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Cold Comfort: Thermal sensation in people over 65 and the consequences for an ageing population

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Abstract
In Australia the preference of most of the ageing population is to age in place. It is therefore necessary that the thermal environment in homes provides comfort for its occupants to promote healthy ageing. Houses that are too hot or too cold are not only unpleasant to live in but may pose a health risk, especially amongst a vulnerable population.

The study reported in this paper is part of larger research into the thermal practices of people over 65 in Adelaide, South Australia. The aim of this study was to examine the thermal comfort of people over the age of 65 during the coldest winter month as well as during a record breaking hot summer month in 2015. A longitudinal comfort study of both living areas and bedrooms was conducted in 10 South Australian households during these periods. The comfort vote survey included the ASHRAE 7-point sensation scale and the McIntyre 3-point preference scale.

Preliminary data indicate these occupants find thermal conditions comfortable at cooler temperatures than predicted by the ASHRAE thermal comfort standard, with significant numbers of neutral votes occurring at lower temperatures than expected. During the warmer conditions however, the majority of neutral votes were in the region predicted by the model.

This research presents a unique perspective of household thermal comfort in older people during two extremes in temperature conditions in Adelaide. This may have implications for healthy housing design for an ageing population.

Keywords: ageing, health, thermal comfort, heat wave, Australia

1 Introduction

Like much of the world, Australia has a rapidly ageing population. By the year 2061, over 20% of the nation's population will be aged 65 or over (Australian Bureau of Statistics 2013). Currently the preference for older Australians is to 'age in place', to remain living independently in either their existing family home or in a smaller private residence. Aged care and other government agencies are then able to provide various levels of care through Home Care Packages (Department of Social Services, 2015).

Ideally the home is a place that is comfortable and healthy. Many housing factors can contribute to the heath of the occupants; temperature, drafts, air quality, damp and associated mould have all been shown to negatively affect occupant health (Howden-Chapman 2004; Martin et al. 1987; Williamson et al. 1997). Conversely, programs which improve insulation and heating in cold climates have shown positive influences on health (Critchley et al. 2007; Howden-Chapman et al. 2008). In this study, the focus is on the thermal environment, and the thermal comfort of older people. Research indicates a higher degree of health problems and deaths during extremes in both heat and cold, especially amongst older people (Nitschke et al. 2007; Wilkinson et al. 2004). These health problems include respiratory and cardiovascular illnesses in the colder temperatures (Analitis et al. 2008) and kidney diseases in extreme heat (Bi et al. 2011).

When examining thermal comfort, it is important to examine not only the environmental conditions themselves, but more importantly the occupant's sensations in those conditions. This is especially true of the older population. Research has shown that as the human body ages, the body's thermoregulatory response is altered and it loses some of its ability to sense heat and cold. Measurements of patterns of sweating, shivering and vasoconstriction in older people have shown quantifiable differences than in younger people (Anderson et al. 1996; Drinkwater et al. 1978; Wagner et al. 1972), with these reactions being slower and/or decreased. A slower response to changes in the external conditions has the potential to cause accidental hypo- or hyperthermia. By studying the self-reported thermal comfort of older people, this study aimed to determine whether older people experience a sensation of comfort in their homes despite the fact the conditions may be considered uncomfortable or indeed unsafe and unhealthy.

2 Context

Adelaide is located at 34.9° South Latitude and 138.6 ° East Longitude, and has a hot Mediterranean climate (Sturman et al. 1996) with hot dry summers and mild winters. Summer extends from December through to February and winter from June to August. The average maximum temperatures in Adelaide during December and February are 27.2° C and 29.5 ° C respectively; however, the city experiences frequent heat waves, during which temperatures often exceed 40° C. These heat waves can occur anywhere from November to March. In July, the average daily minimum and maximum are 7.5° C and 15.3° C respectively (BOM 2016a)

In 2015, conditions in both July and December were markedly different from typical years. July is typically the coldest month of the year; however, whilst the average minimum in July was 6.7 ° C, the temperatures dropped as low as 1.8 ° C, and both maximum and minimum temperatures across the city were close to 1 degree colder than average across the city (BOM 2015). Typically February is the hottest month in Adelaide; however, December 2015 recorded averages equal to that of February and was the hottest December on record for the Adelaide region. Maximum temperatures were 5.4 degrees higher than average, and minimum temperatures more than 2.5 degrees above average (BOM 2016b). Heat wave conditions occurred in the third week of December, with six consecutive days over 36 degrees, four of which exceeded 40 degrees. In the month of December there were 7 days with temperatures over 40 degrees, the highest number of days above 40 degrees in a single month on record. For this reason, this study focuses on the experiences of older people during these two months, to compare and contrast their thermal comfort experiences during these extremes in conditions.

