

Does the age of the residents influence occupant heating practice in UK domestic buildings?

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Abstract

The UK Government is committed to reducing CO₂ emissions by 80% of 1990 levels by 2050. To meet this target significant reductions in energy consumption are required from the UK housing stock. Space heating is the most significant end use of energy in residential buildings. Behaviour that relates to the direct interaction of residents with heating systems is termed occupant heating practice (OHP). More empirical evidence is required to determine if OHPs relate to socio-demographic and economic status of households. Improved knowledge of OHP will aid policy makers in successfully targeting energy efficiency measures. To build the evidence base for OHP, a large-scale city-wide housing survey was carried out in Leicester, UK in 2009-2010. Internal temperature measurements and details about household composition were collected in over 300 dwellings. These data are used to explore the links between OHP and the age of occupants. Results of the initial analysis suggest that older occupants demand higher living room temperatures but may heat a lower proportion of their dwelling. 36% of dwellings were observed to have lower than average temperatures. Continued analysis is required to find out if energy efficiency measures could improve the thermal comfort of occupants or if low temperatures are a result of short daily heating periods. A more detailed monitoring study is required to investigate the variation in internal temperatures throughout dwellings and to gain further insight into OHP.

Introduction

The 2008 Climate Change Act committed the UK government to reduce CO₂ emissions by 80% of 1990 levels by 2050 (DEFRA, 2008). To meet this target a significant reduction in energy consumption will be required from residential buildings. Space heating is the most significant end use accounting for 57% of residential energy consumed (BERR, 2008). Self report survey research has concluded that domestic energy use is related to climate, built form of properties, efficiency of heating systems, socio-economic factors and occupant behaviour (Steemers & Yun, 2008; Meier & Rehdanz, 2009). Monitoring and modelling research has shown that energy performance of residential buildings is dependent on occupant behaviour (Summerfield et al., 2009; Firth et al., 2010). The occupant behaviours that relate to space heating energy use can be categorised as direct and indirect. Direct behaviours include demand temperature (the temperature required by building occupants, often controlled via a thermostat), daily heating period (total time in hours when the heating system is in use) and the proportion of the dwelling that is heated (variation in temperature throughout the dwelling, controlled via thermostatic radiator valves or secondary heat sources). These behaviours are the result of occupant interactions with heating systems and are referred to as occupant heating practice (OHP). Indirect behaviours include window opening and the use of internal doors.

Temperature monitoring studies have been undertaken in UK residential buildings. Oreszczyn et al., (2006) monitored temperature in 1,604 low income dwellings and found that average living room and bedroom temperatures were 19.1°C and 17.4°C respectively. It was concluded that temperatures in many of the properties were inadequate for sedentary occupants. Other studies reported similar average temperatures and are presented in Table 1. It is important to note that these studies reported only average temperatures not demand temperature. Shipworth et al. (2010) analysed daily temperature profiles and calculated demand temperature during heated periods. Mean demand temperature was estimated to be 21.1°C. As a whole these studies have reported a large range in internal temperatures and OHP. Differences in OHP between dwellings will lead to a large variation in energy consumption for space heating (Firth et al., 2010). This makes it difficult to predict the energy savings that would result from energy efficiency initiatives. Therefore more empirical evidence is

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required about OHPs and to identify if they are related to social (e.g. age of occupants, household income) and technical (e.g. heating system efficiency, built form) factors. Improved knowledge of internal temperatures and the related OHPs will aid policy makers in targeting cost effective strategies for increasing energy efficiency and reducing fuel poverty.

