Residents' comfort perceptions in domestic heritage buildings

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Abstract. Reducing energy and associated carbon emissions from the existing built environment is critically important to meet our climate goals. Heritage buildings are often presented in the literature as energy inefficient, and uncomfortable to inhabit. There is however little research into residents' perceptions of comfort in these buildings to support this view, while there is some evidence to suggest that heritage buildings may be more thermally comfortable than generally assumed. This paper interrogates a survey of 147 residents of pre-1940 heritage buildings in Cumbria, UK, to examine residents' comfort perceptions. This survey is compared with secondary data from other UK studies on residential comfort. Results are elucidated with more detailed responses from interviews with 16 heritage households. Three key findings were made. First, heritage buildings are perceived to have broadly comparable thermal performance to more modern UK buildings by their residents. Second, the survey results and interviews found that residents perceive their buildings to perform particularly well in summer, keeping comfortably cool in hot weather. In contrast, the literature suggests that newer homes often appear to suffer from overheating. Third, although many Cumbrian residents found their buildings draughty, a large percentage would not prefer less ventilation, with case study participants citing their enjoyment of fresh air. These results are highly relevant for successful approaches to renovation and the implementation of the European Renovation Wave. Renovations are often promoted to heritage residents for their comfort improvement potential. However, if buildings are already perceived as broadly comfortable this may not be a key driver. Alternative motivations may therefore need to be identified to drive renovation uptake. The findings also highlight the importance of maintaining positive aspects such as good summer performance.

1. Introduction

The built environment is responsible for around 39% of global carbon emissions each year [1]. In Europe most of the building stock for 2050 is already extant, with replacement rates of around 1% per year [2]. The reduction of energy and associated carbon emissions from existing buildings is therefore critical for efforts to mitigate climate change [3]. The need to take more account of residents' energy behaviours in carbon reduction strategies is well known [4] and comfort perceptions have an important influence on these behaviours, with heating being the main source of energy use and carbon in residential buildings in northern Europe [4]. Buildings with cultural heritage value are often assumed to be energy inefficient and uncomfortable to live in [5]. Improving comfort in these buildings is therefore often considered to be a key motivator for residents' renovation decisions [6]. However there is limited evidence for this in northern Europe as heritage residents' comfort perceptions have received little research attention [7]. Furthermore, research from other climates has found that residents of older buildings may in fact perceive them to perform as well as, and sometimes, better than, more modern buildings [8–10]. There is thus a clear need to interrogate the comfort perceptions of heritage building residents in more detail.

Perceptions of temperature and ventilation have been identified as key factors for comfort in buildings [11,12]. These comfort parameters will therefore be explored for residents in pre-1940 heritage buildings in northwest England via a survey and case studies. Residents' perceptions in these cultural heritage buildings will also be compared with those of residents in more modern UK buildings through an analysis of relevant secondary data in the academic literature. The implications that these perceptions have for renovation approaches will then be examined.

2. Methods

The context for the study is the county of Cumbria in northwest England, a rural area with a high proportion of cultural heritage buildings, which includes the Lake District National Park World Heritage Site [13]. An online survey seeking the views of residents of pre-1940 Cumbrian buildings was conducted in autumn/winter 2019 and is described more fully in [14]. The survey attracted 147 total responses and included questions on residents' perceptions of thermal, ventilation, and overall comfort.

A review of the literature was undertaken to identify secondary data with suitable parameters on comfort perceptions in residential buildings for comparison with the survey results. The number of UK studies on this topic is limited, with a focus on public and commercial buildings rather than homes [7]. However, four studies with comparable parameters were identified and a further study, from Ireland, on modern buildings (constructed between 1994-2000) [15] was also included as both the climate and built environment are similar enough to enable comparison. These studies included 667 participants in total. One focussed on modern sustainable housing (constructed post 2005) [16], one on two apartment buildings (1966) [17], another, on a mix of building ages pre- and post-renovation [18] and a final study included both pre-1945 and post 2000 homes [19]. Further details of the studies can be found in Table A1 in the appendix. An additional study in a humid subtropical region of China [8] was also included because it investigated heritage and modern buildings and had several similarities which made the data readily comparable.

The different studies included parameters around residents' perceptions of current thermal conditions, their desire for future conditions, and their overall satisfaction with thermal comfort. This data was put into a similar format for each study to enable comparison with the Cumbrian results for each parameter. Only the Irish study contained data on ventilation perceptions so thermal comfort has been the main focus of the comparison.

