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Lessons on visual feedback from the eViz Project: The evidence for using thermal images as a visual intervention

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Energy-Feedback Symposium 2016: Extended Abstract

Lessons on visual feedback from the eViz Project: The evidence for using thermal images as a visual intervention.

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Abstract

Thermal images can play an important role in feeding back the consequence or outcome from energy use behaviour and through providing a platform to motivate energy efficient home improvements.

This article describes four studies conducted through the eViz project, which used a variety of qualitative and quantitative methods, to investigate the impact that thermal images can have on householder retrofit behaviour. Results from thermal image investigations were benchmarked against carbon footprint audit and control cases, and ranged from simple generic letters on energy efficiency to more tailored in-depth thermal image reporting.

Findings have suggested that thermal images do provide motivation for householders to undertake energy efficient improvements on their house. The extent to which thermal images promote a behavioural effect is likely to depend on the personal nature of the images' subject, and the degree to which the viewer can elaborate on the images..

Moving onto the next steps, this article reports on an on-going project to scale up this work to a citywide context in Canada.

1.1 Introduction

Energy-feedback has generally focussed on providing energy users with information about their energy use. This can be in the form of numbers, graphs and via apps or in-home displays, for example. Often this usage relates to appliance use and research in this area focuses on evaluating the impact of representing current energy use and analysing how to represent energy usage data (Fischer, 2008; Hargreaves, 2010). This type of feedback tends to dominate the literature and yet there are other ways to feed information about energy use back to householders. Indeed there have been calls to develop and test innovative feedback devices, especially those that have user engagement in mind (Buchanan, Russo & Anderson, 2015). Space heating is an important issue also for energy demand reduction. In the UK, heating a home can make up 66% of overall energy use (DECC, 2013).

The eViz Project (Energy Visualisation for Carbon Reduction) evaluated the use of

thermal images in a series of studies as a behavioural intervention aimed at reducing the energy used to heat a building. Feedback is regarded as a consequence strategy, communicating the consequence or outcome that is contingent on a desired energy related behaviour. Using visual images such as thermal images can provide such feedback in that the technology acts as a medium to communicate firstly the areas of heat loss and secondly, by inference, the consequence of energy efficiency actions targeting that specific heat loss. Indeed, they can provide situation and behaviour specific information to a building user, prompt new goals and motives for energy efficiency (Goodhew, Pahl, Auburn & Goodhew, 2015).

We discuss the evidence for the use of thermal images as such an intervention, drawing on an overview of the results of four studies using mixed qualitative and quantitative methods with householders in the field, ranging from in-depth, tailored approaches to simple letter communications showing thermal images of typical houses.

We present a collection of typical thermal images taken in and around domestic homes and discuss what they can communicate to building users, in terms of building defects. Next we summarise the evidence, which suggests that viewing such images can promote the take up of energy efficiency actions. We discuss the conditions that maximise or minimise such a behavioural effect across the four studies. Finally we report on a current collaboration with Canadian partners aiming to scale up thermal imaging approaches. In conclusion, thermal imaging is a powerful method to communicate heat and energy loss to householders that can lead to better understanding of heat loss and motivate retrofit actions.

1.2 The Affordances of thermal images, feedback on building defects, and heat loss.

Thermal imaging provides visual evidence of building defects (conduction, ventilation, draughts, missing insulation). A thermal camera is used to measure the thermal radiation emitted from a feature, which is then converted into a visual image, where differences in colour patterns signify differences in apparent surface temperature. Using this technology, areas of unexpected heat loss in building features and potential building defects can be inferred. Figures 1, 2, and 3 present example thermal images of typical building defects.

Many have seen the images as a potential behavioural intervention to encourage the uptake of energy efficiency measures amongst householders (Burchell, Rettie & Roberts, 2014, with Smart Communities and many UK Community group projects including The CHEESE Project in Bristol, Transition Bath, South West Oxfordshire). The underlying premise is that seeing (normally invisible) unexpected heat loss from a building will motivate the viewer to take action to stop that loss.