Due to the aforesaid hot Mediterranean climate, much of the focus of public health messages is on extreme heat conditions. Indeed, as there are frequent heat waves this seems to be the prudent approach. However, recently attention has turned to the dangers of cold, even in mild winters (Cheng 2015; Gasparrini et al. 2015). Unfortunately houses in Adelaide are typically not designed for colder conditions, with few houses having central heating and many having fixed heating only in the living area, and relying on portable heating appliances for other rooms. Similarly few houses, especially older ones, have whole house cooling, but may have individual reverse cycle appliances (or similar) in living rooms and bedrooms.

3 Methods

3.1 Participants

Participants were recruited from an earlier survey of housing and health in which they could volunteer for the longitudinal study (Bills and Soebarto 2015). For the earlier survey, the participants were recruited through invitations distributed by local councils and church groups. Some participants were also recruited through the University of the Third Age, "a worldwide organisation for 'over 50s' who wish to expand their interest in the world, increase their knowledge by learning and to pass on the experiences of life to others" (University of the Third Age, n.d). In total, 18 households participated in this longitudinal study; however, this paper only focuses on results of the study from 10 households (4 men and 7 women), as the collection of data from the other participants is still ongoing. These 11 participants completed comfort vote surveys during the study period. One participant did not complete the study due to ill health.

3.2 Protocol

Unobtrusive data loggers were installed in the bedrooms and living rooms of the participants' houses. These recorded air temperature, humidity and globe temperature every 15 minutes. Participants were asked to regularly complete short comfort vote surveys which included the ASHRAE 7-point thermal sensation scale (ASHRAE 2013) and the McIntyre 3-point preference scale (McIntyre 1973). They were asked to rank their clothing pictorially out of 6 and their activity level pictorially out of 4 (see Figure 1). They were also asked to indicate whether other environmental factors such as ventilation and the operation of any heating, cooling or fans were employed. Times and dates in July and December when surveys were completed were recorded and responses matched with data from the loggers.

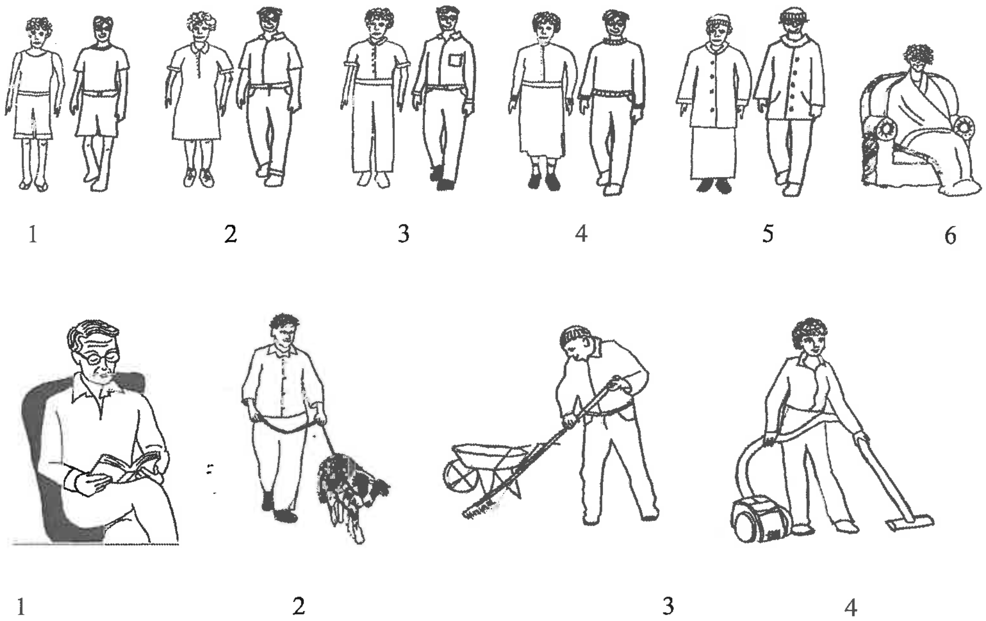


Figure 1 – Pictures used to represent clothing and activity levels in the comfort vote survey

The air temperature and humidity data at the times of the neutral sensation votes (3, 4 or 5 on the ASHRAE 7-point sensation scale) were analysed using the Graphic Comfort Zone Method of ASHRAE 55 (ASHRAE 2013). This model was chosen over the Adaptive thermal comfort model due to the high percentage of votes filled out when heating or cooling was in use. The votes were filtered to remove responses made when very high levels of clothing were being worn, or when very high levels of activity had been completed in the last 15 minutes before completing the survey.

