Exploring Mental Representations of Home Energy Practices and Habitual Energy Consumption

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ABSTRACT

Domestic energy consumption is the product of many different behaviours and decisions made by householders. Current energy interventions, such as smart meters, do not account for such variation and do not consider how householders themselves understand the systems that use energy within their homes. We present two studies which seek to address this issue. Study 1 explored mental representations of domestic energy use through categorisation. Study 2 presents survey data collected as part of a larger interdisciplinary project which reveal that a range of energy consumptive behaviours are indeed influenced by habits and other psychological constructs to different extents. The combined findings have implications for the design of energy reduction interventions and energy policies.

Introduction

Domestic energy consumption is the end result of a large range of actions, inactions decision-chains, many of which happen unconsciously. This means householders can consume energy without being aware they are doing so. Current domestic energy interventions such as smart meters with in-home displays often fail to take this into account. Instead, they work on the tacit assumption that the key barrier to energy-saving is a lack of information about the overall amount of energy being consumed in the home. They do not account for whether householders understand the units in which this information is presented, and nor do they take into account householders' understandings of where energy is used in their homes and how behaviours might be changed to save energy.

Here we present two studies which use psychological approaches to explore householders' understanding of energy consumption, using clustering techniques to reveal shared patterns in the way that people think about domestic energy consumption and how their behaviours are influenced. Such information about how people understand energy consumption will be essential if in-home displays are effectively to communicate information to end-users. Given that many of the behaviours energy consuming around the home are repeated frequently, long term curtailment of these behaviours is likely to lead to large energy savings. It is therefore important that behavioural interventions are as effective as possible.

The work presented below is part of a larger, ongoing interdisciplinary project (ENLITEN[1]). The overarching aim of the project is to develop an intelligent, interactive, in-home advice system to facilitate domestic energy savings. ENLITEN is currently monitoring energy consumption and environmental conditions in approximately 70 social housing properties. The householders are simultaneously invited to take part in surveys and interviews, to provide information on the range

[1]ENergy LIteracy Through an Intelligent Home ENergy Advisor (ENLITEN). www.cs.bath.ac.uk/enliten
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of social and psychological factors that are related to energy use.

Study One: Exploring How Householders Understand Energy Use

An energy intervention is much more likely to be accepted if it considers how the public understand energy use. This need to allow for recipients' pre-existing ideas has been demonstrated in many fields from risk communication and strategic management to usability [7, 12, 20]. A person's perception of how a system operates is often referred to as a 'mental model' [19]. Our task here was to begin to reveal the structure of domestic energy consumption mental models in the UK public.

Different conceptualizations of mental models exist within the literature, each endorsing different methodology to access the content of such models (for a detailed comparison of the different conceptualizations of mental models see [23]). For the purposes of the current study the definition of a mental model is operationalized generally as an internal, mental representation of external phenomena. People use mental models to explain to themselves, and to predict, observable outcomes from a system. For example, a person using a car might have a mental model of what happens within the engine. Their mental model might come from what others have told them or simply from experimentation with the controls – and in both cases their mental model might or might not be accurate.

One method for revealing internal representations of systems and concepts is the card sorting technique. The technique is based on the principle that individuals use categorization to make sense of the world around them because treating every object or concept encountered as a unique example would require a large amount of cognitive resources [27]. The task requires the participant to categorize items or concepts by their relative similarity and thus reveals the structures of mental models by providing an indication of the extent to which people perceive similarities and differences between items [24]. The methodology has long been employed in psychological research [11] and more recently in the field of usability, particularly in the design of websites [2].

Overview of Method

A card sorting task was completed by fifty seven participants (32 female, 25 male, Mean Age= 41.63, SD=23.10). Participants arranged a set of cards each displaying the name of 'something that uses energy around the home' into discreet piles depending on how they felt the cards naturally 'went together'. Each pile could be any size larger than a single item. Participants then gave each pile they created a name to describe its contents and why they belong together. The piles of items were analysed in the statistical package R [22], using hierarchical cluster analysis with Ward's method (using squared Euclidean distances) to group the piles that contained similar appliances. Ward's method tends to avoid very small clusters (as these are unlikely to reveal general patterns) and allows the differences between clusters to be maximized. The resulting clusters were described and labelled by examining the names that participants gave to the piles within each cluster.

