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‘Transforming Feedback’

A study of how interactive, engagement-oriented feedback can enhance behaviour change around electricity consumption

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Abstract

The ‘Transforming Feedback’ pilot study aimed to explore the impacts of a form of feedback that was designed to engage users in the process of interpreting and re-visualising data about their home electricity consumption. This report describes the aims and methods of the study and outlines the system used to engage people with feedback about their consumption. The study was conducted between August 2013 and February 2014. The paragraphs below discuss some of the implementation of the research design and list the main themes that have so far emerged from the data analysis.

For a period of three weeks, twelve households were provided with equipment that measured the electricity consumption of their household and were asked to spend 5-10 minutes each day using an online software application that enabled them to view how their consumption varied minute by minute, label that consumption according to the activities or devices associated with it and test out different visualisations of the resulting information set. Following the three-week trial, participants were interviewed about their experiences and an analysis made of the digital trace left by their interactions with it.

"My main surprise was that as soon as I came home at 4pm my usage started to slowly go up. I would come home at 4, put the oven on to put something in to cook dinner and I suppose I never thought of it before, but yeah, it was interesting to see how it was low, low, low, low, low but as soon as I walked through the door at 4 o'clock it was going up, up, up, up [laughs]!" [female participant]

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1 Introduction

Behavioural feedback is increasingly being seen as a means of enhancing individuals' awareness of their behaviours and thereby exposing these behaviours to the greater possibility of change. The provision of feedback, particularly digital feedback, is being used in a wide range of social policy domains relevant to the accomplishment of a *sustainable society*. Examples include the promotion of healthy behaviours (e.g. Harries et al 2013), the management of long-term health conditions and efforts to reduce the consumption of limited resources (e.g. Harries et al 2012).

However, feedback systems are often designed on the assumption that recipients will be largely passive; i.e. users are expected to assimilate information by negotiating their way round a mobile app or web-page and reading the graphical or numerical representations of data that are offered to them. This pilot project set out to test the impacts of a system that provides a more interactive form of feedback: FigureEnergy (Costanza et al, 2012). FigureEnergy allows users to annotate and manipulate visualisations of feedback data so that they can more easily relate that data to the ways they live their lives; this, the system designers hoped, would not only encourage interaction with the data but also make it more salient to users' lives and, therefore, more likely to impact on behaviour.

Although selected here mainly as a case-study for the trialling of a more engaged type of feedback, the control of domestic electricity consumption is itself of great importance in contemporary social policy. In the 2008 Climate Act, the UK government committed the nation to ensure that it was producing no more than 80% of its 1990 levels of carbon emissions by 2050; the reduction of electricity consumption is a key part of efforts to reach this target (Defra, 2006; DECC, 2010; HM Government, 2009). Domestic consumption constitutes 31% of total electricity demand (DECC, 2011) and, as illustrated by a 0.1% increase in 2010 (Firth *et al.*, 2008), is rising – partly due to the growth in consumer electronics and domestic appliances and.

A trial of a previous version of FigureEnergy is reported by Costanza et al (2012), who concluded that the system had benefits over and above those of a more traditional system. They found that it changed user perceptions of how much electricity was used by devices that were low-intensity consumers of electricity but remained on for long periods of time (e.g. the television). They also found that it encouraged users to relate energy consumption to activities (e.g. cooking) and not just to devices (e.g. the microwave). These benefits, they

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argued, were the results of features that were not present in more conventional meters, most of which only show users current consumption rates and none of which allow significant user interaction with the data.

The current pilot extends the work reported by Costanza et al (2012) in a number of important ways. First, the empirical data collection and analysis places greater emphasis on the subjective experiences of the users and the effects of the system on their awareness, understanding and electricity-consuming behaviours. Secondly, a number of additional features and usability improvements were included in the system prototype following exhaustive testing of the system by the team and its early piloting with two participants before the main trial. Thirdly, while most of the participants in the earlier trial were highly numerate university staff, the sample in the current was drawn from a much more representative population. Fourthly, in the collection and analysis of spoken data, emphasis was laid on the dynamics of the relationships of household members and how these influenced use of the system and, more particularly, of energy.

