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# Inducing [sub]conscious energy behaviour through visually displayed energy information: A case study in university accommodation

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ABSTRACT

Direct feedback on energy use presented by in-home displays (IHDs) has been found to be useful in helping people learn about their energy use and make a reduction. However, it is not yet clear what is the best form in which to present energy information. Two six-week experiments were carried out in student residences at the University of Bath, UK, to investigate how visually displayed energy information presented in different ways could encourage reductions in energy use. Experiment 1 compared three energy display interface designs (one giving numerical information, one using analogue dials and one using emotional faces) all presenting the same information. This resulted in a 7.7% savings over baseline. Experiment 2 examined how well participants responded to ranking information in numerical format about their own consumption. This resulted in a 2.5% reduction from baseline. Although there was a trend towards the ambient faces display performing best, all the displays led to a reduction in energy use. A significant decrease in consumption was also seen in the groups that saw ranking information, whether compared to their baseline consumption or to the control groups. In conclusion, it would appear that the mere presence of a display device can reduce energy use, even when participants are not engaged with the display.



## 1. Introduction

A common problem encountered by households attempting to reduce their energy use is the invisibility of energy. A lack of feedback on consumption could hinder even those with a good understanding of the impact of behaviour on energy use from using energy more efficiently [1].

In the UK, energy meters are often hidden out of sight and are usually not easily accessible. The only feedback provided, typically, is through quarterly energy bills, where energy information is poorly presented and difficult to understand. This is further aggravated by infrequent meter reading, which means billed usage is often estimated, resulting in lack of knowledge, awareness, motivation and engagement for energy-use reduction. People who pay by regular automated payments (Direct Debit), which is encouraged by most energy providers, are particularly unlikely to receive any feedback on their consumption as they pay automatically every month without having to open their bills. Pre-payment meter users have strong engagement but feedback is still limited [2,3].

Another issue preventing users from taking control of their energy use is the mismatched understanding of how much energy each appliance in the house actually consumes. Previous research [4–6] has looked at householders' understanding of energy use compared with their estimates with actual usage. Results suggested that householders frequently underestimated their heating bills, while energy used for appliances, lighting and cooking was overestimated. The increasing number of electronic appliances with a standby/sleep mode also contributes to invisible energy use and wastage. Electronic devices put on standby/sleep mode continue to result in up to 12% of total domestic energy being wasted [7].

Feedback on energy use presented by in-home displays (IHDs) has been found to be useful in helping householders learn about their energy use and make energy-use reductions at home [8]. However, there are very few studies that investigate the presentation of energy information on real-time displays [9,10], and it is not clear whether different display presentations of energy information benefit energy users equally. There is also a need to understand what motivates energy-efficient behaviour and how to maintain this over various periods of time.

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The present work examines the impact of energy smart meter display designs in a live context through two quasi-experiments[1], one looking at the effect of different types of display design and one investigating self and peer comparisons. The experiments were conducted in a student residence at a UK university. Although people living in university accommodation might not in some respects be representative of typical householders, university accommodation provides a well-controlled environment to study the effects of short-term energy saving interventions on users' behaviour for a number of reasons:

(1) The study venues are in buildings with similar physical and construction characteristics, services, room layout and size, and appliances. These properties cannot be modified by their inhabitants;
(2) Participants may have similar demographic features in terms of age, education level and environmental attitude;
(3) Student households may have similar size, lifestyle and composition.

On the other hand, there are ways in which university accommodation might show differences from residential settings. Students, unlike homeowners or tenants, are charged the same all-inclusive fees as their neighbours and do not receive bills or information on their energy consumption. This means they do not have a financial motivation to reduce consumption and might not be conscious about the energy demands or their behaviours [11]. Conversely, however, as many of the students are living away from home for the first time in their lives, this may be the best time to introduce the concept of energy awareness before their habits have been formed [12]. If students can be made aware of their energy consumption by providing them with direct feedback, and if they feel motivated to save energy through rewards or comparisons (whether self- or other-related), this work could potentially become a useful learning opportunity for them to develop energy conscious behaviour.