4 Results

4.1 Outdoor and Indoor Conditions

Average outdoor maximum and minimum temperatures were sourced from the Australian Bureau of Meteorology and were taken from the weather stations closest to the participating houses. Table 1 shows the comparison between the average outdoor conditions during the study and the average conditions inside the 10 houses studied.

In July, the average, minimum temperatures in the living rooms and bedrooms were close to the outdoor maximum. Maximum temperatures in the living rooms were slightly warmer than in the bedrooms. Many respondents reported not using or not having heating in the bedrooms, which would account for this slightly cooler temperature. All had some form of heating in the main living areas, and movement of this warmer air upward and outward could potentially pull warm air from other areas, like the bedrooms, into these living spaces. However, solar gains from windows and thermal mass from the brick walls, would act to keep the bedrooms warmer than the outside conditions during the day in July.

Table 1: Average outdoor and indoor maximum and minimum temperatures

	Average Outdoor Maximum (°C)	Average Outdoor Minimum (°C)	Average Living Room Maximum (°C)	Average Living Room Minimum (°C)	Average Bedroom Maximum (°C)	Average Bedroom Minimum (°C)
July	14.1	6.7	20.8	14.8	18.0	14.8
December	32.5	18.1	26.7	22.9	26.7	23.0

In December, the average indoor maximum in the living rooms and bedrooms was approximately 6 degrees cooler than the average outdoor maximum. In general the living rooms and bedrooms were very similar in temperature, despite fewer participants reporting using air conditioning in their bedrooms than in their living rooms. The movement of cooler air from the living areas into the bedrooms as well as the effect of shading and insulation may explain these temperatures.

4.2 Thermal sensation votes and preference

In total, 183 thermal comfort votes were completed by participants in July, and 147 in December. Overall, more neutral thermal sensation votes (TSVs) of slightly cool, just right, slightly warm were recorded during December (78.4% neutral votes) than July (47.7% neutral votes). There were subsequently more votes at the extreme ends (cold and hot) during July than December (29.3% vs 6.3%) (Figure 2). This is despite the fact that during the cold July period, participants recorded having heating on 54% of the time in the living area and 41% of the time in the bedrooms. In contrast, participants only recorded using cooling 40% of the time in the living room and 31% of the time in the bedroom in December.

Despite the higher number of 'cold' votes during the winter, participants were less likely to express a desire to be warmer when it was 'cold' (66.7% of the time) than they were to express a desire to be cooler when voting at the 'hot' end of the scale (100% of the time) (see Figure 3). When they reported being 'cool' or 'warm', they were still slightly less likely to report desiring change in July (46% of the time) than in December (58.8 % of the time).

