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Design to Thrive

Coping with discomfort at home and its effect on the internal climate. The case of traditional Scottish buildings before and after a retrofit

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Abstract: This study investigates the relationship between users and internal climate in traditional buildings. Built upon principles of social practice theory, the results presented here compare and contrast occupants' daily practices of comfort with the physical characteristics of the indoor environment. Specifically, this study explores the effect of coping with discomfort on the internal moisture loads (difference in water vapour content in g/m^3 between indoor and outdoor air). A cross-sectional study was designed to gather qualitative and quantitative data from households of traditionally constructed buildings before and after a thermal retrofit of the envelope. The results revealed that the 'meaning' of comfort has a crucial impact on how daily practices of comfort (such as heating or ventilation) are shaped. More importantly, the comparison between narratives and measurements showed that households where comfort was more difficult to achieve were those with higher moisture concentrations. The results of the study also showed that the adjusting mechanisms chosen by the users - that is, the way in which users coped with discomfort – and how long they lasted were heavily influenced by their perception of how easily comfort could be restored.

Keywords: traditional buildings, retrofit, discomfort, internal climate, practice theory

Introduction

Internal wall insulation has a significant potential to reduce energy demand in traditional buildings. It would improve envelopes' thermal performance significantly while overcoming most of the limitations and concerns encountered when retrofitting traditional properties (cost, disruption and aesthetics) (Herrera 2016). However, long term performance of solid walls after a retrofit is still unclear due to the risk of interstitial condensation caused by the application of the insulation on the warm side of the envelope. Interstitial condensation is the result of vapour diffusion through the wall and moisture generated by occupants' activities can therefore be a crucial parameter, even comparable to wind-driven loads (Tariku et al. 2015). As illustrated by Padfield (1998), from a hygrothermal point of view, people are merely sources of water. Unfortunately, previous research has demonstrated that simplified models used to define internal climate might not be able to represent the complex interaction between users and buildings (Herrera 2016). Ultimately, hygrothermal assessment of walls' performance can only be as accurate as the definition of their boundaries and therefore further exploration of users' daily activities affect the internal climate is needed.

Social practice theory and energy use

The importance of users' role on the reduction of energy consumption in buildings has been illustrated saying that "*buildings don't use energy, people do*" (Janda 2011). However, practice theory principles challenged this idea based on the premise that consumption occurs in the course of engaging in particular practices. That means that consumption of energy is not a goal per se but an outcome of ordinary practices adopted by the user such as heating, eating, cooling and showering. Consumption, therefore, cannot be equalled to demand and the efforts to reduce energy consumption should be directed to the understanding of how practices that require energy are reproduced and how can be changed. This paper uses an analogous rationale for the exploration of users' impact on the indoor environment of traditional buildings. The internal climate of buildings is analysed as an outcome of users' practices of comfort (such as heating, ventilating or laundering). That is especially relevant in residential buildings where householders are most often in charge of their own comfort (Tweed et al. 2013).

Despite the agreement on the definitions of 'practice', this theory often lacks clarity and applicability in empirical research (Gram-Hanssen 2010). In this study, the approach proposed by Shove & Pantzar (2005) is adopted as it provides the most helpful framework for the empirical application of practice theory ideas (Hargreaves 2011). Shove & Pantzar structured practices around three main concepts: meaning (images or symbolic aspects of practice), materials (physical objects that are required to develop the practice) and competence (skills required to use materials according to the meaning).

Methods

According to Yin's definition, a case study is *"an empirical enquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident, and where multiple sources of evidence are used"* (Yin 1984, p.13). In this case, a multi-case study approach was chosen and the cases were analysed as a whole in search of common patterns. The sample was formed by 26 households of traditional buildings located in the North-East of Scotland. The dwellings, built using solid masonry granite walls and pitched roofs covered with slates, were at different levels of conservation but for the analysis buildings were categorised as *"retrofitted"* or *"non-retrofitted"* according exclusively to the insulation of the external wall. A comprehensive study of users' behaviour was carried out with the aid of interviews, questionnaires and home tours with the occupants. Interviews were focused on users' perception of comfort and their energy related patterns. Information regarding heating, ventilation and moisture production habits was collected in order to achieve a better understanding of users' interaction with the buildings. Temperature and relative humidity were monitored at 15 minutes intervals in two rooms per property (living room and bedroom). External conditions were recorded by a dedicated weather station.