Fig 1: An example of conduction heat loss and thermal bridging

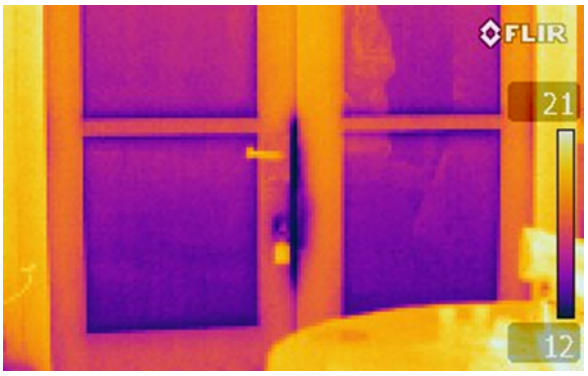

Fig 2: Example of ventilation heat loss from the interior of the home

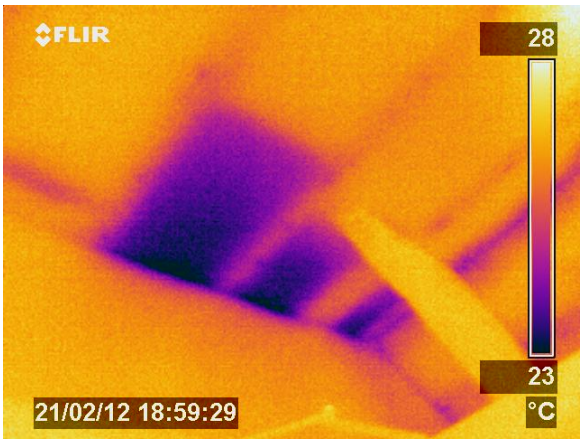

Fig 3: An example of missing insulation

1.3 The behavioural background

The behavioural context is that asking people to take voluntary actions to increase energy efficiency measures in their homes can be problematic due to the nature of heat/energy use. There is potential for individuals to be disconnected from the energy they use to heat their home. They may not be aware of the degree of heat, which is leaving the building (heat egress), through poorly insulated walls, lofts, fireplaces, curtain less windows, or how hard their heating system is working to achieve their desired comfort level. Thermal images can show the normally invisible heat as visible; thereby presenting visual evidence of unexpected areas of heat loss (Fox et al., 2015; Pearson, 2011). If the householder knows the building they might be able to connect their energy efficiency actions/inactions and behaviours to the heat loss. In this sense, thermal images can provide a visual medium (Midden, Kaiser & McCalley, 2007) through which heat loss issues are easily communicated and the consequence of energy efficiency actions can be imagined. It is a feature of visualisations that they can communicate messages quickly, powerfully and support the conceptualisation of complex messages (Sheppard, 2001; 2005; Nicholson-Cole, 2005).

The visual nature of thermal images may be important in motivating the householder. This is because making the invisible visible attracts attention (Gardner & Stern, 2002). Energy use and the potential of energy efficiency tends to be hidden, therefore the ability to attract attention to heat loss is important. A key step in changing behaviour is encouraging the active attention to energy issues (Page & Page, 2011).

Aside from attention and interest, visual images are strongly related to emotions; we respond quickly to visual images, compared to the same information in textual form

(Holmes & Matthews, 2010). In particular vivid colours in images (red to blue spectrum) appear to promote an increased emotional response compared to black and white representations (Giacomin & Bertola, 2012). These images can become internalised as mental images, which are more readily remembered (Andrade et al., 2012; Smith & Shaffer, 2000) and in turn connect to motivation and the formation of goals (see Fig 4). To summarise, the psychology literature suggests that visuals can 'attract attention, evoke emotions, facilitate memory and trigger goals' (Pahl, Goodhew, Boomsma & Sheppard, 2016).