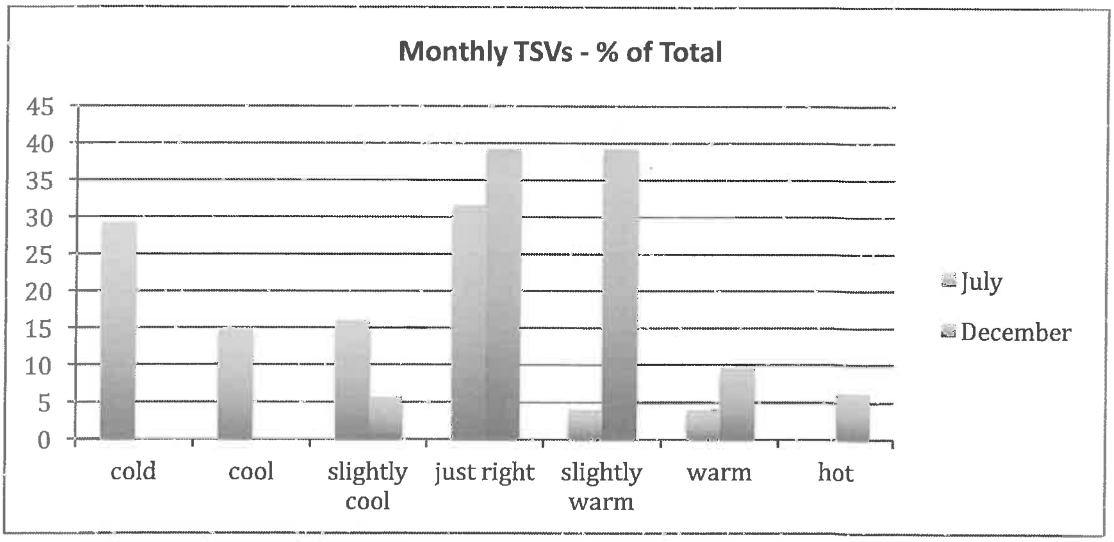


Figure 2: Percentage of total of each TSV separated by month.
Votes in July are in blue. Votes for December are in Red

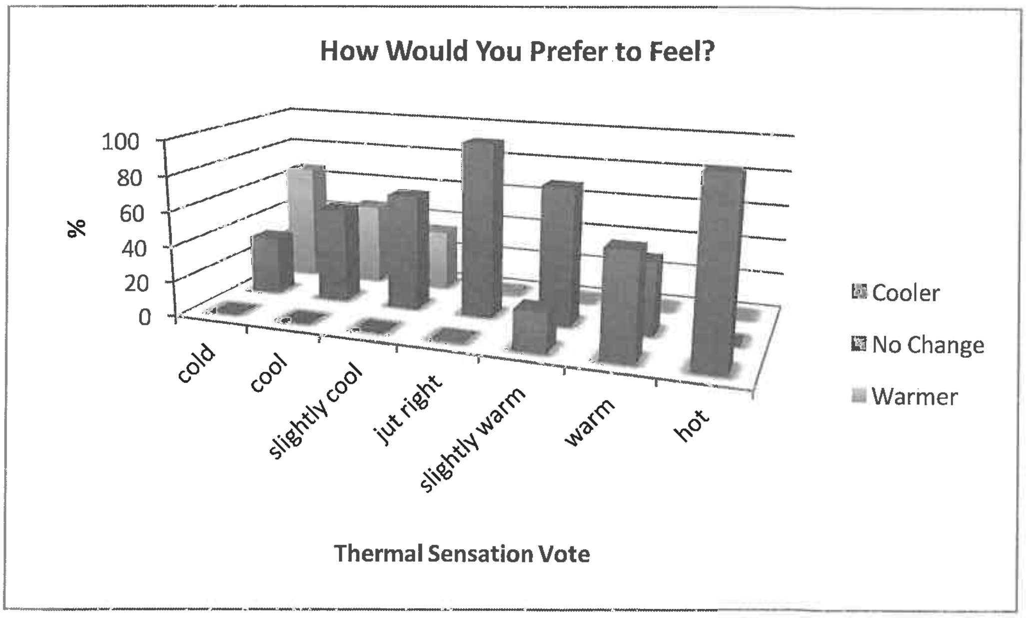
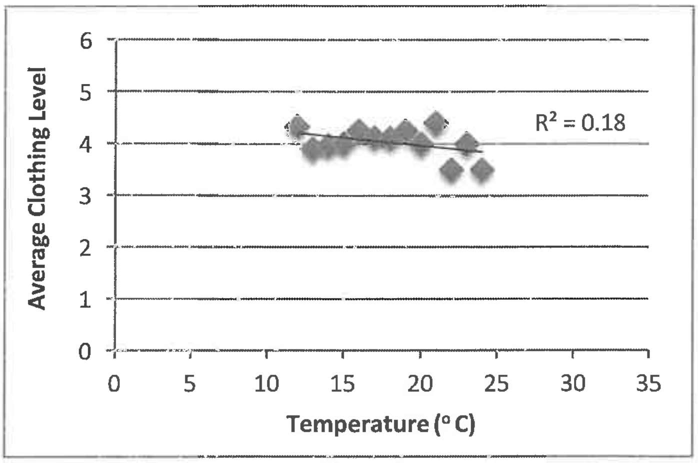


