to contribute and created a sense of guilt if they did not. Although creating negative feeling might sound contradictory to gamification, no participants reported lower engagement due to the aversive feelings. Moreover, the participants found it reminded them to reflect on what they did wrong and what could be improved. This could suggest that aversive feedback does not harm the fun of gamification as long as the participants have the ability to change. This implication is in line with the findings of study BinCam [36] and study Power Ballads [14], which both indicate that evoking aversive feelings, such as guilt, does not deter user engagement and could motivate the users towards a target behaviour.

The two motives mentioned above were more extrinsic while the last motive was a more internalized instinct. The participants also used the data EnerSpace showed for a competition with themselves. Managing to save more energy than before created a sense of achievement that satisfied and motivated them. This intrinsic motive is an interesting finding that might suggest how a self-driven person views a persuasive gamification such as EnerSpace. As this user group have their internalized criteria and clear demands, when designing a gamification, it is important to satisfy their mental model first and then add the gamified elements or strategies to create extra fun.

Although an increase of energy awareness was found, how the energy awareness transformed into behaviour is an interesting topic to discuss, considering the mind-behaviour gap mentioned in previous literature [11]. To achieve a behaviour change by persuasive technology, a motivation, trigger and ability to change are also required [11]. In this case, the trigger was the gamified visualization and the motivation was mentioned as above. The ability to change will influence the occupants’ energy-saving behaviour. According to the results from data analysis, the participants achieved a decrease of 21% energy consumption during playing the EnerSpace. With a 23% decrease in the working hours, the consumption decreased by 81% on weekend. Those results proved the effectiveness of the EnerSpace on energy conservation. However, the energy consumption in the non-working hour in a workday increased by 48% during the game. A possible reason was the experiment period was too short. Another reason might be due to a limited ability to change. As the participants mentioned during the interview, although they were aware that keeping the computer on when absent was a waste, they still had to keep some simulations and experiments running. If they were leaving for a long time such as weekend, they would consider turning it off completely. These explanations fit the results that the greatest decrease of energy consumption was found on weekend and an increase was found during the non-working hour in a workday. As the participants might not have much control over the consumption during the non-working hour in a workday, weekend might be the time period with a larger energy saving potential in off-duty hours. As for the non-working hour in a workday, both a better way of baseline calculation and a longer period of baseline collection will be needed in order to investigate the consumption pattern during this period closely.

In general, this study filled the gap that the previous gamification for energy conservation lacks a combination of group cooperation and individual feedback. By providing the main page that shows how the competition as a team goes on as well as an individual view reporting personal data, the EnerSpace satisfies the need for a community and a sense of personal contribution. As mentioned in the literature study, the persuasive strategies used in this study were the simulation, personalization, competition, cooperation, goal setting and suggestion. While most participants were motivated by the competition, cooperation seemed to appeal more to the participants when they did not behave well and got a poor in-team ranking. The main motive was a sense of guilt to the team when one over-consumed, but a sense of honor to make a difference to the group was not mentioned by any participants. It could be due to the fact that the team was made up randomly in the experiment. Although some participants reported that they checked the game together and discussed it with teammates, this happened mainly between colleagues who sit physically close. Therefore, the participants did not feel much belongingness to the team. To promote the
cooperation in the future design, it could be better to have the participants make up their own team or use the existing team such as department or research group. Not only because the bonding between teammates would be stronger, but also because the teammates are more likely to talk to each other around the energy conservation.

6.2 Gamified Data Visualization
Generally, all participants considered the gamified feedback of the spaceship and avatar engaging and fun in the interview. The participants also mentioned that the movement of the spaceship helped them visualize their efforts. Those results proved that the game indeed helped build the connection between one’s behaviour and the results. Participants’ reaction to the avatar’s suggestions on energy saving matched the finding in a previous study that people were easier to be persuaded by someone who was similar to them [6].

In EnerSpace, data was visualized in both abstract and factual approaches according to the previous study Coralog [24]. As suggested by the Coralog, this study improved the abstract gamified visualization by displaying an animated avatar and combined factual and abstract visualization by adding accurate factual data to the animation such as the current energy consumption and saving. All the participants liked this combination and considered it better than displaying solely factual data, which again was in line with findings from previous studies [21]. This combination might suggest a balance between abstract and factual visualization that the factual data is needed for providing trust-worthy and detailed consumption feedback while abstract visualization makes the users more willing to check their consumption.

