Chapter 7

Assessing human resilience: A study of thermal comfort, wellbeing and health of older people

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Abstract: This Chapter reports on the findings of a research project aimed at investigating the actual thermal environment of the housing of older occupants (aged 65 or over) in South Australia. The study documented their thermal preferences and behaviours during hot and cold weather and relationships to their wellbeing and health. Information was collected in three phases, a telephone survey, focus group discussions and detailed house environmental monitoring that employed an innovative data acquisition system to measure indoor conditions and record occupant perceptions and behaviours. The research covered three climate zones and extended over a 9-month period. The detailed monitoring involved a total of 71 participants in 57 houses. More than 10,000 comfort/wellbeing questionnaire responses were collected with more than 1,000,000 records of indoor environmental conditions. Analysis of the data shows the relationships between thermal sensation and self-reported wellbeing/health and the various adaptive strategies the occupants employ to maintain their preferred conditions. Findings from the research were used to develop targeted recommendations and design guidelines intended for older people with specific thermal comfort requirements and more broadly advice for architects, building designers & policymakers.

Keywords: Thermal comfort, wellbeing, older people, South Australia

Introduction

As we age, unavoidable physiological changes can affect our thermal perception, sensitivity and regulation (Blatteis, 2012; Dufour and Candas, 2007). Overall, physical ageing is commonly associated with a significant compromise in the efficiency of our thermal defence mechanisms and our ability to respond effectively to temperature fluctuations, upsetting in some the homeostatic balance of health and wellbeing. The physiological changes, include reduced vascular reactivity, lower metabolic rate and reduced muscle strength, all of which can affect our thermal sensitivity and regulation (Blatteis, C., 2012). A number of age-related medical conditions, such as cardiovascular disease, respiratory disease and diabetes mellitus can also be exacerbated by hot environments (Ishigami, A., et al, 2008). These conditions decrease the body's ability to adapt to changes in environmental situations, potentially leaving older people less able to cope with thermal change (Lomax, P. & Schonbaum, E., 1998).

As thermoregulation plays a vital part in human survival, older people can become vulnerable to temperature extremes in their environment, therefore demanding special understanding of their thermal needs and preferences (Shibasaki et al., 2013). This problem comes to the fore when we appreciate that the vast majority of older people (at least in Australia) want to continue living independently for as long as possible in their own home. These homes, that could otherwise protect their occupants, are often older housing stock that likely show reduced resilience to any future adverse weather conditions.

Previous studies exploring whether the thermal requirements of older people differ from those of younger people are inconclusive. One review of both climate chamber studies and field studies concluded that there were no significant differences between the comfort temperatures of young and older people once clothing, metabolic, and anthropometric differences were taken into account (Wang, Z. et al., 2018). Other studies reported that older people preferred higher temperatures (Rupp, R.F. et al., 2015; van Hoof, J. & Hensen, J., 2006; Schellen, L., et al., 2010) or lower (Bills, R. 2016; Tartarini, F. et al., 2016), and that their comfort range was narrower (Hwang, R.-L. & Chen, C.-P. 2010) or wider (Yang, J. et al., 2016).

In a literature review of the terms "resilient design, resilient buildings, resilient energy systems, resilient comfort" Schweiker (2020) found that overall, there is little research that takes a holistic approach to building resilience that takes into account human resilience and knowledge of the surrounding variables. The work described here shows, in part, how such research can be undertaken and some of the results obtained. The research project involved a study aimed at investigating the actual thermal environment of the housing of older occupants (aged 65 and over) in South Australia together with their thermal preferences and behaviours during hot and cold weather and relationships to their health and wellbeing.

Study Setting

The State of South Australia (SA) is located in central southern Australia and has a population of approximately 1.7 million, most of whom (77%) live in the State's capital city of Adelaide. In general, South Australia experiences warm to hot summers (December to February) and relatively mild winters (June to August). For energy-efficient building design the National Construction Code identifies three climate zones in the State - (1) semi-arid, (2) warm temperate, and (3) mild temperate, specified as climate zones 4, 5 and 6 (NCC, 2019). These are similar to the *BSk*, *Csa*, and *Csb* zones in the Köppen-Geiger climate classification system (BOM, 2014) and these classifications are used here.

