To Save or Not to Save? Let Me Help You Out: Persuasive Effects of Smart Agent in Promoting Energy Conservation

Guo Yu, Pei-Luen Patrick Rau(✉), Na Sun, and Xiang Ji

Department of Industrial Engineering, Institute of Human Factors and Ergonomics, Tsinghua University, Beijing 100084, China
rpl@mail.tsinghua.edu.cn

Abstract. In public places, people's energy conservation decisions and behaviors are easily suppressed by contextual and/or personal factors. To perform and maintain energy-saving behaviors, people need to be empowered both externally and internally. This research explored how a smart agent could help. The first study revealed that when a smart agent empowered people externally by offering help, people would be more active and resolute in decision-making and more likely to save energy, while some would be unaffected and decide to use energy. The second study found that the acknowledgement of behavioral impact could significantly facilitate people's evaluation processes and enhance their self-efficacy, but such effects would be moderated by the time cost of a task, which was proved positively correlated with the perceived task difficulty. Both theoretical and practical implications for energy conservation were discussed, and six guidelines for smart agent design were proposed.

Keywords: Energy conservation · Self-efficacy · Persuasive agent · Empowerment · Behavioral impact

1 Introduction

As the internet of things is burgeoning, there have been more possibilities that we can promote energy conservation by building an intelligent home or office environment (Roalter et al. 2010) since energy use could be visualized, monitored, and controlled with ease.

The advantages of an intelligent energy-saving environment would not be fully exploited if human factors were omitted. For instance, if notifications or feedbacks were not properly designed, it would hardly boost people's awareness of energy use (Anker-Nilssen 2003). Furthermore, however powerful an intelligent system is, we should remember that it will take time for the system to spread and get fully implemented, and any system could fail, hence people's own determination and efforts are indispensable in intensifying and sustaining their optimal performance in energy conservation. Therefore, this research tried to find out what design features of the system could make energy conservation noticeable in a certain context, easy to achieve, and durable without external aids, as well as how would people react to those features and why would they

P.-L.P. Rau (Ed.): CCD 2016, LNCS 9741, pp. 808–815, 2016.
DOI: 10.1007/978-3-319-40093-8_80

do so? Two empirical studies were conducted to answer these questions and a set of guidelines for persuasive agent design were proposed.

2 Literature Review

2.1 Motivators and Barriers to Energy-Saving Behavior

Most models think that user's environmentally behavior is determined by user's environmental consciousness or environmental concern (H'Mida et al. 2008). Two groups of factors would influence user's intension and behavior. One is internal/psychological factors, including user's value, attitude, knowledge, skill and ability, and perceived self-efficacy. The other is external/situational factors like social norms (Griskevicius et al. 2010), information, and other external incentives (Sahakian and Steinberger 2011). There are also some barriers. A model that explains the barriers between environmental concern and actual action (Kollmuss and Agyeman 2002) identified three barriers as individuality, responsibility, and practicability. Specially, individuality refers to barriers caused by passive attitudes (i.e., laziness, lack of environmental concerns) and personal needs (i.e., keeping warm at home) (Van Raaij and Verhallen 1983).

2.2 Self-efficacy and Behavioral Change

Self-efficacy refers to the self-appraisal to one's own capability of coping with a certain task. People would eschew the predicament which they reckon as beyond their coping capabilities, but confidently undertake what they judge themselves capable of managing (Bandura 1977). To obtain information in forming perceived self-efficacy, people would generally refer to performance attainments, vicarious experiences, verbal persuasion and physiological states (Bandura 1982). To make information instructive, cognitive appraisal should be activated, hence cues or indicator should be provided (Bandura 1981). People's self-efficacy also have a causal relationship with their action (Bandura et al. 1982). Empirical studies have proved the performance of actions to vary in response to different levels of perceived self-efficacy. Meanwhile, this causation between perceived self-efficacy and action performance could be a mutually enhancing process: At first, people's prejudgment about their self-efficacy and coping capabilities would partly determine how much efforts they would devote, then their skill acquisition and performance mastery, if satisfying, would boost their self-efficacy in return (Bandura 1982), thereby shaping a positive feedback cycle.

2.3 Persuasion and Energy Conservation

Persuasive technologies have brought new possibilities into energy conservation. One method is to visualize the energy use, enabling people to monitor energy use and get timely feedback of behavioral impact (Fischer 2008; Pierce and Paulos 2012). But many energy monitors have usability problems like users feeling "money were seeping out" as the digits flickering, or feeling routine activities like heating water being disturbed.

