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Living environment, heating-cooling behaviours and well-being: Survey of older South Australians

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ABSTRACT

At a time when the population is ageing and most people choose to live in their own home for as long as possible, it is important to consider various aspects of supportive and comfortable environments for housing. This study, conducted in South Australia, aims to provide information about the links between the type of housing in which older people live, the weather and occupants' heating and cooling behaviours as well as their health and well-being. The study used a Computer-Assisted Telephone Interviewing (CATI) system to survey 250 people aged 65 years and over who lived in their own home. The respondents were recruited from three regions representing the three climate zones in South Australia: semi-arid, warm temperate and temperate. The results show that while the majority of respondents reported being in good health, many lived in dwellings with minimal shading and no wall insulation and 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 low incomes. Findings from this study highlight the importance of providing information to older people, carers, designers and policy makers about the interrelationships between weather, housing design, heating and cooling behaviours, thermal comfort, energy use and health and well-being, in order to support older people to age in place independently and healthily.

1. Introduction

On average, people over 60 years of age spend 75–80% of their time inside their own dwellings [1,2]. In Australia, as in other countries, the population is steadily ageing [3] and people prefer, and are encouraged, to remain living in their homes (i.e., "age-in-place") rather than moving to an aged-care facility [4]. Therefore, it has become more important than ever to ensure that the qualities of the living environment in the homes of older people are conducive to their health, comfort and well-being. One aspect that is often overlooked in design guidelines for ageing-in-place is that of the indoor climate and thermal comfort.

Previous studies have identified an increase in mortality associated with both hot and cold weather [5]. Older people are one of the groups most vulnerable to weather-related illness and vulnerability is increased for those who have pre-existing medical conditions, who live alone, or live in poor housing [6].

As people age, they experience physiological changes such as reduced vascular reactivity, lower metabolic rate, and reduced muscle strength [7–9] all of which can affect their thermal sensitivity and regulation. Mortality connected to strokes, cardiac conditions associated with changes in blood pressure, and illnesses such as arthritis, influenza, pneumonia and asthma are exacerbated by living in cold conditions [9]. Similarly, during heat waves or very hot days, physiological conditions in older people can worsen [10,11] with several studies highlighting the impacts of heat waves on the health and well-being of older people [12–14]. In extreme cases, illnesses triggered or exacerbated by hot or cold conditions may result in hospitalisation or transition to residential aged care, at a cost to the individual, their families and society as a whole.

The use of air-conditioners is commonly suggested by health authorities as a preventative measure for older people to cope with hot

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weather [15]. A study by Hansen et al. [10] on the health-behaviours of older people in South Australia found that more than 80% used air-conditioning to help them cope with the heat during a severe heat wave that occurred in 2009. Similarly, using heating devices during cold weather is a common strategy, with reports suggesting that on average heating accounts for more than 30% of the total residential energy use in Australia [16]. Reliance on air-conditioning or heating, particularly electric heating, however, can be problematic during blackouts, as evidenced in two weather-related power outages in South Australia in 2016 [17]. In addition, the reliance is a concern for people on low and fixed incomes [18].

Appropriate house designs that do not require high energy use to provide thermal comfort are fundamental to ensuring that older people can continue to comfortably live in their own homes. Formulating optimal house designs for older people requires an understanding of the relationship between the occupants, their house, and their heating and cooling behaviours; however current sources of information about these issues are either not up-to-date, not location specific, or do not deal specifically with older people. Focusing on older people, or those aged 65 years and over [3], who live independently in South Australia, the aim of this study was to advance our knowledge of the thermal behaviour of older people and to investigate whether there were associations between climatic conditions, housing types and constructions, heating and cooling behaviours and the health and well-being of the occupants.

2. Method

The study employed a survey questionnaire method based on previous work by Hansen et al. [10,19], which focused on health-related behaviour of older people during heat waves; Bills et al. [20], which focused on the housing condition and thermal behaviour of older people; and Daniel et al. [21], which focused on the thermal behaviour and comfort of occupants in naturally-ventilated homes. The Computer-Assisted Telephone Interviewing (CATI) method was used in the study. Although the use of the Internet and mobile phones by older people is increasing, the most recent Australian data show that half of people aged 80 years and over are not Internet users [22], hence the telephone-based interviewing system was deemed more appropriate to recruit a wide age range of older participants.

At the time of the study, there were approximately 284,000 people in South Australia aged 65 years or over who lived in a house or a unit that they owned or rented, or in an “independent living unit” (ILU) of an aged care facility [23,24]. This group was relatively homogenous, i.e. aged 65 and over, and living at home, thus we assumed that the proportion answering in a certain way would approximate 80% [25]. Therefore, based on 80% proportion, 95% confidence level and a standard error of 5%, the calculated minimum sample size was 246, and we set the number of respondents to 250.

2.1. 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 [26]. In general, South Australia experiences warm to hot summers (December to February) and relatively mild winters (June to August). There are three main climate zones in the State defined by the Australian Building Code Board [27]: (1) semi-arid, (2) warm temperate, and (3) mild temperate, or climate zones 4, 5 and 6. These are similar to the *BSk, CSa, and CSb* zones in the Köppen-Geiger climate classification system [28].

This study focused on regions in each climate zone with relatively high concentrations of older people [26]. Therefore, the semi-arid climate region 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 was represented by the Greater Metropolitan Adelaide region, while the mild temperate climate region was represented by the southern coastal area in the Fleurieu Peninsula and parts of the Adelaide Hills. Note that for brevity in this paper we will refer to the Greater Metropolitan Adelaide as ‘Adelaide’ and the Fleurieu Peninsula and Adelaide Hills as ‘the Fleurieu’. Fig. 1 shows the three regions for the study.

Fig. 1. Climate zones in South Australia and the three study regions.

The number of respondents were n = 90 from Adelaide, n = 120 from the Fleurieu, and n = 40 from the Iron Triangle. The higher proportion of respondents in the Fleurieu was due to the fact that the proportion of older people to the total adult population in that region was higher than that in the other two regions. For Adelaide, as the size of the region is comparatively large (870 km^2), the study population was selected, based on the latest available data [26], from suburbs with a higher density of older people living in private dwellings, indicated with the darkest shade in Fig. 2.

Fig. 3 shows the monthly mean maximum and minimum temperatures as well as relative humidity at 9am and 3 pm at meteorological monitoring stations located in the three climate zones: Whyalla (semi-arid), Adelaide (warm temperate) and Victor Harbor (mild temperate). Of the three climate zones, the monthly maximum temperatures in Whyalla are the highest, though only slightly higher than the temperatures in Adelaide, and Whyalla has the lowest minimum temperatures during the colder months (May to September). Victor Harbor has the lowest monthly maximum temperatures while the minimum temperatures during the colder months are similar to the temperatures in Adelaide. This region also has higher relative humidity compared to the other two regions due to its coastal location while Whyalla has the lowest relative humidity, as it is the driest area of the three regions.

