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Saving energy in an office environment: A serious game intervention

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ABSTRACT

Serious Games are virtual simulations of real-world activities that can both educate users and prompt behavioral change. This study evaluated the effectiveness of a virtual pet game in reducing plug-loads in a mid-size commercial office. Participants were 61 resident workers. The energy consumption of 288 appliances was monitored for 24 weeks using plug-load sensors. After 4-weeks of baseline, 42 participants were introduced to the "Energy Chickens" serious game, which they played for 12 weeks. Within the game, daily energy consumption data for each individual's devices were used to manipulate animated chickens living on a personalized virtual farm. Changes in device-specific energy consumption were reflected in the improving or declining "health" of the corresponding chickens. Healthy, energy-saving chickens laid eggs that the user could collect and use to purchase accessories for their virtual farm. Across all intervention days, average energy consumption declined by 13%. Participants achieved 23% reductions on non-work days and 7% reductions on workdays. At the conclusion of the intervention, 69% of participants indicated that the game helped them be more energy conscious, with some indicating changes in their energy use outside the office. Results highlight the effectiveness of behavioral interventions on plug-load energy consumption within commercial office settings.

1. Introduction

1.1. The role of individuals in controlling energy use in commercial buildings

In the United States, residential and commercial buildings consume 40% of the total energy used and buildings account for 72% of electricity used. Of that amount, 33% of electricity use is consumed by plug and process loads; more than lighting, space heating and cooling, or ventilation [1]. By 2030 plug loads are expected to account for 49% of total electricity use, in part because of the increasing efficiency of building envelopes but also as a result of the proliferation of office automation equipment, from desktop computers to cellular telephone chargers [1]. Historically lighting and heating and cooling have been viewed as the large energy consumers whereas plug loads have been viewed as essential to the function of the organization, a necessary and unavoidable use. However, while much of the energy used by interior climate control can be moderated by automatic controls, plug load energy use is usually directly under the control of individual office workers, and may be reduced through changes in individual behavior.

1.2. Feedback on energy use to influence energy using behavior

Providing feedback to energy users has long been regarded as a key mechanism in persuading individual end users to voluntarily reduce their energy use. A wide variety of mechanisms from education about energy use to financial incentives and competitions have been used and described in a number of surveys of the field [2–6]. While the vast majority of the studies included in these reviews focus on residential settings, those focusing on energy consumption in office settings report energy savings ranging from 4 to 10% [7–10]. Other studies have employed information provision in combination with various social marketing tools such as commitment, prompts, norms, and incentives in office settings and report 2–9% energy reductions in office buildings [11,12]. Of these, few examine the persistence of energy saving behaviors but where

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those do occur they are associated with the development of new habits over longer periods of time. When feedback included incentives, removal of the incentive tended to result in energy saving fading away [2].

Among the numerous strategies employed to develop persistent energy-saving behaviors, common desirable characteristics for feedback have been identified–user friendliness; actual consumption; frequent feedback; interaction and choice; appliance-specific; comparative; and given over an extended time period [2,4,13]. Early strategies comprised the use of explanatory billing and of facility-level energy use dashboards. More recently and to address the strategies identified above, there has been an increasing emphasis on individual-level real-time and interactive feedback either explicitly or implicitly drawing on insights from behavioral sciences, human-computer interface design and social media [14–19].

1.3. Social media interventions in energy using behavior

In response to the evolution in thinking outlined above, computer games, real-time data visualizations (dashboards), and other interactive social media have emerged to address energy saving [2,20], driven by the belief that actively engaging energy users in energy saving is more effective in changing behavior than simply providing information about energy conservation.

“Serious games”, emerging in 2002 as an initiative of the Woodrow Wilson Center to encourage the development of games to address policy and management issues [21], are a sub-set of the broad range of social media interventions that might be employed to bring about energy-saving behavior. The game-based models and simulations at the root of serious games enable users to develop knowledge about the energy-saving strategies available to them and then explore alternative means of achieving energy saving.