The study focused on regions in each climate zone with relatively high concentrations of older people. Therefore, the semi-arid climate region (*BSk*) was represented by three towns known in SA as the "Iron Triangle" (townships of Port Augusta, Whyalla and Port Pirie) in the mid north of SA. The warm temperate climate region (*Csa*) was represented by the Greater Metropolitan Adelaide region, while the mild temperate climate region (*Csb*) was represented by the southern coastal area in the Fleurieu Peninsula and parts of the Hills area east of Metropolitan Adelaide. Figure 7.1 shows the three regions for the study.

<FIGURE 7.1 HERE>

Study Method

In the first stage, a general survey of 250 randomly selected older people was conducted to investigate whether there were associations between climatic conditions, housing types and constructions, heating and cooling behaviours and the participants' health and wellbeing (Soebarto et al, 2019). Additionally, to obtain insights about the strategies to achieve thermal comfort undertaken by older people as well as existing problems related to planning and house design, a series of focus group discussions were held in a number of locations in the three climate zones (van Hoof et al, 2019).

Finally, to gain further understandings of the actual living conditions of older people and the relationships between indoor environment and occupant's perceived health and wellbeing, monitoring and occupant surveys were conducted in 57 homes involving 71 older occupants. The monitoring included a period of summer, autumn and winter. The participants were recruited from those who participated in the initial survey and focus group discussions as well as from publicity in various media outlets. Based on the findings, a set of recommendations or guidelines were developed aimed at informing older people on design features and operating conditions that would produce the best settings to maintain comfort and wellbeing.

Monitoring

Houses involved in the detailed monitoring were mostly typical of the construction types in South Australia: external walls of cavity brick or brick veneer construction and roofs of corrugated steel sheeting or concrete tiles. The older houses had suspended timber floors while newer houses had concrete slab-on-ground construction. The approximate floor area of the separate and semi-detached houses taken together was 156 sq.m., smaller than the current average floor size of Australian homes which is 186.3 sq.m (CommSec, 2018). All houses had heaters and all but two houses had air-conditioners (coolers) in at least one room of the house, generally the living area; however, for the majority of the time the houses were operated as free-running (FR), that is, without heating and cooling. About 23% of the houses were located in a retirement village setting. A sample of the houses monitored is shown in Figure 2A

Information was collected with an innovative data acquisition system which is described in detail in Soebarto et al., (2020). A logger that recorded environmental conditions routinely every 30 minutes was placed in the main living room of the house. A portable Tablet allowed the participant to record their responses to a 17-question survey (referred to as a vote) in either their living room or their bedroom (see Figure 7.2B). A HOBO® U12-013 data logger was placed in the main bedroom of each house to measure temperature and humidity. Files of hourly weather data from the Bureau of Meteorology (BOM) were obtained from the station closest to each house.

<FIGURE 7.2 HERE>

Participants were asked to vote regularly, if possible, at least once per day. The questions asked on the survey Tablet, aimed at recording ‘point-in-time’ conditions and preferences are shown in Table 7.1. Each completed survey was time matched with co-incident records from the logger recordings of the environmental variables.

<TABLE 7.1 HERE>

Data files of the recordings together with the vote information were uploaded daily via the cellular phone network. A computer script was developed to assemble all the data from the loggers, HOBOs® and BOM weather files for analysis.

Findings

The findings presented here focus on the participant behaviours and resilience. Resilience is seen in two features of behaviour, an “ability to cope” and to “express satisfaction with the situation”.

Results of the initial telephone survey have previously been reported (Soebarto, V., et al., 2019). The results showed that while the majority of respondents reported being in good health, many lived in dwellings that did not comply with current Building Code requirements in terms of envelop insulation, shading or weatherstripping. Households appeared to rely on the use of heaters and coolers to achieve thermally comfortable conditions. Concerns over the cost of heating and cooling were shared among the majority of respondents and particularly among people with lower incomes.

Outcomes from the focus group discussions are summarised in van Hoof, et al. (2019). The discussions revealed that getting older had affected their perception of the thermal environment. One participant in a focus group meeting said “As I’ve aged, I fear the cold and I feel the cold more than when I was younger. The heat doesn’t affect me as much, I haven’t noticed suffering from heat, but I do know that as I’ve become older, I suffer more from the cold weather”. Other participants indicated that ageing had affected their activity levels and mobility and this had implications for their thermal comfort, “I think that in many cases we’re not as active as we used to be so we’re not warming ourselves up but we’ve also got a lot more time to think about it rather than when we had a job.”. They were also aware that their health can be affected by changing thermal conditions, with arthritis being a common complaint.

