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Longitudinal analysis of normative energy use feedback on dormitory occupants

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HIGHLIGHTS

- Two yearlong field experiments for normative feedback messages have been conducted.
- The normative messaging duration positively influences the durability of behavior change.
- High norm individuals are positively induced to change their energy use behavior.
- Low norm individuals are negatively induced to change their energy use behavior.

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ABSTRACT

Behavior interventions aiming to reduce energy consumption in the built environment are becoming increasingly common. The application of individual feedback and use of social norms have shown promise in the short-term at improving occupant energy use behavior. Yet, the long-term effects, role of messaging duration, and relative effect of normative elements in feedback messages remain less clear. This paper attempts to address these gaps in the literature by conducting and analyzing two yearlong field experiments that test the effect of normative feedback messages on energy consumption in dormitories. The analysis finds that adding normative elements to feedback messages had no effect on energy consumption in the short-term. When examining behavior change conditional on an occupant's concern for social norms, it was found that individuals with a high concern for social norms positively responded to the normative elements with an estimated treatment effect of −14% (consumed less). Conversely, individuals with a low concern for social norms had the opposite reaction, with an estimated treatment effect of 5%. Further, it was discovered that the duration of messaging positively influenced the long-term durability of behavior change. The long-term effect of behavior change was twice as prevalent in individuals with high concern for social norms.

1. Introduction

Buildings account for two-fifths of all energy consumption and carbon emissions in developed countries, and significant effort has been given to reducing these anthropogenic sources of carbon emissions [1–5]. Energy use behavior interventions approaches are becoming an increasingly common and viable means to reduce energy consumption in the built environment [6–13]. In contrast to traditional capital-based approaches to reduce energy consumption in buildings, e.g., the promotion of highly efficient equipment, behavior interventions do not require expensive upfront investments [14]. As such, behavioral techniques that aim to modify an individual's energy use behavior have proven to be a cost-effective method to reduce consumer energy consumption.

Pro-environmental behavior interventions, and specifically energy use interventions, have been developed based on a number of different theoretical models of how humans behave and make decisions. A few of the prominent behavior models that have been used to develop intervention techniques that have been applied to the field are the education deficit models [15,16], norm-based models [17,18], and rational actor models [19]. These models have been used to create a wide variety of behavior intervention

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techniques including the use of feedback, goal setting, commitment, gaming, cognitive dissonance, social modeling, prompts, justification, social norms, rewards/penalties, and declarative information [20,21]. Among these techniques, the use of feedback has received the most attention by interveners and researchers [21].

In the extensive literature on testing pro-environmental behavior interventions, these techniques have been found to have varying levels of success in the short-term. Yet, very few studies have investigated treatment effects in the longer term, anything beyond a few months [6,21,22]. In a rare study that investigated the long-term effects of behavior interventions, Staats et al. [23] found that the Eco-team approach, an intensive and in-depth intervention methodology that combines many intervention techniques, produced durable behavior change. However, most studies to date apply an intervention and measure change in behavior only over a short period, a few months or less [6]. The intervention is then withdrawn and no additional measurements are taken. No data is collected and no insight is gained into whether or not treatment effects persist over time or what contributes to the persistence of treatment effects. This is despite the fact that understanding the long-term effects of behavior interventions is of great importance in order to meet energy reduction targets and goals [24].

Recently, partially due to advances in technology, the application of individual feedback and the use of social norms for normative messaging have become more prevalent. Interveners can present participants energy use feedback using a variety of means including email, SMS messaging, paper, media platforms, and/or home energy management systems [7,14,25]. Researchers have also found that the mode that is used to provide feedback along with how messages are framed can have an impact on its effectiveness [26,27].