2.2. Survey design

The survey consisted of questions about the participants’ demographics, general health, living arrangements, dwelling type and construction, and the thermal comfort-related features of their home. Other questions related to exposure to information and advice about energy use. A series of questions asked about the impact of hot and cold weather on health and well-being. Questions about quality of life were

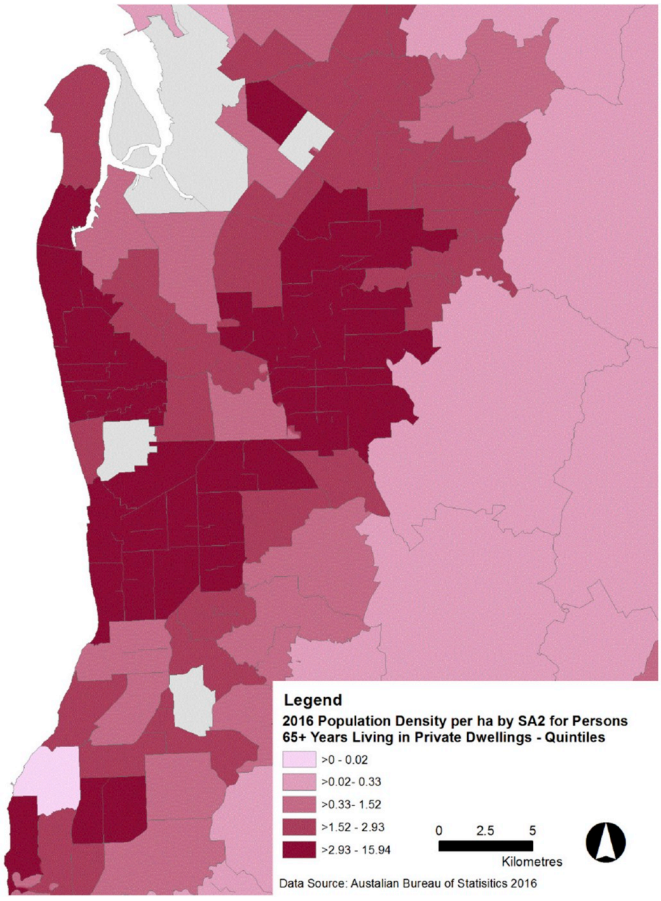

Fig. 2. Population density of persons 65 + years living in private dwellings in Adelaide region. Source: Compiled from Australian Bureau of Statistics 2016 Census of Population and Housing Data, by Danielle Taylor.

adopted from the 5-level EQ-5D descriptive system (EQ-5D-5L) questionnaire [29], which covered five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression.

The survey questionnaire was piloted twice with 20 older South Australians and amended accordingly prior to the survey being undertaken.

2.3. Survey execution

All telephone interviewing was carried out by professional interviewers between 17 and 29 May 2018 and complied with the Market and Social Research Privacy Principles (M&SRPPs) and ISO 20252 accredited processes [30]. Households were selected via random sampling from a commercially available listing of the South Australian Electronic 'White Pages', containing both landline and mobile phone listings. To further randomise the chance of selection from within households, the 'last birthday' random sampling technique was utilised. This is a standard technique in which interviewers ask to speak to the person in the household who was last to have a birthday. Only those aged 65 years or over who lived in their own home and were able to communicate in English were included. Calls continued to be made until the required number of participants in each climate zone, as discussed in section 2.1, was reached.

In total, the interviewers made 4449 calls to 2496 telephone numbers to yield the required 250 responses (response rate 10%). Unsuccessful calls included: numbers disconnected, no answer, busy tones, answering machines, calls to modem/fax machines and non-residential numbers, refusals by the call receivers, receivers too ill to participate, not speaking English or having hearing impairments, and when no-one in the household met the inclusion criteria.

2.4. Data analyses

As an aim of the study was to investigate whether there were associations between climatic conditions, housing types and constructions, heating/cooling behaviours and the health and well-being of the occupants, the data were analysed statistically (using the statistical package SPSS Version 25 [31]). Descriptive analysis was conducted on respondents' demographic profile, dwelling profiles, and general heating/cooling behaviour. Cross tabulations were conducted to compare the dwelling profiles, heating/cooling methods, and adaptations to deal with hot/cold weather. Chi square tests were conducted to measure the association between two categorical variables. Similarly, correlation analyses and regression analyses were conducted where responses were recorded using Likert scales. Only statistically significant variables ($p < 0.05$) were used in later analyses.

Ethics approval for the study was obtained from the Human Research Ethics Committee of The University of Adelaide with approval number H-2018-042.

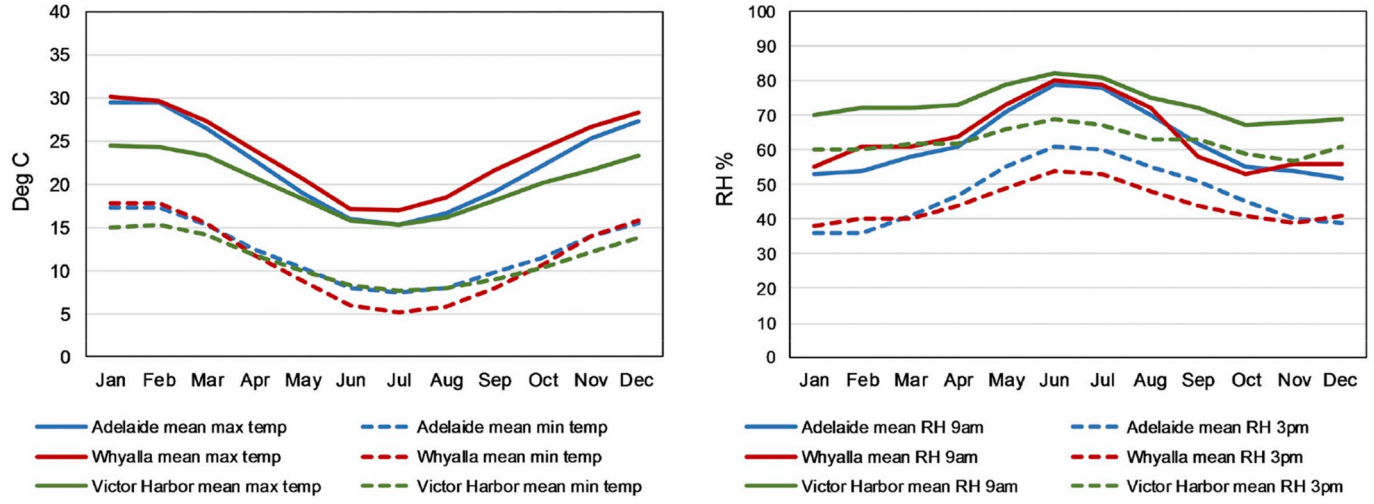

Fig. 3. Monthly mean temperature and relative humidity in Whyalla (semi-arid), Adelaide (warm temperate) and Victor Harbor (mild temperate). Compiled based on data from Australian Government Bureau of Meteorology.

Table 1
Socio-demographics of respondents (n = 250).