Results and Discussion

Participants generated three relatively consistent clusters of household appliance-groupings, as shown in Figure 1. These clusters therefore represent shared ideas about which household

appliances can be classified together or separately.

Cluster 1 primarily contained piles of cards naming electronic items such as television and computer games console and was most commonly labelled ‘leisure’ or ‘entertainment’. Cluster 2 was made up of piles of cards naming items used for the storage and preparation of food, and was most frequently labelled ‘Kitchen’. These two clusters were the most distinct clusters revealed in the analysis, which suggests that these groupings are more consistent across participants, that is, people largely agreed that the items in each of these clusters were quite similar to one another *and* distinct from the items in other clusters. Cluster 3 had no consistent description and the piles of items within the cluster showed no clear patterns. This set of card-piles was therefore termed ‘everything else’. The relatively large size of this cluster means there is a substantial disagreement amongst people about how most appliances can be grouped together, which in turn means that people show little consistency in their mental models of these appliances. This is in contrast to the leisure and cooking appliances, which most people agreed ‘fitted together’ similarly.

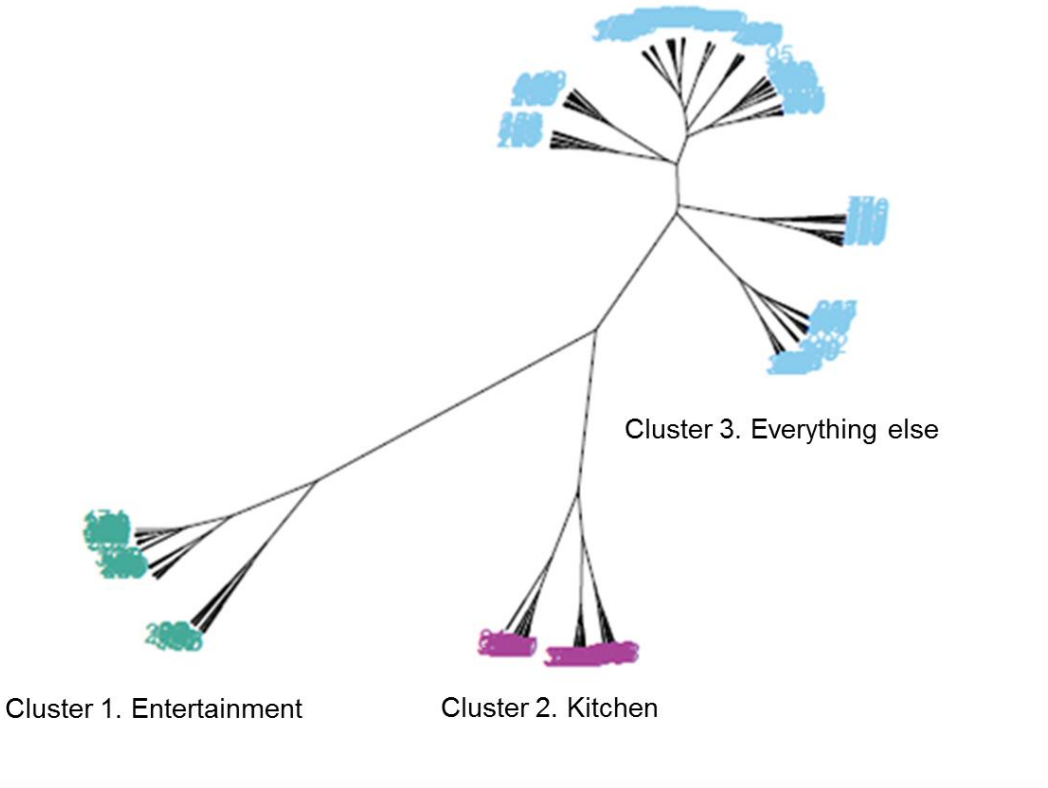

Figure 1. Phylogenetic tree representing the squared Euclidean distances revealed using Ward’s method for piles made during the card sorting task.

