A PRELIMINARY INVESTIGATION OF THE POTENTIAL FOR THERMOGRAPHIC IMAGES TO INFLUENCE HOUSEHOLDERS UNDERSTANDING OF HOME ENERGY CONSUMPTION.

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Thermographic imaging has been applied to the investigation of heat losses and other building related phenomena for a number of years. More recently, its use in the sustainability domain suggests a psychological effect; that householders, after viewing thermal images of their homes, are more likely to engage in energy conservation behaviour. In particular it is hypothesised that a thermal image will frame information in a personalised, visible and salient manner more likely to achieve behaviour change (Stern, 1992). The aim of this paper is to consider the potential for this use. 10 UK householders were shown thermographic images of their own homes; their reactions recorded and analysed. Results suggest that viewing the images may trigger a reasoning process leading to energy saving behaviours, but there are pitfalls. Data from 2 of these interviews are presented here as an illustration of this reasoning process and of the contrasting reactions to the energy saving potential inferable from the images.

Keywords: behaviour, buildings, energy, homes, infrared, thermography.

INTRODUCTION

Thermal images show where a home could be leaking heat. In this sense, they have potential to help householders' understanding of how to conserve energy at home. Recent use of thermal imaging suggests a psychological effect on the householder; that after viewing an image of their home in infrared, they are likely to engage in energy saving behaviours; such as improving the glazing, closing curtains at night or draught proofing. This paper presents the results of some initial research suggesting potential for thermographic images to be used to prompt a reasoning process in an individual's mind, which leads to specific energy saving ideas. The paper also discusses some potential pitfalls in using thermal images in this way.

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Energy Efficiency in Households

Energy suppliers in the UK face a high demand for energy despite compelling evidence that greenhouse gas emissions from energy consumption are a major contributor to global warming (IEA, World Energy Outlook, 2006) and that worldwide energy resources are limited.

Household energy demand is one of the major sectors targeted for reductions in energy usage (DTI, 2007) consuming 30% of the total energy in the UK. This represents a 26% increase on 1970's levels and a 12% increase on 1990's consumption levels (DTI, 2005). 84% of final energy demand in 2003 was used for space heating in homes (DEFRA, 2003) and there is potential for the equivalent of a 9MtC energy saving to be made by targeting energy efficiency in the household sector (Energy Review Report, 2006).

There are 2 conjoined approaches to reducing energy usage amongst households; improving building fabric/services and encouraging energy conserving behaviours. Post 1970's homes have been subject to increasingly stringent building regulations and planning systems which have forced developers to upgrade and adopt technologies, therefore these homes generally have better thermal properties. However the majority of the housing stock is older than the 1970's, this suggests that appropriate adaptation of our existing stock is a priority. Upgrading of pre thermal regulation buildings is commendable, although technically more difficult, particularly amongst solid or system built walls. When faced with large numbers of buildings, particularly homes that cannot be thermally improved without expensive and intrusive upgrades one of the major methods of reducing demand is to encourage energy saving behaviours amongst the occupants of these buildings.

Despite the potential in energy savings through efficiency measures; there is a problem in their uptake. 40% of the population are still doing nothing to conserve energy (EST, 2007). 56% of homes which could benefit from cavity wall insulation are not insulated (ACE, 2008). Indeed, in the US a 30% reduction in energy consumption via household efficiency measures has been estimated as possible for 30 years, without being achieved (Gardner and Stern, 2008). Why might this be? Clearly there are large barriers to action, for example, finances, but in some cases no cost or low cost actions have yet to be taken. Households are not taking the full potential of energy efficiency and the 2005 Energy Efficiency Innovation Review outlined the reasons as lack of appreciation of true energy costs and long term benefits of energy efficiency measures along with "a lack of inertia, interest, knowledge or awareness" (Energy Review Report, 2006). Energy using behaviour is hard to change. Additionally, individuals may be mistaken about the efficacy of their energy saving measures. Energy misinformation is common amongst individuals (Stern, 1992). For example, there is a tendency to overestimate the effect of visible behaviours (turning on lights) on energy usage and underestimate less visible uses (energy involved in heating water). Individuals tend to see the greatest potential for efficiency in curtailing their activities; switching off appliances. In contrast, one-off efficiency measures often have greater potential for energy conservation (installing loft insulation, replacing older appliances) (Gardner and Stern, 2008). Similarly, many people are unaware of energy usage on a daily basis (DEFRA, 2008) and recent interventions (eg smart metering and historical data on bills) have recognised the importance of feedback to customers in order to improve householders' awareness of actual energy usage (Darby 2008, DTI, 2007). It is possible therefore that some individuals may have difficulty in making connections between the thermal properties of their home and its energy usage, efficiency and comfort. There may be a potential in aiding householders' understanding of heat loss by displaying visibly, the heat in, around and from their own home. Householders may then take action to mitigate that loss. The focus of this work is the psychological impact of viewing these images and whether these might prompt effective energy conserving behaviours.