Table 1

Average living room and bedroom temperature reported in temperature monitoring studies in UK dwellings in the last five years

	Average temperature (°C)	
	Living room	Bedroom
4M - this study (n = 214)	18.3	17.4
Oreszczyn et al. (2006) (n = 1604)	19.1 ^a	17.4 ^a
Summerfield et al. (2007) (n = 14)	19.1	17.1
Yohanis & Mondol (2010) (n = 25)	19.4	18.4

^a standardised for 5°C external temperature

Oreszczyn et al., (2006) found that older occupants demanded higher living room temperatures and lower bedroom temperatures. This work aims to explore if OHP is related to the age of household occupants. A large-scale city-wide housing survey was carried out in Leicester, UK in 2009-2010 as part of the 4M project (see below). Temperature was measured in over 300 dwellings over a 9 month period. An initial insight into OHP was gained by analysing temperature data from February 2010. Average temperature and estimated demand temperature for weekday and weekend periods were calculated as indicators of OHP. The relationship between these indicators and age of the oldest occupant were explored.

Methodology

Data collection:

The data analysed were collected during a large-scale city-wide housing survey carried out in Leicester, UK in 2009-2010 as part of the 4M project (Lomas et al., 2010). The 4M project - Measurement, Modelling, Mapping and Management (4M): An Evidence-Based Methodology for Understanding and Shrinking the Urban Carbon Footprint - is a collaboration between 5 Universities funded through the EPSRC. 4M intends to study CO₂ emissions and sinks within urban areas and has collected data from households within Leicester City including internal air temperatures within residential buildings. Dwellings were selected using a stratified sampling technique. Initially 1000 households were approached to take part in the study. 575 households were involved in face to face interviews which were conducted by the National Centre for Social Research (NatCen). Hobo data loggers (Figure 1) were used to monitor air temperature every hour between July 2009 and March 2010. The sensors were calibrated by Tempcon Ltd and were found to be accurate to ±0.4°C. NatCen interviewers asked the occupants to place the Hobos in the living room and main bedroom. Guidance on placement of sensors was provided and included that the Hobos should be placed away from heat sources and not in direct sunlight. At the end of the monitoring period the Hobos were returned to Loughborough University in pre-paid envelopes.



Figure 1 Hobo data logger used to measure air temperature in the living room and main bedroom

Data analysis:

Variation in OHP may be related to socio-demographic and economic factors (Druckman & Jackson, 2008). For this initial analysis only the age of the oldest occupant was considered. Temperature data from 214 households were analysed for February 2010 as it was assumed that heating would be used throughout the whole month. Households were excluded from the analysis if data was only available from one of the temperature sensors or if data loggers could not be downloaded. Households with average and estimated demand temperatures lower than 10°C in the living room were also excluded as it was assumed that the sensors in these properties were placed incorrectly resulting in erroneous measurements. Whole day temperature profiles were plotted for dwellings where low average temperatures were observed to check whether rooms were heated (Figure 2). No properties were excluded from the analysis due to the observation of high temperatures. As all of the properties are located within Leicester City it was assumed that external temperatures were uniform across the whole sample.

Average temperature and estimated demand temperature were calculated for weekday (Monday to Friday) and weekend periods. The average temperature is an indicator of both daily heating period and demand temperature. The estimated demand temperature was calculated in both spaces by identifying the averaging the daily peak temperatures for weekday and weekend periods. These indicators were plotted against the age of the oldest occupant. Further analysis was carried out by grouping households by age ranges based on age of the oldest occupant. Four age ranges were chosen to broadly represent different life stages: 20-35 (n=35), 36-50 (n=63), 51-65 (n=65) and 65+ (n=51). Average and estimated demand temperatures were plotted against age range and trends were observed.

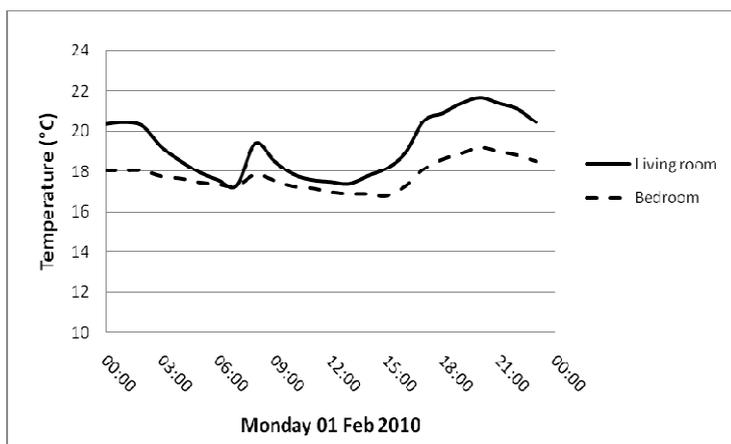


Figure 2. Temperature profile showing bedroom and living room temperatures measured in one house on the weekday 1st February 2010