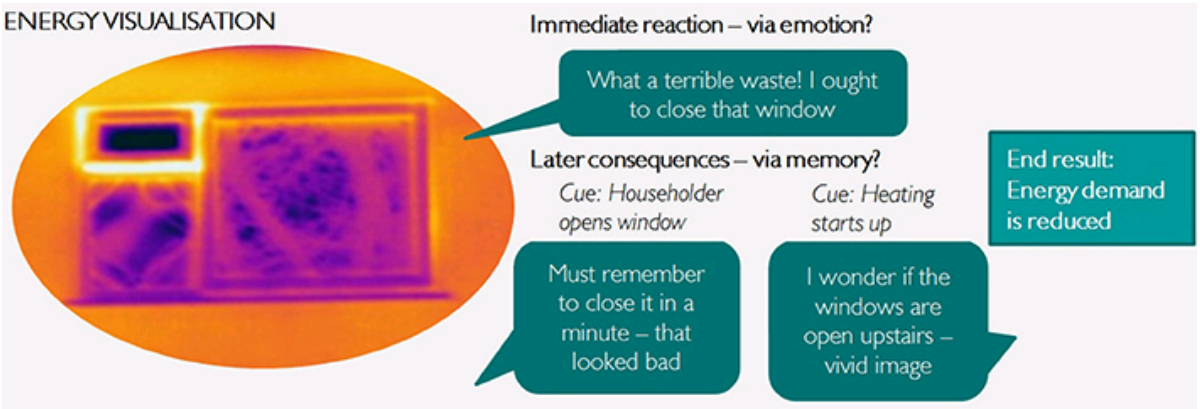

Fig 4: The suggested psychological process from energy visualisation to behaviour (Pahl et al., 2016).

1.4 The evidence that thermal imaging promotes energy efficiency actions

The eViz team at Plymouth University has investigated the behavioural impact of thermal images when used with householders. Four studies have investigated the connection between seeing thermal images and the uptake of energy efficiency behaviour in domestic homes. The first study provided evidence that seeing thermal images promoted the uptake of energy efficiency actions amongst householders. This small-scale study conducted in a small UK town (with participants' homes within a 3 mile radius, therefore experiencing the same weather conditions) consisted of three experimental conditions. Householders either saw thermal images of their home and completed a carbon footprint audit of their home (thermal image group, n = 17) or completed the carbon footprint audit without seeing thermal images (audit only group, n = 17), or they were placed in a control group (n = 9). All households had a home visit from the researcher. One year after the intervention, the thermal image group had reduced their carbon emissions as calculated from their household energy bills (comparing the year before and after the intervention, see Fig 5). Additionally, as can be seen in Figure 6, the behaviours they took were directly related to the type of energy efficiency issues visible in the thermal images (Goodhew, Pahl, Auburn & Goodhew, 2015).

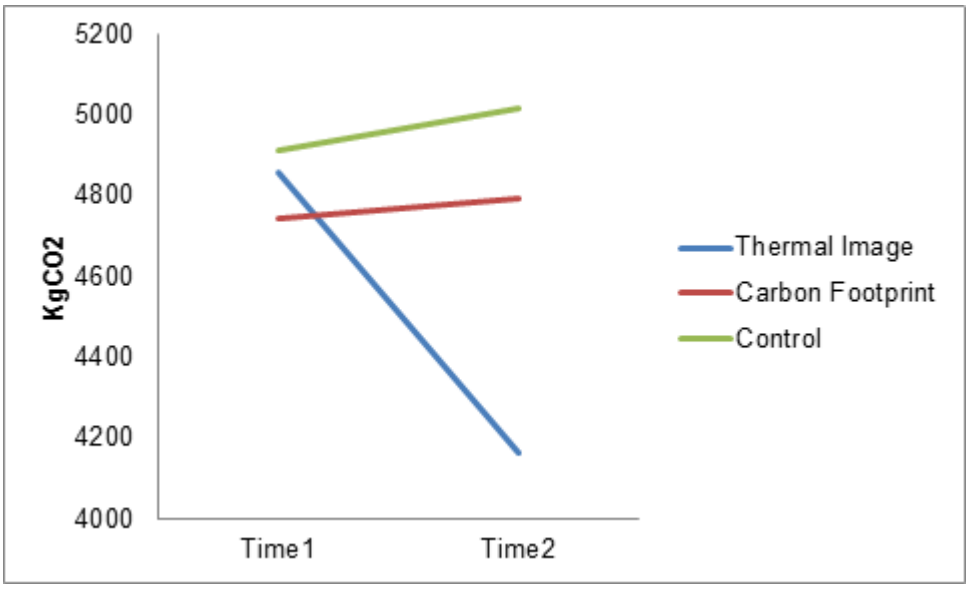

Fig. 5: Change in mean annual carbon emission from domestic energy use before and after the thermal images were seen.