To provide more depth to the quantitative survey results, 16 case studies were developed for further exploration and included semi-structured interviews, with questions on residents' perceptions of comfort in their homes. The case studies were chosen from amongst the survey respondents to cover a range of building types, ages, locations, and household compositions. More details on the case studies can be found in [20]. Both the survey and case studies received ethical approval.

3. Results

3.1. Thermal comfort

The mean values from the survey for residents' perceptions of current thermal conditions are compared with the four other studies that reported this parameter (**Figure 1**). Residents in UK and Chinese heritage buildings appear to have a more positive perception of temperatures than those in more modern buildings. The mean value for Cumbrian residents is the closest to neutral -neither too hot nor too cold- in both seasons. These values are well within the range (grey shaded area) that has been identified as comfortable by [18], although the standard deviation (shown as error bars) show that some residents perceive temperatures outside this comfort range. All the studies used the same seven point scale, although exact terms varied slightly, i.e. very cold/much too cold, too cool/too cold, and some studies [17,18] only considered winter. In winter, Cumbrian residents, followed by those in the modern sustainable buildings [16] had average thermal perceptions closest to neutral. In summer however residents in both the Cumbrian and Chinese heritage buildings have the most positive perceptions of current temperatures, and the more modern buildings are perceived to be significantly hotter.

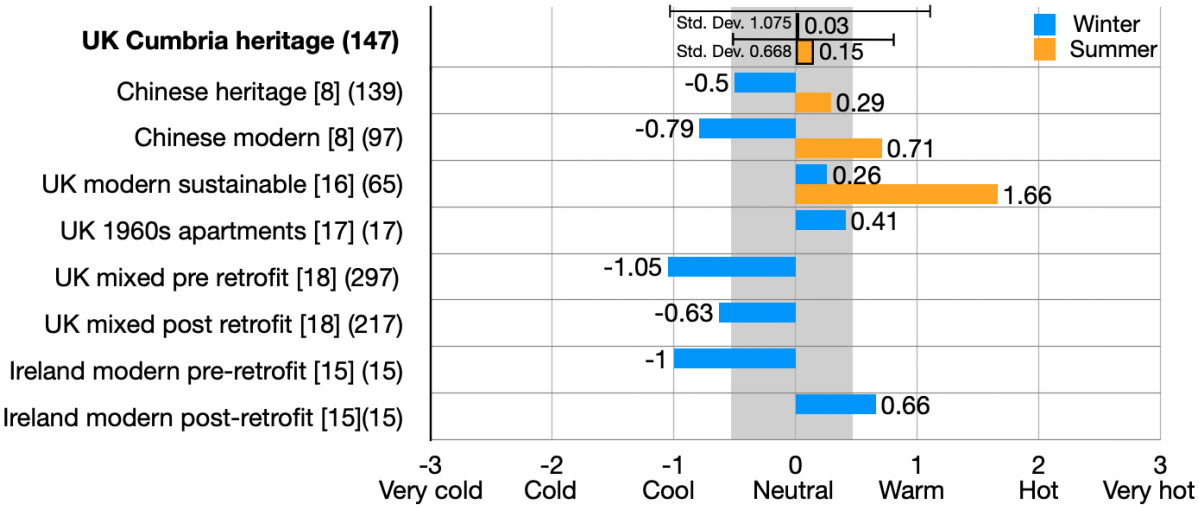

Figure 1. Thermal perception across different studies; winter and summer

The thermal preferences of residents across applicable studies are also compared (Figure 2). When asked what conditions they would prefer a significant minority (45%) of Cumbrian heritage residents would prefer warmer homes in winter, although the majority are content with current conditions which reflects the mean value for thermal perception above. In summer however 93% of Cumbrian residents are content with current conditions, the highest proportion, followed by the Chinese heritage residents. In contrast the modern Chinese and UK modern sustainable residents have the highest percentage desiring cooler summer conditions, supporting the findings on thermal perception above. This perception of better summer performance in heritage buildings may result from their generally higher thermal mass acting as a buffer to smooth out excess temperatures.