Figure 3: Participants preferences for change by thermal sensation vote

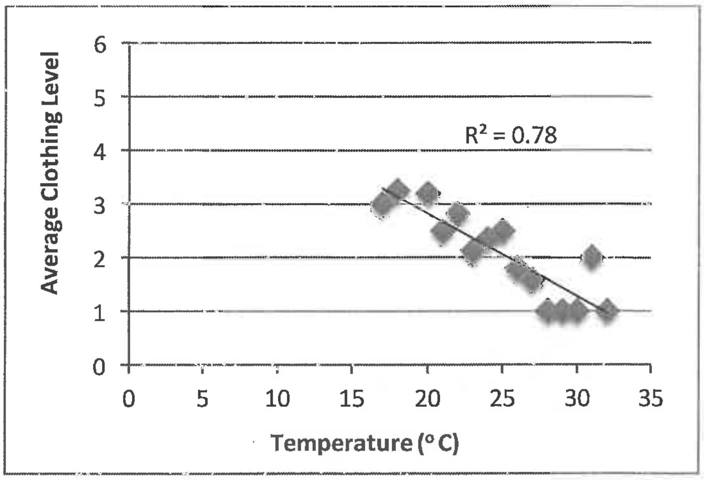
4.3 Clothing

The average clothing level was obtained by binning the clothing scores per degree of indoor operative temperature and calculating the mean.

During July, the results showed that there was no correlation between the clothing worn and the indoor air temperature (Figure 4a). The clothing worn remained very similar regardless of the temperature, around a level 4 (refer to Figure 1). In December there was a clear negative correlation between air temperature and clothing worn. Participants reported much lower levels of clothing as temperatures increased (Figure 4b).



(a)



(b)

Figure 4: Binned average clothing levels for each degree of temperature in (a) July and (b) December.

4.4 Comparison with ASHRAE 55 acceptable range of temperature and humidity

When comparing the air temperature and humidity at the times neutral votes were recorded (figure 5) with ASHRAE 55 acceptable range of temperature, there is a difference to experiences of comfort in July when compared to December. In July, participants were more likely to express feelings of comfort at colder temperatures than suggested, whilst in December participants expressed comfort in conditions more aligned with the operative temperature zone outlined in solid lines (see Figure 5). This was observed not only when the neutral votes were considered, but also when participants indicated no preference for a change in thermal conditions, and when participants indicated that conditions were thermally acceptable, as shown earlier in Figure 3. In contrast, most of the neutral votes collected during the December period fell within the comfort zone, with far fewer falling outside.

