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A practical review of energy saving technology for ageing populations

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ABSTRACT

Fuel poverty is a critical issue for a globally ageing population. Longer heating/cooling requirements combine with declining incomes to create a problem in need of urgent attention. One solution is to deploy technology to help elderly users feel informed about their energy use, and empowered to take steps to make it more cost effective and efficient. This study subjects a broad cross section of energy monitoring and home automation products to a formal ergonomic analysis. A high level task analysis was used to guide a product walk through, and a toolkit approach was used thereafter to drive out further insights. The findings reveal a number of serious usability issues which prevent these products from successfully accessing an important target demographic and associated energy saving and fuel poverty outcomes. Design principles and examples are distilled from the research to enable practitioners to translate the underlying research into high quality design-engineering solutions.

1. Introduction

1.1. Fuel poverty and the elderly

Fuel poverty is the confluence of several key research grand challenges. It is brought about by poor energy efficiency, in particular the thermal efficiency of housing stock and heating sources; low household income; and high fuel costs. These in turn reflect back on national energy mixes, the drive towards renewables, and even the geo-politics of an increasingly globalised and interconnected world economy. Definitions of fuel poverty differ. In Scotland, where this study was conducted, a household is in fuel poverty if it requires more than 10% of its income to be spent on household fuel use in order to maintain a satisfactory heating regime. The Scottish and UK Governments have set aggressive targets for tackling this important issue.

Ageing is a particular hallmark of the extreme 'fuel poor' due to higher and/or longer heating requirements combined with declining incomes (Department of Energy and Climate Change, 2014). There is a worldwide demographic trend towards a rising median age, and as such it is becoming much more important for older people to become willing to invest in, understand, and trust home energy saving technology. This is seen as a key enabler for helping ageing populations feel empowered about their ability to make informed decisions about energy use, and prevent more households falling into fuel poverty. This paper reports on an assessment of the behavioural and usability aspects of a range of commercially available home energy saving technologies, and their ability to benefit ageing populations in this way. The assessment was conducted as part of a significant UK Engineering and Physical Sciences Research Council (EPSRC) project called APAtSCHE (Ageing Population Attitudes to Sensor Controlled Home Energy) which investigated the technical and social issues surrounding the development and deployment of home automation technology in residential premises inhabited by older people (EPSRC, 2014).

1.2. Home energy products

The market for home energy products is currently large and growing. There are two main types of product: home energy monitors and automated energy systems.

Home energy monitors are designed to increase householders' awareness and understanding of energy usage, connecting routine behaviour to consumption in order to motivate conservation behaviour and reduce energy bills. Most energy monitors are made up of three parts: an in-home display, a sensor, and a transmitter.

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The sensor clamps on to a power cable connected to the electricity meter and measures the current passing through it. The transmitter sends the data wirelessly to the display unit. Typically, electricity usage is displayed in units of energy used (kWh), cost (£) or carbon emissions (CO_2).

A previous survey of energy use has concluded that typical central heating controls, such as room thermostats, "seem to live incognito in many homes" (Shipworth et al., 2010, p. 31) and that householders are more likely to change their behaviour if new controls are designed that are appealing and usable. On the plus side, research has shown annual electricity savings of 5–15% resulting from home energy monitors (Darby, 2006). This energy saving potential provides part of the explanation for the current enthusiasm for new domestic technologies. On the debit side, users have reported difficulty understanding the displays, ranging from confusion over the features available to misinterpreting or misapplying the data (Darby, 2010; Strengers, 2011). This highlights a persistent need for improved user interfaces. Even when householders are able to understand the display, there is limited evidence that simply presenting information about energy usage reliably causes people to take action. This assumption is contained within the Information-Deficit Model (Hargreaves et al., 2010). The model assumes that the householder, once in receipt of the 'correct information', will make rational, economic decisions about energy consumption based on their individual attitudes and beliefs. Despite this model running counter to over forty years of research in decision making and cognitive biases (e.g. Kahneman, 2011), and the model itself being widely refuted in the literature (e.g. Strengers, 2011; Hargreaves et al., 2010; Gram-Hanssen, 2008), most home energy research still relies on the assumption that if the 'correct' information is 'made 'visible' then users will respond in ways that are predictable and desirable. In reality, an initially high level of engagement with information providing devices diminishes over time due to disinterest once the initial discovery phase has passed. Turning devices on and off, and watching how much energy is used, is initially compelling for users. Alerting householders to everyday practices considered to be 'non-negotiable', such or tumble-drying rather than air-drying laundry, are not. Suggestions of this kind fail to address embedded social norms around comfort and cleanliness (Pierce et al., 2010; Snow et al., 2013; Strengers, 2011). Shove (2004) argues that policy makers' preoccupation with technical efficiency has "blinded" (p. 1054) them to major transformations in what people take to be normal and ordinary. The example of washing is again pertinent. Domestic machines are increasingly efficient with people washing at lower temperatures, however, concepts of cleanliness have changed resulting in more frequent laundering, thus negating the net efficiency gain.