	Adelaide (warm temperate) n = 90	Fleurieu (mild temperate) n = 120	Iron Triangle (semi-arid) n = 40
Age group (years)			
65–69	19 (21%)	16 (13%)	7 (17.5%)
70–74	18 (20%)	30 (25%)	12 (30%)
75–79	18 (20%)	29 (24%)	11 (27.5%)
80–84	14 (15.5%)	17 (14%)	6 (15%)
85–89	16 (18%)	18 (15%)	4 (10%)
90–94	5 (5.5%)	9 (8%)	0
95–99	0	1 (1%)	0
Sex			
Female	55 (61%)	72 (60%)	25 (62.5%)
Male	35 (39%)	48 (40%)	15 (37.5%)
Country of birth			
Australia	70 (78%)	90 (75%)	23 (58%)
Outside Australia	20 (22%)	30 (25%)	17 (42%)
Living arrangements			
With a partner	48 (53.3%)	77 (64%)	19 (47.5%)
Alone	39 (43.3%)	41 (34%)	21 (52.5%)
With relatives	3 (3.3%)	2 (2%)	0
Work status			
Part/full pension[a]	48	79	32
Self-funded retiree[a]	40	45	9
Work part/full time[a]	3	5	1
Annual income ($AU)			
Less than $30,000	32 (35.5%)	40 (33%)	17 (42.5%)
$30,000 - $75,000	29 (32%)	49 (41%)	23 (57.5%)
More than $75,000	14 (15.5%)	7 (6%)	0
Don't know	6 (7%)	18 (15%)	0
Declined to answer	9 (10%)	6 (5%)	0
Education			
Primary school	3 (3%)	4 (3%)	4 (10%)
Secondary/high school	34 (38%)	66 (55%)	25 (62.5%)
Community/ technical college	18 (20%)	26 (22%)	4 (10%)
University	35 (39%)	24 (20%)	(1) 7 (17.5%)

[a] More than one category may apply.

3. Results

The results presented below outline the study respondents: demographics, housing, attitudes to, and use of, heaters and coolers, and self-reported health and well-being; as well as the interrelationships between these factors and the location.

3.1. Respondent characteristics

Table 1 summarizes the demographic characteristics of the respondents. Overall there were more female participants (61%) than males and the majority of respondents (73%) were born in Australia. The age of respondents ranged from 65 to 95 years old with a median age of 76 years and mean of 77.2 years.

3.1.1. Living arrangement

In total, 58% of the respondents lived with their spouse or partner, 40% lived alone while 2% lived with relatives. Although the proportions of the living arrangement in each region varied, the differences were not statistically significant ($p > 0.05$). There was, however, an association between the age of respondents and living arrangement ($p = 0.01$) as 70% of those aged 80 years and under lived with a spouse whereas 62% of those aged 81 years and over lived alone. There was also a strong association between the sex of respondents and their living arrangement ($p < 0.005$). Of the female respondents, the percentage of those who lived alone was the same as those who lived with a partner/spouse (49%). By contrast, 27% of the male respondents lived alone and 70% lived with a partner/spouse (the remaining lived with relatives).

3.1.2. Education level

There was a strong association between the region and highest education level ($p = 0.005$). The highest proportion of respondents from the Adelaide region were those with university degrees (nearly 40%), whereas for the majority of respondents from the Fleurieu and Iron Triangle the highest educational attainment was secondary or high school education and 20% or less were university graduates.

3.1.3. Financial situation

The majority of respondents (64%) received a part or full government pension while 38% were self-funded retirees. Note that those who received a partial government pension can also be self-funded retirees. There was a strong association between the region and income level ($p < 0.005$). The respondents in the Adelaide region had a wide spread of income levels while the respondents from the Fleurieu were mostly from the middle income bracket ($30,000 - $75,000 pa) followed by the lower income bracket (< $30,000 pa). None of the respondents from the Iron Triangle were in the higher income bracket (> $75,000).

3.1.4. Weather preference

When asked about their preference for cold or hot weather, more respondents in Adelaide and the Fleurieu, both males and females, and of all ages, preferred hot over cold weather (39% versus 28% of the total respondents in each region). In the Iron Triangle there was no clear preference for either cold or hot weather. However, no strong association was found between the preference over weather and the age of the respondents or with the region ($p > 0.05$).

3.1.5. Health and well-being

The respondents were asked to rate how good their health was at the time of the survey on a scale of 0–100, where 0 indicates the worst and 100 indicates the best perceived health. The majority of respondents considered themselves to be quite healthy and almost 75% of the 249 responses (one did not give an answer) gave a rating of 70 or higher. The highest percentage of respondents giving a rating of less than 70 were from the Fleurieu (35%) followed by Iron Triangle (31%) and Adelaide (20%) (Fig. 4). However, the difference was not statistically significant ($p > 0.05$).

When asked whether they had health problems that required them to stay at home the vast majority of respondents stated that they did not (94%) and a similar percentage (95%) stated that they could count on someone if they needed help. The majority of respondents (74%) did not require any mobility aids and only 16% used walking sticks, 10% used wheeled walkers (referred to in Australia as walking frames) and 1% used wheelchairs.

The final health and well-being related questions were based on the EQ-5D-5L questionnaire. The results showed that, in general, the majority of respondents perceived themselves to be healthy (Fig. 5). There

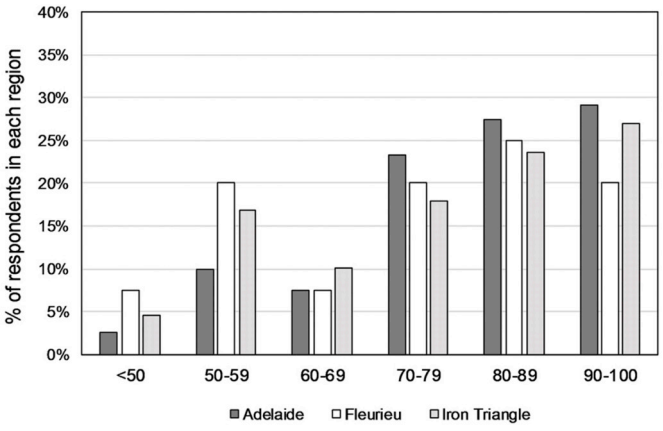

Fig. 4. Self-reported health rated as 0–100 in the three regions.

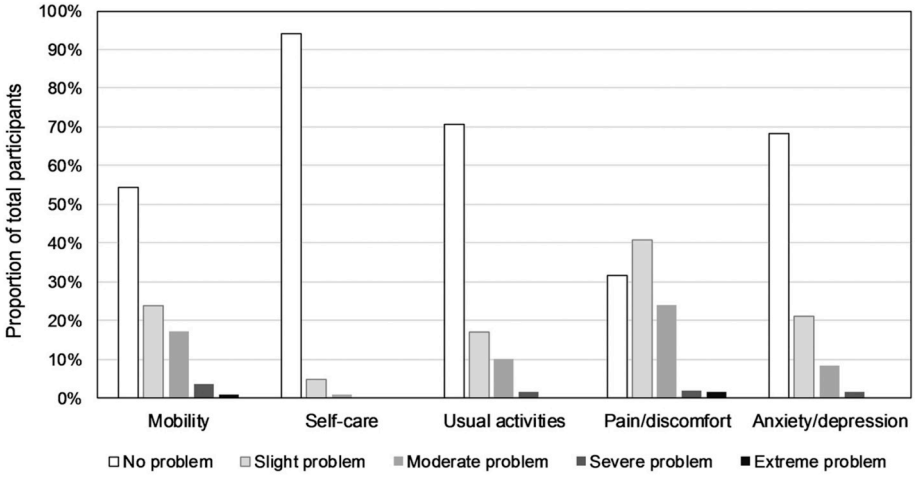

Fig. 5. Responses to the EQ-5D-5L (quality of life) questionnaire.

were some differences in the responses between regions however these differences were not statistically significant ($p > 0.05$). Overall, 77% indicated having slight to no mobility problems and these more or less correspond to the previous result that 74% did not require any mobility aids. Thus, even though 23% indicated that they had slight mobility problems, they did not require walking aids. More than 90% had no problems with self-care, and about 70% stated they could do usual activities without any problems and did not experience any anxiety or depression problems. However, more than half of the respondents indicated they had slight to extreme problems relating to pain or discomfort.

