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Designing and evaluating smart domestic technologies which use infrequent interaction

John V H Bonner, Andol Li, Jo Robinson

live:lab, Dept of Informatics, School of Computing and Engineering
Huddersfield University, Huddersfield, HD1 3DH
E-mail j.v.bonner@hud.ac.uk

Video can be found at http://vimeo.com/2966429

Literature review and context for study

In the last decade research into ubiquitous computing has begun to examine the home environment both commercially and academically such as MIT, Samsung and Microsoft [Taylor et al 2007] although, as yet, smart homes have yet to move into significant reality [Davidoff et al, 2006b] due to old housing stock [Edwards & Grinter, 2001] which will require these new technologies to be integrated into a wide variety of legacy environments [Tolmi, 2007]. One of the reasons why the home has become important is simply due to the number of household computer-based systems available [Wray, 2007] making it a commercially valid exercise [Hindus, 1999] to-date this has been primarily driven by technical innovation with user needs considered as a secondary issue [Hemmings et al. 2002; Haines et al. 2007]. However, domestic situations do not have the same focus on efficiency nor the same sense of shared objective as found in the workplace [Crabtree & Rodden, 2004] and must therefore be addressed differently to identify suitable technological solutions and social needs. Designers must understand routines, functions and social restraints within the home [Bernhaupt et al. 2008, Edwards & Grinter, 2001], in both the development of product concept [Gaver et al. 1999, Davidoff et al. 2006b] and the physical integration [Haines et al. 2006, Crabtree & Rodden 2004] to deliver useful and marketable domestic technologies. Many of the products used and proposed in these studies above place little emphasis on the potential frequency of their real-world use and how this might relate to behaviour and acceptance; therefore, in this study, we have begun to investigate whether or not intermittent use requires special attention in the design and evaluation process and whether this can be successfully anticipated and measured within a controlled laboratory environment.

New tools to inform the development of ubiquitous computing for the home are therefore required. Crabtree and Rodden [2004] have used a mix of participant observation ethnographic techniques. The use of ethnography in the home is relatively new and under evaluated compared to ethnography in the workplace and is constantly evolving [Hemmings et al. 2002]. In an effort to gain deeper understanding of natural behaviour, Gaver et al [1999] have devised self-documentation methods with the implementation of a “cultural probe” pack containing documenting tools such as maps, postcards and cameras to encourage unexpected ideas to shape concepts of new domestic technologies A further development of the ethnographic observation approach has come with ‘living laboratories'. These are home simulations with a rich technical infrastructure that enables the study of ubiquitous technology in a home setting [Markopoulos et al. 2004, Intille et al. 2005]. Supporters purport that these compliment existing ethnographic and laboratory-based methods of data collection by capturing activity that may not be observed by the researcher although temporary attendance of the participant in the facility may be misrepresentative of natural behaviour and only capture general behavioural trends [Intille et al. 2006].

In recognition that not all data can be captured comprehensively, we decided to examine what can be revealed or predicted about long –term intermittent use of smart novel devices using short laboratory studies. This paper documents the very early initial investigation of this aim. Emphasis at this stage was placed more on developing functional design for the device, rather than making methodological improvements in line with our aim. This will unfold in future studies.

Design and evaluation methodology

We began the design process by developing a relatively conventional wall mounted control panel device; a control panel which provides more immediate information and feedback between utility suppliers, predicted consumption, usage patterns and consumption costs to alter consumption behaviour in order to reduce fuel bills, consumption and therefore CO_2 emissions. We designed the device with features like temperature setting, energy supplier switcher, independent room temperature control and information of estimated real time consumption with percentage gain or loss from previous quarterly consumption figures. The principle feature of this design was the ability to prominently display the predictive cost of forthcoming quarterly gas or electricity bills. To date, we have carried out two empirical studies and technical development work of a third iteration which exploits more novel and engaging interaction.

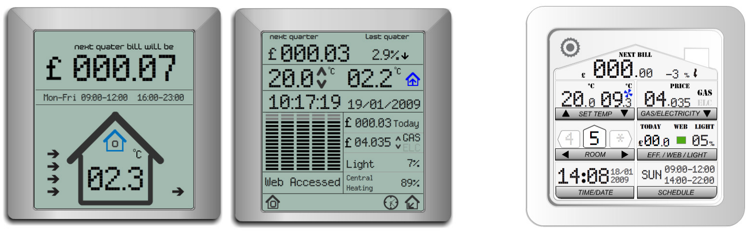

Fig. 1. Left and Middle - Initial interface design proposals Right – Second design proposal

Figure 1 illustrates the prototype interfaces used in the two studies. In the first study, four participants were asked to use the device as they would at home and to explore the features of the device. Participants were asked to read a scenario to help contextualise the product and to understand their role and purpose of the study. Participants were given one opportunity to use the device and become familiar with it. Participants were then asked to 'teach-back' to the researcher what they had learnt about the device. Finally, they were asked to complete a questionnaire to identify functions they liked or disliked.