The psychology behind the use of visual prompts.

Psychological approaches attempt to encourage pro-environmental behaviours or discourage damaging behaviours. The general approach taken is to employ antecedent and/or consequence approaches. A consequence strategy is assumed to influence the determinants of behaviour, after the desired behaviour has occurred, by providing a consequence, contingent on the outcome of that behaviour (such as receiving a financial reward for reducing energy use) (Lehman and Geller, 2004, Abrahamse, 2005). An antecedent is a specific stimulus which prompts a desired behaviour. Examples of such prompts include prior information, education, tailored feedback, and requests. Prompting can be visual, written or auditory, and signal that it is appropriate to engage in an act (such as the stickers above light switches reminding users to switch off lights upon leaving a room). In this paper, thermographic images are a form of antecedent and in principle can be used to overcome individual barriers to act. Prompts target specific behaviours, and this visual prompt will target key energy saving behaviours; one –off efficiency or curtailment behaviours (Gardner and Stern, 2002).

There remains the challenge to attract the attention of the householder to a prompt. The manner in which prompts are framed may be critical to the success of the overall intervention. Stern has argued for attention to be paid to the way that pro-environmental antecedents are conveyed (Stern, 1992). The way in which retrofit programmes in the USA in the 1980's were marketed affected their take-up; some approaches achieved a rate of take up which would have seen the programme completed in 5 years, other approaches would have reduced that timescale to 70 years. One of the factors that can affect the success of a prompt depends on how noticeable, vivid, self explanatory and positive it is (McKenzie Mohr, 1999). Thermographic images are positive in that they can show areas of heat loss which may be able to be dealt with, they are vivid and noticeable (especially if they are of a person's own home). They therefore may offer the potential for a new psychological prompt for energy conservation, by vividly signalling, to the householder, the appropriateness of certain energy efficiency actions.

Thermography and Buildings.

Thermal imaging technology aids the diagnosis of building defects and can be used as a means of inferring heat escape from a building, such that action can be taken to limit that escape and conserve energy. Infrared cameras take images showing the infrared radiation from the surface of the building and show the apparent surface temperature of the house. By comparing temperatures around the house, it may be possible for the viewer to learn more about where heat, and so energy, could be conserved in the home. Typically thermal images are taken from the outside or the inside of the house and tend to show patterns of heat loss, tending to target the following energy conserving actions (see Table 1) (dependent of course on each individual house imaged):

Table 1: Examples of energy saving actions typically evident from thermal images with their energy saving potential

Energy Saving Action Typically Visible on a Thermal Image	Energy Saving Potential
Efficiency Behaviours (One off actions/purchases)	
Loft insulation	5%*. Typical Annual Saving of £50 – £60 (for top up of existing insulation)**Typical reduction in energy costs of 20%**
Wall insulation - cavity or external/internal	Typical Annual saving 130 - £160**. Heat loss reduced through walls by 60%
Draught proofing	1.9%*. Typical annual savings of £20**
Improved glazing	2.8%*
Improved insulation at windows and doors	n/a
Curtailment Behaviours (Repeated habitual changes)	
Closing windows when the heating is on	n/a
Not heating unused rooms	n/a
For comparison, some examples of potential energy savings at home, not prompted by the thermal image.	
Replacing boiler with a condensing boiler	Typical annual savings of £130 - £160**
Heating Control Package	Typical annual savings of £70 - £90**

(*Gardner and Stern, 2008), (**EST, Domestic Energy Primer, 2005).

Note: (%'s are of total household energy consumption in the US).