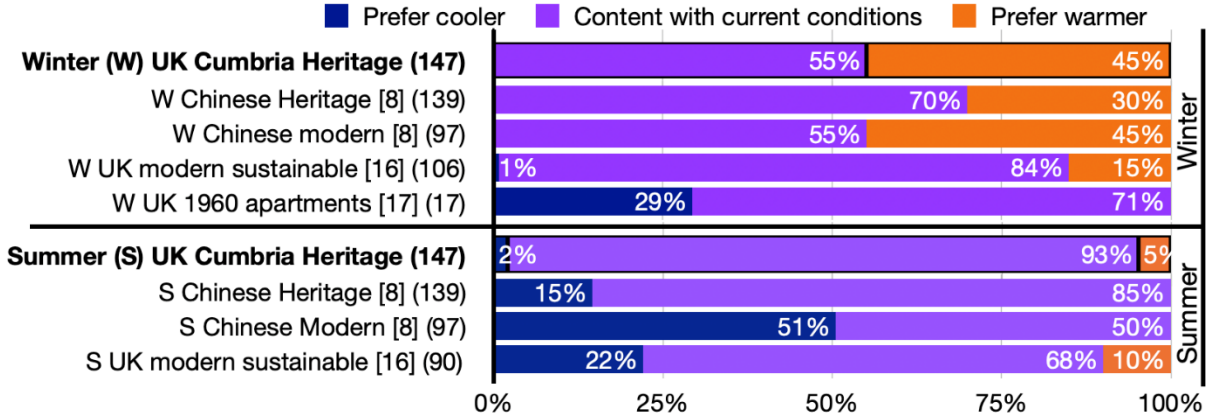

Figure 2. Thermal preference across different studies; winter and summer

Interviews with the case study participants also confirmed residents' positive perceptions of summer conditions for all the cases:

- CS9: In summer it's a wonderfully cool house, when it actually gets hot, it's such a cool house, it's lovely
- CS12: You really notice it, when it's baking hot outside, it's lovely and cool inside.

In contrast to the survey respondents, almost all case study participants were content with current thermal conditions in their homes, apart from CS2 and CS10 who were both dissatisfied with their current heating systems and were actively looking to improve them. Many of the participants (CS1, CS5, CS6, CS11, CS12, CS14) who were thermally comfortable nevertheless recognised that their homes have lower than average temperatures and that visitors sometimes found conditions cold [20]. They identified that they had acclimatised to conditions in their homes, and moreover, that they engaged in practices such as wearing additional layers which meant that they found their buildings comfortable.

Several participants (CS6, CS12, CS13, CS16) with more recent extensions to their buildings also highlighted the positive performance of the older, thicker walled, parts of their homes in contrast to their more modern extensions. This is a perception in clear contrast to the assumptions often made about the performance of the traditional construction of heritage buildings.

- CS13: Particularly this side of the house, because it's got really thick sandstone walls… Even in the middle of winter, if you've not got a draught, it stays a reasonable temperature as well. The back less so, as it's a more modern building [c1999].
- CS16: This room… was a fairly modern extension about forty years ago so it's brick rather than stone walls, and the temperature fluctuates a lot more.

Residents' overall satisfaction with their current thermal environment is compared in **Figure 3**. Some caution is required with this comparison as the Cumbrian satisfaction relates to year-round overall comfort. However, a similar association to the thermal preference comparison in figure 2 can be seen. Some residents of older buildings are dissatisfied in winter, but they appear to have significantly higher satisfaction with their buildings in summer than residents in more modern buildings. These results particularly highlight the dissatisfaction of those in the UK modern sustainable homes in summer but can also be seen in the UK summer pre-1945 and post 2000 study.

