DEVELOPING CONCEPTS THAT PROMOTE ENERGY SAVING TECHNOLOGY FOR AGEING POPULATIONS

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ABSTRACT
Fuel poverty is a critical issue for a globally ageing population. Increasing heating/cooling requirements combined with declining incomes has resulted in a global challenge that requires urgent attention. Three Scottish Universities/College collaborated on a user centred and user led concept development process that focused on empowering elderly users to take steps to make their energy usage more cost effective and efficient. This study starts by analysing a cross section of home energy products and then develops and evaluates concepts with a range of stakeholders, including housing associations. The study benefited from Research Teaching linkages/projects across undergraduate and postgraduate levels. From the initial research, it was concluded that there are serious usability issues with existing products. These failings prevent the products from being successful within the chosen demographic and ironically add to the energy challenge. Design concepts were developed by academic (teaching and research) staff from a diversity of backgrounds including: Electronic and Electrical Engineering, Interaction Design, Product Design Engineering, Psychology, Ergonomics and Social Sciences. The concept and design development benefited from engagement with the target audience and the paper will present the findings of this engagement. Key evaluation targets for the concepts were based on user insights, including: user-friendly interface; informative displays; ease of implementation and understanding of data. Concepts also had to fundamentally gain the confidence of the demographic through demonstrating how one could reduce energy consumption, therefore reducing fuel poverty. This step change in the acceptance would be a critical driver during the development of the concepts.

Keywords: Design-led approaches, energy saving technology, older people.

1 INTRODUCTION
The APAtSCHE (Ageing Population Attitudes to Sensor Controlled Home Energy) project investigated the technical and social issues that surround developing and deploying home automation technology in residential premises inhabited by older people [1]. In the UK, advancing years is one hallmark of the extreme 'fuel poor', where a resident cannot afford to heat their home to an acceptable standard [2]. Coupling this with the demographic trend worldwide towards a population with a rising median age, the APAtSCHE project proposed that it is important that older people are willing to invest in, understand and trust, home energy saving technology in order to empower them to make informed decisions about energy usage and to prevent more and more households falling into fuel poverty. This paper describes the development and evaluation of three concepts for addressing this challenge, beginning with a preliminary review conducted by students of energy saving technology for ageing populations. The evaluation and analysis of this study was fundamental in developing key user requirements and expectations for APAtSCHE concepts.

1.1 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 to motivate conservation and reduce energy bills.

Most energy monitors are made up of three parts: an in-home display, a sensor, and a transmitter. 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 survey of energy use concluded that typical central heating controls, such as room thermostats, 'seem to live incognito in many homes' and that householders are more likely to change their behaviour if new controls are designed that are appealing and usable [3]. On the plus side, research has shown annual electricity savings of 5-15% resulting from home energy monitors [4]. On the debit side, users have also exhibited difficulty understanding displays, ranging from confusion over the features available to misinterpreting or misapplying the data [e.g.5]. Even where householders understand the display, there is limited evidence that simply presenting information about energy usage reliably causes people to take action. EG, turning devices on/off and watching how much energy is used is initially compelling, but alerting householders to everyday practices considered to be 'non-negotiable' such or tumble-drying rather than air-drying laundry fails to address embedded social norms around comfort and cleanliness [e.g.6]. It has been argued that policy makers' preoccupation with technical efficiency has 'blinded' them to major transformations in what users take to be normal and ordinary [7].

Given the challenges faced by energy monitors in motivating long-term change, more sophisticated automated energy systems have been proposed, such as systems incorporating occupancy sensing, prediction and machine learning to automatically control home heating [e.g.8]. Interestingly, studies often propose finding a balance between automation and user interaction to maximise energy savings and respect users' desire for comfort and 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 [9]. Taking control away from householders may also inadvertently legitimise high-demand practices and disengage householders from understanding and managing their resource use [10].

These existing related studies highlight a persistent need for improved design of home energy saving technology, for whom elderly consumers are a key future market that this research seeks to address.

2 METHOD

2.1 Participants

A total of 81 participants aged over 50 years took part in the preliminary review of energy saving technology (48 female, 33 male). A total of 15 social housing tenants aged over 50 years (10 female, 5 male) and five members of social housing staff took part in the subsequent concept and design development of improved energy saving products. Participants were recruited from residential areas of South Western Scotland and via stakeholder organisations such as Glasgow and Dumfries and Galloway Housing Associations who were part of the APAtSCHE project.