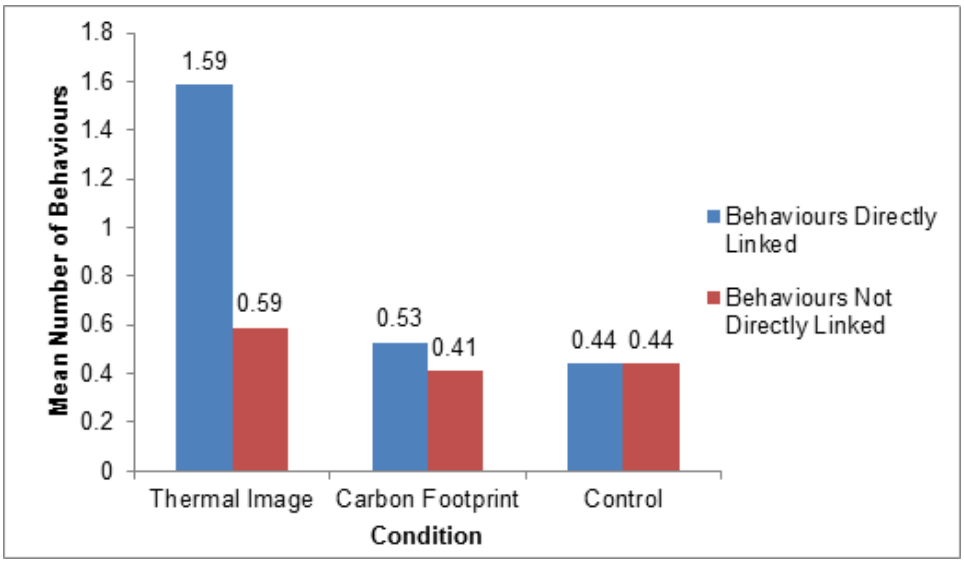

Fig. 6: Behaviours directly related to thermal images vs. not directly related.

A second study employed a larger sample of 87 householders who all, during a home visit from an energy auditor, completed an energy audit for their home. Of these, 54 houses were imaged, whilst 33 homes made up the control group and did not receive any images. After approximately 6 months, the households who had seen thermal images were almost 5 times more likely to have installed draught proofing than the households who had not seen thermal images (Goodhew, Pahl, Auburn & Goodhew, 2015). These two studies provide evidence that seeing feedback in the form of thermal images of one's own home can promote the take up of simple energy efficiency measures.

Fig. 7: Example of thermal image taken during Study 2, showing dark (cold) areas where there is cold air ingress around the surround of the doorway, which leads outside (Goodhew, et al., 2015).

The two studies reported above used thermal images personalised to the householder (i.e. of their own home). A third study (Boomsma, Goodhew, Goodhew & Pahl, 2016) sought to explore this aspect and focussed on the importance of personalising the thermal images. The question was whether a less personalised thermal imaging approach could also trigger goals to conserve energy in the home. A homeowner may not easily connect their own behaviour with information in a generic thermal image (an image of another person's home), and generic images are likely to be perceived less relevant to the householder. This study consisted of three conditions. One group of householders received an e-mail report containing the images taken during a visit from a thermographer. A second group received the same type of report but containing thermal images of 'typical homes in your area' whereas a third condition received a report with text only information (i.e. no images). Householders (N = 233) reported that they recalled thermal images better than text information, but the personalised group reported the images as more intrusive (the images 'popped into their heads' more often. Personalised thermal image reports were elaborated by the householders more than the generic images. Householders said they looked at the personalised images more often (Fig. 8) and shared them with others more than did the comparison groups. Furthermore the householders who saw the personalised thermal images reported a stronger belief that they would benefit from energy efficiency measures and were more likely to report that they had changed their plans for their homes.

