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Thermal experiences of older people during hot conditions in Adelaide

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Abstract: This study examined the thermal experiences of older people during extreme heat and summer more broadly. A longitudinal field study of thermal comfort and thermal acceptability of conditions during summer 2015-16 was conducted as part of a larger project into the overall thermal comfort of older people in Adelaide, South Australia. The experiences and preferences of the participants were arranged into 3 categories: acceptable thermal sensation votes, warm and hot thermal sensation votes and votes recorded on extreme heat days when the maximum outdoor temperature was 35^{o} Celsius or above during the study period. In each category, participants reported sensations of 'warm' and 'hot' within the acceptable range of operative temperature and humidity suggested by ASHRAE Standard 55. Participants also expressed a desire to feel cooler within this acceptable range, and described conditions within this range as 'thermally unacceptable'. These results show that older people may be experiencing thermal conditions differently to younger people. Specifically, it appears that these participants have a desire for cooler temperatures than predicted by ASHRAE Standard 55. The study poses a series of challenges for future research to ensure comfortable and healthy homes for ageing Australians.

Keywords: thermal comfort, ageing, heat waves, Australia.

1. Introduction

Adelaide, South Australia has a temperate climate with a Köppen classification of Csa (McBoyle, 1971). It has warm summers, but frequently experiences periods of extreme heat. The frequency, length and intensity of these heat waves is likely to increase in the future (Meehl and Tebaldi, 2004). In Adelaide these extreme heat events are associated with increases in mortality, hospital admissions and ambulance call outs in the general population and these pose specific concern for more vulnerable groups, including older people (Bi *et al.*, 2011). As older people have a tendency to spend more time inside, it is important that internal conditions remain comfortable and safe during periods of extreme heat.

Whilst the earliest thermal comfort work suggested there was no difference in the conditions preferred by older people and younger adults (Rohles and Johnson, 1972; Fanger and Langkilde, 1975), more recent research has indicated that this may not be the case (Collins and Hoinville, 1980; Schellen *et al.*, 2010). Changes to physiology and perception amongst older people means they experience thermal conditions differently to younger people. As such, it is important to ensure they experience their surroundings in such a way that is not detrimental to their health.

This research examines the thermal comfort of a cohort of people aged 65 and over in Adelaide during summer 2015-16, including data from a number of extreme heat days which occurred between October and January. It investigates comfort, acceptability of the thermal environment and the thermal preferences of the occupants during warm weather. All of these variables are considered rather than the more traditional approach of simply making the assumption that the central category votes on a 7-point thermal sensation scale means conditions are acceptable and that no change for warmer or cooler conditions is preferred. The study was done to obtain a very specific picture of the actual experiences of the participants.

2. Methods

2.1 Participants

Participants were recruited from an earlier survey of housing and health in which they could volunteer for the more in-depth longitudinal study (Bills & Soebarto 2015). Participants were recruited through invitations distributed by local councils and church groups. Some participants were also recruited through the University of the Third Age. This paper focuses on the results from 15 households with a total of 17 participants (8 Female, 9 male). Data were from October 2015 to January 2016. Despite only December and January typically considered to be “summer”, Adelaide experienced several extreme heat days in October and November 2015 and for this reason data from these months was also included in the study.

2.2 Protocol

Unobtrusive data loggers were installed in the bedrooms and living rooms of all participants. These recorded air temperature, humidity and globe temperature (as proxy of mean radiant temperature) every 15 minutes. Participants were asked to regularly complete short comfort vote surveys which included a vote on the ASHRAE 7-point thermal sensation scale (TSV) (ASHRAE, 2013) and the McIntyre 3-point thermal preference scale (TPS) (McIntyre, 1980). The comfort vote survey also asked participants to indicate their current level of clothing and their level of activity for the previous 30 minutes. Participants were also asked about ventilation via doors and windows, and whether ceiling fans or heating or cooling were in use.