Figure 2 shows a temperature profile for one dwelling for one weekday. Internal temperatures can be observed to increase when heating is being used. Two distinct heating periods can be seen, in the morning around 7:00am and the evening between 3:00pm and 8:00pm. Peak temperature is reached at 8:00pm and the estimated living room demand temperature for this day is 21.7°C.

Results and discussion

The average temperatures and estimated demand temperatures for bedroom and living room spaces are presented in Table 2. The average temperature for weekdays in the living room and bedroom was 18.3°C and 17.4°C respectively. A large range of average and estimated demand temperature can be observed equating to approximately 15°C variation (Figure 4). This finding confirms those from previous studies (e.g. Oreszczyń et al., 2006; Yohanis & Mondol, 2010). This implies that there is significant variation in internal temperatures in UK dwellings. This variation is a product of the many factors that may influence internal temperatures including built form, efficiency of heating systems and other social and technical factors. Estimated demand temperature for living room spaces was calculated to be 20.8°C during the week and 21.1°C during the weekend (Table 2). These figures are similar to the estimated demand temperature of 21.1°C reported by Shipworth et al. (2010). Weekend average temperature (Living room = 18.7°C) and estimated demand temperature (Living room = 21.1°C) were observed to be marginally higher than those measured in the week (18.3°C and 20.8°C). This could relate to longer weekend heating periods due to the increased length of time the dwelling is occupied over the weekend.

Table 2
Internal air temperatures measured in living room and bedroom spaces in 214 dwellings in Leicester, UK, February 2010

		Average temperature (°C)		Estimated demand temperature (°C)	
		Mean (min, max) standard deviation		Mean (min, max) standard deviation	
Living room	Week	18.3	(11.1, 26.0) 3.0	20.8	(11.5, 29.7) 3.3
	Weekend	18.7	(11.0, 25.9) 3.0	21.1	(12.1, 31.3) 3.2
Bedroom	Week	17.4	(8.5, 24.4) 3.0	19.1	(9.1, 27.6) 3.2
	Weekend	17.7	(8.4, 24.9) 2.9	19.4	(8.7, 29.4) 3.2

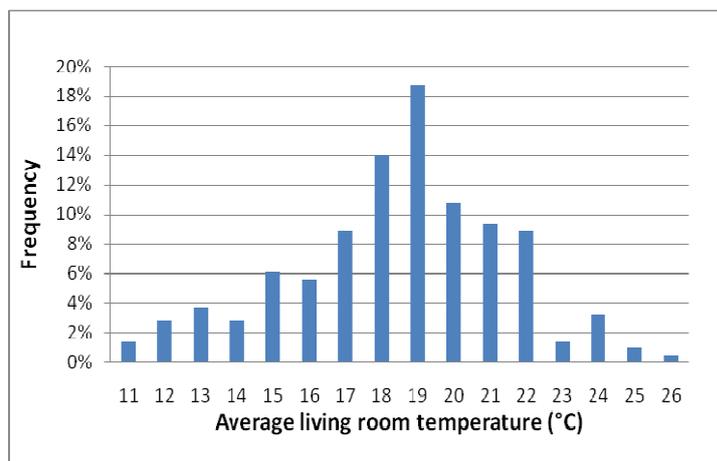


Figure 3 - Frequency of average weekday living room temperature recorded for February 2010 in 214 dwellings in Leicester