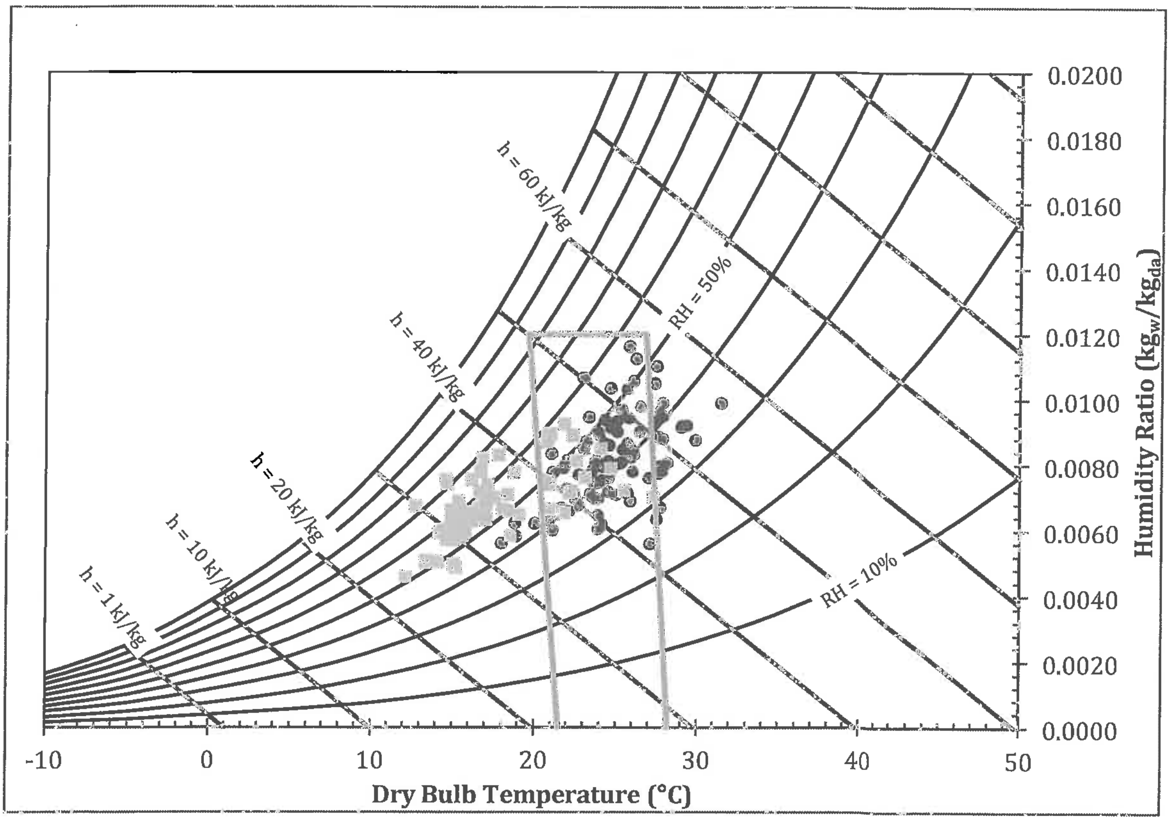


Figure 5 – ASHRAE-55 Acceptable Comfort (1 clo Zone) - Temperature and humidity ratio at times when neutral Thermal Sensation Votes (3,4, or 5 on the ASHRAE thermal sensation scale) were recorded by participants. Votes recorded in July are labeled blue whilst those recorded during December are labeled red
Note: The Comfort Zone assumes clothing 0.5 ≤ clo ≤ 1.0 and metabolic rate 1.0 ≤ met ≤ 1.3
Source: Adapted from ASHRAE 55-2013, Figure 5.3.1

5 Discussion

Overall, the older people in this study expressed sensations of thermal comfort at colder temperatures than predicted by the ASHRAE standards most of the time, but rarely reported feelings of comfort at warmer temperatures than predicted. Their neutral thermal sensations during the hot month of December were largely within ASHRAE's acceptable operative temperature and humidity, despite very hot weather throughout the month. In the cold months however they expressed feelings of neutral thermal sensations at temperatures as low as 12 degrees inside, even when only wearing moderate levels of clothing and at times when they were largely at rest.

There are a number of reasons that older people might describe feelings of thermal comfort in conditions that are otherwise considered uncomfortably cold. First, the results indicated that the participants wore heavier clothing in July, with majority wearing long pants, long sleeve jumpers or sweaters, socks and shoes. The results also showed that there was very little correlation in July between the level of clothing and thermal sensation in winter (R^2 = 0.18) compared to those in December (R^2 = 0.78, Figure 4b), indicating that they wore similar clothing throughout July regardless of the indoor temperatures. Wearing heavier clothing seems to be the personal strategy that older people in the study employed to keep themselves comfortable, rather than, for example, turning on the heater. However, it is also worth noting that upon closer examination, the clothing level at lower temperatures (i.e. 13 to 14 degrees) was slightly less than at temperatures above 14 degrees (Figure 4a) even at times when they were largely at rest. Physiological changes associated with age, behavioural factors and adaptations to conditions over the life course are all possibilities as suggested by Hitchings et al. (2011) and Horvath et al. (1955) respectively, but the exact reason for this unexpected clothing value at lower temperatures is still unknown. Also, despite the exclusion of votes where high levels of clothing were reported, and despite of every effort taken to tailor the survey to the clothing typically worn by older people, the actual clothing worn by the respondents in cooler conditions may still be heavier than assumed by the ASHRAE standard for winter (i.e. 1.0 clo). Nevertheless, further research is needed to investigate these peculiar results.

Ageing brings with it inevitable physical changes. The metabolism slows, and general frailty increases which can lead to a decrease in physical activity, all of which changes the body's response to thermal conditions. Ageing has also been shown to reduce the body's ability to feel changes in temperature. When examining the data from the cold month of July, any of these could be contributing factors. For instance, a person's activity level can influence their perception of thermal comfort. In general, participants were more active during July than in December, with 50% reporting being at rest at the time of the survey, whereas in December participants reported being at rest 66% of the time. There was a range of frailty in the participants, with some being very sedentary and some being quite active. However, when the data were analysed by participant, respondents were equally represented across the whole range of votes. In contrast, during the warmer weather, participants' votes were largely in the expected range, suggesting that at least in warm conditions they are sensing temperature as expected. Further biomedical testing of metabolic rate and other physiological changes may help in understanding the changing thermal perceptions of older people, and why these changes seem to be limited to colder conditions.