Data analysis

The purpose of a multi-case study approach was to explore dynamic processes considering them as a whole. Transcript coding of interviews and field notes was discarded as it resulted into a large compilation of disconnected concepts. Instead, this study looked at the qualitative data to reconstruct users' narratives (Paddock 2015). Exploration of narratives, as stories, has the potential to contribute to the understanding of how users structure and make sense of their comfort practices. Of the households investigated, only the narratives of four of them are presented here. This approach – similar to those adopted by Paddock (2015), Gram-Hanssen (2010) or Tweed et al. (2013) – allows for a more detailed analysis of the practices and their context. The narratives were chosen on the basis that these households represented the most information-rich stories while presenting themes that were prevalent across the sample. The narratives selected to be presented here, although cannot be considered ideal types of any user, cover most of the topics found in the data. Besides, these narratives illustrated four very different scenarios, two cases did not have any improvement of the envelope while the other two cases had been insulated and draught-proofed. Internal climates also differed greatly, for each scenario (insulated and non-insulated) one household had low moisture loads while the other had high values.

For analysis, environmental data was sorted according to seasons. Winter (or heating season) was analysed using measurements from December to March, while summer included the measurements from June to September. Moisture loads (difference between indoor and outdoor water vapour concentration) for each room were calculated based on temperature and relative humidity recordings. Moisture load, in contrast to relative humidity, allow weighting the effect of temperature and make the comparison between households easier.

Results

In order to facilitate the comparison between quantitative data and users' practices of comfort, a summary of households' environmental conditions and their corresponding narratives is presented in Tables 1 and 2 respectively.

Table 1. Summary of environmental conditions. Values in parenthesis represent ± one standard deviation. T: temperature, RH: relative humidity, ML: moisture load, S: summer, W: winter, Lv: living room, Bd: bedroom.

	Case 6				**Case 8**				**Case 12**				**Case 13**			
	Summer		Winter		Summer		Winter		Summer		Winter		Summer		Winter	
	Lv	Bd	Lv	Bd	Lv	Bd	Lv	Bd	Lv	Bd	Lv	Bd	Lv	Bd	Lv	Bd
T [°C]	18.9	18.3	16.2	13.3	21.8	20.7	17.5	17.6	17.2	16.6	13.7	11.2	21.3	20.2	19.4	16.9
	(1.9)	*(1.6)*	*(1.3)*	*(1.4)*	*(1.5)*	*(0.9)*	*(2.1)*	*(0.5)*	*(1.9)*	*(1.8)*	*(3.5)*	*(3.5)*	*(1.8)*	*(1.3)*	*(2.5)*	*(1.4)*
RH [%]	66.6	65.6	64.7	63.8	65.2	72.2	63.3	66.5	74.1	76.2	58.9	70.7	59.5	66.0	51.6	64.2
	(5.8)	*(6.4)*	*(8.3)*	*(5.2)*	*(3.5)*	*(2.9)*	*(1.9)*	*(3.2)*	*(5.4)*	*(4.3)*	*(5.3)*	*(10.4)*	*(4.8)*	*(4.0)*	*(4.8)*	*(4.1)*
ML [g/m^3]	0.8	0.2	3.2	1.8	2.5	3.0	3.9	4.3	0.8	0.8	1.7	1.6	1.1	1.6	3.1	3.7
	(0.8)	*(0.7)*	*(1.5)*	*(0.9)*	*(1.3)*	*(1.3)*	*(1.6)*	*(1.2)*	*(1.1)*	*(1.1)*	*(1.4)*	*(1.2)*	*(1.3)*	*(1.3)*	*(1.5)*	*(1.5)*

In Case 6, average bedroom temperature in winter was almost 3 °C lower than the living room (Table 1) as a consequence of the different use of space heating (Table 2). Relative humidity was similar in both rooms during the entire year and the different patterns of ventilation described by the user only became clear when comparing moisture loads. Average moisture load in the living room was 0.8 g/m^3 in summer and 3.2 g/m^3 in winter, while the loads in the bedroom were 0.2 g/m^3 (summer) and 1.8 g/m^3 (winter) due to higher ventilation rates. Despite the low satisfaction levels of the user in Case 8, average temperatures were considerably higher than those recorded in Case 6. It is worth noting that both dwellings formed part of the same tenement and had very similar construction characteristics. The high values of moisture load recorded in case 8 (Table 1) are in agreement with user's description of poorly ventilated rooms (Table 2).

