Resilience to overheating in homes in southern England: householders' awareness and preparedness

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Keywords: climate change resilience, housing, occupation behaviour, overheating.

Abstract

In southern England, climate projections show increasing likelihood of the number and duration of heatwaves. With over 80% of the 2050 UK housing stock already built, the householder is an important gatekeeper to making the built environment more resilient to overheating. The National House Building Council and others have issued recommendations for mitigating actions, including more insulation, better ventilation, shading and reflective external surfaces. Research on overheating has tended to investigate building physics, overlooking the role of the householder in making modifications. Important questions remain, including to what extent do householders perceive a threat of overheating events; are they aware of recommendations for precautionary actions; have they taken or do they intend to take action and what has guided actions that have already been taken. The current study aims to address these questions and to provide a baseline against which changes in the effects of the experience of overheating, perception of threat and level of action in future years can be compared.
A survey was conducted with a large-scale sample (n = 1007) of urban/suburban householders in the south of England, balanced across housing type. Of the sample, 67% had already experienced overheating in their home but perception of risk and awareness of the recommended actions were low and intention to take further action was very low. Nonetheless, actions had been taken, ranging from ventilation (82.8%) to awnings/shutters to glazing (9.4%). Reasons for taking action varied by action type, with comfort featuring heavily for insulation and ventilation, and aesthetics for planting and a pale exterior surface. Although reducing overheating was the top reason for installation of awnings or shutters, very few householders had taken this action. Recommendations for policy are discussed including differential targeting of population segments and using messages that align with householders' motivations.

INTRODUCTION

By 2016, global warming had already exceeded 1.1˚C above late 19th century levels (NASA, 2017) and is likely to surpass a 2˚C threshold even if national commitments pledged at COP21 to reduce greenhouse gas emissions are achieved (Rogelj et al., 2016). One of the many consequence of warming planetary systems is the increased risk of higher temperatures, and the likelihood of increased frequency and severity of heatwaves for many geographical locations. Traditionally hot places have experienced record high temperatures in recent years (Bureau of Meteorology, 2017) but more temperate zones including the UK and mainland Europe have also been exposed to hotter weather. The risk to public health from higher temperatures was evidenced by the August 2003 heatwave in Europe which led to 15,000 excess deaths (PHE, 2015a). Climate projections for the UK predict that mean daily temperatures will increase, particularly in summer, over the coming decades. Under a high emissions scenario, average summer temperature increases of between 2.8 and 3.1˚C (central estimates) are estimated for midland and southern England by the 2050s, increasing to between 4.4 and 4.9˚C in the 2080s, compared to the 1961-1990 average (UKCP, 2009). Likelihood of extreme temperature events also increases, with the probability of a heatwave as severe as that in 2003 estimated already to be between twice and four times more likely due to human influence on climate (Stott, Stone, & Allen, 2004).

Excess deaths due to higher temperatures have been estimated in the UK at 75 extra deaths per week per degree increase (PHE, 2015b). Evidence from research in London suggested that excess deaths can be calculated when temperatures rise beyond 19 ˚C (Hajat et al., 2002). Individuals especially vulnerable to the effects of higher temperatures include older people, infants, those with chronic or severe illnesses or alcohol/drug dependence, and those living in south-facing flats or in urban areas (PHE, 2015b). It is notable that, depending on the severity and duration of a heatwave, adverse effects can strike healthy, fit and able-bodied adults and children. Beyond increased mortality, higher temperatures can lead to lower productivity, disturbed sleep and reduced concentration, increasing the risk of accidents (Mavrogianni et al., 2015; NHBC, 2012).

The built environment can exacerbate the risks from overheating or help to mitigate the adverse effects. In the UK, it is estimated that people can spend over 90% of their time indoors (Schweizer & al., 2007) thus the resilience of the building stock to overheating has a major role to play in protecting citizens from excessive heat. While there has been investigation of the contribution of building regulations and Passivhaus standards to overheating, particularly for new build (Lomas and Porritt, 2017), the focus here is on weather-related overheating in existing domestic building stock.

