SITUATION AWARENESS AND HOME ENERGY REDUCTION: A STUDY

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Abstract

Reducing home energy consumption is a complex activity involving commitment, planning, monitoring and revision. In other domains (aviation, emergency response), feedback devices supporting similarly complex activities have been shown to have multiple points of failure (Endsley 1995). Importantly for our academic-industrial-local government collaboration on the ENLITEN project, the identification of those failure points has been used as the basis for extending the support provided to the users of complex feedback systems. In this paper we examine the applicability (or otherwise) of literature describing situation awareness failure to home energy.

We report on a focus group set up to consider domestic energy reduction from the perspective of the situation awareness (SA) literature. The participants in that focus group reported multiple under-researched SA failures that impede their ability to reduce domestic consumption. We also report on the mitigation strategies that they employ/envisage when working around those failures.

The paper draws upon a multi-disciplinary research base (SA, human-computer interaction, design science), investigates failures in home energy reduction and proposes amendments to home energy feedback devices as a result. It contributes to discussions of home energy reduction and its impact on consumers economic, health and sustainability concerns.

Keywords: Situation Awareness, Home Energy Reduction, Feedback, Design.

1 INTRODUCTION

Managing home energy usage is a complex, dynamic activity. Whilst managing their home energy consumption, people balance multiple benefits (e.g. comfort, entertainment, social contact) with multiple costs (energy usage, financial outlay, time and effort) [10]. The decision made around these costs and benefits can vary from household to household and from situation to situation [11]. A growing body of literature highlights the importance of user awareness of both costs and benefits, with many different forms of information and feedback proposed in support of this awareness and decision making e.g. real time smart meters, ambient energy displays and mobile energy feedback [2, 6, 9]. Investigations of these different forms of feedback show the effect on long term energy use to be mixed. Whilst some studies report reductions in home energy usage when new energy consumption feedback is provided [1], others report that these effects are less pronounced in the longer term [3, 4, 5].

The causes of these disappointing results are, however, less well studied than the final outcomes; as reported above, research shows that long-term user engagement with novel feedback devices has been lower than expected and long-term reductions in home energy usage have been hard to achieve. Importantly, whilst existing research reports on these results, less is known about the causal factors that bring them about. We do not, for example know whether the information provided is hard to access, hard to understand, hard to use as a means to assess progress towards one or more goals, not particularly relevant to the particular blend of energy and other goals being pursued in peoples homes or deficient in some other characteristic that would otherwise encourage user engagement.

One starting point in the development of a greater understanding in this area is to focus on the awareness that home energy users feel that they need when making decisions about home energy usage. More specifically, a situation awareness focused approach causes us to focus on the problems surrounding perception of energy related information, interpretation ('comprehension') of that information and the assessment of its likely impact in the future ('projection'). This approach complements developing research and practice in home energy, which focuses on increasing user engagement with home energy reduction and

delegating some home energy decisions to automated systems [8].

The advantage of this situation awareness focused approach is that a great deal of research exists in other domains (e.g. aviation, medicine and military operations), which describes potential barriers to the construction of awareness during complex, dynamic management activities [3]. Importantly, that research also highlights areas in which a deeper understanding of situation awareness failures has been used as a basis for enhancing user interaction (e.g. developing principled extensions to existing feedback and information displays). In their widely applied description of situation awareness, for example, Endsley et al. [3] propose that the construction of awareness depends upon (and can therefore fail during)

- The perception of relevant information sources
- The comprehension of the (potentially dynamic) indicators/data perceived.
- The projection of likely effects and outcomes in the future.

If (as we expect) parallel problems are observed in the complex, dynamic management activity surrounding home energy usage, existing situation awareness literature can be used both as a starting point for the development of causal models describing the difficulties surrounding existing and novel home energy displays and as a source of inspiration for the extension of those displays.

To this point, however, prominent situation awareness models have not been widely applied to the home energy domain. We do not know for each of the point systems introduced above，whether the home energy users' failure to maintain reductions in their energy use over the longer term is influenced by breakdowns in situation awareness entirely, to some degree or not at all. More specifically, we don't know whether or to what extent reports of low energy reduction in response to novel feedback mechanisms can be attributed to difficulty perceiving crucial information on the those displays, difficulty comprehending that information once perceived and/or difficulty understanding the long term implications of that information (e.g. long term impacts on health and/or financial cost).

With this in mind, the remainder of this paper reports on an initial study investigating the extent to which home energy users report situation awareness as a factor impeding the decision-making and activity inherent in home energy management.

In developing this study, we noted that (situation) awareness models developed in other domains might not be applicable to home energy. As a consequence, we understood that our initial study might not encourage further application of the models developed by Endsley [3] in the home energy domain. More specifically, we understood that the categorisation of failure proposed by those models may not be useful when considering barriers to home energy decision making and that the interaction designs developed in response to those categorizations might not provide us with useful starting points when enhancing and extending existing home energy interactions.

