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National survey of summertime temperatures and overheating risk in English homes

A. Beizaee*, K.J. Lomas [1], S.K. Firth [2]

School of Civil and Building Engineering, Loughborough University, Leicestershire LE11 3TU, UK

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ABSTRACT

This paper presents one of the first national scale studies of summertime temperatures in English dwellings. Living room and bedroom temperatures were recorded in 207 homes across the England during the cool summer of 2007. Data was also collected by face-to-face household interviews. Fourteen homes (7%) were observed to be heated for part or all of the analysis period (July to August). Based on the BSEN15251 adaptive thermal comfort model, the 193 free-running dwellings would, in general, to be considered as uncomfortably cool. Over 72% of living rooms and bedrooms had more than 5% of hours below the BSEN15251 Cat II lower threshold, with over 50% having more than 5% of hours below the Cat III threshold. Detached homes and those built before 1919 were significantly cooler ($p < 0.05$) than those of other type and age. Static criteria revealed that, despite the cool summer, 21% of the bedrooms had more than 5% of night time hours over 26 °C; which is a recommended upper limit for bedrooms. The bedrooms of modern homes, i.e. those built after 1990 or with cavity walls, were significantly warmer ($p < 0.05$). The bedrooms in homes built prior to 1919 were significantly cooler ($p < 0.05$). The living rooms of flats were significantly warmer than the living rooms in the other dwelling types ($p < 0.05$). The incidence of warm bedrooms in modern homes, even during a cool summer, is of concern, especially as there is a strong trend towards even better insulation standards in new homes and the energy-efficient retrofitting of existing homes.

1. Introduction

The UK climate has been warming, with the central England annual average temperature increasing by about 1 °C [1] over the last century. This trend is expected to continue resulting in an increase in the annual average temperatures across the UK of about 2–3.5 °C by 2080 [1]. As a part of 2008 Climate Change Act, the UK government committed to reduce the greenhouse gas emissions by at least 80% compared to 1990 levels by 2050 [2]. The domestic sector accounts for 32% of total UK final energy consumption in 2010 [3], with 61% of the sector's energy consumption being dedicated to space heating [3]. Winter temperatures and reducing heating energy consumption have therefore attracted considerable attention within UK academia and the government. This paper focuses though on the summertime temperatures in English homes.

The impacts of high summertime temperatures in UK dwellings were experienced during the last decade's hot weather events. The European heat wave of August 2003 resulted in over 2000 (16%) additional deaths in England and Wales, with the highest impact in London and on the elderly [4]. Hajat et al. [5], by investigating the relationship between heat and mortality in London for a 21 year period, concluded that a growth in heat related deaths begins at a relatively low average external temperature of about 19 °C. The duration of exposure to high temperatures was also found to be an important factor in determining increased mortality.

Even if existing dwellings are adapted to accommodate temperature change, there is a risk that domestic mechanical air conditioning will become much more common in warmer areas of the country. Peacock et al. [6] used dynamic thermal simulation to investigate internal temperatures and estimated that 18% of householders in the south of England would install air conditioning by 2030 if they responded to warm temperatures in the same way as US householders. This would equate to 550,000 homes equipped

Abbreviations: ASHRAE, American Society of Heating, Refrigeration and Air-Conditioning; BADC, British Atmospheric Data Centre; CaRB, Carbon Reduction in Buildings; CI, confidence interval; CIBSE, Chartered Institution of Building Services Engineers; DTM, dynamic thermal modelling; GOR, Government Office Region; NatCen, National Centre for Social Research.

* Corresponding author. Tel.: +44 (0) 7754 367879.
E-mail addresses: a.beizaee@lboro.ac.uk (A. Beizaee), k.j.lomas@lboro.ac.uk (K.J. Lomas), s.k.firth@lboro.ac.uk (S.K. Firth).
[1] Tel.: +44 (0) 1509 222615.
[2] Tel.: +44 (0) 1509 228546; fax: +44 (0) 1509 223981.

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with air conditioning in London alone. Domestic air conditioning would further compound the difficulties associated with meeting the national carbon reduction targets.