2.2 Preliminary research

A preliminary review of energy saving technology for ageing populations was conducted by 15 (8 female, 7 male) 5th Year MEng Product Design Engineering students from the Glasgow School of Art and University of Glasgow, supervised by academic staff working on the APAtSCHE project. The students formed into teams to review a range of 12 home energy products: nine energy monitors— EnviR [11], Eco-Eye Elite [12], Eco-Eye Mini [13], Efergy e2 Classic [14], Efergy Elite Classic [15], OWL +USB [16], OWL Micro+ [17], Belkin Conserve Insight [18], and Energenie Energy Saving Power Meter [19]; and three automated energy systems—LightwaveRF [20], EnergyEGG [21], and Salus ST320 [22].

The review was exploratory and adopted an approach orientated around two key methods: a high-level task analysis created in order to perform a product walkthrough. Following these core methods the students deployed a wide range of other methods as guided by the issues discovered and Human Factors lectures given by the academic staff, the willingness of the participants, and the characteristics of the product in question. These included immersion analysis [e.g.23] including simulating physical disabilities such as arthritis and poor vision by taping weights to fingers and wearing glasses smeared with petroleum jelly; abstraction hierarchy—system modelling to identity opportunities for improvements; and Design with Intent Toolkit [e.g.24]—using cards and worksheets that act as different 'lenses' through which common problems can be viewed and new perspectives gained. The

use of a large sample of participants and products enabled these exploratory findings to be pooled. The students and academic staff convened at the conclusion of the preliminary research and undertook a presentation workshop in order to synthesis, cross check and group the findings.

2.3 Concept and design development

Based on the results of the preliminary research and presentation workshop, a general specification was created for energy saving technology for ageing populations. The specification informed the development of three concepts by academic staff working on the APAtSCHE project, who had a diverse range of backgrounds: Electronic and Electrical Engineering, Interaction Design, Product Design Engineering, Psychology, Ergonomics and Social Sciences. Screen mock-ups of the concepts (non-interactive), which are described in section 3.2, were demonstrated to tenants from two Scottish social housing organisations partnered with the APAtSCHE project: the Glasgow Housing Association and Dumfries and Galloway Housing Partnership. During two half-day workshops, participants were asked for their views as a group on the features, functionality and aesthetics of each concept, which were captured on flip chart paper. This feedback informed the development of the designs.

3 RESULTS AND DISCUSSION

3.1 Key problems identified

The preliminary research, described in section 2.2, identified behavioural and usability problems with the packaging, set-up process and user interface of home energy products. These failings prevent the products from being successful within the chosen demographic and ironically add to the energy challenge. A number of age-related impairments were reported by participants or observed by the students including poor vision, arthritis, loss of hand dexterity and weak hand strength.

Key problems identified are as follows:
1. Opening shrink-wrapped packaging, often requiring a knife or scissors.
2. Identifying the power cable connected to the electricity meter, and attaching the sensor due its stiffness.
3. Reading and understanding instructions with a large volume of small sized text and few information graphics.
4. Pairing or linking devices, where no prior experience can be drawn upon.
5. Interpreting ambiguous icons and needing to put on spectacles to read user interface elements.
6. Understanding electricity usage when expressed as kWh or CO_2, and finding and entering tariff information.
7. Operating small and awkward to reach controls.
8. Reading fixed LCD screens with narrow viewing angles and no backlighting.
9. Understanding visually busy information displays.
10. Distracting beeping sounds and flashing lights.

3.2 Design concepts generated and reviewed

3.2.1 Concept 1: thermal printer

Constructed in white high-gloss plastic and wood, Concept 1 provides the householder with a print out of their energy consumption at the press of a button or according to a defined schedule (Figure 2). The scenario for demonstration purposes was a print out of the householder's weekly energy usage in cost (£), the reduction in cost (£) compared to the previous week, and an energy conservation tip. In contrast to most utilitarian-looking energy monitors, Concept 1 has been designed to offer aesthetic value and promote energy conservation behaviour by encouraging sustainable interaction through evoking a positive emotional response.

Workshop participants liked the aesthetics and perceived simplicity of Concept 1, the data that was printed (people were mostly interested in cost) and the tangibility of the print out. The value of paper was observed during the preliminary research and it was apparent that paper was used frequently for notes, prompts and reminders. Therefore, the physical element of this concept and the added value of paper provided the team with a product feature worthy of further exploration. The general view was that a lot of older people do not understand high-tech devices. One participant commented 'People think we're just not trying [with technology], but it's not that'. One participant, whose partner has

dementia, speculated that the simpler design might be more appropriate for people with mild cognitive impairment, based on lived experience of her partner not understanding their home energy monitor because it is too complex. It was suggested that the simpler design might be more accessible to children who, as family members, are also responsible for their consumption behaviour, and that the print outs could be filed with other energy and gas utilities documents. One participant commented 'That would be a good way to stop them diddling you!'