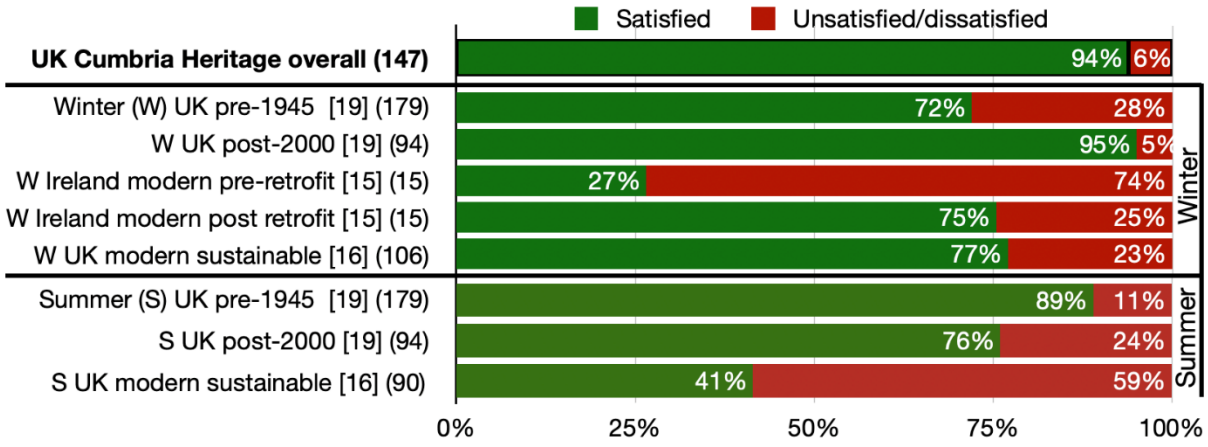

Figure 3. Satisfaction with thermal comfort; all seasons, winter, and summer

The Cumbrian survey results are also reflected in the overall satisfaction of the majority of the case study participants. This suggests that, although there is a need to increase winter comfort for some of these heritage residents, the majority currently find their buildings comfortable. It also suggests that comfort is not a significant driver for change for many of these residents.

3.2. Ventilation perceptions

As reported in [14], a significant proportion (54%) of the Cumbrian survey respondents perceived their homes to be draughty in winter. This is comparable with residents in modern Irish housing (53%) [15]. However only a fifth of the Cumbrian residents would prefer less ventilation in winter while 72% were

comfortable with current levels and 7% would actually prefer an increase in ventilation This implies that just under a third of the Cumbria survey respondents are happy having draughty homes.

This interpretation is supported by some of the case study interviews.

- CS12: We're obsessed with fresh air… So we like draughts from a positive point of view, not from an 'ooh it's draughty' point of view, I've lived in a cold, draughty house and this isn't one

A significant number of participants (CS1, CS10, CS11, CS12, CS14 and CS16) specifically emphasised their enjoyment of, and desire for, ventilation, particularly in bedrooms where many kept their windows open all year round.

- CS14: Our bedroom window is open unless we get to about -10ºC and a storm… we need ventilation in our room, we don't sleep well without it.
- CS16: [in our main bedroom] we don't have the radiator on… the main bedroom [window] we have open at night… sleep cold!

From an energy use perspective this may be considered undesirable. However, as illustrated by CS16's comment, the vast majority of participants who exhibited this behaviour kept their bedrooms unheated as they appreciate a cooler space for sleeping. The impact on energy use is therefore much reduced.

The theme of being less satisfied with performance in more modern sections of their home, or in other buildings they had used, was also noted by participants (CS1, CS6, CS8, CS10, CS16) with regard to draughts and ventilation:

- CS1: That building [modern workspace built c2012] was outrageous in the summer, we had to prop doors open, there was no proper ventilation… You couldn't actually get enough air through the building, which isn't a problem here, if you open windows and things you can always get air through… This building is great in summer
- CS6: The most annoying draughts are sadly in the most recent structure [c1995]. …even though it's meant to be well insulated in the roof space, I don't think it's particularly efficient, you can feel draughts around the lamps [recessed spotlights].

The case study participants were all very happy with their ventilation in summer although three (CS8, CS9, CS13) did identify individual problematic draughts in winter. The vast majority (93%) of the survey respondents meanwhile were content with current ventilation conditions in summer (6% wanting more ventilation, 1% less). It would therefore appear that Cumbrian heritage residents in the current study are satisfied overall with current ventilation levels in their buildings and that, while a significant percentage find their buildings draughty, most are content with the situation and do not desire change.

4. Discussion

Improving comfort is often considered a key driver for residents to engage in renovation activities in their cultural heritage buildings, as these buildings are often presented as uncomfortable to live in when compared to modern buildings. The results of this research however challenge this assumption, painting a more nuanced picture of residents' comfort perceptions in their heritage buildings. The survey results did indicate that a significant minority of residents would prefer their homes to be warmer in winter. Most of the case study participants however were comfortable with current conditions even though they recognised them as cooler than average, and some compared the performance of older elements of their house favourably with modern extensions. This suggests that although increasing thermal comfort may be a renovation driver for some residents, it will not be for all, or even the majority, and that other reasons will need to be presented to residents to increase the uptake of energy renovations to the required levels to mitigate the climate crisis.

In summer meanwhile, the Cumbrian heritage buildings were perceived to perform very well by both survey respondents and case study participants, with the best performance compared to the secondary data examined. This is particularly relevant in the context of future climate predictions for rising temperatures and increasing numbers of extreme heat events. It also has implications for renovation approaches and policy because it is critical that efforts to reduce winter discomfort and the need for carbon intensive heating do not negatively affect the excellent summer performance that many heritage buildings appear to exhibit. In particular a situation must not be created where renovation leads to demand for air cooling in summer that merely replaces the previous carbon emissions from winter heating demands in northern Europe [16,21].