A final difference was that the range of labels available for users to annotate their consumption was extended to include practice labels as well as device labels. This change was designed to allow the investigation of whether householders prefer to disaggregate their consumption of energy in terms of the devices that use it or, alternatively, in terms of the social practices in which these devices play an instrumental part. It could be argued that householders would respond more readily to energy saving discourses if they focussed on activities that are generally perceived as central to the life of the home (e.g. providing food, entertainment, caring for others), rather than devices whose putative purpose is to perform those activities.

This study set out to discover how members of the public use the FigureEnergy system. By so doing it aimed to improve the understanding of how users can be encouraged to engage more actively with feedback and to assess how this affects their understandings, perceptions and behaviours.

2 The FigureEnergy system

FigureEnergy is an on-line system that provides users with two main data screens: 1) a real-time line-graph showing how the consumption of electricity changes over time and 2) a visual representation of the types of usage that comprise the overall consumption. For both screens, users are able to choose the time-frame of the data represented (e.g. current day, previous day, last three days, last five hours).

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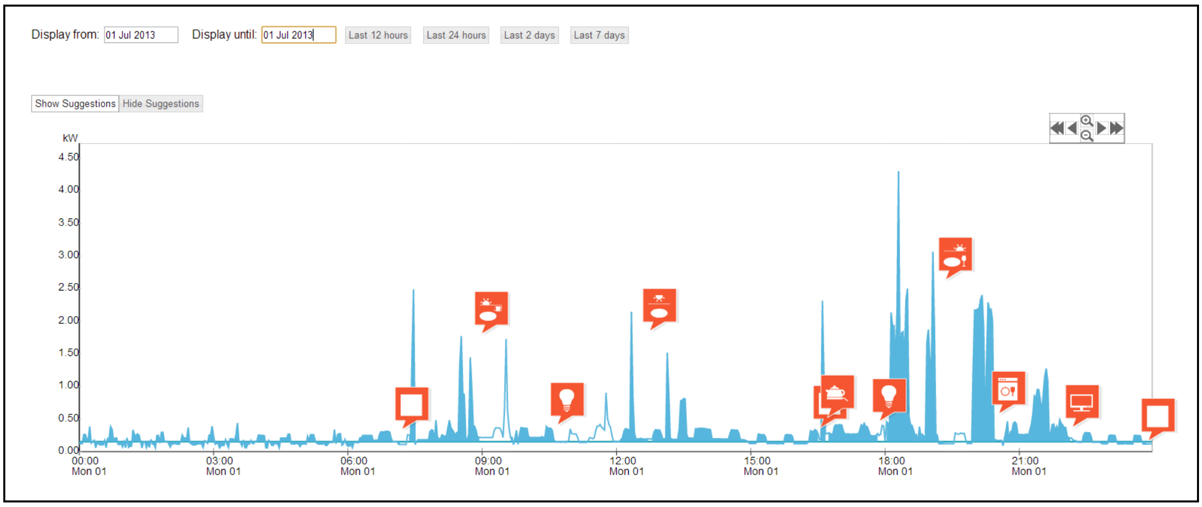
Screen 1: real-time consumption graph

The screen first seen by users when they entered the system is shown in Figure 1. This offered a number of interactive features. As seen at the top of the figure, users were able to set the time-span covered by the graph, with the options of ‘last 12 hours’, ‘last 24 hours’, ‘last 2 days’, ‘last 7 days’ or the period between any two chosen dates. They were also able to navigate backwards or forwards in time using the arrows and to zoom ‘in and out’ (between shorter and longer time-spans) using the plus and minus buttons (see the top right of Figure 1).

Figure 1: Screen 1 – the line graph



As well as displaying the variation in household consumption over time, the screen allowed users to attribute devices or practices to each element of consumption by annotating it with icon from the library provided (Figure 2). To do this, users highlighted a portion of the graph by selecting it with their computer mouse.