“Sometimes my arthritis tells me there’s going to be bad weather ….. when I get more arthritis that really affects me because I get frustrated; I can’t do things that I want to do.” They were often concerned about the costs associated with heating and cooling a house. ”….. because we all live on our own it’s easier for us to make do rather than have to pay extreme electrical costs of running anything, heating or cooling. Like I said, my throw rug only costs me 4 cents an hour to run”.

Also revealed during these discussions were some of the more unusual strategies for dealing with weather extremes. One person, for example, reported sitting with her feet in a tub of cold water and another said she kept a dress in the freezer during very hot weather, “I’ve got a shelf in the freezer that I have two dresses during the summer and one goes in the freezer and one of them I put on. After an hour or so I’ll change them. I know that I’ve always got something cold ….. When my air-conditioner broke down that was a godsend”.

Likewise, in colder weather there was a general awareness that the situation could be ameliorated somewhat by adopting simple changes in daily habits, “I certainly do change our diet slightly for more warming food, [my husband] makes the soup and we have soup for lunch. I usually will do a casserole or two, warmer food but salads in the summer”. Or, “I’ve always hated the cold all my life, so it’s always been dress more, dress more and dress more”.

Overall these conversations revealed that the strategies that individuals employed to keep cool in hot weather and warm in cold weather were complex, inter-related and influenced by a range of issues including personal factors and preferences, people’s beliefs and experiences, the type and design features of the dwelling, the type of heating and cooling equipment, as well as their concerns about the environment or financial situation.

Internal temperatures

The weather in South Australia is generally described as Mediterranean with hot dry summers and cool mild wet winters. While there may be short periods where cooling is required, in general, in each climate zone heating requirements dominate.

Temperatures measured in the living room and main bedroom of houses showed considerable variation and reflects not only the external weather conditions, but factors such as the occupants’ behaviour, their use of heating and cooling appliances, as well as aspects of the house design.

Figure 7.3A shows the percentage of all hours for houses in each climate zone when the dry bulb temperature was below 15oC and above 28oC in living rooms and bedrooms. Temperatures outside this range would normally be considered undesirable. A surprising observation is the proportion of time when both living room and bedroom temperatures were below 15oC. While this Figure shows the average, a number of houses in Zones *Csa* and *Csb* recorded temperatures in the living room and the bedroom below 15oC for more than 30% of hours even if in all cases heating was available.

The relatively low percent of time above 28oC is indicative of several factors; the fairly mild temperatures during most of the monitoring period, house construction that ameliorates temperature extremes, and adaptive behaviours, for example, applying shading devices where available and finally the use of air-conditioning (cooling).

Thermal sensation and preference

Figure 7.3B shows the frequency of responses recorded for the question "How do you feel right now?" over the whole monitoring period - the thermal sensation vote (TSV). For climates *Csa* and *Csb* the balance of votes was slightly on the cool/cold side, while for zone *BSk* the balance was about equal.

<FIGURE 7.3 HERE>

A crosstabulation of TSV and responses to the question "How would you prefer to be?" (Preference) is shown in Table 7.2 for all votes

<TABLE 7.2 HERE>

Each climate zone showed similar results. Of significance is that around 77% of the time the participants had a preference for "No change" and more than 25% of these votes corresponded to a TSV other than neutral with a significant number (13.4%) expressing the sensation of "Slightly cool" and a preference for "No change". This indicates that the preference for, or acceptance of, non-neutral thermal conditions should be considered when preparing design recommendations.

Thermal sensitivity

The aggregate thermal sensitivity of occupants in each of the three climate zones was assessed by plotting the internal operative temperature against their TSVs. The regression coefficient or gradient of these plots is interpreted as being inversely related to the occupant's thermal adaptability, the greater the slope the more sensitive (or less accepting) are they to temperature changes. A slope of 0.13/K was reported by de Dear et al. (2018) in their study of houses in Sydney and Wollongong, New South Wales. Daniel et al. (2019) reported a slope of 0.11/K for a cohort of occupants monitored during cold weather in Adelaide, SA. Williamson and Daniel (2018) showed a regression coefficient of 0.31/K for a cohort in naturally ventilated houses in Darwin, NT.