Not surprisingly a strong association was identified between the age of the respondents and use of mobility aids, particularly walking sticks and wheeled walkers ($p < 0.005$). The self-rating health scale discussed above was found to have strong associations with mobility ($p < 0.005$), ability to do usual activities ($p < 0.005$), experiencing depression or anxiety ($p < 0.005$) and pain or discomfort ($p < 0.005$), with those indicating a self-rating health scale of below 60 indicating having issues with the above factors. Experiencing anxiety or depression was found to be associated with income level with the majority of people reporting slight to severe anxiety or depression being from the lowest income bracket ($p < 0.05$).

3.2. Dwelling characteristics

3.2.1. Dwelling types and constructions

Table 2 summarizes the dwelling characteristics. Around 70% of the respondents in the study areas lived in detached dwellings and the majority were single storey buildings. More than 50% of the respondents had lived in the same dwelling for 10–40 years and 16% had not moved from the same dwelling for more than 40 years.

There was a significant difference in the composition of the dwelling types between regions ($p < 0.005$) with a greater proportion of semi-detached houses, townhouses or units in Adelaide and a higher proportion of those living in retirement villages in the Fleurieu. The proportion of those who lived in the same dwelling for more than 20 years in the Iron Triangle was significantly higher than that in the other two regions ($p < 0.005$).

The majority of dwellings in all three regions were constructed of brick, however there was a significant difference in the construction types between the three regions ($p < 0.005$). Compared to Adelaide, the Fleurieu and Iron Triangle had a higher proportion of dwellings with lightweight construction.

There were strong associations between the presence of wall insulation and the region, age of the dwelling and dwelling type

Table 2
Dwelling characteristics (n = 250).

	Adelaide (warm temperate) n = 90	Fleurieu (mild temperate) n = 120	Iron Triangle (semi-arid) n = 40
Dwelling type			
Separate house	58 (64%)	96 (80%)	29 (73%)
Semi-detached/unit	17 (19%)	6 (5%)	8 (20%)
Apartment or flat	5 (6%)	2 (2%)	3 (8%)
ILU[a] of retirement village	10 (11%)	16 (13%)	0
No of storeys			
Single storey	68 (81%)	100 (85%)	40 (100%)
More than one storey	17 (19%)	18 (15%)	0
Age of dwelling			
Less than 10 years	5 (6%)	7 (6%)	0
10–20 years	12 (13%)	43 (36%)	3 (7.5%)
More than 20 years	70 (78%)	70 (58%)	34 (85%)
Don't know	3 (3%)	0	3 (7.5%)
How long lived in dwelling?			
Less than 1 year	1 (1%)	0	
1–10 years	27 (30%)	46 (38%)	4 (10%)
11–20 years	22 (24%)	47 (39%)	4 (10%)
21–30 years	12 (13%)	15 (13%)	8 (20%)
31–40 years	9 (10%)	5 (4%)	9 (22.5%)
41–50 years	13 (14%)	7 (6%)	7 (17.5%)
More than 50 years	6 (7%)	0	8 (20%)
Dwelling's wall materials[b]			
Brick or brick veneer	85	97	27
Stone	6	6	3
Weatherboard	2	19	6
Metal cladding	1	3	1
Concrete	3	1	2
Other	1	2	2
Wall insulation installed?			
Yes	21 (23%)	56 (47%)	9 (22.5%)
No	41 (46%)	28 (23%)	20 (50%)
Don't know	28 (31%)	36 (30%)	11 (27.5%)
Ceiling insulation installed?			
Yes	78 (87%)	107 (89%)	28 (70%)
No	5 (6%)	5 (4%)	5 (12.5%)
Don't know	7 (7%)	8 (7%)	7 (17.5%)
External shading on windows?			
Yes	57 (63%)	49 (41%)	22 (55%)
No	33 (37%)	71 (59%)	18 (45%)

[a] Independent Living Unit.
[b] Total in each location is more than n because a dwelling may have more than one wall material.

($p < 0.005$). The proportion of dwellings with wall insulation was highest in the Fleurieu. The majority (94%) of dwellings with no wall insulation were those that were more than 20 years old. The majority (83%) of ILUs had wall insulation, whereas most other dwelling types did not.

There was no significant association between the presence of ceiling insulation and the region or age of the dwellings ($p > 0.05$), although there was a strong association with dwelling type ($p < 0.005$) in that all ILUs had ceiling insulation, whereas 8% of other dwelling types did not.

There was almost the same number of respondents who stated that their dwellings did or did not have external shading (awnings or outdoor blinds). The percentage of dwellings with external shading was higher in Adelaide than in Fleurieu and Iron Triangle (63%, 41%, 55% respectively), while the percentage of dwellings with no external shading in the Fleurieu was significantly higher than that in the other two regions.

3.2.2. Heating and cooling systems

3.2.2.1. Heating. Only two respondents (both in the Iron Triangle) stated they did not have a heater; one because of concerns about the cost and the other because she or he "did not need it". Of the other 248 respondents the majority used a reverse-cycle system to heat their dwellings (Fig. 6). A reverse-cycle system, also called a heat pump, can be used for heating or cooling a single room as a 'split' system or ducted throughout the house often with the provision to supply heating or cooling to selective rooms as required. The differences in the heating systems used in the three regions were found to be statistically significant ($p < 0.005$).

3.2.2.2. Cooling. Seven respondents did not have any coolers in their house; one in Adelaide, five in the Fleurieu and one in the Iron Triangle, with the main reason given that they "did not need it". Of those who had coolers, the majority of respondents used a reverse-cycle air-conditioner, either split system (56%) or ducted reverse-cycle (36%). A significant difference was found in the type of coolers used in the three regions ($p < 0.005$). Ducted reverse cycle was the main cooling system in Adelaide while the split reverse cycle system was the main cooling in the Fleurieu and Iron Triangle (Fig. 7).

3.3. Dealing with cold and hot weather

3.2.1. Personal actions

Respondents were asked both about the 'first action' and 'other actions' they undertook to keep warm in cold weather. The first action taken by the respondents from all regions was either to turn on the heater (41%) or put on more clothing (40%) (Fig. 8). There were, however, significant differences between the first action taken by female and male respondents ($p < 0.05$). Turning on the heater was the first action reported by more male than female respondents (55% vs 31%) whereas putting on more clothing was reported by more female than male respondents (43% vs 37%). Other 'first actions' to keep warm indicated by some respondents were closing up the house and closing doors between rooms (12% female vs 3% male), wrapping a blanket around oneself, using knee rugs (8% female vs 2% male), and staying in bed longer (2% female vs no males). 'Other actions' taken by the respondents included closing internal blinds and curtains at night, having hot drinks or meals, and being more active.

In contrast, there was more variety of 'first actions' to keep cool during hot weather reported by the respondents. These include turning on the air-conditioner (32%), closing indoor blinds and curtains during the day (23%), closing external blinds (12%), wearing lighter clothing (11%), and turning on fans (5%) (Fig. 9). Unlike dealing with cold weather, no significant difference was found between the 'first actions' of female and male respondents ($p > 0.05$). There was also no association between the actions taken to keep cool and the region, living arrangements, education and income levels of the respondents ($p > 0.05$).

The majority of respondents (88%) kept the house warm or cool for their own comfort, but some stated that they did so for other reasons such as for their pet, for other people such as guests, or to protect indoor plants, books, artworks and furnishing.