Figure 2: labels provided in the system library

Label category	Example label	Examples of other descriptors
Practices	‘breakfast’	‘dinner’, ‘cooking’, ‘DIY’, ‘gardening’, ‘housework’, ‘heating’, ‘watching TV’
Devices	‘television’	‘computer’, ‘dishwasher’, ‘toaster’, ‘lights’, ‘shower’

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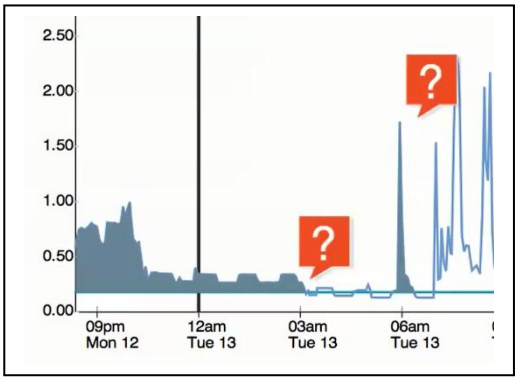
User-defined	'other B'	'other A' (triangle), 'other C' (circle), 'other D' (star)

Each time a label was used by a participant, they were also offered the opportunity to type in a description of that event. Subsequently, hovering over the icon would prompt that description to be displayed.

The functionality of this screen also offered users the opportunity to have the system automatically select portions of consumption that its in-built algorithm suggested might represent electricity-consuming events. As shown in Figure 3, each suggested 'event' was labelled by the system with a question-mark icon; this could be replaced by the user with a label from the library. To disable this function the user would click on the 'hide suggestions' button shown near the top-left of Figure 1 and to re-enable it, click on 'show suggestions'. On each occasion of their entering the system this function would be enabled.

Figure 3: the auto-annotation of household 'events'



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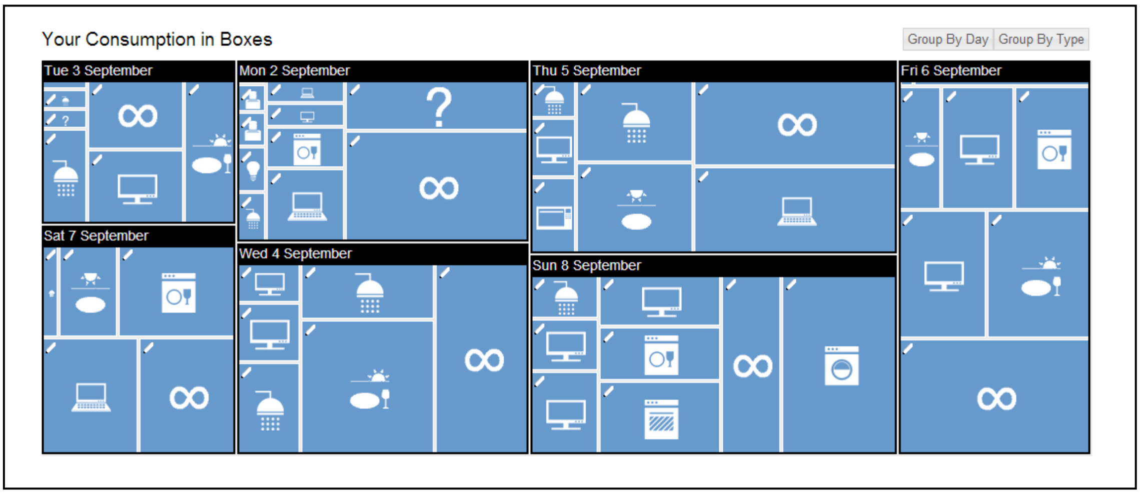
Screen 2: 'consumption in boxes'

The second screen offered by FigureEnergy displayed energy consumption in a number of boxes, where the size of each box represented an amount of Kilowatts. This allowed the user to compare the 'volume' of electricity consumed on different days and by different practices or devices. Figure 4 shows one household's consumption for a one-week period in September.