Low average temperatures and high standard deviation values recorded in winter in Case 12 matched the description of the sporadic use of the space heating. High ventilation rates reported by the users resulted in low moisture loads (0.8 g/m^3 in both rooms in summer and 1.7 g/m^3 in the living room and 1.6 g/m^3 in the bedroom during the winter). Average temperatures in Cases 8 and 13 were similar but occupants' satisfaction in Case 13 was much higher and discomfort was mainly caused by operation of the heating system and building's exposed location. The different ventilation patterns across the year resulted in different levels of moisture. During the summer, the levels of relative humidity and moisture load (1.1 g/m^3 in the living room and 1.6 g/m^3 in the bedroom) were relatively low. In winter, despite the use of a dehumidifier, moisture load results were much higher (3.1 g/m^3 in the living room and 3.7 g/m^3 in the bedroom) and comparable to those obtained in case 8.

Table 2. Summary of users' narratives of comfort at home.

	Case 6	Case 8	Case 12	Case 13
Scenario description	Victoria has lived in the same rented flat (non-retrofitted, 1 bedroom flat in the city centre) for the last 20 years. She is in her 50s and works as a waitress in a hotel. She would like to have some aspects of the flat improved but she is reasonable content in her home.	Amy lives with her new-born baby girl and a dog in a non-retrofitted 1 bedroom rented flat in the city centre. She usually works full time as an office manager but now is in maternity leave and spends most of the time at home looking after the baby.	Mark and Claire are in their 40s. They moved to a renovated two bedroom cottage a year and a half ago. They have lived in the countryside for the last twelve years. They are both outdoor people and enjoy going out for a hike or a bike ride.	Monika and Viktor live in a deeply renovated cottage with their two children and a dog. Viktor works abroad most of the time but when he is home he does not work at all. Monika is at home for most of the day, looking after the baby and working on her studies.
Meaning of comfort	Victoria likes to take a shower, cook dinner and sit in the living room in the evening. It is easy for her to be warm as 16 to 18 °C is usually enough for her. Victoria likes to have fresh air while she sleeps and the window in her bedroom is usually left open.	Being warm is the most important aspect of comfort for Amy. She has lived in the same flat for the last five years and feeling warm has always been a problem. The flat has electric radiators and storage heaters but Amy never fully learnt how they work.	Quietness is a priority regarding comfort and the main driver to choose their new home in a fairly isolated setting. They do not like being too hot or feeling that the air gets too stuffy and rather wear warm clothes at home.	Temperature is the most important factor for Monika, while Viktor is never cold and it is minor for him. He values other factors such as having a quiet environment. Their different liking in terms of comfort is also visible in the clothes they wear at home.
Coping with discomfort	Living room windows are usually closed. She finds the noise from the traffic too loud and prefers to keep it shut. She only opens the window when she is cooking something very steamy in the open plan kitchen. The extractor fan is also very noisy and is not used often either.	Amy decided to buy a portable bottled gas heater after a cold winter and has been using it since then. All doors in the flat are kept closed and fitted with draught excluders. The bedroom window is also permanently shut and it has been partly covered with an insulating board.	They usually do not use the heating for more than three hours a day. If they feel cold, Mark would sooner light the stove than using the oil boiler. They never leave the fire on overnight as he does not mind lighting it again the next day if they need it.	A wood burning stove feeds both the heating and hot water, so they have to keep it on during the day. The house is in a very exposed location and airing the rooms when it is raining is not possible. Instead, they bought a dehumidifier. It is also very helpful for drying laundry.

Coping with discomfort: the effect of how easily comfort can be restored

Within the small sample of four narratives presented here, very different meanings of comfort were found. Beyond the differences in meanings, what the comparison between narratives and measurements showed was that those households where comfort was more difficult to achieve (whatever meaning it had) were those with higher moisture concentrations.