Figure 1. Concept 1: Participants particularly liked the uncluttered user interfaces.

Figure 2. Concept 2: participants particularly liked the bigger sized text on the larger screen.

3.2.2 Concept 2: TV display

Concept 2 combines an energy monitor, where the householder's main television (TV) is the in-home display unit, with remote controlled appliances such as a lamp or radio (Figure 3). The scenario for demonstration purposes was a menu that popped-up on the TV screen with buttons labelled 'Hide', 'Show' and 'Schedule'. Using the TV remote controller, selecting the 'Hide' button removed the menu; selecting the 'Schedule' button allowed the viewer to define when the pop-up menu appeared; selecting the 'Show' button bought up a sub-menu with buttons labelled 'Energy Usage', 'Turn Devices Off', 'Tips' and 'Change Supplier'. The 'Energy Usage' screen displayed a graphical chart of energy consumed over the past seven days compared to the previous week. The 'Turn Devices Off' screen allowed the viewer to remotely turn off home appliances. The 'Tips' screen provided a local weather forecast and the 'Change Supplier' screen allowed the viewer to change their energy supplier. Workshop participants liked the idea of a home energy system utilising technology and controls that they were already familiar and comfortable with, although there was variation in how often they watched TV. Reaction to the 'Energy Usage' screen was also mixed, with some participants finding the information graphics clear and helpful and others finding them complex and confusing, suggesting the need for different levels of information. The most popular feature/functionality was the 'Tips' information screen and ability to remotely turn off appliances. Reaction to the 'Change Supplier' screen was mixed: all participants saw the benefit, but are distrustful to varying degrees of energy suppliers and advertised tariffs. One participant had a very strong view that his supplier 'robs people'.

It was also observed that more effort is required to access information via the TV i.e. information is not available 'at a glance'.

3.2.3 Concept 3: thermostat control panel

Concept 3 is a home automation system that comprises: a digital room thermostat linked by Wi-Fi to a room control plate(s); Wi-Fi enabled radiator valves and electrical plug sockets; and occupancy sensing to turn off lights and unused appliances (Figure 2). The thermostat and control plate are constructed in white high-gloss plastic, stand proud from the wall so that backlighting can diffuse around the surface, and incorporate a touchscreen interface. The thermostat displays the current temperature (ºC) of the room in which it is sited, with a plus and minus button to globally increase or lower the set point (desired temperature) for all rooms in the house. A white glow indicates that the set point has been reached; an amber and blue glow indicates that the room is heating up and cooling down respectively. The control plate incorporates three toggle buttons for controlling lighting, heating, and power. Pressing the lighting and power buttons sets the lights and appliances to automatically turn off if no one is in the room. Pressing the heating button allows householders to override the global set point and increase or decrease the temperature of the actual room in which it is sited.

Workshop participants felt that Concept 3 would be good for both adults and children. A control plate in each room was thought to be very useful, as not all rooms are usually used. An observation was that it would be crucial to trust the system to turn off appliances that would be dangerous to leave on e.g. hair straighteners. Also, while automatically turning unused appliances off is a good idea, generally speaking, some appliances are left on deliberately because they require to be reset each time they are switched on such as a Sky Box. No one was uncomfortable with the prospect of occupancy sensors installed in each room of their property. A member of housing staff commented that older or vulnerable adults become used to having activity sensing equipment (PIRs) installed in their homes; while there may be initial uneasiness with the sensor and the blinking light, people necessarily do get used to it. One participant suggested that the system would be good for sensing activity, or lack of, and raising an alert if someone hadn't moved for a while.

3.3 Validation and Impact on design education

This project provided an opportunity for the students to engage with a growing demographic that would benefit from their product development process and enable them to apply Human Factors methods to a live project. In adopting this live approach, feedback on smaller design elements could be gathered in a semi-structured way on usability. For the students this allowed the checking of design knowledge and theory relevant to the process, not to fully validate the design, this would come later from within the academic team, but to guide the design and highlight issues related to verification and validation ahead of producing engineered solutions.