After a period of use, people got used to it gradually, so the feedback was no longer incentive (Hargreaves et al. 2010). Both problems could be explained by self-efficacy. People obtained more pressure than efficacy from the system, so the external incentives failed to translate into people's interests in saving energy. Therefore two features could be added to strengthen the persuasive effects of energy monitors. Firstly, let the monitor act as an embodied conversational agent (Kirby et al. 2010) that could provide recommendations in explicit or implicit ways (Xiao and Benbasat 2007). It could result in less decision time, less cognitive load, higher decision quality and higher self-confidence, hence people would gain more self-efficacy. Secondly, let the agent execute simple and repetitive tasks for people, so people would feel perceive tasks easier, and their behavioral intention can increase along with the increasing sense of control.

3 Research Framework

Based on the literature above, some hypotheses were proposed regarding user's perceived necessity of energy use, the empowerment of agent and the time cost which lead to user's perceived task difficulty and self-efficacy, as well as user's behavioral impact which leads to the evaluation process and user's perceived self-efficacy.

Necessity:

H1.1: In public places, when people need to make decision and perform action in person, they do not have obvious consensus on the necessity of a certain energy use.
H1.2: In public places, the perceived necessity of using energy would not change whether or not a smart agent could provide help, while the perceived necessity of saving energy would increase if the agent could provide help.

Empowerment and Time Cost:

H2.1: In public places, people would be more active and resolute in making decision when being served by a smart agent that could provide help compared to the one that could not.
H2.2: In public places, people would be more likely to save energy when being served by a smart agent that could provide help compared to the one that could not.
H3.1: The perceived time cost and perceived difficulty of a task would be positively correlated with the actual time cost of the task.
H3.2: The time cost of a task would moderate the effect of acknowledgement of behavioral impact.

Behavioral Impact:

H4.1 The acknowledgement of behavioral impact would reduce the time people spent in the evaluation processes.
H4.2 The acknowledgement of behavioral impact would enhance people's self-efficacy-related perceptions.

4 Study 1 – Empowerment

4.1 Methodology

Study 1 explored how people's decisions of using/saving energy would be influenced by a smart agent. 48 students of Tsinghua University (22 females, 26 males; average age = 24.48, SD = 2.24) were invited as participants. A primary-secondary task methodology was adopted in the experiment: Participants were told that their primary task was to watch a 30-min video then answer 5 questions about it. During their watching, a smart agent named Intelligent Energy-Saving Environment would interact with them on SNS, and participants were free to reply or not.

This independent variables include the Empowerment of agent and the Scenario of energy use. Empowerment was a two-level between-subject factor, classified as In Person level (Participants were both the decision maker and performer, while the Intelligent Energy-Saving Environment acted as a reminder) and Agent level (they system acted both the reminder and performer, while participants merely made decisions). Scenario was a within-subject factor with seven levels like turning off unused lights in the corridor and turning off unused water heater in the lab. To measure the influence of the Intelligent Energy-Saving Environment on the participants, their voluntary responses to the reminders were collected as an indicator of their behavioral intention. For either group, on receiving the same message, participants could choose "Save" decision, "Use" decision or "Not Decide".

4.2 Results

Chi-square test was done among the numbers of participants in the In Person group choosing "Save" decision, "Use" decision and "Not Decide" on each of the seven scenarios. It was found that in the first six scenarios, the incidence of the three types of decisions show no significant difference (all $ps > .05$), while in the seventh scenario, the incidence of S to prevail over that of U or N significantly ($p = .01$). Therefore, H1.1 was partly supported for the first six scenarios, and was not supported by the seventh scenario (Turning off unused printer in the lab). Paired t-test was done on the number of participants choosing "Use" decision between the In Person and the Agent groups. The difference was not significant ($t = 0.464$, $p = .659 > .05$), therefore the first part of H1.2 was supported. Then nonparametric test was adopted to compare the mean. There was significant between two groups ($p = .001 < .01$). Hence H2.1 was supported. For the number of participants choosing "Save" decision, paired t-test was adopted. The difference between two groups was significant ($p = .011 < .05$), indicating people made more energy-saving decisions when the smart agent could help, and hence the second part of H1.2 and H2.2 were both supported.

5 Study 2 – Self-efficacy

5.1 Methodology

Study 2 explored how people's evaluation processes and self-efficacy in energy conservation could be influenced by task difficulty and behavioral impact. 24 students of Tsinghua University (12 females, 12 males; average age = 22.4, SD = 1.24) were invited as participants. A prototype of mobile App named Energy-Saving Building would send each participant six task reminders, showing that some appliances were still on in some classrooms that had not been scheduled a class, and asked s/he to go there and have a checkup, then evaluate task from several aspects.