Figure 4: An example of the display on Screen 2



Each of the larger boxes represents one day and each of the smaller ones, a device or practice. The labels reflect those used and displayed in Screen 1, so the richness of meaning in this screen depended on the degree to which users had labelled their data.

The one label not familiar to users from Screen 1 is '∞'. This was allocated by the system to all consumption that it considered to be 'baseline' or 'always on'. In most cases, this will have consisted of the electricity used by fridges, freezers and devices on stand-by; devices accidentally left on for long periods (e.g. lights in attics or garages; heaters in conservatories) may also have contributed to this calculation. The 'always on' consumption is represented visually in Screen 1 by the unshaded area under the horizontal blue lines (see figures 1 and 3).

Screen 2 had two main interactive features. First, it enabled users to ask the system to reconfigure the display so that the primary organising principle for the boxes was the device/practice rather than the day. This is illustrated in Figure 5, where it can be seen that consumption is now grouped according to the labels rather than by day. This allows users an easy visual means of

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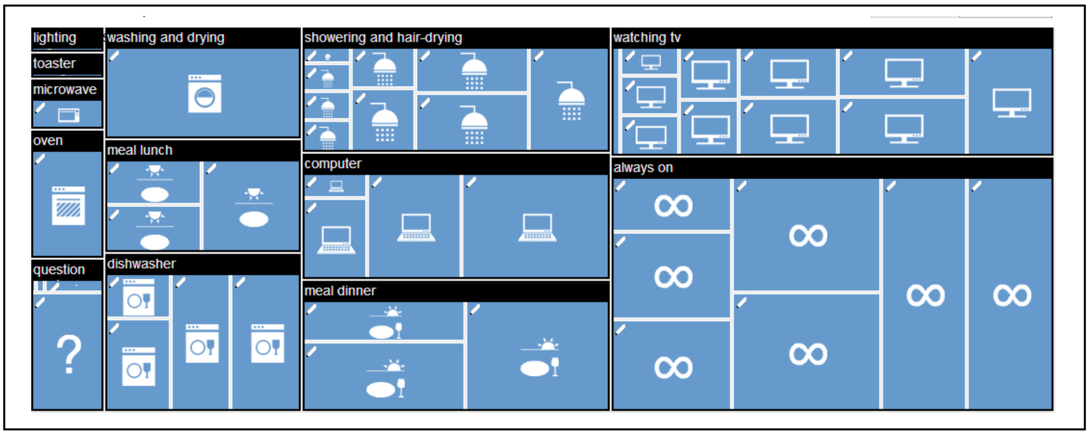
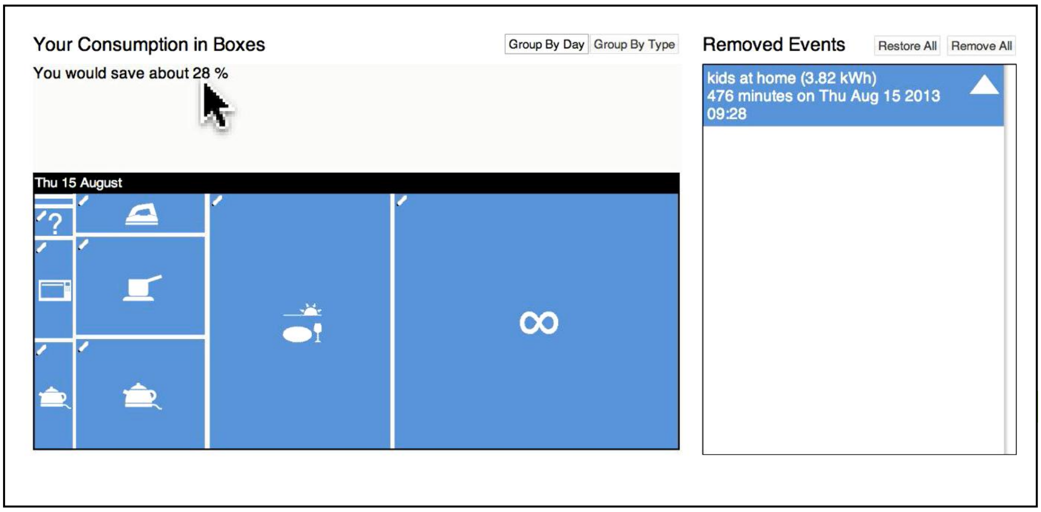
assessing which practices/devices use the most and the least electricity. For example, Figure 5 shows that for the period of time selected the largest share of electricity was consumed by devices that were 'always on' (fridges, devices on stand-by etc.) and the second-largest, by the practice of 'watching TV'.