3.2.2. Changes to dwellings

Most respondents (65%) had made changes to their dwelling at some stage to improve thermal comfort. Of all who did (n = 65 in Adelaide, n = 70 in Fleurieu, n = 27 in Iron Triangle), the main change was to install air-conditioning systems. Other improvements included adding external blinds, installing ceiling fans, adding a verandah or pergola, internal blinds, installing insulation, sealing cracks around openings, and installing double glazed windows. Fig. 10 shows the percentage of respondents in each region who made changes to the dwellings to improve thermal comfort.

There was a strong association between the age of the dwellings and whether or not changes were made to improve thermal comfort ($p < 0.005$) with modifications mainly made to dwellings that were more than 20 years old. No association was found between the changes made to improve thermal comfort and the region ($p > 0.05$) except for

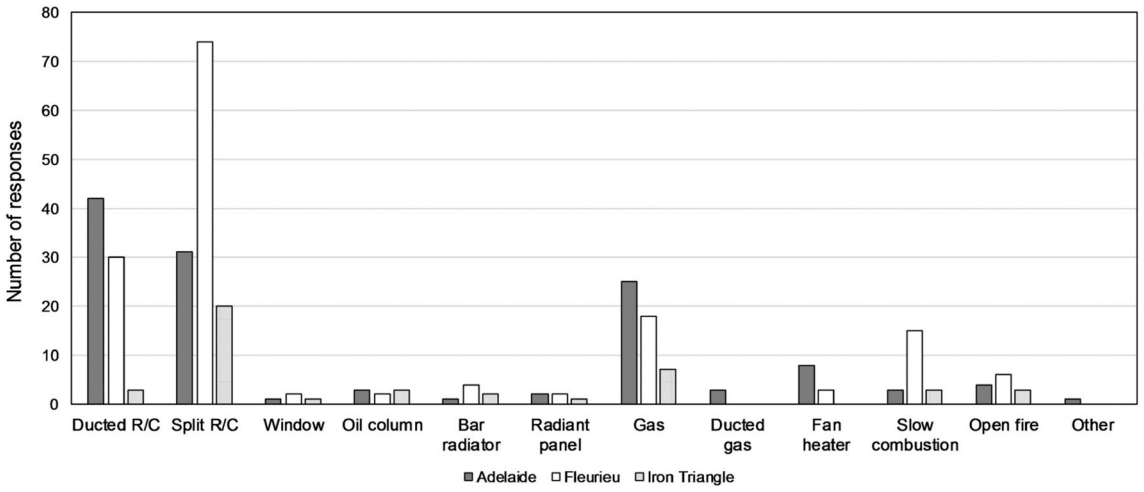

Fig. 6. Types of heaters used in the three locations.
(n > 250 because one dwelling may have more than one type of heater).

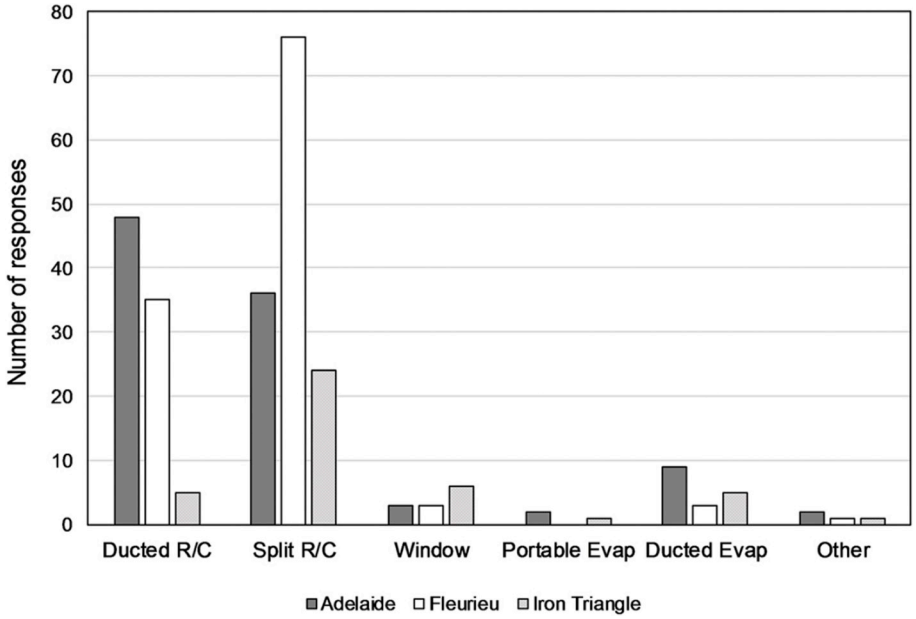

Fig. 7. Types of coolers used in the three locations.
(n > 250, one dwelling may have more than one type of cooler).

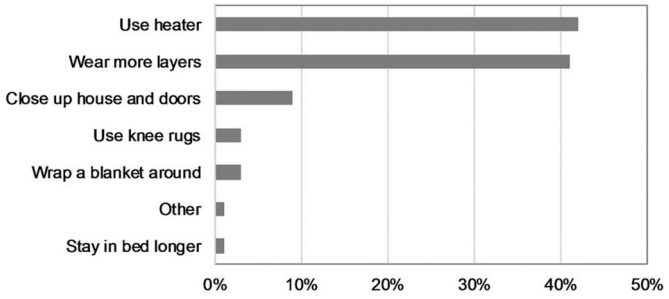

Fig. 8. First action taken to keep warm during cold weather (n = 250).

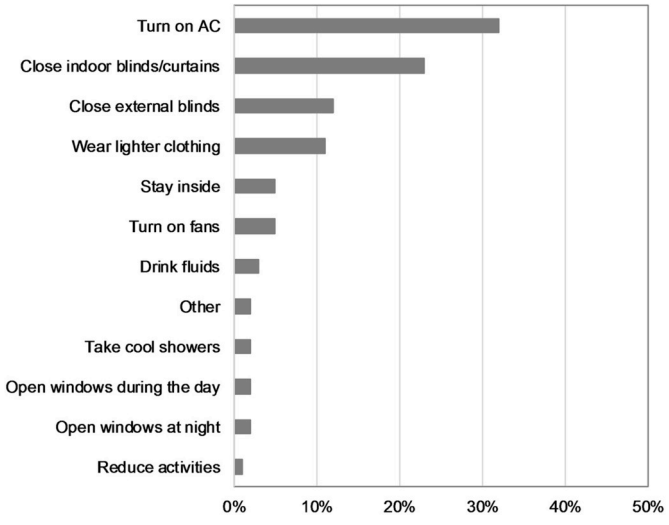

Fig. 9. First action taken to keep cool during hot weather (n = 250).

the installation of ceiling fans ($p < 0.05$), with the proportion of respondents who installed fans higher in the Iron Triangle (30%) compared to the other two regions (23% in the Fleurieu and 8% in Adelaide).

3.2.3. Use of heaters

Although 30% of all respondents (69 dwellings) had the ducted reverse cycle system for heating, only 12 used the system to heat the entire house. The majority of respondents heated only certain rooms, particularly the living room. There was a significant difference in the proportion of the respondents who did so in each region ($p < 0.05$): 87% in the Iron Triangle, 78% in the Fleurieu and only 64% in Adelaide. The next room heated was the dining room, often combined with the kitchen (38% of the total respondents heated this room), then family room (25%) and main bedroom (24%). Only 2% of the respondents stated that they heated other bedrooms.