Within the construction literature, the issues around overheating in current stock have received growing attention. In a 2007 study of 252 homes across England, Beizaee et al. (2013) found overheating across all housing types during the coolest summer since 1993, and a 2009 study of 268 dwellings in Leicester, a city in central England, measured overheating in almost 90% of bedrooms (Lomas and Kane, 2013). A small opportunity sample of 89 households in the London area also found evidence of overheating, and noted that only 6% of properties investigated had overhangs, awnings, shutters or vegetation to provide shade (Mavrogianni et al., 2017). The importance of passive mitigation was underlined by Porritt et al. (2011) who argued that Victorian terraced dwellings (a common form of UK housing dating from the late 19th century) could avoid overheating even in medium-high scenarios for 2080 through passive measures alone, which included provision of exterior shutters, wall insulation and a pale exterior surface. Although Gupta and Gregg (2012) disagreed that overheating in a 2080 scenario could be fully mitigated through passive measures, they concurred with Porritt and colleagues (2011) on factors that could enhance resilience, with external shading the most effective. Evidence suggests that few households have air conditioning - the study of Mavrogianni et al. (2017) found air conditioning in only 4% of homes in their sample. Increased energy demand caused by greater prevalence of household air-conditioning would exacerbate greenhouse gas emissions, emphasising the importance of effective and widespread passive approaches to minimising overheating. Thus the literature has shown evidence of overheating already occurring across the UK, albeit in small scale studies, with evidence for the effectiveness of passive mitigation measures.

Based on such research, a number of industry and government reports have proposed modifications to existing homes which can provide effective mitigation of overheating, including solar reflective or pale coatings to external façades, wall insulation especially external, maintaining exposed thermal mass, external shading such as shutters and awnings, effective ventilation and managing the microclimate adjacent to the building through provision of green spaces, trees and water features (ARCC CN, 2013; PHE, 2015b).

The UK domestic built environment is characterised by a predominance of old stock and a low rate of new build. Boardman (2007) has proposed that 87% of the dwellings that will be in use in 2050 are already built. The existing housing stock therefore merits attention as the primary target for measures to mitigate overheating. Although a number of studies have examined the measures that can be taken, the few studies that have considered occupant behaviour have been limited to reactive responses to high temperatures (Baborska-Narożny et al., 2017; Coley et al., 2012; Mavrogianni et al., 2017). Such studies overlooked the behavioural aspects of commissioning retrofit measures to minimise overheating. The householder is a critical gatekeeper who determines whether or not 'hard' adaptation will be conducted on an existing home. In seeking to understand how the current building stock can be upgraded to become more resilient to the warming climate, it is necessary to examine householders' propensity to take action to upgrade the home. In this, the overheating literature is some way behind that of flooding, in which the need for both precautionary and reactive behaviours is better understood (Bubeck et al., 2013; Grothmann and Reusswig, 2006; Poussin et al., 2014). Precautionary behaviour, taken in advance of a flood, can provide potentially significant reduction in damage when compared to reactive behaviour taken during a flooding event (Grothmann and Reusswig 2006). Precautionary behaviour taken in advances of high temperatures has important social benefit, protecting not just the decision-maker but family, tenants and visitors. The warning period for heatwaves is very short, and most deaths occur within the first two days, so preparedness can save lives (PHE, 2015a). From the perspective of construction research, precautionary behaviour is of special importance in that the building sector may act as the agent through which a householder achieves greater resilience.

The focus in this paper is on preparation or precautionary action taken in anticipation of a possible future event, that is, action triggered by the householder to install mitigating measures. To our knowledge, UK householders' preparedness to take precautionary action against overheating has not yet been explored in the literature. Some indication of potential influencing factors may be found in studies on flooding.