## 2. Experiment 1: Display design types

### 2.1. Background

Previous research suggests that people are more likely to adopt energy-efficient behaviour if they can see their energy use and savings [13,14]. Electronically displayed feedback provided by IHDs can help make energy use visible, by thus making the link between actions and their effects more immediate and salient to the householder. Such intervention could help raise awareness of energy consumption and possibly motivate energy savings.

While many studies e.g. [8,11,15] have shown general support for a positive effect of IHDs on reducing energy consumption, there is a wide range of variations in the presentation of feedback and it is not yet clear as to how such visual feedback should be best presented. Now that the general utility of IHDs has been established, it is important to begin a process of optimising their design. The work presented in this paper builds on a previous laboratory experiment [16]. This earlier study examined different types of energy display design, assessing participants' subjective preferences as well as how easily people could detect changes on the various displays when they were looking for these changes. The present study built upon the last by looking at how these displays worked to influence energy behaviour in a residential setting, where people might or might not be actively looking for information on their energy use.

This last issue is important because numerical displays, which are used on most current IHDs, provide detailed and quantitative information but will likely require users to make a specific effort to study the information. As such, they might reasonably be expected only to work in real-world setting with people who are already engaged with issues of energy use. Analogue dial displays (speedometer dials were used in the experiment) illustrate the scale of consumption and might make it easier to compare and evaluate past, current and future states of energy use than numerical displays [17]. Ambient displays make use of colours, flashing lights, sounds or pictures to provide a general impression to the situation and do not require users' detailed attention [18]. Two-dimensional cartoon-like faces with emotions representing different energy use levels were introduced in the ambient design in the laboratory experiment [16] for their attention capturing property [19,20].

Our working hypothesis was that the extent to which a display influenced behaviour would be a function of the extent to which it required active engagement from a user, with the ambient faces design likely to have the greatest influence and the numerical design the least.

### 2.2. Methods

#### 2.2.1. Participants and baseline

The study evaluated electricity consumption[2] of a student residence[3] for first-year undergraduate students, which occupied the top five floors of a nine-floor campus building at the University of Bath, UK, in a 6-week period between 16 February and 28 March 2012. Each floor had four kitchen groups consisting of between six and nine students per group. Each group had two separate sub-meters measuring electrical lighting and power in the kitchen, corridor, shared bathroom and study bedrooms, and so between these all the students' residential energy use was captured. A total of 6 kitchens, shared by seven students each, on floors 7–9 were selected as experimental groups. Two of the remaining non-participating kitchens were used as controls[4].

Twelve days prior to the start of the experiment were used as the baseline period[5] in the analyses. Neither the control nor experimental groups were informed of when the baseline period was at any time during the experiment. These baseline data were used to show participants how their current energy consumption compared to their consumption before the study began. The idea of establishing baseline from historical data was rejected as there was no clear way to establish whether consumption by the groups under study would be comparable to student groups in previous

[1] A quasi-experiment allows the researcher to assign participants to conditions by using set criteria, but usually without control over the manipulated variables, e.g. male or female. Therefore quasi-experiments lack random allocation of participants to conditions or control, but are often the only method available when studying phenomena in real-world settings [23].

[2] This was considered appropriate since the study was designed to test differences in presentation for the same end use, rather than responses to different end uses. Further, on-campus electricity sub-metering is widespread with over 1100 sub-meters on campus whereas meters for other end uses are at aggregate level (typically 4–5), limiting our ability to use them in these experiments.

[3] This particular student residence, unlike most of other campus residences at the University of Bath, had Wi-Fi coverage and separate meters for each kitchen, which meet the requirements for the wireless data technology to be used to monitor individual kitchen groups.

[4] Not all the historical consumption data of the non-participating groups in Experiments 1 and 2 were retrievable. Therefore the number of control groups in both experiments was different.

[5] Baseline period is the time period during which no energy saving interventions are installed and the consumption data from which are representative of the average level, so that the data can be compared with those from the experimental period (when interventions are installed) in order to determine the effectiveness of these interventions. The lengths of the baseline periods were different in Experiments 1 and 2 to account for the timing of the teaching terms during which the experiments were conducted.