Independent variables include the Acknowledgement of behavioral impact as a between-subject factor, and the Time Cost of a task as a within-subject factor. Participants were divided into two groups. The Energy-Saving Building App would only show one group (denoted as Unshown) how many appliances they turned off without specific information of behavioral impact, whereas it would show the other group (denoted as Shown) how many appliances they had just turned off and how much energy they could conserve on each appliance. Among the six tasks assigned to each participant, three tasks took 25 s (Short) and the other three took 50 s (Long). For hypotheses testing, both objective and subjective data were collected to measure how the two factors would affect participants' evaluation processes and the perceptions related with self-efficacy.

5.2 Results

Nonparametric test of Mann-Whitney U was adopted to compare the difference. The correlation of actual time cost and perceived time cost was .627 ($p < .001$), of actual time cost and perceived difficulty was .490 ($p < .001$), and that of perceived time cost and perceived difficulty was .428 ($p < .001$). A task that took shorter time had resulted in a significantly smaller estimate of time cost compared with a task that took longer (22.74 s < 46.66 s, $U = 428.000$, $p < .001$), and similarly, a shorter task generally received a lower rating on task difficulty than a longer task (3.23 < 4.24, $U = 1190.500$, $p < .001$). Therefore H3.1 was supported. When the time cost was short (25 s), only two measurements manifested difference between two groups, whereas under longer time cost (50 s), eight measurements were significantly influenced ($p < .05$). Therefore, the hypothesis H3.2 was supported.

When the task took a longer time (50 s), all the time measurements of the Shown group were significantly smaller than the Unshown group, including the time spent on evaluating the time cost, behavioral impact, task difficulty, behavioral meaningfulness, and sense of achievement (all ps < .05). Therefore, H4.1 was supported in that the acknowledgement of behavioral impact had reduced the time in people's evaluating process. Similarly, when the time cost was long, the subjective ratings given by the Shown group on the self-efficacy-related measurements were significantly higher than the Unshown group, including the perceived behavioral impact, perceived behavioral meaningfulness, and the sense of achievement (all ps < .05). Hence H4.2 was supported for the acknowledgement of behavioral impact had enhanced people's self-efficacy.

6 Discussion

From the perspective of user's experience, it's important how users would perceive the energy-saving tasks, especially their understanding on whom that took credit after saving the energy? This question calls for the concept of agency in the field of cognitive neuroscience (Moore and Haggard 2008). Humans are also agents: They have the capacity to take actions intentionally to change the external world, and they could consciously experience such capacity through their actions. The experience of agency is, therefore, "person's sense of being in control of their actions and through this control of being responsible for, or having ownership of, the consequences of those actions" (Coyle et al. 2012). Meanwhile, people would also experience agency when interacting with an intelligent system. Empirical studies have proved that the more assistance a system provides, the less sense of agency a user would gain. Arguably, in this research, participants aided by the Intelligent Energy-Saving Environment would experience lower agency and think, "The energy was actually saved by the intelligent system", while the Energy-Saving Building would make people believe that "It was me that saved the energy!" The Intelligent Energy-Saving Environment and the Energy-Saving Building would produce disparate experience in the user-agent interaction, and result in different behavior and self-efficacy in energy conservation. At current stage we could not predict which one would be better: the Intelligent Energy-Saving Environment could make tasks much easier, but people could neither experience much agency nor gain much self-efficacy; the Energy-Saving Building could enhance self-efficacy and agency, but such incentives might satiate users in long-term.

Design Guidelines: Based on the findings and theoretical basis, the following six design guidelines for smart agent were proposed, which are designed to persuade people to save energy.

- Give users a nudge, remind them and hint the necessity.
- Let users feel the power of control, and believe the positive outcomes are all due to their decisions.
- Understand users in different situations, and assign tasks according to users' habits, level of self-efficacy, and current situation.
- Retain reasonable uncertainty.
- Present behavioral impact.
- Keep the history, and create something new.

7 Conclusion

To promote user's energy conservation behavior in public places, this research focused on the persuasive effects of smart agent and carried out two empirical studies. The first study found that when an agent could empower people with control, people would be more active and determined in decision-making and more likely to make energy-saving decisions. The second study found that providing information about behavioral impact would facilitate people's evaluation processes and enhance their self-efficacy, and those effects would be moderated by the time cost of task, which was positively correlated to the perceived task difficulty. Then this research discussed who should take credit after saving the energy and proposed six guidelines for persuasive agent design.

Acknowledgments. The authors would like to acknowledge the sponsorship provided by the National Natural Science Foundation China grant 71188001.

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