Most respondents indicated that they turned on the heater in late afternoon or early evening or when they felt cold, and some significant differences among the three regions were identified in when the heaters were used. More than 50% of the respondents in Adelaide and the Fleurieu used the heater only in late afternoon or early evening but only 31% of the Iron Triangle respondents did so ($p < 0.05$). The respondents from Adelaide and the Fleurieu stated that they turned on the heater when they were watching television, but none from the Iron Triangle ($p < 0.05$). Few also stated that they did so just before they went to bed, or when they had visitors.

The majority of the respondents (62%) set the temperature for the heater between 21 and 25 °C in the winter but 11% set it at less than 21 °C. There was, however, no significant difference in the temperature settings of heaters among the three regions.

3.2.4. Use of coolers

Similar to heating, only 11% of the total respondents cooled the entire house despite the fact that 35% stated that they had installed the ducted reverse cycle system to be used for cooling. Out of those who cooled the entire house, more than half were those with the split system. The majority of the respondents cooled only certain rooms particularly the living room (71%) and there was a significant difference in the proportion of the respondents who did so in each region ($p < 0.001$); 85% in the Iron Triangle, 76% in the Fleurieu and 57% in Adelaide. In all three regions, some respondents also cooled the kitchen (46%), main bedroom (33%), family room or a den (27%) and study room (4%). There was, however, no significant difference among the three regions in the use of coolers in other rooms of the dwellings.

Nearly 50% stated they turned on the cooler late in the afternoon or

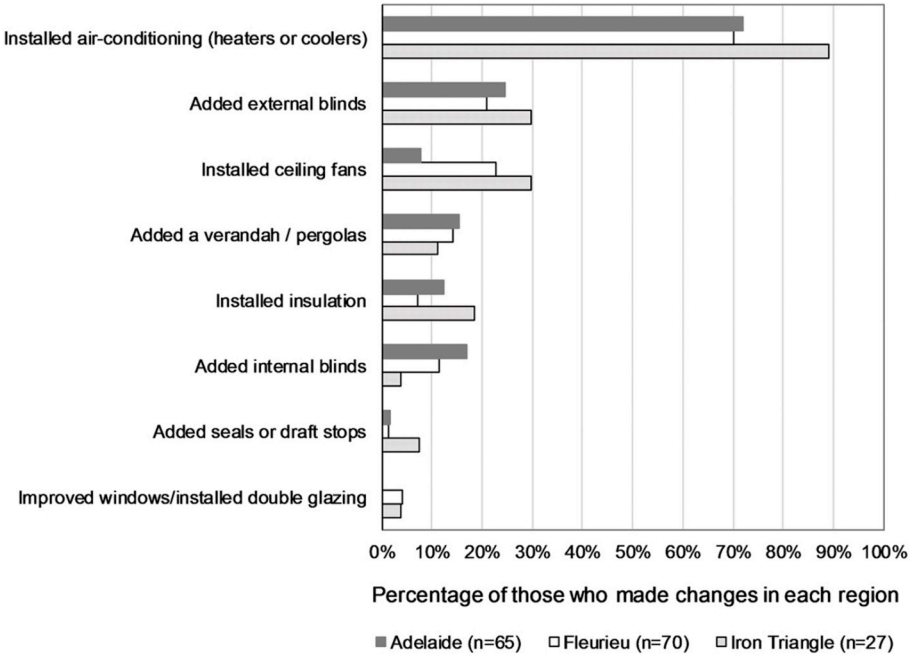

Fig. 10. Changes made to home to improve comfort (as percentage of those who made changes in each region).

early evening, 46% only when they felt hot, and 16% in the morning when it was a hot day. Only 4% turned on the cooler in the bedroom before they went to bed. No difference was found in when the respondents used the coolers, among the three regions.

Although the majority of respondents in all three regions set the cooling thermostat between 21 and 25 °C in the summer, more than 25% of the Fleurieu respondents set it below 21 °C, whereas in Adelaide only 11% and the Iron Triangle only 3%, did so ($p < 0.05$).

3.2.5. Using fans

Seventy two percent of the respondents used either ceiling or pedestal fans for cooling, with the percentage of female respondents higher than that of males (76 vs 61%) ($p < 0.05$). A strong association was found between the use of fans and lack of external shading or blinds ($p < 0.05$). Fans, particularly ceiling fans, were mostly used in the bedrooms, as reported by 80% of respondents from the Iron Triangle, 71% from Adelaide, and 67% from the Fleurieu.

3.4. Consequences of cold and hot weather

3.4.1. Problems using heating and cooling

While the majority of respondents had no problem using their heaters or coolers, a small percentage (4%) stated they had difficulties in controlling the system. Four respondents mentioned that the setting was confusing, a further four stated that it was difficult to read the numbers or words, while one person said it was difficult to press the button.

Another 5% stated that they did not necessarily use their heaters or coolers, even though they had them. The reasons for this was either they did not think they needed them, the heating or cooling equipment was too noisy, they did not like the feel of the air blowing on them, or they were concerned about the environment.

3.4.2. Costs

When asked if there was anything that made them hesitant to use either their heater or their cooler, 30% and 34% respectively, mentioned cost or affordability.

More than 70% of the respondents who had heaters and coolers had some level of concern over the running costs (even though they were using them), including 15–18% of the respondents being extremely concerned (Fig. 11). Even though none of the respondents from the Iron Triangle were in the higher income bracket, 42% of the respondents from this region said they were “not at all concerned” about the running cost of the heater or cooler, compared to only 24% in Adelaide and 23% in the Fleurieu, and this difference was significant ($p < 0.05$).

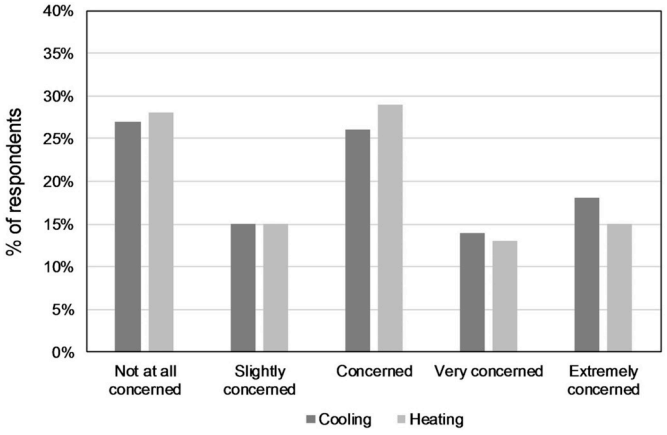

Fig. 11. Level of concern about running costs of heaters and coolers.

A strong association was identified between concerns over the running cost of the heaters and coolers and the annual income of the respondents ($p < 0.05$). Almost 50% of those who were concerned came from the lowest income bracket in the study (less than $30,000 per year) and 30% came from the middle income brackets (between $30,001 and $75,000). There were 7% of those from the highest income bracket who were hesitant about using air-conditioning due to concerns over the running cost. Most of the people who were extremely concerned about the running costs were pensioners. A strong association was also found between hesitation to run the air-conditioning due the cost implications and the respondents' mobility ($p < 0.005$), ability to do usual activities ($p < 0.005$), and experiencing pain/discomfort ($p < 0.005$).