What is *not* revealed during such an analysis can also give us insight into the public’s mental models surrounding energy use. The fact that large numbers of very distinct clusters were not revealed suggests that the public do not hold consistent mental representations of which household appliances show commonalities – had most participants agreed that heating systems and refrigerators belonged together whilst not belonging with all the other appliances, for example, our method would have revealed this as a distinct cluster. This interpretation, which

sees people as having ill-formed taxonomies of appliances, fits nicely with earlier research demonstrating that householders do not understand domestic energy consumption very well [4, 9, 13]. One concept that is frequently commented upon in the energy literature is the notion that energy is 'doubly invisible' [10] in that energy is arguably abstract in nature, and as a commodity we do not witness it entering our homes. In addition, its consumption is tied up 'inconspicuously' in our everyday routines [e.g. 26]. Indeed, evidence suggests that energy is consumed with little awareness of the quantity or is impact on the environment [e.g. 30].

Where there were consistent clusters in our data, the descriptions people appliance-groupings clearly indicate that people understand domestic energy use in terms of practices (i.e., leisure, & cooking). These findings to some extent draw parallels with social practice theory e.g. [26] however, the current study for the first time directly suggests that people think about energy-consuming appliances within their homes in this way. Although people could have instead classified appliances into, say, high and low energy consumption, or essential and non-essential, in most cases they chose not to do this and instead classified them according to the tasks for which they were used. Given such clustering, one might expect other types of energy relevant social practices to be revealed by the analysis, for example laundering or comfort (e.g. thermal comfort). Indeed one might expect most people to agree that washing machines and tumble dryers belonged together and do not belong with other appliances. However, this was not the case in the present study. Taken together, these interpretations might suggest something important about how people conceive of the appliances in their home, and might be important for how information about behaviour-change is communicated.

Study 2: Influences of Domestic Energy Behaviour

As previously mentioned, the concept that energy is an invisible commodity has been repeatedly acknowledged. This idea has led to a large effort to make energy use more visible via feedback, which has been employed with varying success [13]. However, there is growing consensus that presenting information alone is not sufficient to promote significant, long-lasting reductions e.g. [5, 15, 17].

As domestic energy consumption is the result of interactions between a range of different actions, inactions, complex decisions and unconscious responses, simply presenting information about the end product of all of these processes gives the receiver little understanding about which behaviours contributed significantly to their total energy consumption. Even when detailed information is given, it is likely that the actions and decisions that contribute to energy consumption are influenced by a range of different factors and will therefore require different intervention strategies. Steg and Vlek [28] advocate that intervention strategies for behaviours with environmental implications, such as energy use, should consider potential causal influences of behaviours and target the most influential determinants. The present study aims to explore the relative influences of psychological factors on a range of different energy-relevant behaviours. Energy consumption behaviours were studied at the level of individual actions associated with a number of the items that consumed energy implemented in Study 1.

Potential influences on consumption were chosen from well-established theory ([e.g. Theory of Planned Behaviour 1]) to reflect distinct psychological constructs which have been shown to influence a wide range of behaviours [3], including those associated with resource consumption and behaviours with environmental consequences (e.g. [6, 18, 29]). The constructs chosen were attitudes, social norms, perceived behavioural control and habits, and were measured via a

household survey.

Habit, as operationalized by our research group, is where, as a result of past learning, a specific context or cue triggers a behaviour relatively unconsciously [32]. Given that many of the energy consuming actions which make up domestic practices take place frequently within stable contexts (within the home) in response to specific cues (e.g., having just woken up) it is likely that a significant proportion of energy consumption results from habitual behaviours. Habits, and more volitional variables such as attitudes and agency, have been shown to have separate influences over domestic resource consumption [16]. Habits are also a barrier between intention and action, and this can interfere with the process of people changing their behaviour in response to new information [31] – the information changes their attitudes but not their behaviours, which are instead triggered by context [33]. Therefore interventions strategies which rely on information provision alone are not appropriate for reducing energy consumption sources with strong associated habits.

As we argue that energy consumption is not the result a single behaviour, or even a set of homogeneous behaviours, investigating the relative influences of a range of behaviours which consume energy should allow intervention designers to assess which intervention may be most successful for a particular behaviour and vice versa. This study assessed, for a range of energy consumptive behaviours, various attitudinal and habit measures. The behaviours were then clustered on their mean responses to these measures to reveal groups of behaviours that are similar in terms of their psychological and behavioural antecedents, and which therefore are likely to response similarly to interventions. Although this study, like Study 1, used cluster analysis to interpret the data, it is important to note that in this case it was behaviours that were being grouped together based on their similarity, not piles of cards as in the first study.