Grothmann and Reusswig (2006) examined the question of why some householders take action to protect themselves against the risk of flooding while others do not, testing socioeconomic characteristics and previous flood experience alongside psychological variables. While home owners had higher levels of intention than tenants to take adaptive action, and previous experience of flooding influenced the level of intention, income and age were not related to intention. In contrast, Zaalberg and colleagues (2009) found that previous experience was not related to intention to undertake preventative action against flooding. Looking at what they termed structural changes to the home to increase protection against flooding, Bubeck et al. (2013) found that previous experience and level of income also showed a positive relationship with intention. So owners were more likely to intend to complete precautionary actions than tenants, age was not a factor and the evidence was inconsistent on the influence of income and previous experience.

Research on climate change preparedness has established that precautionary actions are risk-specific (Grothmann and Patt, 2005; Porter et al., 2014). The perception of threat from overheating is different from the case of flooding in terms of recency of extreme events, visibility and vulnerable populations. It is therefore important to investigate householders' preparedness and the influencing factors in their decisions on implementing precautionary mitigating actions against overheating.

The current research aimed to answer the following questions:

- To what extent are householders in southern England prepared for overheating, in terms of
  - perception of threat
  - awareness of mitigating measures
  - actions already implemented?
- What has motivated actions already taken?
- What are the determinants of precautionary actions taken against overheating?

METHOD

Selecting the south and midlands of England as more threatened by increasing temperatures, an online survey was conducted in September 2016, using an established market research organisation. A total of 1007 completed questionnaires were collected. Rather than retrospectively assessing response rate, representativeness was achieved through completion of quotas mirroring national ratios for key criteria: gender, age, home owner versus tenant, and house type.

Sociodemographics included *age, personal income* and *level of education*. Property/occupant characteristics included *age of property, house type* (see Table 1) and ownership/tenancy. Respondents were asked whether they had experienced overheating [*overheating experience*] in their current home (scale of 1 to 6, labelled as Never, Once, On a few occasions, Quite often, Frequently, Constantly). Overheating was defined with respect to householder subjective experience: "*By 'overheating', we mean that the temperature inside the home is high enough to make it difficult to sleep at night or uncomfortable to do what you want to do during the day, on at least one occasion."*

Perception of threat was measured with an established measure termed *threat appraisal*, based on Poussin et al. (2014) with two items measuring threat risk and two items measuring threat severity. Cronbach alpha was .89, indicating a reliable scale.

Based on national guidelines for reducing overheating in homes (DECC, 2015; NHBC, 2012), nine actions were selected and *awareness of the recommended actions* to mitigate overheating was measured on a scale of 0 to 12 (nine recommended actions and three exacerbating items). For each of the nine actions, participants were asked if they had already implemented the action, and the reasons why they had done so: five options were offered ("It makes my home more comfortable", "Some of my friends or neighbours have this", "It makes my home look nicer", "It helps to reduce overheating", "It adds to the financial value of my home"), each rated on scales of 1 to 6 anchored at Strongly disagree (1) to Strongly agree (6). The mitigating actions were grouped into five categories for further analysis: insulation (walls, roof), ventilation (including night ventilation), shutters/awnings or overhangs to glazing, pale exterior façade, and planting (trees, grass, water features near the external walls).

FINDINGS

Table 1 summarises participant and property characteristics (n = 1007).

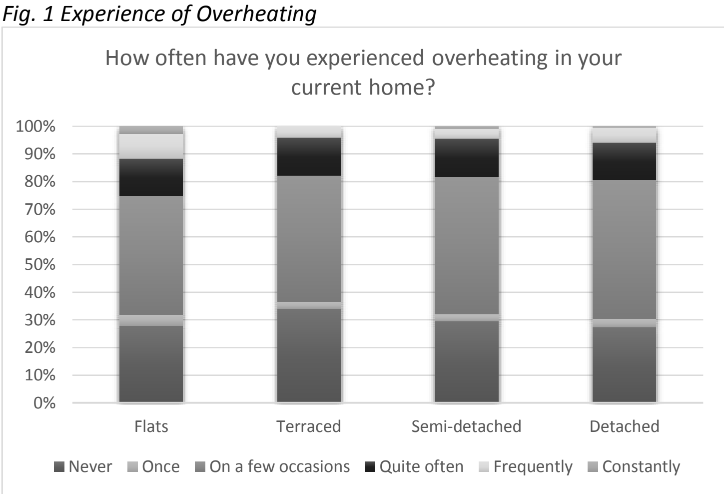
Table 1 Sociodemographic and property-related variable: descriptive statistics