Figure 5: Consumption grouped by usage type



A second interactive feature was the ability for users to temporarily remove categories of consumption from the central display in order to see what percentage of overall consumption this represented. Figure 6, for example, shows what a user would see if they wanted to find out what proportion of electricity was used during the part of their day when their children were at home (where 'kids at home' was a description given by the user to one of the user defined ('other') labels. As shown in the figure 6, this category was responsible for 28% of the consumption on the day in question. Should she wish to, the user would be able to repeat this exercise for other categories of consumption, by restoring 'kids at home' to the main box and removing, for example, 'dinner', 'hob' or 'always on'.

Figure 6: The removal of categories of consumption



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System Technical Implementation

FigureEnergy relies on off-the-shelf, digital, networked electricity consumption sensors such as AlertMe and Current Cost[1]. A split ferrite ring clamp measures the electric alternating current (AC) that flows through a household's mains cable and an RF (ZigBee) transmitter sends this data to a hub that then transmits it to an Internet server (run by AlertMe or Current Cost) through a home broadband connection. The sensors provide data on real-time power (kW) and a historical record of energy consumed (kWh). Their reading periodicity generally falls in the range of seconds (for real-time view) to minutes (for historical data). Data is retrieved from the AlertMe and Current Cost servers to be processed and stored Data in a MySQL database on a server at the University of Southampton, from where it is presented to the users through a Web interface.

The system was implemented using open source tools and open APIs (Python and the Django web framework for the back-end; HTML 5 and JavaScript with the jQuery, jQueryUI, and d3.js libraries for the frontend). This architecture was chosen to make the system more portable to mobile platforms, for future developments.

3 Aims of the system

The innovative features of the system aimed to achieve a number of objectives. Firstly, by ceding control of the time-frames over which consumption was displayed, it was hoped that the system would encourage users to use time-frames that were more relevant to the structure of their lives, and that this would enable them to better relate electricity use to their own domestic rhythm. For example, it was hoped that they might begin to compare half-term with school-weeks; when they had guests with when the guests had left, or periods when they worked at home with periods when they worked at the office. This, it was anticipated, would increase awareness of the impact of particular activities on overall consumption – e.g. additional use of electronic games during school holidays; use of the electric shower in the guest-room, or use of lighting and computers when working at home.

[1] See http://www.alertme.co.uk and http://www.currentcost.com

Secondly, as suggested in Harries et al (2012), feedback on overall consumption levels may be less effective than the provision of data that has been disaggregated to a more meaningful level such as that of the device. This, it was expected, would lead to more interest in the data and more learning about the specific dimensions of domestic consumption. Furthermore, it was hoped that this effect would be magnified by allowing users to parcel-up consumption in ways that relate more meaningfully to their everyday lives as they experience them.