Overview of Method

A survey was completed by 45 householders (30 female, 15 male, Mean Age= 51.7, SD=15.4) all of whom are taking part in the ongoing sensor monitoring study ENLITEN. The survey was structured in such a manner that respondents answered the same set of questions for a range of energy consuming behaviours. Some of the items from Study 1 were changed into behaviours by adding the prefix ‘using’ (for example, ‘kettle’ became ‘using the kettle’). The selection was chosen to represent the most commonly found within the homes of the respondents and participants only answered questions about items they owned.

Each psychological variable was presented in the form of a statement and responses were measured on a 5-point Likert scale which ranged from 1 “Strongly Disagree” to 5 “Strongly Agree” unless otherwise indicated. Habits were measured by an abbreviated version of the self-reported habit index ([SHRI; 32]). This consists of 6 items that capture various aspects of habit including frequency, automaticity, self-identity and routine. Perceived behavioural control was measured by the statement “It’s up to me when and how I use *(item X)”*. Similarly, injunctive social norms were measured by the statement “Most people would say I should use *(item X)* less”. Descriptive norms were measured by the statement “Compared to you, how often do you think other people use *(item X)*?” and participants chose a response from 1 “Much less often than me” to 5 “Much more often than me”. Finally, four attitudes towards each behaviour were measured on a 5 point semantic differential scale. The attitudes were measured by asking participants to place the behaviour on scales ranging from pleasant to unpleasant, enjoyable to unenjoyable, useful to useless and necessary to unnecessary, with higher scores indicating

more positive responses.

The mean response was calculated on each of these measures for each behaviour and the behaviours were then clustered to assess their similarities across these measures. As in Study 1 we used hierarchical cluster analysis (with Ward's method using squared Euclidean distances) to avoid small clusters and maximise the differences between clusters. Once these clusters of behaviours were known, the mean responses to the survey variables for each cluster were plotted to illustrate how clusters differed from one another on the measures that went into their creation. This approach is novel in the way that the energy-consumptive behaviours, rather than participants, were the cases, thus allowing us to identify behaviours that showed similar psychological profiles across people.

Results and Discussion

The analysis revealed seven relatively distinct clusters, which are displayed in Figure 2. The behaviours that were clustered together can be seen in Table 1 and the mean response to each variable was plotted for each cluster and can be found in Figure 3. Examination of figure 3 shows that, in general, the clusters differed primarily on attitudes towards the behaviours and scores on the SRHI. These differences are described below.

The mean SRHI score across the behaviours in Cluster 1 was relatively high, suggesting that they are associated with fairly strong habits. The behaviours were not rated as particularly pleasant or enjoyable, but they were mostly considered useful and necessary by participants. This suggests that using the items in cluster 1 (see Table 1) are used as part of household routines and perhaps considered chores.

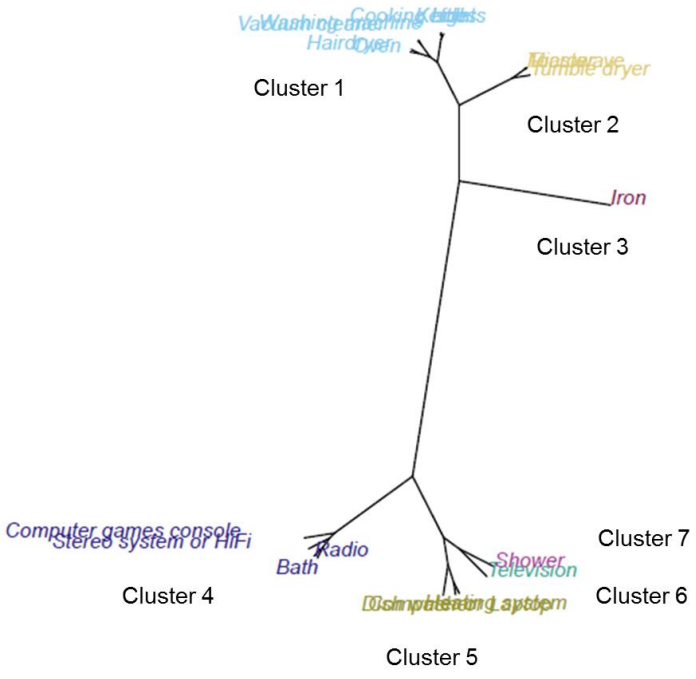

Figure 2. Phylogenetic tree representing the squared Euclidean distances revealed using ward's method for the survey data.