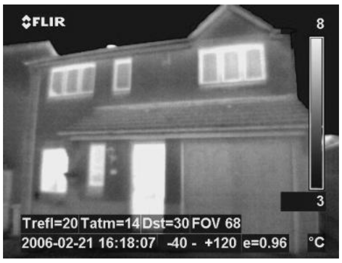


Figure 1: Thermographic Image of a Typical 1990's Home

Consider Fig 1. The scale indicates the temperature of the exterior of the house and from this the inference is that the bright, closed door has a much hotter external temperature than the walls around, suggesting that this is where heat may be leaking from the house. A thick curtain at the door or a better insulated, door might reduce some of the heat loss from the house, maintaining the thermal comfort of the home more efficiently, thereby reducing energy use. This is quite visible to the householder. The attention is drawn to these areas easily and requires little deliberation, creating a visual prompt for information not easily conveyed succinctly in other ways.

As well as prompting specific actions, there may be a general influence on the householder's attitude to energy saving. Seeing the 'invisible as visible' tends to attract attention (Gardner and Stern, 1996); and attracting attention is one of the barriers to engaging in energy saving behaviours as identified earlier. Midden, Kaiser and McCalley (2007) highlight the potential for using technologies to promote concern for environmental issues. Using their rationale, thermographic images of homes may have the potential to catch attention and to draw that attention to specific energy saving issues, so mediating a person's understanding of heat loss in their homes and as such may change ideas (Verbeek and Slob, 2006). They argue that presentation of information using technologies such as this can add 'persuasive significance' to traditional forms of communication, by operating at the level of direct, visual sensory experience rather than indirect traditional information.

This study investigates the potential psychological influences on the householder, when viewing a thermographic image of their own home exterior. Since responses to the technology have not been documented in the energy saving domain and the study was preliminary; the rationale was broad; to capture and analyse the response of a householder to the image, what sense they made of these images and the implications for energy conservation. Preliminary findings, in the form of 2 contrasting responses to the images, are presented here. The work hypothesised that vivid, visual intervention, in this case a thermographic image of a householders own home, would prompt energy saving behaviours.

Methodology.

10 householders in the South West of the UK, recruited with the help of a local climate action group, were interviewed using a semi structured interview style. Thermal images were shown to the householders, at the outset of the study but after they had completed a questionnaire designed to measure attitudes related to their use of energy in their home, with particular regard to space heating. The actual energy usage of each of the featured properties was measured from their quarterly fuel bills and then re-measured after a year had passed. The images were introduced during an in depth recorded interview where the researcher explained the images, referred to parts of the images and sought the householders responses. During the semi-structured interview a series of questions were asked relating to the householder's reactions to the images, the building fabric and services related to their property. Participants completed questionnaires using the Energy Savings Trust Home Energy Condition form which records data related to the house age and construction method.

A FLIR S65 HS infrared camera with zoom attachment captured the thermal images of homes in the so-called iron bar palette (red to black). General methodological issues concerning the problems and best practice of thermographic imaging of buildings can be found in a number of texts including several volumes published by BSRIA, (Pearson, 2002). To ensure that the images showed just heat loss and no confounding effects of (eg. moisture or solar heating through the day) the images were all taken at night (from 7pm onwards) on dull days when there had been no rain. Images were taken through the winter heating season of 2007, February to April. A video camcorder or digital voice recorder captured 10 of the householder's responses to the image and the subsequent discussion. Images of the home of the householder were displayed electronically using a laptop, in the participants own home. Participants were not time constrained when giving their responses to allow for free responses. Transcripts were analysed using an inductive thematic analysis where the data was closely examined for themes/ideas emerging naturally from the interviews.

Results and Commentary.

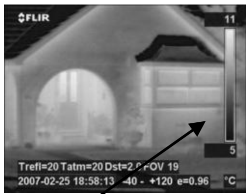
Preliminary analysis of interviews from the cohort suggests that viewing the images can prompt the householder along a reasoning process which culminates in them suggesting energy saving actions, but this may be context dependent. One participant’s reaction encapsulates the impact of viewing the image:

Example 1:

“I think that it (the image) is very immediate, looking at something like that and you can see, wow, look at all that heat escaping. You can see the heat escaping”.

Two detailed examples are presented here to illustrate the reasoning process evident in the interviews. The extract from example 2, see Table 2, shows a ‘successful' process; energy saving actions are identified. In contrast Table 3 illustrates a failure to promote energy saving actions. Both extracts are part of lengthier interviews; the extracts have been chosen to illustrate contrasting responses at each stage of the iterative sequence of the reasoning process. In the example below, on the return visit, the householder had taken the energy saving action that he suggested (placed reflective radiator panels behind the radiator).