Finally, Screen 2 was designed to remedy one of the problems associated with the depiction of consumption data along time-lines. It has been noted in the literature (e.g. Tufte, 2001) that users' attention tends to be drawn to the occasions when consumption changes and, in particular, to high-intensity, short-duration events that show up as peaks. These occasions do not, however, necessarily represent the largest proportion of consumption, so an emphasis on peaks can distract users from those practices or devices that offer the greatest potential savings. For example, although the sharp consumption spike produced by using a kettle generally catches the eye (e.g. see Figure 1), the overall proportion of electricity used by kettle-boiling will often be relatively low. In contrast, the less immediately visible consumption of appliances that have ongoing low-level usage (such as fridges and always-on PCs) can sometimes add up to quite high overall levels of consumption. By focussing on proportional consumption rather than changes in consumption, Screen 2 was intended to address this problem. For example, a user viewing the Screen 1 display in Figure 6 might have her eye caught be the visual spike produced by use of the kettle. However, when she viewed Screen 2, her perception of the importance of kettle would be corrected by the relatively small size of the 'kettle' box. (See for example Figure 6).

4 Research Design

In the study reported here, the FigureEnergy system was trialled with twelve members of the public. A pilot study was conducted in two households during August-September 2014 and the main trial (ten households) in October-December 2014. Participants were recruited by a combination of convenience sampling and snowball sampling from the area around Chertsey, Surrey. The sample frame was designed using the principles of purposive sampling, with quotas ensuring a balanced representation across different types of household (single person; couple with children; couple without children). In addition, because the sample in the similar, earlier study by Costanza et al (2012) comprised mostly very numerate participants, an effort was made to avoid

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participants from professions that demanded high levels of numeracy. Also, because we believed that women were likely to be more familiar with domestic practices than men, we aimed to recruit more females than males.

Table 1 – The achieved sample

Household structure			Participant age		Employment				Gender	
Single occup-ant	Adults only	Adult/s & children	35-55	65+	Full-time	Part-time	Retired	Home-maker	Fem-ale	Male
2	5	5	8	4	8[2]	1	2	1	9	3

As an incentive to participate, householders were given £10 at the start of the trial and a further £40 on its successful completion. Participants were told that they would need to use the app at least once a day for 5-10 minutes.

In order to encourage engagement with the system, participants were emailed one simple task for each week of the trial and were asked to provide answers online. In week 1 they were asked what percentage of their consumption they had labelled and which types of consumption used the least, and the most, electricity. In week 2, they were asked, "If you had to reduce your electricity consumption by 10%, how would you do this?" The week 3 question read, "Imagine you had to move 10% of your total weekday electricity consumption to the weekend. What would you change in order to achieve this target?"

All twelve participants were interviewed about their experiences at the end of the trial by members of the research team. These interviews were recorded and transcribed verbatim and the transcripts used to inform the generation of themes for the subsequent analysis.

5 Emerging themes

An in-depth analysis of the data collected through the interviews is still ongoing (two academic papers are in preparation at present). However, we list here a number of themes that emerged during the initial phases of this analysis.

[2] two administration officers workers, two project managers, one social worker, one secretary, one recruiter and one sales manager

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- The representation offered by Screen 1, the real-time consumption graph, appears to attract users' attention more strongly than the 'energy in boxes' display in Screen 2. In particular, participants' comments confirmed our suspicion that the peaks in line-graphs draw attention away from other features. While this finding echoes previous results, it also highlights opportunities for design improvement, as some of the benefits anticipated from the boxes visualization (including an increased awareness of the role of always-on consumption) were not realised.
- The need to annotate events related to domestic energy consumption appeared to increase users' engagement with their data and helped them relate variations in consumption to their day-to-day behaviours.
- Users seemed more willing to attribute elements of their consumption to some household practices and devices than to others. This is perhaps a result of the emotional value of some practices and devices and their importance for self-identity.

  Although participants more often annotated the energy they themselves had used than that used by others, some enjoyed using the system to gain insights into the behaviour of other family members during their own absence.
- Any suggestion of reducing energy consumption seems to provoke the discourse of 'waste' and an attempt to identify consumption that is perceived to result in no additional value to the household or individual. For this sample of householders, the idea of reducing energy consumption did not appear to prompt any consideration of more fundamental curtailment of, or changes to, established practices.
- There was little evidence of the auto-annotation function encouraging people to annotate their consumption or assisting them with the selection of which portions of consumption to label. In fact, this facility seemed only to confuse participants.
- Although participants reported that the system helped them to learn and reflect about their energy consuming behaviour they were unsure whether the changes they had made to their behaviours would endure in the long term.