Table 1. The appliances associated with the behaviours within each of the resulting seven clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Kettle Lights Washing machine Hairstyling appliance Oven Vacuum cleaner Cooking hobs	Microwave Toaster Tumble dryer	Iron	Computer games console Stereo system or HiFi Radio Bath	Computer/ Laptop Heating system Dish washer	Television	Shower

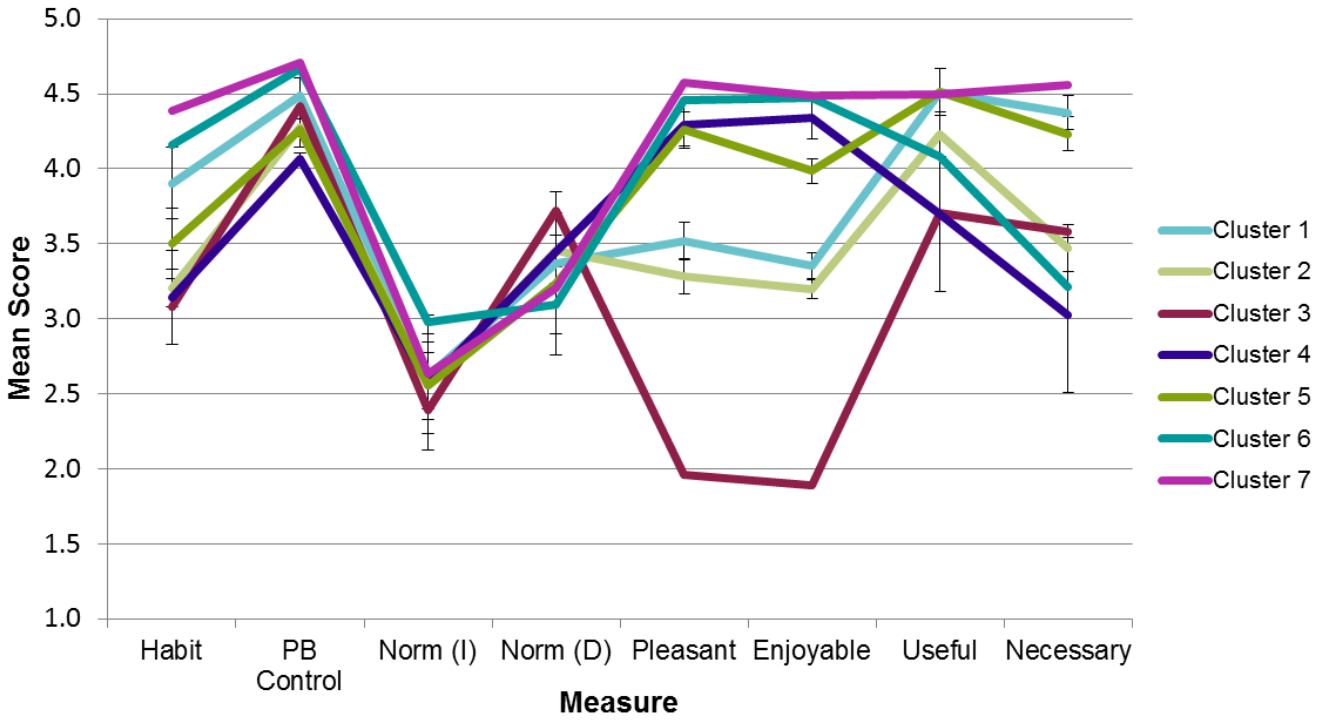

Figure 3. The mean response to the survey variables for each of the seven clusters

Cluster 2 was amongst the lowest-scoring clusters on the SRHI, and received lower positive attitude ratings than cluster 1, with the exception of the useful-useless differential scale. The behaviours were not considered particularly pleasant, enjoyable or necessary; however, they were rated fairly useful.

Cluster 3 consisted of ironing only, which was found to be largely non-habitual on the SHRI. Ironing was given the lowest scores on all attitude measure with the exception of the necessary-

unnecessary distinction, on which scores were higher than the midpoint suggesting it is considered fairly necessary.

Cluster 4 was also associated with lower SRHI scores indicating lower habits. The behaviours were rated positively, with high scores for the pleasant and enjoyable scales and fairly high scores on the usefulness distinction. The behaviours within this cluster scored fairly low on the necessary distinction, suggesting that these behaviours are considered non-essential luxuries.