Variable	Category	
Gender	Female	50.8%
	Male	49.2%
Participant age	Mean	50.58
	Range	18 - 85
Income (personal monthly net)	Less than £1,000	23.2%
	£1,001 - £2,000	35.2%
	£2,001 - £3,000	17.4%
	£3,001 - £4,000	8.0%
	Over £4,001	6.2%
	Not given	10.0%
Home ownership	Owner	66.0%
	Tenant	31.8%
	Other	2.2%
Property type	Flat	24.9%
	Mid-terrace	26.8%
	Semi-detached	27.9%
	Detached	18.9%
	Other	1.5%

Experience of Overheating

Two thirds of the sample had experienced overheating on at least a few occasions (see Fig. 1). A chronic problem in a proportion of flats was apparent with 11.6% of these respondents experiencing 'frequent' or 'constant' overheating. For other housing types, frequent or constant overheating was reported in an average of 4.8% of homes. The proportion of homes with occasional overheating is similar across the categories, ranging from 42.8% of flats to 50.0% of detached homes.

Fig. 1 Experience of Overheating



Threat Appraisal

Threat appraisal (perception of threat from overheating) was moderate to low (range 1 - 6, mean 2.71, std. dev. 1.21) with perception of the severity of impact of overheating lower than perception of the likelihood of occurrence (threat severity 2.6, std. dev. 1.19; threat risk mean 2.83, std. dev. 1.49). Flat dwellers' perception of threat was greater than that of house-dwellers at a statistically significant level (flat dwellers mean threat appraisal 2.95, house-dwellers mean 2.63, $t = 3.45$, $df = 391$, $p < .01$). Examining differences in perception of threat between owners and tenants, no significant difference was found either for overall threat appraisal or for the perception of risk but tenants perceived the potential severity of overheating to be greater (owners mean 2.53, tenants 2.74, $t = 2.56$, $df = 650$, $p < .05$).

Regression analysis was conducted to examine factors associated with the perception of threat. Influencing factors included age ($\beta = -.22$, $p < .001$) and overheating experience ($\beta = .54$, $p < .001$; $F(9,981) = 88.6$, $p < .001$, Adj. $R^2 = .45$). Income and level of education were not significant. That is, older people had lower perception of threat, while those who had more frequent experience of overheating had higher levels of threat appraisal.