Regardless of the reason for the acceptance and tolerance of colder temperatures, there are concerns about various health conditions that may occur when older people are chronically exposed to cold temperatures. During the study period between the months of May and October, 2 of the female participants reported having fallen, and 2 male participants also reported that their wives (who were not completing comfort vote surveys) had fallen. Falls are of a particular health concern amongst the older population, and their occurrence has been linked to colder temperatures in women(Lindemann et al. 2014) Fractured bones, especially hips are a common result of a fall. Aside from injuries sustained in a fall, other problems can arise. Around half of those who fall are unable to get up unassisted (Tinetti et al. 1993). If left on the floor for a prolonged period, there are risks of hypothermia, pneumonia, pressure sores, dehydration and in some cases death (Tinetti et al. 1993). For those who fall and fracture a hip, there is significantly increased mortality; reports of between 12 and 37% mortality within 12 months exist in the literature (Foster 2015). Half will not be able to continue to live independently following the fracture (Wolinsky et al. 1997). Whilst there are other contributing factors, provision of a healthy thermal environment may thus be important in preventing falls amongst the aged and the subsequent morbidity and mortality.

Along with the changes in sensation amongst older people, there are certain behaviours and attitudes which may also be at play. Older people may have a tendency to be reluctant to identify as an 'old person' and therefore distance themselves from the problems and vulnerabilities of ageing (Day et al. 2011; Hitchings et al. 2011). Some may not regard themselves as being vulnerable due to age and may therefore ignore public health warnings from government and other agencies regarding health and wellbeing during extremes in weather which may be aimed specifically at older people (Day et al. 2011). Having always coped in the past they see no reason to change their behaviours now. This makes a certain amount of sense when potential loss of sensation to cold is taken into consideration. However dissociation from vulnerability could in fact make an older person less likely to take steps to adapt to a cold environment, and therefore increase the risk of health complications from the cold.

Assuming the operative temperature zone assumed by the ASHRAE Standard is appropriate to the Australian context, it would appear that the participants in this study are largely able to keep their houses at an appropriate temperature during hot conditions. In colder temperatures, it seems they keep their houses cooler than would be expected and recommended. Despite this, these participants expressed satisfaction with these cooler conditions. It is possible that this is a cultural acceptance of the cold, due to the fact that the winters in Australia are generally considered to be mild. It is also possible that extensive public health campaigns in recent years have made participants more aware of the dangers of the heat, and therefore more likely to keep their houses cooler during the extreme heat. These public health campaigns are founded in research that has examined mortality during the summer months ((Hansen et al. 2011; Hansen et al. 2008; Nitschke et al. 2011), but as yet few studies of morbidity and mortality during winter have been conducted in Adelaide. Studies during colder weather are complicated by the chronic nature of conditions associated with the cold, such as respiratory infections, as opposed to the more acute nature of health conditions which arise during extreme heat, such as heat stroke and dehydration.

One of the difficulties when conducting residential thermal comfort studies in Australia is the lack of understanding of how the public at large experience thermal comfort to compare possibly outlier groups against. It is reasonable to assume that the climate and culture of Australia means the operative temperature zone used by the ASHRAE standard is not the zone in which Australian people will feel most comfortable, despite the predictions of the thermal comfort model. Such a study has yet to be undertaken in Australia, so any conclusions that may be drawn from residential studies of particular groups are cautious at best. In terms of creating policies and building standards that may improve conditions for older people, the preferences of the general population must also be understood in order to fully understand any changes that are occurring.

6 Conclusion

Some older South Australians appear to experience sensations of acceptable thermal sensations in a wider range of conditions that would otherwise be predicted by the ASHRAE Standard. This study of thermal comfort during the winter months shows experiences of neutral thermal sensation at colder temperatures than expected. It is still unclear what is causing this, and a number of factors including physical and physiological changes, behavioural changes and adaptations over time may be at play. Further research into the reasons for these observed results is required to make definitive statements about the cause. It is important to understand the mechanisms and any health consequences so that interventions can be recommended to ensure older people can remain healthy and comfortable in their own homes.

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