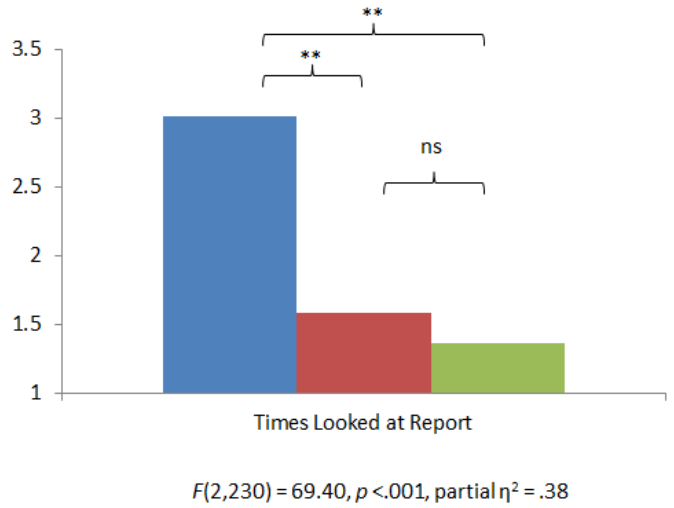

Fig. 8: Study 3: Number of times the occupants looked at the report

Finally, Study 4 explored the efficacy of using thermal images in a mass communication (Goodhew et al., in preparation) in collaboration with Plymouth City Council and the Behavioural Insights Team. It investigated whether inserting thermal images into a letter announcing a scheme to install solid wall insulation, would promote the uptake of the scheme. In this study 5483 eligible homes (those of solid wall construction) were randomly allocated to one of three letter types announcing the insulation scheme. One letter contained thermal images of two 'homes like yours,' one of which showed a house without solid wall insulation and one showed a house with solid wall insulation; the second letter type included one thermal image of a house without insulation and the control letter contained text only (no images). The behavioural measure was whether the householder made a telephone call to enquire about the scheme. Call rates were extremely low and preliminary analysis suggests that the no-image group rang up slightly more frequently than the two-image group. Further analysis is underway taking into account sociodemographic characteristics by geographical area. The initial analysis suggests that this more 'shallow' approach of a letter through the door addressed to 'the householder' does not work as well as the in-depth and personalised thermal imaging approach. Moreover, it is also known that solid wall insulation is a very difficult action to promote (Rosenow & Eyre, 2015).

1.5: The conditions that maximise the efficacy of thermal images as an intervention

In conclusion, the lessons from the eViz project suggest that thermal images can promote the uptake of energy efficiency measures in the type of information they feed back to householders.

Thermal images communicate energy waste and efficiency in a manner, which is difficult to achieve using other forms of communication. They can attract attention, encourage the viewer to connect their behaviour in the home to the images, they invoke emotion, trigger new goals and so promote action. Further, the four studies reported above together suggest that energy efficiency actions are promoted where there is increased elaboration by the householder. Thermal imaging feedback in the form of a letter (unannounced) containing images of other homes did not promote a behavioural effect. Yet, non-personal images were recalled better than textual information in a report on energy efficiency. This suggests that

images attract attention anyhow; however, personalised images were recalled more and were more intrusive; they 'popped into people's heads'. Additionally, the personalised images were looked at more often and shared more. Ultimately, energy efficiency actions were promoted when images were personal to the householder. The behavioural effect is likely to be stronger the more personalised the images are to the householder viewing them and the greater the opportunity that the householder can elaborate and act on them.

1.6: Future work and scaling up thermal imaging as a feedback intervention

Recent work by Plymouth University in this field has scaled up the use of thermal imaging for visual intervention. This has been undertaken in collaboration with the University of British Columbia, where mass/large scale thermal imaging (drive-by thermography) is proposed as an intervention to motivate carbon reduction within entire neighbourhoods (several thousand homes) in a large Canadian city.

It is common in large-scale thermal imaging projects (e.g. drive-by and aerial thermography) for those who commission them to run out of time, money and enthusiasm before undertaking community engagement. The impact of such thermal imaging projects therefore often fails to deliver any meaningful or measureable energy reduction improvement at an individual homeowner level.

This work, which is due to be undertaken in winter 2016/17 will seek to bridge the gap between undertaking large scale thermal imaging projects and understanding the level of engagement, where thermal images are used to motivate homeowners to undertake energy upgrades.