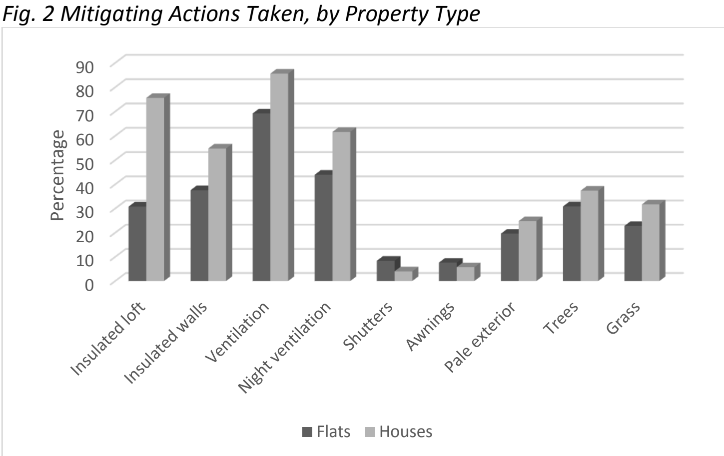
Awareness of Mitigating Actions

Awareness of mitigating actions was moderately low across the full sample (range 0 - 12, mean 4.92, std. dev. 2.92). ANOVA by property type showed significant difference in awareness ($F(3, 987) = 10.98$, $p < .001$) and post-hoc Bonferroni analysis found that the level of awareness of householders in detached properties to be significantly higher than that of those living in semi-detached and terraced houses and flats (all $p < .01$). We speculated that there may be a relationship between householders' freedom to undertake particular types of actions and their level of awareness so we additionally examined levels of awareness of owners versus tenants. A significant difference was found in the expected direction (tenants mean 4.22, owners 5.26, t = 5.51, df = 688, $p < .001$). Thus there may be an interaction between awareness of what mitigating actions can be taken and the householder's perception of what actions are feasible in their physical context.

Regression analysis was conducted on awareness of mitigating actions. Sociodemographic variables of age (β = .29, $p < .001$), level of education (β = .16, $p < .001$ and Income were significant (β = -.06, $p < .05$). Property/occupant characteristics also contributed: age of property (β = .1, $p < .01$) and house type (β = .14, $p < .001$). Finally, experience of overheating was also significant (β = .12, $p < .001$; $F(9.981) = 19.51$, Adj. $R^2 = .15$, $p < .001$). That is, older people and those with a higher level of education were likely to be more aware of the mitigating actions that could be taken. Lower income participants were also more likely to have greater awareness although this was only marginally significant. Occupants of older properties and people with more experience of overheating had greater awareness of mitigating actions. Residents of detached and semi-detached homes showed higher levels of awareness than those of terraced houses and flats.

Actions Implemented

Fig. 2 Mitigating Actions Taken, by Property Type



Note: 43% flat dwellers marked an insulated loft as not applicable.

In terms of actions taken which can help to mitigate overheating, the proportion of flats in which mitigating action had been carried out was lower than that of terraced, semi-detached and detached houses on all measures except shutters and awnings. While the proportion of homes with shutters or awnings was very low (9.4% of the sample overall), 16.1% of flats had installed these measures compared to 9.7% of houses. Figure 2 demonstrates a low rate of implementation of mitigating actions for those actions to the right-hand side of the chart which could be expected to be more convenient and cheaper to install.

Motivations for Actions Taken

Fig. 3 compares motivations for mitigating actions by action type (means and standard deviations are presented in the Appendix). For each measure, all motivations are different from motivation to mitigate overheating at a statistically significant level with the exception of comfort and aesthetics for a pale exterior.

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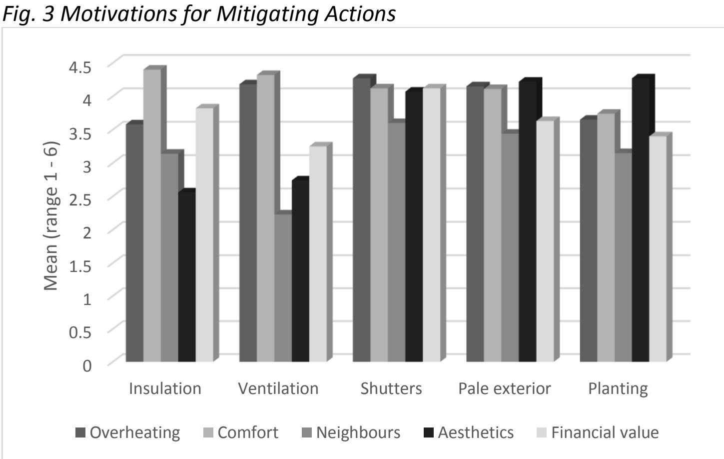
Fig. 3 Motivations for Mitigating Actions



The strongest motivation for implementing insulation and ventilation measures was comfort, although alleviating overheating was also important for ventilation. Overheating was the strongest motivator for installing shutters and awnings, with comfort and adding financial value to the home also highly ranked. The strongest motivation for a pale external façade was aesthetic value with comfort and overheating also important, and aesthetics was the primary motivator for planting close to the property.