4   CONCLUSION

We have presented key problems with energy saving technology, identified from a review of a broad cross section of home energy products, and described three novel concept designs for addressing these problems and promoting energy saving technology. Cross institutional collaborative research projects can, at times, result in work packages not fully engaging with project partners and overall research focus. By adopting a user focused and insight driven development process from the outset, the quality of outputs and associated evaluation has generated highly feasible design-engineering solutions. The process that is outlined in the paper may provide a framework for multi-disciplinary academic teams and targeted demographics to apply and develop in future projects. The value to design engineering education can be measured by the success of the project. Students and staff have received favourable feedback at dissemination events and focus groups. This validated their process and provided them with the confidence to learn from and apply methods in future projects.

REFERENCES

[1]   EPSRC. *Aging population attitudes to sensor controlled home energy*. Available: http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/K002708/1 [Accessed on 2016, 11 May].

[2]   GOV.UK. *Annual fuel poverty statistics report*. Available: https://www.gov.uk/government/publications/annual-fuel-poverty-statistics-report-2014 [Accessed on 2016, 11 May], (2014) 12 June.

[3]   Shipworth M., Firth S.K., Gentry M.I., Wright A.J., Shipworth D.T., Lomas K.J. Central heating thermostat settings and timing: building demographics. *Building Research & Information*, 2010, 38–69.

[4]   Darby S., 2006. The effectiveness of feedback on energy consumption a review for defra of the literature on metering, billing and direct displays. *Environmental Change Institute University of Oxford*, 2006, 1-21.

[5]   Strengers Y. Designing eco-feedback systems for everyday life. In *SIGCHI Conference on Human Factors in Computing Systems, CHI '11*, 2011, pp.2135-2144.

[6]   Pierce J., Fan C., Lomas D., Marcu G., Paulos E. Some consideration on the (in)effectiveness of residential energy feedback systems. In *8th ACM Conference on Designing Interactive Systems, DIS '10*, 2010, pp.244-247.

[7]   Shove E. Efficiency and consumption: Technology and Practice. *Energy & Environment*, 2004, 15, 1053–1065.

[8]   Koehler C., Ziebart B.D., Mankoff J., Dey A.K. TherML. In *ACM international joint conference on Pervasive and ubiquitous computing, UbiComp '13*, 2013, pp.103-112.

[9]   Rubens, S. and Knowles, J. *What people want from their heating controls: a qualitative study*. Available: https://www.gov.uk/government/publications/what-people-want-from-their-heating-controls-a-qualitative-study [Accessed on 2016, 11 May], (2013) 21 October.

[10] Strengers Y. Smart metering demand management programs. In *20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat, OZCHI '08*, 2008, pp. 9-16.

[11] Current Cost. *EnviR*. Available: http://www.currentcost.com/product-envir.html [Accessed on 2016, 11 May].

[12] Eco-Eye. *Eco-Eye Elite 2*. Available: http://www.eco-eye.com/product-monitor-elite [Accessed 2016, 11 May].

[13] Eco-Eye. *Eco-Eye Mini 2*. Available: http://www.eco-eye.com/product-monitor-mini [Accessed 2016, 11 May].

[14] Efergy. *e2 Classic 2.0*. Available: http://efergy.com/eu/e2v2-monitor [Accessed 2016, 11 May].

[15] Efergy. *Elite Classic*. Available: http://efergy.com/uk/products/electricity-monitors/elite-classic [Accessed 2016, 11 May].

[16] OWL. *OWL +USB*. Available: http://www.theowl.com/index.php/energy-monitors/standalone-monitors/owl-usb/ [Accessed 2016, 11 May].

[17] OWL. *OWL Micro+*. Available: http://www.theowl.com/index.php?cID=185 [Accessed 2016, 11 May].

[18] Belkin. *Conserve Insight*. Available: http://www.belkin.com/conserve/insight/ [Accessed 2016, 11 May].

[19] Energenie. *Energy Saving Power Meter*. Available: https://energenie4u.co.uk/index.php/catalogue/product/ENER007 [Accessed 2016, 11 May].

[20] LightwaveRF. *LightwaveRF*. Available: http://www.lightwaverf.com/ [Accessed 2016, 11 May].

[21] energyEGG. *energyEGG*. Available: http://energy-egg.com/the-energyegg/ [Accessed 2016, 11 May].

[22] Salus. *ST320 S-Series Digital Thermostat*. Available: http://www.salus-controls.com/products/thermostat/digital-thermostat/_c1_20_sseries-digital-thermostat/ [Accessed 2016, 11 May].

[23] Hanington B. and Martin B. Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. *Rockport Publishers*, 2010.

[24] Lockton D., Harrison D., Stanton N.A. The design with intent method: a design tool for influencing user behaviour. *Applied Ergonomics*, 2010, 41, 382–392.