Another interesting finding around the consumption data was that all participants showed a great interest in adding a line chart that showed how the energy consumption changed over time and history data of themselves. This result was in conflict with the findings during the design process of EnerSpace. When designing the EnerSpace, 6 occupants were asked to vote between 6 data from 1 (the most interested) to 6 (the least interested). The results from the voting suggested that the participants were the most interested in their current consumption and saving, and the least interested in the line chart presenting history. The conflict might be partly because of the small number of participants, since the participants in the experiment were all engineers who might be keen on numbers. Another possible explanation was that the participants in the data voting did not have a clear idea of what kind of data they wanted when they did not engage with it. As for the participants in the experiment, they had the first-hand experience. Once they were engaged with the topic, they would like to know more. If so, this conflict might indicate the participants were closely involved with the energy conservation due to the EnerSpace. It also provides an indication for future work that an increasing amount of visualized consumption data could be provided step by step, which is in line with the growing curiosity of the participants. Another interesting idea would be that the team could gain more detailed data and game tools by behaving well. For instance, if they have saved energy in consecutive days or reached a goal of collecting resources, they gain a view showing more detailed consumption data as a reward.

6.3 Limitations and Future Work
This study designed and implemented a working cooperative gamified visualization and evaluated its impact on energy saving with 8 participants in a two-week experiment. Limitations exist on the hardware and the setup of the experiment. Firstly, the connection between FIBARO Wall Plug and the VeraPlus Controller was not very stable, which resulted in the low frequency of consumption data gathered during nighttime. Although the unstable data logs were fixed by the formula of how the total consumption was calculated, the consumption data was not as accurate as it should be. Secondly, during the experiment the participants’ presence or not in the office was not taken into consideration. If the participant leaves the desk without shutting down the devices in the working hours, their consumption data will still be compared to the baseline of working hour, which lowers the accuracy of energy saving. Moreover, the initial idea of having the EnerSpace in the Fika room was that participants could check it when waiting for coffee. However, in the Fika room used for this experiment, the coffee machine and the monitor were mounted on different sides of a wall. As one participant mentioned, he would not see the monitor if he only came for a quick coffee. Although the participants would see the monitor if they sit down on the monitor’s side, so the setup was not ideal although it still was used. Last but not the least, although EnerSpace was found to have positive influence on the energy awareness and energy-related behaviour, how long this impact could last remain unclear. The experiment only lasted for two weeks with a small number of participants due to the limitation of time and cost. A longer experiment and more participants would be needed for observing more obvious and stable reactions.

Besides the hardware challenges, the future work on the EnerSpace lies in the improvement of the design. One of the main work would be a more detailed and comprehensive data visualization of the consumption data such as the line chart the participants asked for. Another work is to make the EnerSpace interactive on portable platforms to increase the scalability of it. A portable version of EnerSpace makes it possible to satisfy more scenarios where the participants want to check their consumption data and the participants could choose what data to see independently. Moreover, the participants used the EnerSpace with their preferred frequency now. Increasing their frequency of using EnerSpace might lead to a more significant change in awareness and consumption behaviour. An interesting idea could be encouraging the
participants to log in the game in consecutive days to unlock special tools. Additionally, the storyline of the game changes occasionally now in order to keep the participants engaged. For a longer run of the game, the baseline could also be dynamically adjusted to the current consumption of the participants so that the difficulty of the game adapts to the increasing energy awareness of the participants. Also, with a proved interest in EnerSpace, the cooperative game could be generalized to more context such as schools, laboratory and personal household.

7. CONCLUSION
In order to explore the occupants’ awareness of energy consumption and motivate the occupants to conserve energy, this thesis went through the process of a field study, design iteration, implementation and evaluation of a cooperative game, EnerSpace. After a two-week experiment with EnerSpace, the participants achieved a 21% decrease in energy consumption during the game week compared to the baseline. All the participants reported an engaging and fun experience with EnerSpace when they were more aware of their energy consumption. The participants found both extrinsic and intrinsic motives that drove them to energy conservation in EnerSpace. The gamified visualization was considered as appealing and persuasive. It also seemed to raise the participants’ interest in knowing more about their energy consumption. Those results could provide inspirations for future design on how to convey the consumption data and create influential motives for different types of person. In conclusion, this study showed that deploying a cooperative game in a public setting could raise the occupants’ awareness of energy consumption as an individual and motivate them to conserve energy in a commercial building.

ACKNOWLEDGEMENT
I would like to express my deepest gratitude to all the people who involved in this master thesis. Thank my supervisors, Goga and Anders, for the guidance and advice. Thank the participants for participating in this study. Thank the RISE Interactive for sharing the knowledge and devices. Thank my friends for helping and encouraging me during the implementation of EnerSpace. This master thesis was supported by ABB Corporate Research Center.

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