Among the various types of social media being used to promote energy savings, the structured rules, goals and challenges of Serious Games in the context of virtual simulations of real-world activities and events both educate users and prompt behavioral change. For energy-saving they can make energy use contextually relevant to daily life, engage users' interest in saving energy, and provide a direct means to influence their on-going energy use. Games that engage the social bonds and affection that players develop for virtual “pets” have been effective in changing behavior in medical and commerce settings, such as in encouraging the adoption of healthy living behaviors [22].

Applied towards reducing energy consumption in office settings, serious games may encourage personal responsibility for energy use, provide an introduction to the issues associated with energy saving, and prepare office workers for more informed engagement with energy issues—without any costly retro-fits or changes to building fabric. As such, a few games have been developed that focus on promoting energy saving behavior using real-time energy feedback [23,24]. Prior to the work reported here, the effectiveness of games in reducing energy use had not been tracked. The purpose of this study was to implement and test the effectiveness of a virtual pet game designed specifically for reduction of plug-loads in a mid-size commercial office setting.

2. Methods

2.1. Participants and procedure

In this study, approved by Penn State's Institutional Review Board (IRB #s 39795 and 40020), 57 resident workers between 23 and 82 years of age (Mdn_{Age} = 48, M_{Age} = 47.4, SD_{Age} = 13.0), 51% female, from a mid-size commercial office complex participated in a serious games intervention trial. The majority indicated they were White (82%) with some representation of Black (5%), Asian (11%), and Hispanic (2%). Energy consumption of 217 appliances in these 57 individuals' office spaces were monitored continuously for ≈6 months using wireless plug-load sensors (between 1 and 5 appliances per person, M = 3.81, SD = 1.13; ranging from desktop computers and monitors to coffee makers and shredders).

At the beginning of the study, all participants' offices were outfitted with up to five plug-load energy sensors. For the next 5 weeks, *baseline* energy use was monitored (without intervention) (Table 1). At Week 6, *Phase 1* of the intervention began and included a poster campaign and the Energy Chickens serious game (see below). Of the 57 participants, 41 consented to join a group that engaged in active play of the Energy Chickens game (*Game* group.) The remaining 16 participants did not play the game but were exposed to the posters and potentially to co-workers that were playing the game (*No-Game* group). At Week 14, the intervention transitioned into *Phase 2*. The posters were removed but participants in the *Game* group continued to play the game. At Week 20, the game ended, and the study transitioned into an 8-week *Follow-up* period, where energy use was monitored without intervention, as during baseline. In total, the 57 participants provided data on 173,437 quarter-days of energy use of 217 office appliances. All participants (*Game* and *No-Game* groups) were entered into drawings for five $100 gift cards as compensation for the energy monitoring portion of the protocol. Participants in the *Game* group were compensated up to an additional $100 for completing the entire protocol, which included pre-, post- and daily surveys to examine effects on participant well-being and productivity during and after the energy-saving intervention. This report concentrates on the energy use results and also reports participants' evaluations of the game. Findings about participant well-being and productivity are not reported here.

2.2. Intervention: Energy Chickens

2.2.1. Serious game

Participants in the *Game* intervention group were provided with a web-based game application, *Energy Chickens*, that could be accessed from their desktop computers. Within the game, real-time daily energy consumption data for each individual's devices were used to manipulate the characteristics of a set of animated chickens that “lived” on a personalized virtual farm that each user maintained. Following typical virtual-pet game mechanics [25], changes in device-specific energy consumption (relative to baseline levels) were reflected in the “health” of the corresponding chickens (Fig. 1). When energy consumption was reduced, the chicken representing that device would grow larger and lay eggs (rewards) that the user could use to purchase virtual accessories for their virtual farm (hats for chickens, bouncing balls, fences, flowers). When energy consumption was increased, the chicken would become smaller, not

Table 1
Study schedule and components.

Group	N	Baseline (5 weeks)	Phase 1 (8 weeks)	Phase 2 (6 weeks)	Follow-up (8 weeks)
Game	41	Sensors only	Sensors, Posters and Game	Sensors and Game	Sensors only
No-Game	16	Sensors only	Sensors and Posters	Sensors only	Sensors only