Numerous studies have used dynamic thermal modelling (DTM) to predicting the possibility of overheating for different UK house types, constructions, occupant behaviours, and climate change scenarios, e.g. Refs. [6–9]. However, being based on modelling, such studies cannot capture the true behaviours of occupants and their interaction with heating and ventilating systems. Further models' limitations in predictive ability are usually ignored, and these limitations are significant. For example, in work by Lomas [10] predictions of peak temperature were found to have a simple resolution[3] of 3 °C for one particular UK house. This means that if one DTM predicts a particular peak temperature of, say, 26 °C, a different DTM might predict a value anywhere between 23 and 29 °C. By ignoring this inter-model variability, modelling studies tend to overstate the reliability of the results obtained.

By actually measuring the internal temperatures in dwellings, occupants' behaviour is fully captured and the limitations of modelling are avoided. Such studies are though, expensive and time consuming and so are rather rare. The data captured in the recent multi-university Carbon Reduction in Buildings (CaRB) project [11] offers a unique opportunity. In this paper, the internal temperatures measured during the summer of 2007 in 252 homes distributed across the England are examined using established static overheating criteria as well as BSEN15251 adaptive thermal comfort standard along with the associated house and household data that was captured through a face-to-face survey.

The aims of this paper are; to further our understanding of the summertime temperatures and thermal comfort in occupied English homes; to investigate the impacts of location, built type, age and wall type on these; and to compare static and adaptive thermal comfort criteria as measures of overheating risk. The paper expands on the work reported elsewhere for the UK city of Leicester [12] and is complementary to the analysis of the CaRB data presented in Kelly et al. [13]. Thus, to the authors' knowledge; one of the first large national scale studies of summertime temperatures and thermal comfort in English homes has been undertaken.

2. Materials and methods

2.1. Data collection

2.1.1. The CaRB dataset

A nationally representative sample of 1134 English dwellings was selected as part of the Carbon Reduction in Buildings (CaRB) research project [11] using stratified random sampling drawn from the Postcode Address File for England [14]. Postcode sectors were stratified by Government Office Region (GOR) and socio-economic class. After stratifying, 54 postcodes, and for each of those 21 addresses were randomly selected. Before approaching a household at their address, the National Centre for Social Research (NatCen) interviewers sent personalised letters about the study and a proposed interview date and time. Interviewers could also enclose a leaflet explaining the study, or they could use the leaflet at the address when asking to interview the householder. Interviewers, who were highly trained in maximising response rates when householders came to the door, would reschedule interview times to suit the convenience of householders and would also call back several times if householders were not at home. Altogether, 427 households agreed to participate in the study (a response rate of 37%). Interviews were conducted from 2007 to 2008 using a questionnaire devised by the CaRB project team that was intended to capture a wide range of information such as the households' energy consumption, heating practices, building characteristics and socio-demographics. Of the 427 households which were interviewed, 390 agreed to house at least one temperature sensor and useable data from 252 of these was used in this study. The HOBO pendant sensors (Fig. 1, Table 1) were to be placed in the main living room and main bedroom of each home either by the interviewer and the householder together, or by the householder on their own and returned at the end of the monitoring period. Written advice was provided to the DomNat surveyors, and a leaflet was provided for householders, advising on suitable sensor placement (between head and knee height, away from windows or doors and out of sunlight or any heat sources). The sensors recorded temperatures at 45 min intervals from 21 July 2007 to 10 March 2008 [15]. This recording interval was selected according to battery life and the internal memory capacity of the HOBO sensors in order to ensure their capability for the long monitoring period while still capturing the short term temperature fluctuations. The HOBO sensors were self-contained data loggers and the recorded data were downloaded from them only at the end of the study once the sensors had been collected from homes. The temperature database, along with the completed survey questionnaires, forms the backbone of the study reported here.

Following data cleaning, only 207 of the 252 households' sensors were found to have produced reliable data (see Section 2.2). These homes are located in 53 different local authorities, in the nine Government Office Regions of England (Fig. 2).

Compared to the English housing stock as a whole, as profiled by the national Census of 2001 [16], the sample studied contained

Fig. 1. HOBO pendant temperature loggers used for indoor temperature monitoring.

Table 1
Technical specifications of the HOBO sensors used for the temperature monitoring [15].

Parameter	Characteristics
Measurement range	−20° to 70 °C
Accuracy[a]	±0.53 °C
Response time	10 min
Time accuracy[b]	±1 min per month
Dimensions	58 × 33 × 23 mm

[a] For the temperature range of 0–50 °C.
[b] At 25 °C.

[3] Simple resolution was defined as the value below which the absolute difference between the predictions of two programs (obtained by skilled users, for the same circumstances) may be expected to lie with a specified probability. In the absence of any other indication, the probability is 95%.