Given the challenges faced by energy monitors in motivating long term change more sophisticated automated energy systems have been proposed. Research by Koehler et al. (2013), Scott et al. (2011), and Yang et al. (2014) report users' experiences with systems incorporating occupancy sensing, prediction and machine learning to automatically control home heating. Interestingly, all three studies propose finding a balance between automation and user interaction to maximise energy savings and respect users' desire for comfort and control. Yang et al. conclude that existing systems can be better designed. For example, while applauded for its pioneering aesthetic design, the Nest Learning Thermostat has been criticised for breaking and ignoring user experience principles and heuristics, including the element of taking away user control. Similarly, a UK Government study into what people want from their heating controls found that participants were sceptical about whether automation would work for them and were generally reluctant to cede control (Rubens and Knowles, 2013). Taking control away from householders may also inadvertently legitimise high-demand practices and disengage householders from understanding and managing their resource use (Strengers, 2008).

1.3. Domestic energy behaviours

Over the past decade there have been numerous policies and programmes to address fuel poverty. In the UK, these include the Energy Company Obligation scheme where obligated energy suppliers liaise with occupiers and landlords to identify and implement suitable energy efficiency measures (Ofgem, 2015); home insulation schemes, e.g. Home Energy Efficiency Programmes for Scotland (Scottish Government, 2008a,b); consumer information, e.g. Home Energy Scotland advice service (Energy Saving Trust, n.d.); and not least smart meters and in-home displays as previously discussed (GOV.UK, 2015). Despite these great changes in the domestic energy landscape there has been remarkably little movement in how individuals like to heat their home (Shipworth et al., 2010; Shipworth, 2011) nor the device they use to do so. In 1984, UK households set their heating thermostats to a mean of 19.3 °C, which is virtually identical to the mean setting (19.6 °C) selected in 2007 (Shipworth, 2011). The typical heating thermostat, with its circular dial, originates from a design released as far back as 1953 by Honeywell called the 'T87 Round'. Shipworth (2011) further highlights that most domestic thermostats were selected and installed by previous owners or landlords, and 90% of respondents in a study by Peffer et al. (2011) rarely or never adjusted them. The advent of programmable central heating controls has done comparatively little to change this situation. According to Peffer et al. (2011) 20% of the programmers they surveyed in a large study were showing the wrong time, 53% were not in automatic mode (and were switched on or off manually by the user), indeed, 85% of people who said they did use the programmable features often did not (45%). As a result, more sophisticated and information-rich central heating controllers can actually use more energy than manually controlled ones (Peffer et al., 2011). This represents a serious challenge to the widespread assumption that if the sophistication of home energy controls is increased, then users will be able to perform more rationally and save energy. It is for the reasons elucidated in Peffer and Shipworth's studies, and others, that the applied ergonomics research is often far less optimistic than the widespread assumptions contained in government policy and the wider engineering community.

At a fundamental ergonomic level, interpretation of a home energy control relies on 'internal constructs' held by users, which "help them to understand the world and select the appropriate course of action" (Revell and Stanton, 2014, p. 363). These mental models are often very limited, particularly with regards to ecological usage patterns (Sauer et al., 2004). This simplicity is revealed by Kempton (1986) 'theories' of thermostat operation. Users holding the so-called feedback theory believe the thermostat turns the boiler on or off and the temperature set on the thermostat is the on/off temperature. For example, if the temperature is set at 22 °C the boiler will remain on until this level is reached, after which it will turn off. This is aligned most closely to how domestic thermostats actually do work. Users can hold an alternative mental model called the valve theory. Users in this case believe the thermostat controls the rate or intensity of heat generation. Like a tap, "a higher setting causes a higher rate of flow" (Kempton, 1986, p. 78). This offers an explanation for why some users will turn a heating control up further than normal when entering a cold room in order to try and heat it more quickly. Other models have been put forward, including the timer theory (Peffer et al., 2011), in which users select greater values of temperature set point for when they desire longer periods of boiler operation (e.g. Revell and Stanton, 2014)and the