2.3 Analytical techniques

The air temperature and humidity data at the times of the votes were analysed using the Graphic Comfort Zone Method of ASHRAE 55 (ASHRAE 2013) as the houses were air-conditioned at times. The comfort zone shown on the following charts includes clothing levels in the range 0.5-1.0 clo and a metabolic rate in the range 1.0 to 1.3 met. The thermal sensation votes (TSVs) were filtered to remove responses given when higher levels of clothing were being worn, or when higher levels of activity had been completed in the last 15 minutes before completing the survey. The comfort zone indicated by this method assumes an air-speed of less than 0.2m/s and a radiant temperature close to the recorded air temperature. In this study, globe temperature was on average within 0.04° of the measured air temperature and therefore no shifting of the comfort zone was required to accommodate for this. Whilst air speed was not measured in the houses in this study, it is the experience of the authors that air movement in houses in Adelaide rarely exceeds 0.2m/s, even with windows open. Whilst some of the buildings were fitted with ceiling fans, which could increase air speeds above 0.2m/s, their use was recorded only about 10% of the time. Typically, thermal comfort studies present the 'acceptable' range of TSVs (-1, 0, or +1 on the 7 point ASHRAE comfort scale); however, in this paper TSVs of 'warm' and 'hot' (+2 and +3 on the ASHRAE comfort scale) have also been analysed in order to demonstrate experiences during extremes in temperature.

3. Results

In all cases, there was a large overlap of instances where the TSVs indicated that conditions were acceptable or unacceptable, and conditions where a preference for change was recorded versus no preference for change. There is no clear threshold where conditions suddenly become acceptable, or where participants felt 'hot' rather than 'slightly warm'. A total of 400 votes were cast during December 2015 and January 2016.

3.1 Thermal comfort in December 2015 and January 2016

3.1.1 Acceptable thermal sensation votes

Upon initial examination of the 305 'acceptable' votes during December and January, it appears that they largely aligned with the range of conditions indicated by the acceptable range of operative temperature and humidity based on the Graphic Comfort Zone Method of ASHRAE 55 (figure 1). Upon closer examination, around 20% (60/305) of the 'acceptable' votes fell outside the comfort zone.

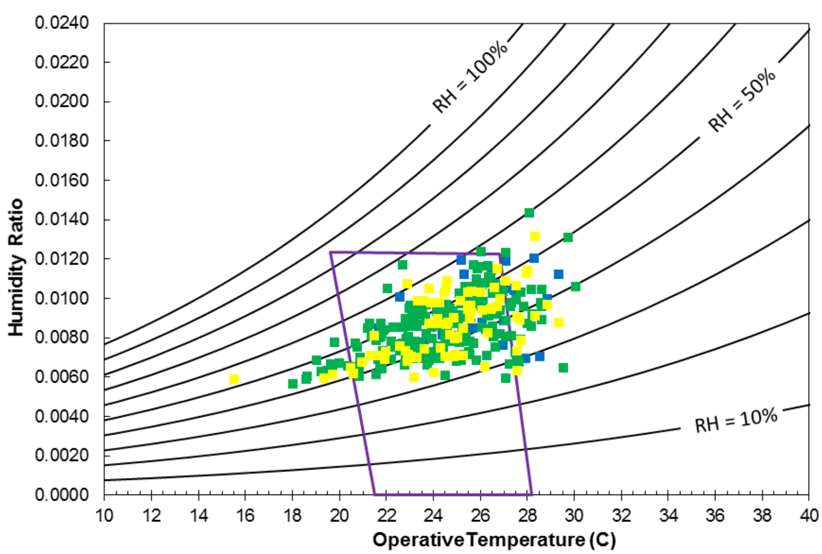

Figure 1: Operative temperature and humidity at times when acceptable Thermal Sensation Votes (-1, 0, or +1 on the ASHRAE thermal sensation scale) were recorded. TSV of -1 = blue, 0 = green and +1 – yellow. *Source: Adapted from ASHRAE 55-2013, Figure 5.3.1*

Out of the 245 'acceptable' votes that fell within the comfort zone, 9.4% (24/245) noted a preference for cooler conditions than they were currently experiencing (Figure 2). Whereas, out of the 305 'acceptable' votes, a preference for cooler conditions was indicated 36 times (11.8%). In other words, of the 36 votes cast indicating a preference for cooler conditions, 66% of the time (24 votes) the conditions fell within the comfort zone. Analysing this data using a two-dimensional Kolmogorov-Smirnov two sample test this finding is significant (d=0. 37, p<0.01).