1.7: Conclusion

This paper has presented an additional way of presenting energy information to householders, focussing on an area of energy use, space heating. It uses visuals to communicate heat loss so that the householder can infer the efficacy of taking action to mitigate that loss and thus save energy (and improve thermal comfort). We call for the debate around the efficacy of feedback, to include innovative and different ways of communicating energy use.

References

Andrade, J., May, J., and Kavanagh, D. (2012). Sensory imagery in craving: from cognitive psychology to new treatments for addiction. *J. Exp. Psychopathol*. 3, 127–145. doi: 10.5127/jep.024611

Boomsma, C, et al. (2016) "Improving the visibility of energy use in home heating in England: Thermal images and the role of visual tailoring." *Energy Research & Social Science* 14: 111-121

Buchanan, K., Russo, R., Andreson, B. (2015) The question of energy reduction: The problem(s) with feedback. *Energy Policy*. 77: 89–96 doi:10.1016/j.enpol.2014.12.008

Burchell, K., Rettie, R., Roberts, T., (2014). Working together to save energy? Report of the smart communities project. Available at: http://business.kingston.ac.uk/sites/all/themes/kingston_business/charmproject/smartcommunities.pdf (Accessed: 16/06/2016).

DECC (2013a). Energy consumption in the UK (2013). Retrieved from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65954/chapter_3_domestic_factsheet.pdf

Fischer, C., (2008) Feedback on household electricity consumption: a tool for saving energy? *EnergyEffic*. 1(1),79–104.

Fox, M., Coley, D., Goodhew, S. & Wilde, P. D. (2014) 'Thermography methodologies for detecting energy related building defects'. *Renewable and Sustainable Energy Reviews*, 40 pp 296 – 310

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

Giacomin, J. & Bertola, D., Human emotional response to energy visualisations (2012) *International Journal of Industrial Ergonomics,* 42, 542- 552.

Goodhew, J., Goodhew, S., Auburn, T., De Wilde, P., Pahl, S. (2009) " A Preliminary Investigation of the Potential for Thermographic Images to Influence Householders Understanding of Home Energy Consumption" In: Dainty (Ed) Procs 25th Annual ARCOM Conference, 7 -9 September 2009, Nottingham, UK, ARCOM, 971-79.

Goodhew, J., Pahl, S., Auburn, T., Goodhew, S. (2015) Making Heat Visible; Promoting energy conservation behaviors through thermal imaging. *Environment and Behavior* (Published online 9th Sept 2014) DOI: 10.1177/0013916514546218.

Holmes, E. A., and Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clin. Psychol. Rev.* 30, 349–362. doi: 10.1016/j.cpr.2010.01.001

Hargreaves, T., Nye, M., J. Burgess, J. Making energy visible: a qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy*, 38 (10) (2010), pp. 6111–6119

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 (1), 155-174.

Page M., Page N. (2011). Green behaviour change: HOT topics. In Bartlett D., editor. (Ed.), Going green: The psychology of sustainability in the workplace. London, UK: British Psychological Society; Vol. chapter 8, p. 65-75

Pahl, S., Goodhew, J., Boomsma, C., Sheppard, S. (2016) The Role of Energy Visualization in Addressing Energy Use: Insights from the eViz Project. *Frontiers in Psychology*. 7. DOI:10.3389/fpsyg.2016.00092

Pearson, C. (2002) Thermal Imaging of Building Fabric. BSRIA, Technical Note TN 9/2002. A best practice guide for continuous insulation

Sheppard, S. R. J. (2001). Guidance for crystal ball gazers: Developing a code of ethics for landscape visualization. *Landscape Urban Plan*. 54, 183–199. doi: 10.1016/S0169-2046(01)00135-9.

Sheppard S. R. J. (2005). Landscape visualisation and climate change: The potential for influencing perceptions and behaviour. *Environmental Science and Policy*, 8, 637-654.

Smith, S. M., and Shaffer, D. R. (2000). Vividness can undermine or enhance message processing: the moderating role of vividness congruency. *Pers. Soc. Psychol. Bull*. 26, 769–779. doi: 10.1177/0146167200269003