Table 2: Transcript illustrating a ‘successful’ reasoning process from householder’s first view of the thermal image of their home to the suggestion of energy saving action:

Stages of the Reasoning Process (Iterative).	Example 2: Participants (P1) response to the image	Thermographic Image
1. Image Attracts Attention/Visualness/Newness	P1: We’re on fire P2: Wow, that looks dreadful	
2. Viewer orientates the picture to their home, superimposing ‘knowledge’		
3. Image contains salient information which is accounted for. 4. Matched to ‘correct’ knowledge, action idea retrieved and suggested	P1“You see this is interesting, I don’t remember where the blinds were in the bedroom. They were probably drawn, eh here, because you can see here that this is darker and they are the blinds in the bay window. Whereas that side of it, is that because it is illuminated from there or are we actually seeing that the blind was only partially drawn on that side? Because we don’t always fully draw	

	them….”. P1“On that basis, one of the things that you could do to minimise the heat loss is to have rather heavier curtains.” P2: “We could put the foil behind the radiators in that bay window”.	

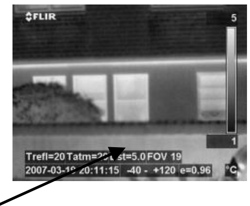
Table 3: Transcript illustrating an ‘unsuccessful’ reasoning process from householder’s first view of the thermal image of their home to the suggestion of energy saving action:

Stages of the Reasoning Process (Iterative).	Example 3participants response to the image	Thermographic Image
1. Image does not attract Attention	(No exclamation of attention/interest)	
2. Viewer does not orientate the picture to their home, superimposing ‘knowledge’	Interviewer (I): That’s the first em, top half of the building and that is the bottom half. P: ‘em yeh……so the blue is?	
In the example to the right, the viewer appears to have difficulty making sense of the images initially,	I: Yes, what sense can you make of those pictures?	
3. Image contains no salient information, no accounting process	P: Dark. Obviously there is a big contrast between the ‘em, there is a lot of contrast obviously between the windows and the rest of the building so…. I; Well, that’s your scale. P: Yes	
4. Matched to ‘correct’ knowledge, action idea retrieved and suggested	I: So, everything that colour is cold and that colour is hot obviously so and that’s in degrees C, so you are	

only actually looking at a 4 degree difference.

P: Oh, I see, yeh.

I: But your windows are quite bright aren't they, in here, but you don't heat this room, you said.



(Here the participant has a virtually unheated home).

P: No, no never. The windows are keeping the heat in then are they?

I: Would …(these images)…do you think prompt people to think about heat and how you use it?

P: Yes, well it would wouldn't it? Yeh. You see it doesn't apply to me because I am powerless to act anyway. There again it depends on your finance.

Discussion.

The results of this preliminary study are tentative, and links between householders viewing thermographic images and actual energy saving behaviours will need to be confirmed. This initial study is informing a larger research programme.

Results support the initial hypothesis. The 2 contrasting interviews suggest the potential that viewing an image has for prompting a reasoning process culminating in the householder suggesting an energy saving solution. The interviews also suggest how viewing an image fails to promote energy saving actions.

In examples 1 and 2, the reactions to the images suggest the householders have had their attention drawn to the issue of energy/heat and have acted on the information portrayed in the images. Indeed the participant in table 2 did place a reflective panel behind his radiator. The discourse in Table 2 shows how viewing the image drew the householder's attention to a salient issue which was interpreted in such a way as to suggest to the householder specific actions which might conserve heat and so energy (minimising heat loss from radiators, shutting curtains at night, draught proofing a door). In this sense the images mediate awareness of heat loss (Verbeek, 2006). Householders 'know' about energy saving actions such as closing curtains at night, but seeing a draught seems more salient and may lead more directly to understanding, than traditional communication methods. However, there are pitfalls. If viewing the images does not trigger any of the elements of the reasoning process, the energy saving action is unlikely to be suggested to the householder. In example 3 the householder sees nothing salient in the image and appears to be finding it difficult to understand the information in the images; no method of saving energy is prompted. To trigger the reasoning process required the following:

1. That the image attracted attention; the image had to contain something salient, either in the image itself, or in the connection that the householder made between the information in the image and their knowledge of their home.