The parallels with between the complex, dynamic decision-making in the home energy domain and the complex, dynamic decision-making reported in the situation awareness literature did, however, cause us to ask whether established situation awareness models provided useful starting points for understanding satisfactory/unsatisfactory decision-making in the home energy domain.

2 FOCUS GROUP STUDY

With this high-level question in mind, we conducted a focus group in which we asked participants to discuss:

- The parts of their daily activity that they understood to have impact on domestic energy usage.
- The situation awareness and decision making inherent in that activity.
- Areas in which they believed that situation awareness and decision making to be difficult or insufficiently supported.
- Ways in which they believed that changes to the feedback they received from home energy systems and elsewhere might enhance their awareness, improve decision-making and/or mitigate the problems reported.

During the development of that focus group, we recruited 7 volunteers (6 male, 1 female), living in south west of England. The participants all rented their homes, used gas heating in the winter and were responsible for paying the domestic energy bill associated with that heating. The mean number of bedrooms in

participant homes was 3 (sd = 1.15) and the mean number of occupants in each home was 2.86 (sd = 0.90). Table 1 summarizes this information.

The study was hosted by 3 researchers in a meeting room, and lasted for about 80 minutes. The focus group interview was recorded using a camcorder placed in the room corner.

We also guided the discussions with following questions:

1. What do you do to manage your home energy usage?
2. Why do you do them?
3. How does that relate to the information or products that are around the house?

Table 1. Participants of Focus Group Study

	Bedroom Number	Occupants Number	Heating Type	Energy Bill	Other
P1	4	2	Gas	Yes	Own
P2	2	2	Gas	Yes	Rent
P3	3	3	Gas	Yes	With parents
P4	4	4	Gas	No	Rent
P5	4	4	Gas	Yes	Rent
P6	1	2	Electric	Yes	Rent
P7	3	3	Gas	Yes	Rent

3 RESULTS

Encouragingly for our interest in situation awareness, participants did report issues surrounding perception, comprehension and projection during the focus group.

3.1 Perception

When discussing the difficulties encountered in obtaining the information needed to manage their heating systems, for example, participants reported that managing the radiator and lighting in different rooms was difficult, and they often forget to turn the radiator off and kept heating empty rooms.

P1: I've got such a big house when I'm doing the heating, I can't remember what rooms I left the radiators on. For example, if we've had guests, obviously I'll turn on the radiators in some of the other bedrooms, then you don't have the heating on maybe for a day or two, and then when you put it on I forget.

Just this weekend I realized that the radiator was on in the guest room and we'd obviously just been heating that room for no reason, so that annoyed me quite a lot really. It's one of those things where you don't remember that it's on, or if you put on a light or something in a room and just close the door without thinking about it.

You want the rooms you're in the most to be warm, not the hall, you don't care if the hall is 21˚. Now you have to go on to this crappy little dial (of the thermostat) and to do the timer you have to.

P5: I left it like that (heating on) for an hour and then I remembered to turn it off, but then once I forgot to turn it off and about a day and a half later I thought, oh shit.

Similar problems also exist when the energy meters.

P4: I put £50 on and I forgot, and it's because it (the electric meter) 's bleeping in the hallway below, I don't hear when it's bleeping.

P1: I found that you just put it (smart meter) on and in the first couple of weeks, you look at it quite a lot and then after that it doesn't really.

3.2 Comprehension

Understanding ('comprehending') the information provided was also reported as a recurring issue. More specifically, participants reported finding it difficult to construct awareness of their energy consumption when using energy devices and meters, (e.g. thermostats and smart meters).

Much of the participant discussion, for example, focused on the fact that the units reported on those devices (e.g. kilowatts per hour), were difficult to understand. Alternatives were proposed that would portray the impact of energy usage rather than the raw usage itself:

P1: They've (smart meter) got the kilowatt-hours but I can't work it out really.

P4: What we want really is some link between the numbers on the device and how much money it costs you, about energy as we see it. So a clear idea the tumble dryer took so much and if you use it…that would definitely help.

P5: when you turn the kettle on or something units / kilowatts hours, it means very little to me, it's like how much does that cost? That's kind of what I want to know from the bill, s o many kilowatt hours it's like, what is that?

It might be nice just to see what your electricity so far today has cost you and you can see that going up rather than this number.

It should be noted, however, that one counter-example was reported. Whilst most participants found it difficult to translate from energy units to those that more directly interested them, one

participant suggested that he could link the number and the energy effectively.