Logistic regression was conducted to examine factors related to actions undertaken (see Table 2).

Table 2 Logistic regression of Mitigating Actions Taken

	Insulation B	Ventilation B	Shutters/ awnings B	Planting B	Pale B
Occupant age	.04***	.07***	-.02**	.01*	.02**
Income	-	-	.27***	.1*	.15**
House type	.52***	.34**	-	.18**	-
Awareness of mitigating actions	.1**	.18***	-	.22***	.17***
Overheating experience	-	.18*	-	-	-
Cox & Snell R^2	.15	.19	.04	.12	.07
Nagelkerke R^2	.22	.32	.09	.16	.11

*Notes: n = 991. B = unstandardised coefficient. Only significant coefficients presented. - non-significant; *** p<.001; ** p <.01; * p<.05.. Larger values of Cox and Snell R^2, Nagelkerke R^2 indicate higher levels of variance explained by the model.*

Older occupants were slightly more likely to have completed wall and/or loft insulation, ventilation, planting and a pale exterior and marginally less likely to have installed shutters or awnings. More affluent householders were more likely to have installed shutters or awnings, painted the exterior a pale colour and have planting near the building. Surprisingly, these are actions that could be expected to be cheaper than installing insulation and improving ventilation. Insulation, ventilation and planting were more likely to have been done on detached and semi-detached properties than terraced and flats, and this could be a result of greater freedom of action in these properties. Awareness of mitigating actions was significantly related to all forms of action with the exception of installation of shutters and awnings. Frequency of experience of overheating was related to actions on ventilation only.

DISCUSSION

While earlier studies on overheating demonstrated problems across a range of property types, they have tended to be small in scale. The current large-scale study provides evidence that, in the opinion of householders in the south of England, weather-related overheating is already being experienced. Two thirds of respondents had experienced overheating on at least a few occasions, across all property types. This stands as an important reminder that, although flats are more vulnerable to overheating than other types of home, the issue of overheating is not limited to denser housing forms and that the frequency of overheating in all types of homes is likely to increase in line with global warming.

The relatively low levels of threat appraisal demonstrate that there is much to be done in informing citizens of both the increasing threat of heatwaves and the potential severity of their impact. Flat dwellers showed a higher level of threat appraisal than house-dwellers, and this is important given the increased vulnerability of many flats to overheating problems. Worryingly, there was a negative relationship between threat appraisal and age, indicating a particular need to ensure that older people, amongst the more vulnerable groups, are educated on the threat.

Householders' awareness of the actions that they could take to mitigate the effects of overheating was low and differed by housing type, with occupants of detached homes more aware than occupants of flats, terraced and semi-detached homes. We also found that homeowners had a higher level of awareness than tenants. It is possible that freedom to carry out changes to a property may interact with awareness: occupants of detached homes may have more space in which to plant trees for shade or soft landscaping, and may be subject to less stringent planning constraints with respect to fenestration for ventilation and pale, reflective external walls. Similarly, tenants may believe they have little power to make changes and so take no interest in changes which could minimise overheating in their home. Future qualitative research could investigate this proposition. Older and more educated participants had higher levels of awareness of mitigating actions, suggesting a need to target younger householders particularly in areas with low educational achievement.