The study was useful in identifying preferred features and helped us to improve the next design iteration by improving the integration of displays, highlighting key buttons and more manipulation clues. Scene setting through the introductory scenario also seemed to help the participants to appraise the device within context, and participants positively reported that this form of display would affect their consumption behaviour. Although this does not provide hard evidence that real-world behaviour would change, it did suggest that our original proposal was worthy of further investigation.

For the second study, we improved the prototype interface and features and modified the questionnaire to improve data gathering precision and replaced the teach-back' with semi-structured interviews. The improved methodology increased the precision and accuracy of feature usability but again did not really help in gaining any reliable insight into reliable predictions about behavioural change, although as we stated at the outset, we were not anticipating deep insight but rather using these studies to help us evolve our methodological thinking.

At this point we then decided to radically re-design the control interface for future investigation. The reasons for this were twofold. First, our intention is to creatively explore new ideas for control devices within the home but also, second, to combine this with understanding how effectively this can be done with quick, rapid prototyping techniques within a laboratory environment. We are therefore at the early stages of building a 'mixed reality' central heating control device which functions by moving and rotating a multi-coloured cardboard cube on a coffee table surface. This design proposal could be achieved through contemporary technology through the use of multi-touch surfaces and sensing devices. However, development costs for such a proposal are prohibitive on our research budget. Therefore, in order to explore and carry out user experience studies of innovative proposals, we have devised a low-cost rapid prototyping solution through the use of a webcam and data projector mounted above the table which can track the cube and recognise the top colour of the cube. Bit mapped images are fed to a Flash application which then projects data onto the table surface. The cube therefore acts as a central heating control and setting device through placement and orientation of the cube. Once this prototype is more robust, we will then begin detailed and extensive user studies.

Conclusions

These two short studies have provided some useful pointers to possible ways of improving the reliability and validity for our approach to this type of evaluation study. The scenario proved very useful in allowing participants to begin from a common point but the scenario needs to be extended to ensure that participants are continually making reliable and valid value judgments that would be made if they were encountering such a device in their own home. To do this we need to elicit and understand each participant's natural behavioural patterns before conducting user evaluations. More tailored scenarios can then be provided for each participant containing pertinent tradeoff decisions that would realistically be made within the context of genuine usage. Ultimately, to evaluate the effectiveness of our future evaluation methods, we will need to compare our findings with functional prototypes in real domestic environments. Our intention in the long term, therefore, is to install projector-based prototypes with sensing capability within a number of domestic environments where we have remote longitudinal control of the functionality and control of the device. This will allow us to make direct effectiveness comparisons between laboratory and field-based studies.

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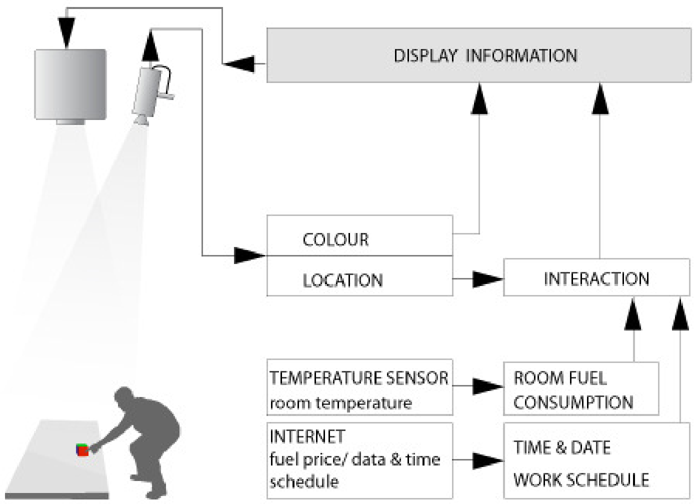
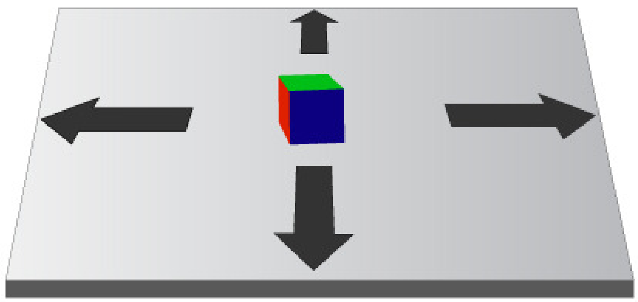
Illustration of central heating control using a coloured cube and smart coffee table



Design schema of rapid prototyping device



Functionality of cube on the table

When green surface is on top and moved from left to right, the coffee table displays the days of the week, beginning with Monday on the left and Sunday at the extreme right. Time settings for each each day can then be set by moving the cube vertically until preferred time is identified.

When blue surface is on top, the table displays the current room temperature and thermostat setting - this setting can be changed by moving the cube vertically to select the correct numerical value.

When red surface is displayed, the table displays the predicted fuel bill consumption for the current quarterly bill. Having a constant reminder of the final bill should encourage consumers to find ways of reducing their bill.