P7: I think showing the number is a very effective way to regulate humans' behaviour, because one of the functionalities in my mobile phone shows the battery life and there's an option to numerate what's left in the battery. ...so I think a smart meter also was the same feeling for me. So it's, oh now this is a higher number than is usual and then I'm trying to find how I can do it to save me some cost for energy.

That counter example notwithstanding, participants also reported other impediments to understanding their energy consumption. Two participants, for example reported confusion around the relationship between overall energy consumption and the amount of electricity consumed by individual devices (a question noted in other research [7]):

P2: You never really know precisely how much something is using, it's just a box that you plug in and some boxes cost a lot and some boxes don't, and if you don't know that difference, then you just treat them all the same.

P5: But because they're all plugged into the same things, they all look kind of the same. So it's like, if I turn that off, and that's the same as leaving that one on or whatever.

Understanding the information provided by thermostats and thermostatic displays was also noted as difficult:

P1: it's (the thermostat) not on the right time and I can't work out what timescale it's on, because you can change it. It's not 24 hours below or behind, the time is not right. So I just do on and off.

3.3 Projection

As it was difficult to understand the energy consumption of different devices and settings, it was also difficult to tell how different activities by human could affect the energy consumption.

P1: when I had mine (smart meter) on the side, I found that after the first couple of weeks there was nothing else that I could really do.

P3: There's no real way at the moment to judge whether or not what you're doing is good, right or whatever I suppose.

P4: I suppose you don't really know what you save by flicking things on and off so it's hard to say I'm saving… I have no idea what it saves in terms of money.

However, if the link between the number and energy consumption budget could be built effectively, it is also possible to take actions.

P7: I set up some budget to pay for my energy consumption and I know some numbers with regard to that budget. So if there's some high number, then there's something wrong, I can guess and in that case, I'm trying to check some devices and things like that.

Understanding the implications of settings on individual devices was also described as a challenge. For example, the eco setting on the washing machine:

P2: Eco setting on my washing machine. Again I don't know the difference that it makes in terms of cost and efficiency and stuff, but it's eco so I press it because it's probably better than not eco.

3.4 Suggestions from Participants

In the focus group study participants also gave suggestions of the future domestic energy system based on the issues mentioned and their requirements.

Energy Consumption Baseline

Another most common requirement is the energy consumption baseline. Most participants showed strong willing to have the history energy consumption data (e.g. day, week, month or year) from smart meters or energy bills. Thus they can use it as a baseline for control the energy consumption in a normal range by monitoring the unusual energy consumption.

P2: I just want to know is it pretty much the normal amount that you pay. ...I'd want to know if I'm going to get a big bill, a normal bill, or a small bill at the end of the month.

P3: I'd want historical data because if you look at today, what was yesterday like and what was the previous week like.

P6: A baseline would be nice, a baseline compared to other similar flats or houses, that would be quite helpful, or if you could enter your own baseline, the average, which would help.

Easier Monitoring and Diagnose

The requirement of monitoring and diagnose the energy devices and settings in real time was mentioned by a participant who owns a big house:

P1: you want the rooms you're in the most to be warm, not the hall, you don't care if the hall is 21˚. Now you have to go on to this crappy little

dial and to do the timer you have to, you get like a thing to do it.

…it's telling you where there's unnecessary use. Because my house is so big so when I'd turn it on, I'd want to check that all the radiators are off or on. In an ideal world, I would like to have something that can tell you, in the fourth bedroom the window is open and the radiator is on, do something about.

…it's alright telling you that your electricity is high this month but it's identifying what it is you can do to change it I think is the main thing.

4 DISCUSSIONS AND CONCLUSION

This paper investigates the domestic energy conservation from the perspective of situational awareness. We conducted a focus group study on participants' energy related activities at home. Although SA is normally studies in military or aviation operations, we found that the model of SA from perception, comprehension and projection could be a useful method to identify the gaps of domestic energy feedback and control.

Our analysis revealed various SA issues. Among all the issues, we noticed that the comprehension and projection are the greatest area of concern. Our participants also suggested possible solutions, such as providing detailed benchmark energy consumption information to help them understanding and monitoring their current energy consumption, and centralize the energy displays so they can monitor and control light and radiators in one place.

According to the results, we find that the SA models could be very useful to categorize the problems of domestic energy feedback design. So designers could use it as a useful framework to analyse potential issues and design solutions.

We also noticed that participants' major objectives includes many aspects， such as comfortable and health. The energy is used to achieve these goals, and they don't want the concern of energy efficiency to change their normal life routine. Furthermore, rather than focus on just saving energy, the energy feedback should also put more efforts on these major objectives at home, so people can take actions to not just save energy, but improve their life in the end.

To extend the understanding of energy awareness at home, future work includes more understanding of SA issues in people's energy consumption activities and planning, as well as interaction design of domestic devices to improve users' awareness

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