2. The image had to be interpreted 'correctly'

3. The viewer's attributes were critical: Knowledge - of how to save energy, how heat operates, Interest, Attention.

So, 'success' is context dependent. This is significant when presenting householders with infrared images of their own home. The image is likely to be idiosyncratic to the building being pictured; so the potential to increase understanding may be lost. In addition, attention may be drawn to actions which do not achieve the best energy savings, although they are visible. For example, draught proofing, whilst sensible and inexpensive, has a lower energy saving potential than improving the boiler (see Table 1). On the other hand, where walls show hot patches, and so prompt the householder to consider cavity wall insulation, this action has a much higher energy saving potential. Further, the viewer has differing attributes and their ability to make sense of the energy saving message in the image will vary.

The findings of this initial study have methodological problems. Clearly, the number of householders interviewed was small. Further quantitative research is ongoing to measure the effect of viewing the images on energy usage and on energy saving behaviours across a larger sample size. The resulting quantitative data will be compared against the qualitative findings. Data collection opportunities are limited as there are strict conditions required for taking infrared images in order that the differential surface temperatures seen on the images infer heat coming from the house and not elsewhere. Note that certain effects can masquerade as heat loss. Solar gain, which has built up during the day will show as a hot patch on a wall with the potential to mislead the householder. Different surfaces emit their own levels of infrared radiation and this could look like an area of heat loss. In conclusion the images need to be taken by (and heat loss inferred by) a qualified thermographer with experience of analysing building structures.

Future Work

Future work needs to determine the influence that differently framed approaches might have on the individual and should consider what energy saving and technical advice should be included. Moreover, thermographic images can be refined using appropriate software. Therefore the ability to 'package' the images to optimise their impact is possible and in such a way that one to one communication may not be a necessity. Further work will need to examine the mechanism by which, a prompt such as this one, translates in to an actual energy saving action.

CONCLUSIONS

The results of this preliminary study make tentative links between a householder viewing a thermographic image of their property and making subsequent energy savings. Results were interesting, suggesting potential for thermographic images to be used to prompt a reasoning process in an individual's mind, which leads to specific energy saving ideas. Follow up work will focus on optimising this potential and ensuring that effective energy saving actions are targeted.

REFERENCES

Abrahamse, W, Steg, L, Vlek, C, Rothengatter, T (2005) A review of intervention studies aimed at household energy conservation. "Journal of Environmental Psychology" 25, 273-291.

Association for the Conservation of Energy, 2008 Retrieved April 31st 2009, from http://www.ukace.org/

Darby S (2008) Energy feedback in buildings - improving the infrastructure for demand reduction. Building Research and Information 36 (5), 499-508

DEFRA (2008). A framework for pro-environmental behaviours. London.

DEFRA (2003) Key Trends in UK Domestic Sector Energy Use.

DTI. (Dept of Trade and Industry, 2005), Digest of UK Energy Statistics.

DTI (2007) Meeting the Energy Challenge; A White Paper on Energy

EST (Energy Savings Trust, 2006), Domestic Energy Primer – an Introduction to

EST ,(2007) Green Barometer, Measuring Environmental Attitude,

IEA, World Energy Outlook, 2006

Gardner, G T, & Stern, P C (2002). "Environmental Problems and Human Behaviour". Boston: Pearson.

Gardner, G and Stern, P.C (2008), The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change. "Environment, Science and Policy for Sustainable Development" Sept/Oct

HM Government (2006), The Energy Challenge; Energy Review

Lehman, P K, & Geller, E S (2004). Behaviour Analysis and Environmental protection: Accomplishments and Potential for More. "Behavior and Social Issues", 13, 13 – 32.

McKenzie Mohr, D, Smith, W., (1999). "Fostering Sustainable Behaviour: An Introduction to Community-Based Social Marketing". Gabriola Island, Canada; New Society Publishers.

Midden, C J H, Kaiser, F G, McCalley, L T (2007). Technology's Four Roles in Understanding Individuals' Conservation of Natural Resources. "Journal of Social issues", 63, 155 – 174.

Pearson, C., (2002). Thermal Imaging of Building Fabric. A best practice guide for continuous insulation, BSRIA, Bracknell, London.

Stern, P C (1992). What psychology knows about energy conservation. "American Psychologist", 47(10), 1224-1232 .

Verbeek, P P, and Slob, A (Eds) (2006). "User behaviour and technology design. Shaping sustainable relations between consumers and technologies". Kluwer: Dordrecht/Boston.