Figure 7.4 shows the weighted regression line with a slope of 0.023/K with internal operative temperatures binned at 0.5K for climate zone *Csa*.

<FIGURE 7.4 HERE>

Similar plots for the other climate zones give, for climate *Csb*, a slope of 0.085/K, and for climate *BSk*, a slope of 0.083/K. A t-test analysis applied to each pair of slopes indicates that the slopes *Csa* & *Csb* (t=7.21, $p<0.05$), *Csa* & *BSk* (t=4.92, $p<0.05$) are significantly different, while the slopes of *Csb* & *BSk* (t=0.18, $p>0.05$) are not significantly different. Compared with other studies this cohort of older residents would seem far less sensitive to temperature variations compared with more general cohorts.

An analysis of clothing and activity levels showed the adaptive actions taken by the participants. As the internal temperature increases there is a strong tendency to decrease both clothing and activity levels, with clothing adjustments being the main adaptive strategy.

Thermal Acceptability

Williamson and Daniel (2020) have outlined a method of estimating thermal acceptability using the preference criteria of “No change”. Here the assumption is that “No change” denotes satisfaction and is therefore a suitable indicator of the thermal acceptability of the occupants. As seen in Table 7.2, participants indicated “No change” for 76.5% of votes. As shown in Figure 7.5A the range for the 80% level of acceptability of the internal temperature was 7.1K, i.e. from 18.3oC to 25.4oC.

Thermal satisfaction

One question on the Tablet survey “How satisfied are you with the temperature in this room?” sought to elicit a response regarding the point-in-time overall approval of the thermal conditions. The results for each climate zone are shown in Figure 7.5B.

<FIGURE 7.5 HERE>

Overall, the participants reported “Very satisfied” or “Satisfied” on 78% of occasions, indicating a great deal of resilience. Only in the cooler climate zone *Csb* were the votes “Very dissatisfied” and “Dissatisfied” greater than 5%. Overwhelmingly the participants expressed satisfaction with their thermal environment in a wide range temperature conditions. Combining the data for all climate zones and binning the internal operative temperature at 0.5K increments Figure 7.6A shows, that including the “Very satisfied” and “Satisfied” votes, conditions that are perceived as satisfactory, extend over a range of 13.2K from 15.3oC to 28.5oC: somewhat wider than current Standards (for example, ANSI/ASHRAE Standard 55, 2017) determine as satisfactory. Referring to Figure 7.5A, this corresponds to an overall thermal acceptability of around 66%.

External versus indoor acceptable temperature

The operational utility of the adaptive comfort concept in Standards such as ASHRAE 55 and EN 15251 that show a relationship between the external running mean prevailing temperature and the indoor neutral or acceptable temperature is obviously useful for determining the performance of a building in a particular climate.

Williamson and Daniel (2020) have proposed an adaptive comfort model based on a large database assembled for temperate regions of Australia and computed by a Modified Griffiths technique,

<EQUATION 7.1 HERE>

Where, Tcomf is the indoor acceptable or comfort temperature, oC.
Tpma(out) is the prevailing mean outdoor temperature as defined in ANSI/ASHRAE Standard 55, 2017, oC

Using the same method, the present data for the entire cohort produces a relationship between the prevailing mean outdoor temperature (alpha = 0.6) and indoor acceptable temperature as shown in Equation 7.2 (R2=0.60, p<0.05) and is plotted in Figure 7.6B.

<EQUATION 7.2 HERE>

The 80% range of all acceptable cases, that is $-1 \leq TSV \leq 1$ with a preference for “No change”, was calculated to have a width of 8.4K and is shown as the shaded area in Figure 7.6B.

Figure 7.6B also shows for comparison these models as well as the ASHRAE 55 Standard model neutral temperature - Tcomf = 17.8+0.31Tpma(out). The present model indicates that the older participants of this study prefer slightly higher temperatures compared to the general population in the temperate regions of Australia. The Figure also illustrates that using the ASHRAE 55 model to assess housing performance in Australia is likely inappropriate

Health and wellbeing

As explained above, the participants in this project were generally aware that thermal conditions could affect their health and wellbeing. Two questions of the survey were designed to explore this issue – "…. describe your health and wellbeing at the moment?" and "… the conditions in this room influence my health and wellbeing?". The crosstabulation of results is shown in Table 7.3.