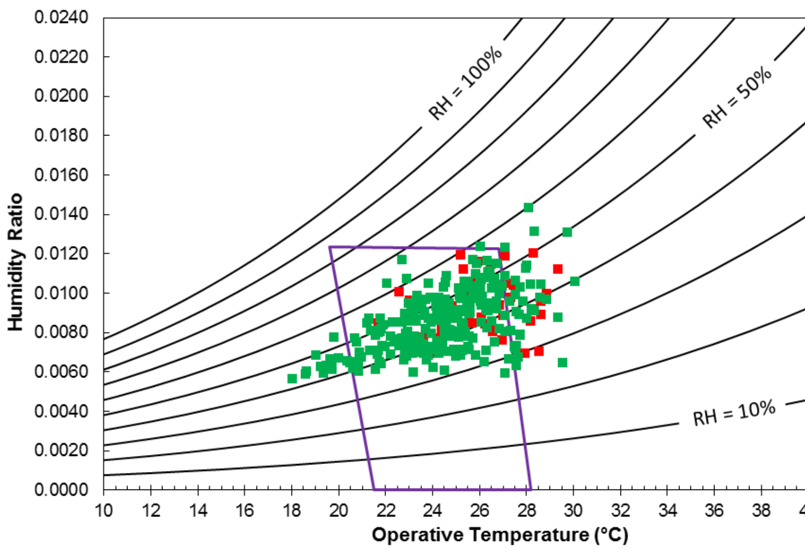

Figure 2: Operative temperature and humidity at times when participants recorded either a) a preference to be cooler (red), or b) no preference for change (green).

3.1.2 Warm and hot sensation votes

Out of the 400 votes, 55 indicated 'warm' and 'hot'. Interestingly, of these 'warm' and 'hot' votes cast during the summer months, 35 (64%) were cast during the conditions that were within the comfort zone specified by ASHRAE 55 (figure 3). Out of these 55 votes, 48 votes (87%) also preferred for cooler conditions regardless of the votes and 63% of these (30/48) occurred when the operative temperatures and humidity were within the comfort zone (figure 4). These indicate that older people may be experiencing discomfort in conditions that would normally be considered comfortable.

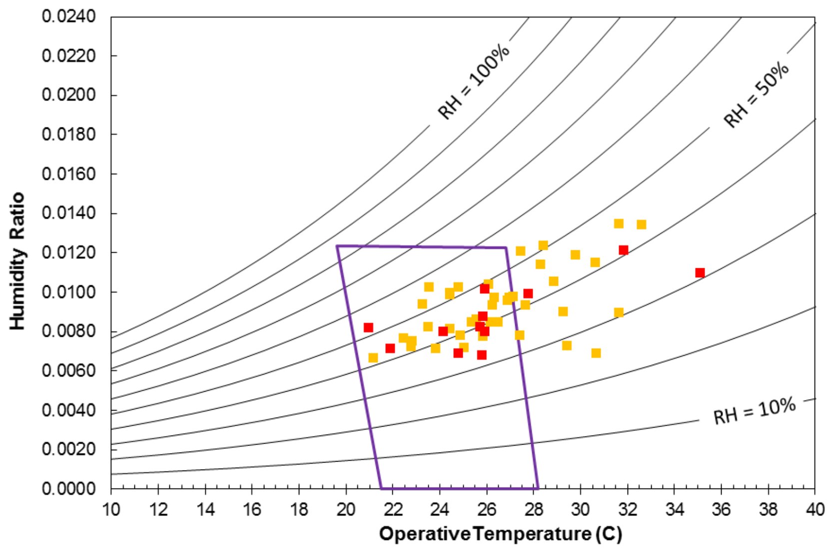

Figure 3: Operative temperature and humidity at times ‘warm’ (orange) or ‘hot’ (red) thermal sensation votes (+2 and +3 on the ASHRAE thermal sensation scale) were recorded during December and January.