3.4.3. Health and well-being related issues

Respondents were asked about health-related conditions associated with cold and hot weather. The majority of respondents did not report experiencing illnesses during cold and hot weather, but of those who did experience them, more respondents experienced them during cold weather (36%) than hot weather (18%). During cold weather, the most frequent health-related condition was colds and coughs (44%), followed by painful joints (33%), shortness of breath (19%), and influenza (14%). An association was identified between influenza and region ($p < 0.005$) with more than 50% of those who experienced influenza during the cold weather being from the Iron Triangle.

During hot weather, the most frequent health-related condition mentioned was fatigue or tiredness (56%), followed by shortness of breath (22%), sleeplessness (17%), and dizziness (17%). Other conditions during hot weather mentioned were nausea and vomiting, falls, headaches and red or hot skin.

The respondents were asked if they had been diagnosed by a doctor with particular illnesses in cold weather or hot weather to which the majority (83%) stated that they had not. Of those who had, bronchitis, asthma and pneumonia were the most common health problems diagnosed during the cold weather while during hot weather it was heart conditions.

The self-rating health scale was found to have strong associations with health symptoms which occurred during hot weather, such as whether or not the respondents experienced dizziness, headaches, falls, fatigue, nausea and vomiting, palpitations, shortness of breath and sleepiness ($p < 0.005$). During winter, experiencing cold sores was the only case where a symptom was found to be associated with the self-rating scale of health ($p < 0.005$). There was however, no association between the results of the self-rating scale of health and the region, or with the respondents' sex, age, income and education level.

3.5. Information and advice

The respondents were asked whether they had heard, seen or received information or advice in the previous 12 months on a number of issues related to thermal comfort and housing. Only a small percentage (14%) had heard, seen or received information about how hot and cold weather could affect their health or how to improve their comfort in hot or cold weather (7%). A larger percentage (42%) had heard about information or received advice about how to reduce energy use in the home with most of this coming from an energy or utility company (39%) newspaper article (36%) or on television (28%).

4. Discussion

This study has advanced our knowledge of the thermal behaviour of older people in order to contribute to optimal housing design for South Australians. The findings discussed below are those factors that may impact on older people's ability to live independently and healthily.

4.1. The occupants

The study found that the percentages of older female and male respondents living alone (49% and 27% respectively) were higher than the national figures (close to 31% for older females and 18% for older males) [24]. The higher percentage of female than male respondents living alone is consistent with global data that show women are expected to live longer than men [32]. Nevertheless, the study found no statistical significance in the correlation between the sex of the respondents and their self-rated health. The percentage of older female respondents reporting having a good health (self-rated health score of 70 or above) was 74%, while it was 73% for the male respondents.

Not surprisingly, there is a significant correlation between the living arrangement and income; those who had the lowest annual income were those who lived alone. There was also a strong association between education level and income. The study also found a strong association between income level and experiencing anxiety or depression problems although no strong association was found between income levels and self-rated overall health.

4.2. House design

The majority of older South Australians surveyed lived in single storey detached dwellings, with the percentage in Adelaide and the Iron Triangle regions being slightly less than the percentage of South Australian population living in detached dwellings (78%) [26].

Of the three regions, the proportion of dwellings more than 20 years old was highest in the Iron Triangle while the proportion of dwellings less than 20 years old was highest in the Fleurieu. This reflects the growth in housing for retirees in the relatively mild climate of the coastal areas of the Fleurieu since 2009 [23]. On the other hand, the regional towns of the Iron Triangle, in decline since the 1970s, have experienced limited new construction and the housing stock tends to be older and of poorer quality than in Adelaide.

In all three regions, housing less than 20 years old was better insulated and more likely to have both ceiling and wall insulation. In South Australia, the installation of ceiling insulation has been common since the late 1980s. By 1999 when 70% of dwellings were reported to have ceiling insulation, only 20% of dwellings had wall insulation [33]. Generally wall insulation is installed at the time of construction while it is usually possible to retrofit ceiling insulation. Findings from the survey show that two-thirds of dwellings that were more than 20 years old, did not have wall insulation.

Interestingly, although overall around one-half of the dwellings did not have external blinds or awnings, two-thirds of respondents' houses in Adelaide (which were mostly more than 20 years old) did. Nevertheless, lack of external shading can result in more solar heat gain during the day, and while this may be desired during cold weather or winter, this is normally unwanted during hot weather. This can be problematic in the Iron Triangle region where the mean maximum outdoor temperature in summer is above 30 °C and the peak can reach 47 °C.

The study did not find any statistical significance in the associations between the use of heaters or coolers and house design, particularly in relation to wall materials and ceiling insulation. The association between the presence or absence of wall insulation and the use of a heater or cooler was also weak; however, there were more respondents living in houses without wall insulation who stated that turning on the heater was the first thing they did to keep warm, than those living in houses with wall insulation (ratio 1.2:1). Likewise, more respondents living in houses without wall insulation stated that their first strategy for keeping cool was to turn on the cooler than those living in wall-insulated houses (ratio 1.4:1). Similarly, while the association between having external blinds or shades and the use of cooler was not statistically significant, more than 85% of those who stated that turning on the cooler was the first thing they did to keep cool came from those with houses that did not have external blinds or shades.

These results indicated that both lack of wall insulation and lack of shading can lead to dwellings that are too cold and too hot, resulting in more reliance on heating and cooling and increasing utility costs [34–36]. Many other design and construction features (such as orientation) were not addressed in the survey but potentially could influence the thermal performance of individual dwellings.

4.3. Heaters and coolers

Heaters and coolers were installed in the vast majority of dwellings regardless of the region. Only 3% of houses did not have cooling and only 2 cases did not have heating. These results confirm the increasing penetration of air-conditioning in Australia, both for cooling and heating. It is estimated that in 1994 only 32% of houses in Australia had

air conditioning. By 2014 this had risen to 74% Australia-wide and 91% of South Australian households [37,38]. The use of mechanical cooling or heating devices was the first thing many respondents thought of to keep them comfortable in hot or cold weather, respectively. This is similar to findings by Hansen et al. [10] and van Hoof and Hensen [39]. Nevertheless it is worth noting that in all three regions the majority of respondents heated or cooled only one room, most likely to be the living room, and only did so during late afternoon or early evening, or when they felt cold or hot, and not overnight. These findings align with those of similar other Australian studies [40,41,46].

The study also found that a small percentage of respondents had difficulties in controlling the heating or cooling system, such as finding the setting to be confusing and having difficulties in reading the numbers or words on the remote control or in pressing the button. This is similar to a finding in previous work by van Hoof et al. [42], which explicitly dealt with thermal comfort and dementia, and this usability-related finding also applies to older people in general. Other concerns about using heaters and coolers related to the negative sensory experiences in using them due to the noise level and strong draft coming from the heating or cooling equipment. Similar results were found in studies by Hansen et al. in Australia [43], Henshaw and Guy in the United Kingdom [44] and Wong et al. [45] in Hong Kong SAR.

The survey indicated that apart from using heaters and coolers, and regardless of the region or climate zone, there was a range of personal actions and adaptive behaviours used to deal with cold and hot conditions, such as wearing more or less clothing and opening or closing external blinds, depending on the weather. Similar findings were reported in studies to explore the thermal behaviours of older people in other states in Australia [46,47] and in Europe [48].