The principle of adaptive comfort states that *"if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort"* (Nicol et al. 2012). Therefore, high moisture loads appeared to be a consequence of practices developed by the users to cope with discomfort. Literature on discomfort in buildings usually classify those mechanisms of adjustment as: (i) environmental or technological (interaction with the building control systems such as heaters or fans), (ii) personal or behavioural (changing activity, clothing or posture) and (iii) psychological (managing emotions or thoughts about the situation) (Heerwagen & Diamond 1992; Azizi et al. 2015).

According to Shove & Pantzar (2005), the links between the elements of a practice are reproduced and maintained by the practitioners, represented as 'carriers'. Moreover, practices emerge, develop and disappear as a consequence of the formation or dissolution of these links. New practices can therefore be generated by breaking the links between elements of existing practices and re-making them in a different manner (Hargreaves 2011). Coping with discomfort, therefore, cannot be considered as a practice on itself but as an adaptation of the practices of comfort at home (including heating, cooking or ventilating). Moreover, the three mechanisms of adjustment described above can be easily likened to the elements of practices proposed by Shove and Pantzar: environmental as material, behavioural as competence and psychological as meaning.

The results of this study showed that the adjusting mechanisms chosen by the users (that is, the way in which users coped with discomfort) were heavily influenced not only by their comfort expectations but also by their perception of how easily comfort could be restored. If comfort was quickly achieved after the cause of discomfort ceased, then users mainly engaged in temporary adjustments of material or competence (wearing a pullover on a cold night or closing the window if the road is too busy and loud). These changes were meant to provide *"rapid and noticeable changes in the environment"* (Heerwagen & Diamond 1992). When the cause of discomfort ceased the practices returned to their normal configuration and comfort was recovered easily. Thus, since the reaction to discomfort did not endure, the adjusting mechanisms did not break any link between the elements of the existing practices and did not produce any lasting change in the internal climate.

On the other hand, the adjusting mechanisms adopted by users that felt that comfort was difficult to restore were almost permanent and involved changes in all the elements of practice (and the links between them) that resulted in new practices. The coping approaches were essentially of two types: the adaptation of the meaning or the modification of the material structure. In the first case, the meaning of comfort at home was altered to match the actual conditions of temperature, humidity, noise, etc. that could be achieved with the available materials and competences. Heerwagen & Diamond (1992) explains this mechanism in plain terms saying that the users try to ignore the discomfort or *"just put up with it"*.

Temperature was inarguably the first aspect mentioned by the majority of occupants when asked about comfort. However, the definition of thermal comfort differed from one case to another. Thus, some users felt comfortable with temperatures in the range of 16-18 °C while other occupants were dissatisfied with even higher levels of internal temperature. This discrepancy in the expectations of thermal comfort was constant throughout the entire sample. Users that felt comfortable with lower temperatures tended to have a common 'image' of comfort adapted to traditional buildings. Among those users, there was a shared perception that "*old is cold*" (Ingram et al. 2011) and the expectations of thermal comfort were adjusted since no higher internal temperatures could be achieved. In those cases, the practices of comfort were permanently reconfigured but only involved the modification of one element (the meaning of thermal comfort) and resulted in environments with low moisture loads (Case 6).

Warmth or internal temperature was not the only aspect of comfort that occupants had in mind when thinking about their homes. In fact, warmth was not the most important factor in many cases. Fresh air, quietness, privacy and cleanliness were also important factors for several occupants. In those cases, the internal temperature stayed in the background when talking about their comfort at home. These occupants were willing to sacrifice thermal comfort, to some extent, by accepting lower levels of internal temperature if other aspects of comfort were fulfilled (Case 12).

A second coping approach consisted in the modification of the material structure and its operation in order to create an environment that matched users' predefined images of comfort. The narrative of Case 8 is a clear example of how the material structure was modified (new portable bottled gas heater; windows, trickle vents and curtains shut; bedroom window covered with an insulation board) as a response to an environment that did not match the expectations of comfort at home (steady high temperatures). In those cases, the mechanisms of coping with discomfort consisted in the reconfiguration of both heating and ventilation practices and involved permanent changes to the material structure that were reflected in the internal environment in the form of high values of moisture load.