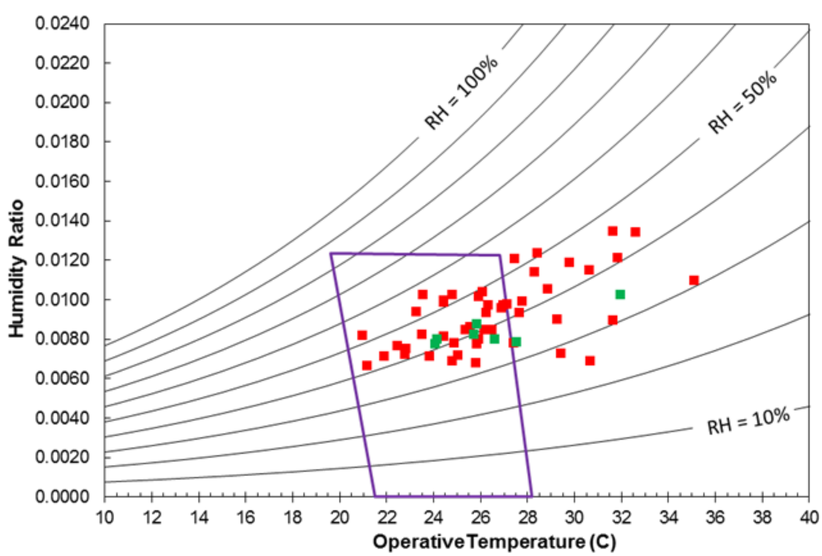

Figure 4: Operative temperature and humidity at times when ‘warm’ or ‘hot’ thermal sensation votes were cast, sorted by whether participants would prefer to be cooler (red) or had no preference for change (green)

3.2 Thermal Comfort on Extreme Heat Days

During extreme heat days (days when the maximum daily temperature was more than 35°C) a total of 209 votes were cast, with 27% (56/209) of the votes cast during conditions that were outside the comfort zone. Out of the 209 votes, 24% (51/209) voted ‘warm’ and ‘hot’ (TSV of +2 and +3), and interestingly, 63% of these (32/51) were cast when the indoor conditions were within the comfort zone (figure 5). Further, 77 of the total votes during extreme heat days (37%) indicated a preference to be cooler (regardless of the votes), and 49 of these instances (64%) were cast during conditions that fell within the comfort zone.

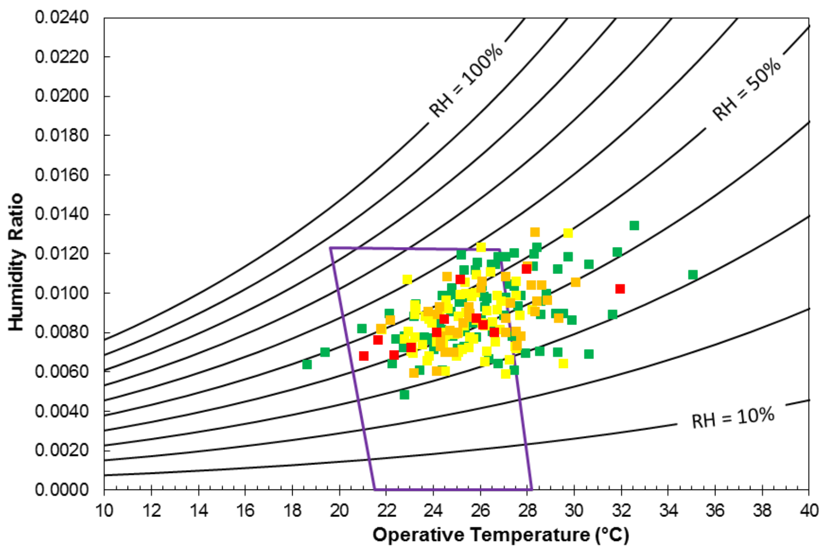

Figure 5: All thermal sensation votes cast on extreme heat days, where green = neutral (TSV=0), yellow = slightly warm (+1), orange = warm (+2) and red = hot (+3)

4. Discussion

These results show that whilst older people experience some thermal sensations similarly to their younger counterparts, there is a worrying trend of experiencing conditions usually considered ‘comfortable’ as unacceptably warm. There is often a preference for a change to cooler conditions than those suggested by ASHRAE as ‘comfortable’; that is, falling within the acceptable range of operative temperatures suggested by psychrometric graphing.