Although the majority of respondents reported having installed measures of insulation and ventilation, a low level of completion of additional mitigating actions was evident. Of particular concern, fewer actions had been taken by flat versus house dwellers, across all action categories. In contrast to expectation, actions that appear likely to be less costly and more convenient to complete (i.e. shutters or awnings, pale exterior, trees and planting) were less in evidence. A noticeable gap in actions undertaken is that of shutters or awnings, with only 9.4% of the sample having installed these measures. Building science research has argued that external shading is amongst the most effective passive building alterations to minimise overheating (Gupta and Gregg, 2012; Porritt et al., 2011): our findings show a significant gap between measures householders have implemented and research-based recommendations. The number of householders who had installed shutters, awnings or overhangs was relatively small (n= 95) but the findings indicate that, whereas awareness of mitigating actions was not related with this action, income was. We suggested that the relationship between income and implementation of shutters or awnings, planting near the property and a pale reflective external surface could reflect fashions or norms in more affluent areas. Future research should investigate these relationship further.

The findings show that householders have a range of motivations for implementing changes to their properties. For alterations that may help to mitigate overheating, alternative motivations such as comfort and aesthetics can influence decisions. Although adding to the perceived financial value of their properties may be a motivator, for actions recommended to mitigate the effects of overheating, this was relevant only for provision of awnings and shutters.

CONCLUSION

Conducted in September 2016, the globally hottest year on record, the study aimed to address the research gap on householders' awareness and preparedness to cope with weather-related overheating, A sample of 1,0007 householders in southern England completed an online survey on their experience of overheating, perception of threat, awareness of mitigating measures and extent of action on these measures. Two thirds of the sample had experienced overheating on at least a few occasions, across all housing types. Perception of the threat of overheating, in particular the perception of the severity of the effects of overheating, was moderate to low. Awareness of actions to mitigate overheating was also low. While most homes had had work completed on insulation and ventilation, ancillary actions including planting and shade near, and a reflective pale finish on, the external walls had been implemented in less than one third of properties. The motivations for taking these measures varied by action type and included comfort and aesthetics. Householders in southern England are ill-prepared and poorly informed on the growing threat of overheating.

The findings have implications for research and policy. Overheating is already being experienced in all types of housing: research on buildings and their occupants should ensure that terraced, semi-detached and detached homes are included alongside flats. Older occupants merit a particular focus, to educate on the threat of overheating and its potential severity. Information campaigns are needed to inform householders of recommended actions they can take to make their home more resilient against overheating. Targeting flat dwellers and tenants is especially necessary. Given the gap between research evidence supporting shutters and awnings as an effective mitigation measure and lack of action by householders, building awareness on this action may be most effective. In seeking to educate and inform, a narrow focus on overheating will miss other means to encourage householders to make their homes more resilient to future heatwaves. Communications and campaigns which emphasise comfort and aesthetics can tap additional motivations. In particular, campaigns targeting energy efficiency through increased comfort may also improve resilience to overheating. Increasing the financial value of their properties is not the most important factor for householders deciding on home improvements and so policies which focus only on increasing financial value or on providing financial incentives will address only a minor aspect of householder motivations. To make homes in England more resilient to current and future overheating, initiatives designed to educate and inform, targeted strategically for older people, flat dwellers and tenants, are necessary and should draw on evidence for householder's multiple motivations for undertaking home improvements.

APPENDIX

Table A-1 Means and standard deviations of motivations for implementing or intending to implement actions which mitigate overheating

	Comfort	Neighbours	Aesthetics	Overheating	Financial value
Insulation	4.4 [1.49]	3.14 [1.77]	2.56 [1.59]	3.58 [1.62]	3.82 [1.52]
Ventilation	4.32 [1.47]	2.23 [1.63]	2.74 [1.57]	4.18 [1.48]	3.25 [1.57]
Shutters/awnings	4.12 [1.43]	3.6 [1.64]	4.07 [1.42]	4.27 [1.34]	4.12 [1.42]
Pale exterior	4.11 [1.53]	3.44 [1.74]	4. 22 [1.5]	4.15 [1.47]	3.63 [1.6]
Planting	3.74 [1.56]	3.15 [1.66]	4.27 [1.49]	3.65 [1.57]	3.4 [1.59]

Note: Mean and [std. dev]. Range 1 to 6 for all variables.

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