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6 Conclusion

Unlike many consumer products, electricity is abstract, invisible, intangible and consumed indirectly as a by-product of other practices (Fischer 2008). As a result, people often have low awareness of whether, and how much, energy is being used by their everyday practices (such as laundering or entertainment). This study provides some insights into how greater awareness can be achieved. It suggests, also, that if we are to progress from awareness-raising to behaviour change, we need to understand the meanings and values that are associated with these practices.

Evidence from the interviews conducted for this study suggests that Screen 1 (the line graph) was more successful at achieving these goals than was Screen 2 (the aggregation of consumption into practice- or device-level usage 'boxes'). The main reason for this appears to be the absence, in Screen 2, of any representation of sequential time. By merging items of consumption that had happened at different times, Screen 2 made it harder for users to link their consumption patterns to the social and domestic events of their everyday lives. As a result, the data in this screen remained abstract and relatively uninteresting to some of the participants. Given that Costanza et al (2012) came to a different conclusion using a sample of more numerate and analytical participants, it seems possible that this screen offers an approach more suitable to such people. In this study, in contrast, the retention of the time dimension in the line-graphs (screen 1) allowed users to interpret elements of this data in a way that connected it to their lived social lives: i.e. what they and other household members had been doing at particular points in time. It was this, the interviews suggest, that most engaged some people with data on their electricity consumption.

However, the desire to attribute consumption to lived events also reduces the effectiveness of the line graphs at generating a balanced awareness of consumption patterns. When looking at the graphs, users' attention is drawn primarily to the spikes (which represent relatively large but short-lived increases in consumption). Such consumption is easy to interpret because it can be associated with particular moments in time. More diffuse consumption events are harder to relate to particular domestic occasions or activities and, as

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a result, were more often overlooked in this study than they were in that by Costanza et al (2012).

Engagement with feedback data also seems to be influenced by the social meanings attributed to different practices. Willingness to consider reducing the consumption of any particular practice appeared to depend on the association of that practice with the notion of 'waste', where 'waste' is understood as the use of a resource for no perceived benefit. However, there was evidence that participants were reluctant to consider applying this notion to practices that supported central elements of their social identity. One example of this was the practice of looking after pet fish (including the heating and lighting of fish tanks), which appeared, for one participant, to be central to his concept of self; another was personal grooming (including the use of hair-driers). With its implicit emphasis on the material, 'waste' did not appear to be considered an appropriate concept for practices of such emotional import. Once again, this points to a difference from Costanza et al's cohort, for a cursory comparison of the two sets of interviews suggests that the participants in the current study were more likely to frame electricity consumption with issues of meaning, identity and relationship.

If correct, this analysis presents a dilemma to those trying to employ feedback to foster behaviour change. When users engage with it, feedback that is abstracted from the patterns of daily life provides a more balanced awareness of consumption and which practices and devices it is associated with. However, a comparison of this study with that by Costanza et al (2012) suggests that less numerically analytical users are unlikely to engage with such feedback because they are unable to link it to emotionally vivid aspects of life such as identity and family relationships.

Not only that, but when users do make the link between consumption and daily life, there is a risk that this will prevent them from wanting to apply a material rationality to some of the practices involved. One way of resolving this tension might be to reduce the emotional content of the messages carried by feedback so that users are more able to apply material rationality to them. This might be achieved, for example, by emphasising the distinction between the two aspects of economy, doing things more efficiently and doing things less often (or not at

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all), and somehow making it clear that the emotional value of a practice need not be threatened by the idea of greater resource efficiency.

This study aimed to complement earlier work by working with a sample of participants who did not have a particular orientation to numerical thinking or material rationality. Its results highlight the difficulties involved in asking such people to apply a frame of material economy to a space that, for many, is essentially social: the home.

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