<TABLE 7.3 HERE>

About two-thirds of responses reported "Definitely yes" or "Probably yes" that the thermal conditions in the room influenced their health and/or wellbeing. On about 61% of occasions the participants indicated that their health was "Very good" or "Good" with a further 35% suggesting "Reasonable". An understanding of these results becomes clearer with a plot of health/wellbeing against internal operative temperature as shown in Figure 7.6C. The influence of temperature is more pronounced (presumably adversely) below about 15oC and over about 28oC. This range corresponds approximately to the "satisfactory" range described above.

<FIGURE 7.6 HERE>

Indoor Air Quality

Beginning in early 2020 most countries of the world experienced the effects of the SARS-CoV-2 (COVID-19) novel coronavirus. Older people, especially those with underlying health issues, were more susceptible to experience life-threatening consequences if infected with the virus (Holt, et al., 2020). The introduction of outside air into buildings (assuming good outside air quality) is recognized as an important risk mitigation measure for controlling the concentration of possible indoor pathogens including the COVID-19 virus (Morawska, et al., 2020).

While dwelling ventilation rates were not directly measured during this research project, the use of windows and doors to provide fresh air was indicated by the responses to the survey question "In this room, windows and door(s) to outside are …. ". Answers showed that 32.4% of the time windows/doors were either All open or Some open/closed. Modelling showed that most windows/doors were closed if the external temperature was below 16.6oC or above 32.8oC. However, around one third of time when a heater or air-conditioner was said to be operating, some windows/doors were also reported open. This, somewhat counter intuitive result, likely represents the desire to maintain a good indoor air quality even at the expense of possible increased energy costs.

The success in operating windows and doors to achieve this aim is indicated in the answers to the question “Do you feel the air quality in this room is:”. Air quality was considered “Very good” or “Good” 70.8% of time with only 1.1% of time considered “Poor” or “Very poor”. In response to the question “Do you think the air in this room is…” only 2.2% of time was the air considered “Stuffy”.

While they do not provide conclusive evidence, these results indicate that these participants generally understood the benefits of introducing fresh air into their dwellings and operated the windows and doors to achieve this outcome.

Cluster and Personal Thermal Comfort Models

With a better understanding of older people’s thermal perception and sensitivity, and the different drivers of their diversity, individualising thermal comfort models for this cohort becomes a natural next step.

Studies on thermal comfort that focus at the population level, for example, on aggregated responses from a group of people as shown in Figure 7.6B, are being supplemented by more individualised and occupant-centric alternatives (Kim et al., 2018). Diversity in preferences and perceptions is being recognised, and occupants whose comfort perception deviate from population averages are considered as relevant. In this context, since older people’s individual differences are wide, much can be gained by investigating their environmental comfort from a more occupant-centric approach.

To explore the diversity among older people, the ‘significant features’ of all research participants were investigated using a hierarchical cluster analysis (HCA) (Steinbach 2004). Six clusters were identified among the participants each characterized by a distinctive thermal ‘persona’. The significant features used to define the clusters include: the participant’s demographics; health and well-being status; their preferred actions to stay warm or cool; their house type, age, and location, and the heating and cooling types they use in the house. The six clusters identified are as follows:

Cluster 1: likely of the younger group (aged 65-74); female; living alone; likely to be in the higher income bracket (> $50,000 per year); likely to have some mobility issues, well-being and health issues; likely to use adaptive strategies to keep cool and heating to keep warm; and very concerned about cost of heating and cooling.

Cluster 2: highly likely of any age group; female; living alone; likely to be from the lowest income bracket (<30,000 per year); but likely to not have any mobility, health and well-being issues; and likely to use personal strategies to keep cool and warm due to cost concerns.

Cluster 3: highly of the oldest group (aged 85+); female; living alone in a retirement housing; from the lowest income bracket; likely to have mobility problems with no other health and well-being issues; prefers to be warm all the time; and likely to use both personal strategies and technologies to keep cool and warm.

Cluster 4: likely of any age group; female living with other(s); from the higher income bracket (> $50,000 per year); with no health and well-being issues except depression and anxiety; and highly likely to have cost concerns over heating and cooling.