The modal average weekday living room temperature was 19°C (Figure 3). 36% of the households had average temperatures lower than the 2006 national average internal temperature of 17.78°C (Utley & Shorrock, 2008). Average living room temperatures were marginally lower than those observed in previous studies (Table 1). This could be due to short heating periods, rooms not being heated or a result of occupant's inability to heat their homes because of poor heating systems or fuel poverty. It is unlikely that the low average living room temperatures were a result of cold external temperatures as the average bedroom temperature is similar to those reported in previous studies. Further analysis is required to identify the proportion of dwellings where low average and estimated demand temperatures are the result of fuel poverty. In these properties energy efficiency improvements are unlikely to reduce CO₂ emissions as occupants are more likely to increase their thermal comfort than reduce their energy use (Lowe, 2009). Improved thermal efficiency of the built form and heating systems in these properties may, however, have a positive impact on the health of occupants and could reduce the number of people in fuel poverty.

Average temperature was plotted against the age of the oldest household occupant for living room and bedroom spaces (Figure 4). In living room spaces a small upward trend in temperature with age can be observed. This trend is reversed for temperatures in bedrooms. This finding supports previous studies that have reported that older people may demand higher living room but lower bedroom temperatures (Oreszczyzn et al., 2006). Average and estimated demand temperature for living room and bedroom spaces were plotted against each age range (Figure 5). Error bars show plus and minus one standard deviation and illustrate the level of variation in internal temperatures. Average estimated demand temperature for the 65+ age range for living room and bedroom spaces were 23.5°C and 21.9°C respectively. This is a large variation compared to the 20-35 age range which had living room and bedroom temperatures of 22.1°C and 22.2°C. Occupants in the 65+ age bracket heat their living room to higher temperatures but their bedrooms remain cooler. This may suggest that occupants above 65 years of age heat a smaller proportion of their home compared to younger occupants. To explore this further monitoring of temperatures throughout the whole dwelling is required.

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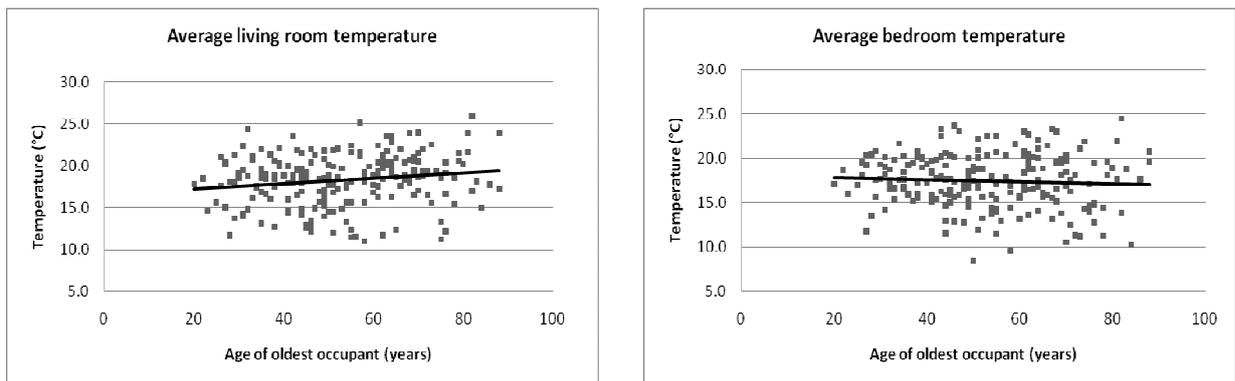


Figure 4. Average weekday temperature in living room and bedroom spaces against the age of the oldest occupant for 214 dwellings in Leicester