This finding also links to residents' ventilation perceptions. Most residents were comfortable with ventilation in their buildings, despite the fact that a significant proportion identified them as draughty. Some case study participants highlighted the benefits of cross ventilation and their appreciation of fresh, cool air in unheated bedrooms. This emphasises the need for a whole house renovation approach that actively considers ventilation perceptions and needs, and post renovation ventilation strategies where infiltration has been reduced [21]. In heritage buildings there may be opportunities to take advantage of traditional design features such as stack ventilation, and internal or external shutters for ventilation and heat reduction in hot weather conditions [22].

The reach of this study has been limited by a lack of comparable UK data and there is a need for larger scale research on residents' comfort perceptions in residential buildings in general and cultural heritage buildings in particular, especially in temperate climates. The heritage nature of these buildings may also affect residents' expectations of thermal comfort and would benefit from further exploration.

This research has, however, identified a diversity of comfort perceptions among Cumbrian heritage building residents and highlights the need to consider the performance of heritage buildings at a detailed level so that renovation strategies can take advantage of the positive aspects that these buildings may already have. Residents' behaviours and comfort perceptions should also be considered before recommending retrofit measures that could be undesirable to residents and which might have no impact on energy use. It also highlights the need to interrogate assumptions about poor comfort performance in heritage buildings as this is clearly not the case for all, or even the majority, of these homes.

5. Conclusion

This research has examined the perceptions of thermal comfort and ventilation held by residents of cultural heritage buildings in Cumbria, through a survey, case study interviews, and comparisons with secondary data. Winter thermal perceptions were found to be varied, with a significant minority desiring warmer temperatures but the majority content with current conditions. In summer, heritage building residents perceived their homes to have excellent performance and this was in stark contrast to the more modern buildings from other studies. This has implications for renovation strategies and the need to maintain these positive aspects, especially in view of future climate predictions. Residents were generally happy with ventilation levels in their buildings, with a significant number actively enjoying draughts and fresh air and practicing window opening in unheated spaces.

This research has identified a lack of UK studies on comfort perceptions in residential, and especially heritage, buildings, and the need for more understanding of this area. In contrast to general assumptions, improvements to thermal comfort may not be a key renovation driver for a significant number of heritage residents who are content with current conditions, alternative drivers may thus be required for these residents to engage in energy renovations. Residents' comfort perceptions should therefore inform renovation strategies to reduce carbon from heritage buildings and help mitigate climate change.

Appendix 1

Table A1 Details of studies from the literature for comparison

Ref	Study location	Brief description	Building Type	Participants	Comparable parameters	Time period
[8]	Fujian Province China	Comparative study of indoor environmental quality (IEQ) in rammed earth heritage buildings & modern rural buildings	6 communal heritage buildings & one rural village with modern houses in the same geographic area	139 heritage households & 97 modern households	Thermal sensation & thermal preference	Questions about general perceptions for both summer & winter seasons
[15]	Ireland, Near Dublin	Study of effect on IEQ of retrofit interventions in social housing	Modern buildings built between 1994-2000.	15 households. Pre & post retrofit measures	Thermal satisfaction and preference	General thermal satisfaction for winter only, pre & post retrofit
[16]	UK, two sites in London & one in Milton Keynes.	Exploration of overheating potential for modern sustainable buildings	Two apartment blocks & one housing development. All prefab timber construction. All recipients of sustainability awards	65 households for general survey. 17 households for diary (106 responses winter & 90 summer)	Survey thermal sensation & thermal satisfaction. Diary for thermal preference	Perceptions for summer & winter seasons and spot temperature diaries for 7-14 days in summer & winter.
[17]	UK Portsmouth	Temperature measurements & interviews with residents of council apartments	Two apartment buildings built 1966	17 households	Thermal sensation & thermal preference	Thermal sensation for winter only & thermal preference at time of interview (Oct)
[18]	UK, urban clusters near Manchester, Liverpool, Birmingham Newcastle & Southampton	Part of the Warm Front study to reduce fuel poverty for vulnerable people across the UK through financial support for retrofitting	Mix of private tenure buildings. All households include vulnerable occupants either: over 60; under 16: disabled; or long-term ill residents	297 households pre retrofit. 217 households post retrofit which consisted of cavity wall and loft insulation.	Thermal sensation pre & post retrofit.	Diary over 11 days with a spot temperature questions morning & evening for main living space. winter only
[19]	Across UK	Survey of residential design quality across a range of building types, ages & locations	UK homes build post 2000 & UK homes built pre-1945	94 households Post 2000. 179 households pre-1945	Thermal satisfaction	General thermal satisfaction for summer & winter

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