In addition to the wide variety of mediums for providing feedback to consumers, the feedback itself can be present in a number of different ways. At the most basic level, feedback simply provides consumers with information on their consumption. With regard to energy use, this amounts to providing the amount of energy consumed since the last feedback cycle (e.g., "You used 37 kW h from 1/1 to 1/31."). This method of feedback may also include historical consumption data, such as the previous month's usage. Energy use feedback can be provided on different time scales ranging from billing cycles to in near real time as well [28]. Typically, the more immediate the feedback is to the behavior that is being monitored (e.g., electricity consumption), the more effective the feedback is [6]. Feedback can also be comparative and provide normative comparisons of one's use with those of a reference group, e.g., neighbors (e.g., "Your average neighbor used 83 kW h last month, you used 142 kW h."). These messages sometimes include injunctive messages that indicate a level of social approval or disapproval of one's behavior; the use of injunctive messaging in energy use feedback is becoming more widespread [29–34]. Normative feedback has been found effective at reducing energy use, but has also been found to prompt consumers who consume less energy than average to increase their energy use to be more in line with the social norm, i.e., the boomerang effect [34]. Consequently, in the aggregate due to this effect, all positive gains can be offset and result in no net energy use reductions [34]. The addition of injunctive elements to normative messages is believed to help combat this phenomenon. Lastly, feedback messages may also be framed in a context other than that of monetary units (i.e., cost) or usage (i.e., kW h). Messages can be framed within a health or environmental context; the latter has received significantly more attention and is known as eco-feedback [35]. Eco-feedback frames messages in an environmental context by translating usage into environmentally meaningful terms such as quantity of CO_2 equivalent emissions and/or provocative images (e.g., polar bears on melting ice) [36,37].

Almost without exception these methodologies have shown promise in the short-term for improving occupant energy use behavior in the home [29–32,34]. Unfortunately, the long-term effects of feedback messages, in particular normative feedback, remain unclear despite the substantial amount of recent research work investigating these intervention methodologies [7].

To date, only a few studies which have investigated normative feedback in the longer term have been conducted, and to the best of the authors' knowledge, all have relied on data from the company oPower (e.g.., Allcott and Rogers [29,30], and Ayres et al. [31]). oPower conducted large scale opt-out messaging experiments on monthly and quarterly feedback cycles. While these studies provide a solid foundation for exploring the durability of normative feedback, they are not without limitation and several key research questions remain unanswered. First, the oPower studies do not isolate the effect of normative messaging. Rather, they confound the effect of the normative messages with individual energy use feedback as well as education and information, making the relative effect of the normative elements of the intervention ambiguous. Participants either received messages or did not. Second, the studies attempt to induce households to engage in capital improvements through financial information/education. This makes it impossible to determine how much energy improvements are a result of behavioral improvements versus capital improvements. Lastly, and perhaps most importantly, the studies only collect energy data. To understand why a method was or was not effective in changing one's behavior it is necessary to understand what determines one behavior, i.e., behavioral determinants. Without data on an individual's behavioral determinants (environmental attitudes, perceived behavioral control, subjective normative, and behavioral intention), it is not possible to gain significant insight into what drives the effectiveness of the intervention (i.e., identify with what type of individuals the intervention is successful and with whom it is not) [6].

Therefore, this paper investigates the durability of feedback interventions and specifically addresses the relative impact of normative feedback on occupants' energy consumption relative to generic individual feedback. The authors conduct and analyze two separate year-long field experiments testing the durability and effect of normative feedback messaging on energy consumption. In the study, the authors specifically aim to answer the follow questions: (1) how do energy use behavioral determinants relate to each other as well as energy consumption?, (2) does adding normative elements to individual energy use feedback messaging improve energy use behavior?, (3) what type of person is affected by normative messaging?, (4) does normative messaging promote more durable behavior change?, and (5) does the duration of normative messaging affect behavior and the durability of behavior change?

Answering these questions will provide insight on the effectiveness of normative feedback and how to develop better interventions going forward. This paper will proceed with an overview of the experiments conducted in this study. This is followed by the empirical strategies employed for analysis, along with the results. Then, a discussion of the results and conclusions is presented.

2. Experiment overview

2.1. Site and population overview

The experiment site is a dormitory complex on a university campus in Seoul, South Korea. Seoul is a heating dominated climate; annually heating is the largest energy expenditure. The site consists of seven mid-rise dormitories up to eight stories tall containing over 1200 units. Units are either single or double occu-