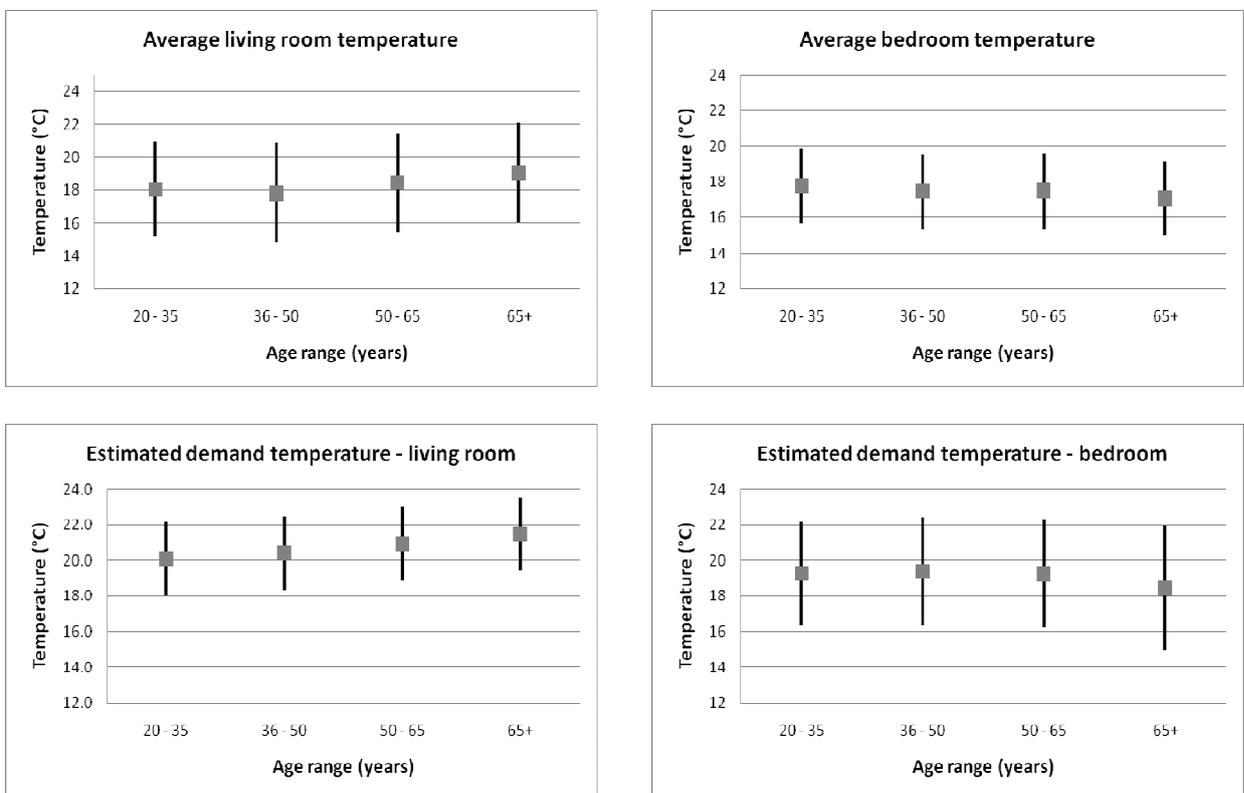


Figure 5. Average and estimated demand temperatures in the living room and bedroom relating to age range of the oldest occupant measured in 214 dwellings in February 2010. Error bars show plus and minus one standard deviation

Conclusions:

This paper presents initial analysis of temperature data collected during February 2010 in 214 households in Leicester. Estimated demand temperature (average of the daily peak temperatures) and average temperature were calculated for living room and bedroom spaces. Results have shown that there is a 15°C variation in average and estimated demand temperatures recorded in both bedroom and living room spaces. Estimated demand temperatures were similar to those reported in a previous study. Average living room temperatures were lower than those reported in previous studies. Further work is required to identify if this is a result of short heating periods, inadequate heating, poorly placed sensors or an indication of fuel poverty. Analysis was undertaken to investigate if there is a relationship between average temperature, estimated demand temperature and the age of the oldest occupant. By focusing on age ranges it was observed that, on average, older occupants

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demand higher living room temperatures but lower bedroom temperatures while younger occupants have more uniform demand temperatures.