Cluster 5: likely of any age group; female living with other(s); likely to have no health and well-being issues; likely to apply personal and household strategies to be comfortable; and highly likely to have cost concerns over heating and cooling.

Cluster 6: likely of any age group; male living with other(s); from the middle-income bracket ($30,000-50,000 per year); likely to not have any health and well-being issues; likely to use heating and cooling to be comfortable; and less concerned about the cost of heating and cooling.

The thermal sensations, comfort and preferences of the participants in each cluster from the monitoring program were then analysed to develop an adaptive thermal comfort model of that cluster. The preferred indoor temperature as a function of the prevailing mean outdoor temperature was based on the methodology developed by Williamson and Daniel (2020). The limits of the preferred indoor operative temperatures for each model corresponded to 80% of the neutral votes by participants in the cluster when they preferred "no change" and calculated by using the mean of the average monthly outdoor temperature for each climate zone for summer (*BSk* and *Csa* = 23oC, *Csb* = 19oC) and winter (*BSk*, *Csa* and *Csb* = 12oC). The results are shown in Table 7.4 and Figure 7.7.

The results show that there are three distinctive ranges of preferred temperatures for Cluster 1, Cluster 3, and Clusters 2, 4, 5 and 6. These results highlight the importance of recognizing the diversity among older people and point to the necessity for any guidelines or strategies to address these differences.

<TABLE 7.4 HERE>

<FIGURE 7.7 HERE>

To further address the diversity among people at individual levels, studies aimed at the development of different forms of individualised comfort models, also known as personal comfort models, are a recent area of research. These new approaches have been developed to overcome most of the restrictions that the PMV and generalized adaptive models present. Instead of an average response from a large population, these models are designed to predict an individuals' thermal comfort responses, using a single person's direct feedback and personal characteristics as inputs.

A preliminary development of personal comfort models for seven of the study participants – and using machine learning algorithms – show that, on average, the individualised models can significantly improve the prediction of thermal preference observations when compared to the performance of individually applying the PMV model converted into three thermal preference categories (prefer to be cooler, no change and prefer to be warmer) (Arakawa Martins et al., 2020).

On average, PMV predicted individual preferences with an accuracy of 46.1% and a Cohen's Kappa indicator of 0.2 (i.e. slightly better than random guessing). On the other hand, the developed personal comfort models predict preferences with an average accuracy of 78.1%, and an average Cohen's Kappa indicator of 0.7. Compared to PMV the personal comfort models improved the prediction of thermal preference on average by 69%.

Considering the personal comfort models' ability to absorb people's diversity and susceptibility to environmental conditions, they could represent an important step towards increasing environmental resilience, enhancing wellbeing, and potentially promoting energy efficiency through better indoor comfort management for older people's dwellings.

Development of thermal comfort guidelines for older people

The study has resulted in recommendations and design guidelines to improve thermal comfort in housing for older people in SA to achieve the preferred temperatures while taking into consideration the occupants' constraints and concerns particularly in relation to the impact on energy use and cost. The guidelines include suggestions for: (1) personal actions that older people themselves can undertake during cold and hot weather, (2) the most appropriate heating and cooling equipment to suit their individual needs, and (3) house design, both for a new design and renovation.

To ensure that the guidelines, particularly the ones concerning house designs, are meaningful and impactful, the full suite address general recommendations as well as the specific requirements of the six different cluster 'personas' described previously. The impacts of applying the suggested strategies on the persona's thermal comfort, energy use and operating cost have been demonstrated using computer thermal performance simulations. Figure 7.8 shows examples of the specific guidelines for Clusters 1 and 3 that are available in printed form and on-line.

For example, for a persona from cluster 1 (living alone with mobility problems and other health and well-being issues but preferring relatively low temperatures in winter), the guideline first suggests that the minimum indoor temperature should be at least 18oC as studies have shown that prolonged exposure to low temperatures can be detrimental to older people's health. However, since there is a great concern over the cost implication from using additional heating, the guideline describes a number of low-cost design strategies or improvements, such as improving the draught sealing around the windows to minimize heat loss, adding improved thermal insulation to the ceiling, and using seasonal or moveable shading devices to reduce heat gain in summer and keep the house cool in summer but to allow for more solar gains in winter. If this person is looking to renovate her existing house or move to another house, then the guideline includes suggestions to search for a house with double glazed windows in the living space, as well as installing energy-efficient heating and cooling equipment. Operating cost savings from implementing such strategies are also shown in the guideline.