Discussion

Although quantitative studies in the area of residential buildings are very scarce (Tweed et al. 2013), reaction to discomfort in working places have already been explored in previous studies. Azizi et al. (2015) found a relationship between the material structure of office buildings and how the users' meaning of comfort is adapted to cope with discomfort. Azizi stated that occupants of 'green' buildings were more likely to accept discomfort and that they were "*engaged in less environmental adjustments, and adopted more personal and psychological coping mechanisms than those occupants in the conventional building*". In this study, a relationship between material and meaning was only found among the occupants of traditional buildings who shared the perception that 'old is cold'. As a consequence, they accommodated their expectations of comfort to this pre-established image and adapted their practices accordingly.

Nevertheless, no correlation between the level of insulation of the building and adaptive comfort practices was found. The results of this study challenge the idea that users of better performing dwellings "*have lower thermostat settings but air their dwellings more often*" creating healthier environments (Raaij & Verhallen 1983). According to the narratives' analysis, meaning of comfort has proven to be more determining than the physical properties of the building. This investigation, therefore, aligns more closely with the conclusions from an earlier study on energy saving houses (Hamrin, 1979, in Raaij & Verhallen 1983) that linked the final success of the energy efficient measures (material) to the energy consciousness of the users (i.e. the meaning). Hamrin found that passive equipment, that involves active engagement of users, is better suited to residents with high levels of energy consciousness.

The conclusions of Hamrin's study – i.e. the type of system (material) should match occupants' meaning of comfort – can be directly extrapolated to this research.

The results of this study also discovered a relationship between the perception of how easily comfort could be restored and the practices finally adopted. Every user occasionally felt uncomfortable and therefore adapted their practices to restore the comfort. However, only those users that were not able to restore their comfort quickly engaged in practices that had a negative lasting effect on the internal climate. A high level of adaptation made by the users to feel comfortable was also reported by Heerwagen & Diamond (1992). In their work, they introduced the term *"coping success"* to describe the ability to effectively resolve discomfort. They also suggested that designers should include more opportunities of personal control to avoid environmental (material) changes and to increase coping success. In line with Heerwagen & Diamond's recommendations, the results of this study highlight the need to facilitate 'safe' or 'compatible' options of adaptation that can provide users with comfort at home while preventing any scenarios of high moisture concentration.

Gram-Hanssen's (2010) work found that standby consumption was the outcome of a series of dispersed practices rather than an integrated practice. She argued that campaigns to make people aware of their standby consumption are trying to convert their dispersed habits into an integrated practice. Analogously, the results of this study showed that internal climate is an outcome of a series of dispersed practices and therefore making people aware of their effect on the indoor environment could connect dispersed practices like laundering and ventilating forming one new integrated practice

Conclusion

There is a large of body of literature using quantitative approaches to explore the use of domestic space heating (Guerra-Santin & Itard 2010), ventilation (Fabi et al. 2012) or laundry appliances (Porteous et al. 2014). However, the results of such studies have proven to be insufficient to explain the mechanisms of user behaviour and often reached opposite conclusions (Wei et al. 2014). This study opted in favour of a more qualitative approach to explore users' effect on the internal environment of traditional buildings. Thus, this research carried an in-depth exploration of the narratives of comfort at home in order to identify the reasons behind users' behaviours.

The results presented here aligned with those obtained by Tweed et al. (2013) who stated that being thermally comfortable has different meanings to different users. The results of this investigation, however, did not only point to the differences in thermal preferences but also to the different meanings of practicing comfort at home. As stated by Madsen (2014), comfort is not limited to temperature as it also includes aspects like *"light, functionality and homeliness"*.

The results of this study corroborated the relevance of discomfort in shaping the internal environment of buildings. Practices developed to tackle discomfort were shaped to create the conditions that users considered acceptable, regardless of those predicted by conventional comfort theories (Tweed et al. 2013), and ignored their effect on the indoor environment. Consequently, adapted practices of comfort at home often resulted in poor environments with high concentrations of humidity and low air change rates. Efforts to explore the role of users on the internal climate of traditional dwellings should be directed to understand how the practices of comfort that affect the environment are reproduced and how can be changed.

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