The results have highlighted a limited relationship between the age of the oldest occupant and OHP. This suggests that further analysis is required to address whether other social and technical factors can explain more of the variation in internal temperatures. The current data set will be analysed to explore relationships between OHP and income, house price, built form, controllability of heating systems, age of property and number of occupants. External air temperature, average temperatures during heated periods and estimations of daily heating period based upon analysis of daily temperature profiles will also be considered.

The current data set is limited as only two temperature sensors were used and consequently it is not possible to identify the proportion of the dwelling that is heated. A further detailed monitoring study is therefore planned in 25 dwellings. In this study temperature will be monitored in every room. Interviews will be undertaken to gain further insight into OHP. The detailed study will also take into account a number of other factors that were not addressed here including the indirect behaviours window opening and the use of secondary heating.

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References

BERR 2008. "UK Energy in Brief" National Statistics".

<http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/energy/statistics/publications/in-brief/page17222.html>

DEFRA, 2008. "Climate Change Act 2008".

http://www.opsi.gov.uk/acts/acts2008/pdf/ukpga_20080027_en.pdf

Druckman, A. and Jackson, T. 2008. "Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model", *Energy Policy*, vol. 36, no. 8, pp. 3167-3182.

Firth, S. K., Wright, A. J., and Lomas, K. J., 2010. "Targeting energy efficiency measures and quality control: a sensitivity study using an English housing stock model". *Building Research & Information*, Volume 38. No. 1, pp. 50 – 69.

Lomas K J, Bell M C, Firth S K, Gaston K J, Goodman P, Leake J R, Namdeo A, Rylatt M, Allinson D, Davies Z G, Edmondson J L, Galatioto F, Brake J A, Guo L, Hill G, Irvine K N, Taylor S C and Tiwary A. (2010) 4M: Measurement, modelling, mapping and management the carbon footprint of UK cities. *ISOCARP Review 06*.

Lowe, R. 2009. "Policy and strategy challenges for climate change and building stocks", *Building Research & Information*, Volume 37, no.2, pp.206 – 212.

Meier, H. and Rehdanz, K., 2009. Determinants of Residential Space Heating Expenditures in Great Britain, *Energy Economics* (2009), doi:10.1016/j.eneco.2009.11.008.

Oreszczyn, T., Hong, S.H., Ridley, I. and Wilkinson, P. 2006. "Determinants of winter indoor temperatures in low income households in England", *Energy & Buildings*, vol. 38, no. 3, pp. 245-252.

Shipworth, M. Firth, S. and Lomas, K. 2010. "Central heating thermostat settings and timing: building demographics", *Building Research & Information*, Volume 38. No. 1, pp. 50 – 69.

Stemers, K. and Yun, G. 2009. "Household energy consumption: a study of the role of occupants", *Building Research & Information*, Volume 37, No. 5, pp. 625 — 637.

Summerfield, A.J. Lowe, R.J. Bruhns, H.R. Caeiro, J.A. Steadman, J.P. and Oreszczyn, T. 2007. "Milton Keynes Energy Park revisited: Changes in internal temperatures and energy usage" *Energy and Buildings* 39 (2007) pp. 783–791.

Summerfield, A. Oreszczyn, T. Pathan, A. and Hong, S. 2009. "Occupant behaviour and energy use" In - A handbook of sustainable building design and engineering: an integrated approach to energy health and operational performance edited by Mumovic, D, & Santamouris, Earthscan, London, Stirling.

Utle, J. and Shorrocks, L. Building Research Establishment 2008. "Domestic energy fact file 2008", BRE Bookshop by permission of Building Research Establishment Ltd.
http://www.bre.co.uk/filelibrary/pdf/rpts/Fact_File_2008.pdf

Yohanis, Y.G. and Mondol, J.D. 2010. "Annual variations of temperature in a sample of UK dwellings" *Applied Energy* 87 (2010) pp. 681–690.