For a persona from cluster 3 (living alone in a retirement housing with relatively no health and well-being issues but always wanting to feel warm in the house while keeping the operating cost down), the guidelines suggest ensuring that all windows receive as much sun as possible in winter by opening all the blinds or curtains during the day and closing them at night to reduce heat loss, to ask the retirement housing provider to check the condition of the existing thermal insulation in the roof and to add insulation if necessary, to weather-strip around the windows to reduce heat loss, and to consider replacing older heating equipment with more energy-efficient appliances. This guideline does not include a suggestion to replace the existing single window glazing with double glazing or to do renovations as suggested to Cluster 1, because the dwelling she lives in belongs to a retirement housing provider.

<FIGURE 7.8 HERE>

Discussion

This Chapter has reported on a study involving older South Australians aimed at better understanding the relationship between external weather, aspects of the built form of the dwelling, the occupants' thermal comfort and wellbeing. The general aim of the project was to investigate strategies and develop guidelines for improving the thermal environment so that as people age, they may remain in their own house with conditions that do not adversely affect either their health and wellbeing or impose a greater financial burden.

Overall, the mass of data collected during the project showed that the older cohort of South Australians who participated in this study were a resilient group who showed themselves to be less sensitive to temperature variations compared to the general population in Australia reported in other studies. On the whole, they expressed satisfaction with the thermal environment in their house even in conditions that might normally be considered beyond Standard comfort limits.

They appeared to be adept at employing adaptive strategies, for example, altering their clothing and activity as a function of temperature as well as the judicious use of heating and /or cooling. Most of the time the participants operated their house in free-running mode, with on average heating or cooling employed for around 33% of the time a vote was recorded. They made judicious use of windows and doors to bring in outside air and therefore maintained a reasonable indoor air quality.

The study, however, did confirm, that even for these ‘comfortable’ houses, there was a prevalence of indoor temperatures that have been shown to have possible adverse health effects. In particular, in each of the three climate zones measurements showed significant portions of time when the temperature, particularly in bedrooms during night time in winter, was below 15oC. Periods of hot weather were found to be less an issue because of adaptive measures adopted by the participants together with the use of air-conditioning, if at a cost, used to alleviate the extremes of temperature.

This apparent resilience or reduced sensitivity to temperature conditions should however be treated with caution as it may put some older people at risk regarding their health. Bills (2016) who studied a similar cohort of householders 65 years of age and over in the Greater Adelaide metropolitan area showed that heat- and cold-related health symptoms were exacerbated when temperatures in a house were consistently outside the range 21oC to 24.3oC, even if the occupants found the wider conditions acceptable.

It is well-understood that, even for the hardiest of individuals, the thermal environment, particularly extreme heat or prolonged cold, and the ability (or inability) of the home environment to ameliorate such conditions, can have significant effects on occupants' wellbeing and health. Thermal comfort, as such, cannot be an exclusive end in its self. To promote genuinely more resilient buildings, work to provide advice on achieving thermal comfort must be expanded to also encompass the wellbeing and health aspects of the occupants. In addition, with one-third of the households in Australia with occupants aged 65 years or above being identified as fuel-poor, costs implications, in the broadest sense, must always be at the forefront of measures to improve housing conditions (Azpitarte F, et al., 2015). This points to the prospect that older people in the lowest socio-economic ranks are the most likely to benefit from improved housing in a future that will probably be different in many ways.

Good advice is required to promote healthy conditions for older people who wish to continue living in their own homes; advice that hopefully will also help reduce overall costs. The study has shown that to be effective and promote prudent resilience, thermal comfort guidelines must reflect the diversity of the occupants, their housing and the complex and context-dependent nature of thermal comfort itself. Each person has a combination of factors that contribute to their thermal personality including their age, medical conditions, living arrangement, financial situation, thermal preferences and ideas and beliefs. This, along with the location and type of house they live in and what sort of heating and cooling appliances they have, will affect how they keep warm in cold weather and cool in hot weather.

Architects and building designers who design accommodation for older people, aged care providers and carers can likewise benefit from guidelines that provide a range of strategies for improving comfort and reducing energy costs in existing and new dwellings.

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