Cluster 5 was rated positively on all attitudinal measures and was considered most useful. The behaviours within this cluster scored fairly low on the SRHI indicating low associated habits.

Cluster 6 consisted of television use only and was also associated with high SRHI scores. Television use was rated as highly pleasant, enjoyable and fairly useful but much less necessary. Again the strong associated habits suggest that television use is a highly routinized behaviour but people feel stronger positive affect towards it.

Cluster 7 consisted of showering only and followed a very similar pattern of responses to television use, in that it was rated as highly habitual, pleasant and enjoyable, and fairly useful. Showering was rated as highly necessary which made it distinct from television use.

Considering the scores on the SHRI, it appears that the behaviours in Clusters 1, 6 and 7 are likely to be most resistant to traditional interventions. The higher associated habit scores suggest that these items are used frequently and with minimal conscious awareness, making volitional effort less effective. Similarly, the behaviours in clusters 2, 3, and 4 are likely to be less resistant to interventions that require conscious behaviour change. In particular, use of the items in clusters 2 and 3, which were rated fairly negatively. It would be tempting to conclude that efforts to reduce energy consumption should concentrate on these behaviours. However, given that some of the more intensive energy-consuming items fall into clusters 1 and 6 (e.g., showering and oven use), it is also worth perusing these behaviours. The results of the current study suggest the way in which these behaviours are targeted should, however, should go beyond motivation and information provision strategies

Scores on the perceived behavioural control measure were high for all clusters. Superficially, this looks promising as the householders seem to feel they have a high degree of control over their own domestic energy use. However, alternative explanations for the lack of variation may be explained by defensive processing. The wording of the statement “it’s up to me/us when and how we use…”, although taken from previous research studies, may have produced reactance [8] in our sample – who are tenants of council owned properties, and who are likely to have more external involvement in their domestic issues that homeowners and perhaps even private tenants.

Similarly, there was little variation in social norms across the clusters. Scores on the measures indicated that people believe that peers approve of using the items in question and that respondent believe they interact with the items as often as other people. This could be seen as evidence of the false consensus effect [25], and suggests that the householders believe their behaviour to be in keeping with social norm, which has implications for social comparison interventions.

General Discussion

The two studies presented here provide some insight into people's understandings of energy use and their associated behaviours. The mental models revealed during Study 1 could provide a useful frame for intervention designers who may choose to present information of about personal energy consumption and strategies for energy-use reduction in terms of these shared categories. Presenting smart meter feedback to householders in a way that is congruent with their mental models, i.e. in terms of entertainment or cooking, may help householders to better internalize the feedback and become more aware of their own energy use in a meaningful way rather than presenting them with abstract feedback about the amount of energy consumed or money spent. On the other hand, Study 1 also suggests that mental appliance categories other than these two are much less likely to be shared across people, and that therefore it might be necessary for feedback on other appliance behaviours to be based around individual high-consumption appliances, or on groups of appliances that are seen as common by each individual householder. This latter approach would require the in-home display to learn about each householder's mental representations of their appliances – a form of tailoring we are currently exploring in the ENLITEN project.

Study 2 supports the argument that different domestic energy relevant behaviours may require different intervention strategies. For example, behaviour such as having a bath, which is highly pleasurable and non-habitual, would require a different intervention to using the washing machine, which is not particularly enjoyed but which is nevertheless repeatedly performed because it tends to be automatically cued by context.

As habit theory research has shown, many consumption behaviours are enacted without deliberation and may be very difficult to change though such a means as social comparison alone. Indeed, existing interventions may benefit from additional strategies which target individual behaviours based on their most influential determinants. For example social comparison could be used to increase motivation to change behaviours in clusters 1, 6 & 7 in combination with strategies known to be more effective for habits [34]. Moreover, a growing body of work on the importance of life-course transitions suggests that the time at which people are given information is not always equal. In line with habit theory, information is most likely to influence behaviour at a time when context, and thereby habit, is disrupted [14, 21, 35].

The studies presented open up valuable avenues of further research, many of which are being considered as part of the ENLITEN project. For example, actual energy consumption data collected during the project may give insight into the behaviours and practices that might offer the highest energy savings based on their consumption combined with their resilience to traditional interventions. Furthermore, the recommendations for intervention strategies offered in the current paper will need to be tested and evaluated in a systematic manner before concrete guidelines on the best practice interventions can be made.

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