The trend toward older people experiencing conditions that would normally be considered comfortable as unacceptable, and expressing a desire to be cooler when conditions are within the comfort zone is both interesting and confusing. Other researchers in the area of thermal comfort amongst older people have almost universally found the opposite; that older people in general need a warmer environment than younger people to achieve thermal comfort (van Hoof and Hensen, 2006; DeGroot and

Kenney, 2007; Schellen *et al.*, 2010). Previously this has been attributed largely to the slowing of metabolism that comes with age, requiring higher ambient temperatures to maintain heat balance. Further explanations have cited clothing levels and other behavioural mechanisms.

There is a significant body of evidence within the field of physiology that shows changes to a range of thermoregulatory functions, such as reduced sweating (Foster *et al.*, 1976; Dufour and Candas, 2007), and altered reactions of blood vessels in older people (Yochihara *et al.*, 1993; Schellen *et al.*, 2010) which ultimately leads to changes in the ability to control core temperature (DeGroot and Kenney, 2007). Thermal sensitivity has also shown to be decreased in older people (Natsume *et al.*, 1992; Taylor *et al.*, 1995). These physiological responses tend to give evidence to the general preference for warmer rather than cooler conditions; any physiological measurements were outside the scope of the current study.

In examining age-related differences concerning the ability to regulate room temperature, Taylor *et al.* (1995) posit that "it is possible that thermal discomfort reflects an integration of previous thermal experiences, with the elderly possibly having a greater history of exposure to such stresses, and perhaps being more accepting of the resultant sensations". This acknowledgement of the importance of an individual's thermal history is important when examining the results in this study. It is possible that living in Australia, widely regarded as having a hot climate, had led to an almost constant desire or preference for cool conditions. This includes in the winter, as previously indicated by earlier results from this longitudinal study where colder conditions than expected were deemed both acceptable and 'neutral' according to the thermal comfort votes during the winter months (Bills and Soebarto, 2015; Bills, 2016). So, whilst the results of this study are different from those of studies overseas, the experience of conditions as warm within what is usually considered a neutral zone is at least consistent within the Adelaide context. Much of the earliest thermal comfort work was conducted in Europe and America, where not only the climate but also the trends in heating and cooling usage differ greatly from Australia. It is perhaps then not surprising then that expectations of coolness outside of the standards derived from this early research exist in a place so very different in culture and environment.

Ultimately, it is a physiologist's job to determine the physiological responses of older people to warmer conditions, and a psychologist's job to analyse the behavioural and psychological responses. The role of the designer and building scientist is to use all the information available to them, and create living spaces which provide comfortable conditions for their occupants whilst nurturing good health. It is thus important that thermal comfort field work continue in varied contexts around the world to provide a greater understanding of how comfort expectations and preferences may change with cultural and environmental milieu. It may well be that for the Adelaide context, designing houses that stay cooler than standards normally suggest is important as people age in place. This would be best accomplished where possible through passive design principles so as to have minimal impact on household energy consumption.

5. Conclusion

In this study, older people showed a preference for conditions cooler than those predicted by existing thermal comfort standards. Whilst a majority of the acceptable votes cast did fall within the standards, of concern is the trend for sensations of 'warm' and 'hot' to also fall within these standards. When conditions were deemed 'unacceptable' and participants expressed a desire to be cooler, these instances again largely occurred at times where conditions met the current standards. This contradicts the current body of research which suggests older people generally prefer warmer conditions to their younger counterparts. Further research across a broad range of climatic and cultural situations should be considered to examine the effect these may have on perception, acceptability and preferences in regards to thermal comfort.

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