4.4. Cost concerns

Not surprisingly there is a connection between the increasing penetration, and use, of air conditioning with concerns about energy costs. More than 70% of the respondents were concerned about the running costs of their coolers and heaters. The vast majority of heating and cooling uses electricity and in the last 10 years electricity prices in Australia have risen 56% in real terms [49]. The study identified a strong association between concerns about running costs and annual income. The majority of concerns came from those in the lowest income bracket in this study, but even a small proportion of those with the highest income had concerns over the cooling cost. This confirms findings from other studies, that for older people on reduced fixed income, the cost of running air conditioners or heaters is a great concern [21].

Fans, which were already used by more than 70% of the respondents, would be a better cooling option as not only are they more cost efficient to run but also cheaper to buy and install than most other cooling systems. In this study, the use of fans was significantly higher in dwellings that lacked external shading or blinds, indicating that the dwellings were warmer than those with external shading. This supports the notion that dwellings that are well designed and have external shading during hot weather, are likely to be easier to cool and have lower energy costs.

4.5. Health and well-being

In all three regions, while respondents experienced more health-related conditions during the cold weather than during hot weather, a significant majority of respondents (83%) stated that they were in good health, had good mobility and few underlying medical conditions. This is consistent with the 2014–2015 National Health Survey which found that nearly 75% of older Australians reported that they had good, or very good to excellent health [50].

Nonetheless, almost 20% of respondents may be more vulnerable to weather-related illness due to the presence of issues such as being less mobile, having problems doing usual activities, experiencing pain or discomfort, experiencing anxiety or depression, or having low income. Similar conditions have been identified in other studies [51–53] as factors that increase the vulnerability of older people to weather-related illness. Compounding this are risk factors associated with the dwelling including living in an older house with inadequate thermal insulation [51]. While there was no statistically significant association between house design and the self-reported health of the occupants, the study found that there were more respondents living in houses without wall insulation who were diagnosed with illnesses during winter, such as asthma, bronchitis, pneumonia, and heart condition, than those living in insulated houses and diagnosed with the same illnesses (ratio 1.4:1). This indicates the importance of improving building design to minimize the risks associated with weather-related illnesses.

It needs to be stressed that the studied population were living independently rather than in an institutional setting, such as a nursing home or and assisted-living facility. There are many studies available on the optimal design of the thermal environment of nursing homes and retirement villages, from both Australia [54,55] and from Europe [56,57]. In general, the populations of these facilities are in poorer health and often deal with the consequences of dementia, and, therefore, have fewer adaptive behavioural strategies at their disposal.

4.6. Importance of information

Ninety percent of respondents said that in the previous 12 months they had not heard, seen or received information about the connection between hot and cold weather and their health and well-being. This supports other studies that have found that people do not realise that some physiological aspects of ageing can increase health risks during hot and cold weather [52]. Most respondents also indicated that in the previous 12 months they had not heard, seen or received information about how to improve their thermal comfort or reduce energy costs.

It is worth noting that the percentage of the Fleurieu respondents who expressed concerns over the cost of cooling was higher than that in the other two regions. At the same time, a higher percentage of respondents from this region compared to the other two regions, set the cooler at below 21 °C, which may have led to high cooling costs. This may indicate a lack of understanding and information about the impact of set point temperatures on energy costs.

Given concerns about electricity prices, information could be valuable to older people, carers and building designers about non air-conditioning adaptive behaviours and cost-effective modifications to houses. Tips for minimising energy use (such as using fans, or how to cost effectively operate an air conditioner) would also be useful. For designers, information would be valuable about the types and location of heaters and coolers and their relationship to the thermal design of a house and the ways older people use their heaters and coolers. Such information needs to address the diversity of housing types and personal circumstances identified in this study.

4.7. Limitations

As the study was conducted through telephone interviews, we acknowledge that this method posed some limitations. First, most people who participated in the study tended to report being healthy, thus introducing an acknowledged sampling bias. Those who were not well enough to speak on the telephone and may have been the most susceptible to weather-related conditions were not included. Second, with a telephone interviewing system there were limitations about how much in-depth information we were able to obtain. Third, while the survey indicated some differences between the three regions, these were not straightforward. The histories and climates of the regions have given rise to particular housing types, construction and design. This in turn influences the presence or absence of thermal-comfort related adaptation features such as insulation or external shading and impacts

on heating and cooling. Similarly, the demographic profile of respondents in the regions influences their behaviour and concerns.

5. Conclusion

Using a telephone survey of 250 older South Australians we have developed a picture of the relationships between house type, location and the heating and cooling equipment of older South Australians ageing-in-place. The analysis of the data has shown that there were some differences in the dwelling characteristics, heating and cooling behaviours and types of heaters and coolers used by older people in the three climatic regions. Some aspects of house design, particularly the presence or absence of wall insulation and external blinds, were shown to have an impact on the occupants' heating and cooling behaviours, even though no correlation was found between these factors and the occupants' perceived health and well-being. The majority of respondents considered themselves healthy although at the same time nearly all used heating and cooling during cold and hot weather.

While no strong associations were found between house design, perceived health and well-being related issues, the results indicate that a range of strategies may be appropriate to minimize the need for heating and cooling. Strategies for those vulnerable to weather-related illnesses, as well as those who are less mobile, have problems doing usual activities, and experience pain, anxiety or depression may be different from the strategies undertaken by those who do not experience these problems. Such targeted strategies are likely to have a positive impact on health and well-being as also suggested by other studies [58,59].

With increasing energy prices and an ageing population, improving existing dwellings and ensuring that new house designs can provide affordable thermal comfort will be essential for the well-being of people ageing-in-place. Providing information to older people, their carers, designers and policy makers about the relationships between weather and health and well-being as well as about the relationships between housing design, heating and cooling behaviours, thermal comfort and energy use, is therefore an important step in supporting older people to live independently and healthily.

While the study had some limitations, the results have added new knowledge to the fields of housing and public health in relation to the ageing population as well as provided useful insights for further studies. More in-depth studies, such as through focus group discussions [60], site visits and indoor environmental monitoring of the dwellings as well as in-depth interviews with the occupants, will provide further understanding about the living environment of older Australians who are aging in place. This further study is currently underway.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.buildenv.2019.03.023.

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References

[1] ABS, How Australians Use Their Time, 2006, Cat. No. 4153.0 Canberra, Australian Bureau of Statistics, 2008.
[2] C.J. Matz, D.M. Stieb, K. Davis, M. Egyed, A. Rose, B. Chou, O. Bryon, Effects of age, season, sex and urban-rural status on time-activity: Canadian Human Activity Pattern Survey 2 (CHAPS 2), Int. J. Environ. Res. Public Health 11 (2014) 2108–2124, https://doi.org/10.3390/ijerph110202108.
[3] ABS, Population Projections, Australia, 2012 (Base) to 2101. Cat. No. 3222.0, Australian Bureau of Statistics, Canberra, 2015.
[4] B. Judd, E. Liu, H. Easthope, L. Davey, C. Bridge, Downsizing Amongst Older Australians, AHURI Final Report No. 214. Melbourne, Australian Housing and Urban Research Institute Limited, 2014, https://www.ahuri.edu.au/research/final-reports/214.
[5] A. Gasparrini, Y. Guo, M. Hashizume, E. Lavigne, et al., Mortality risk attributable to high and low ambient temperature: a multicountry observational study, Lancet 386 (2015) 369–375 https://doi.org/10.1016/S0140-6736(14)62114-0.
[6] M.S. O'Neill, K.L. Ebi, Temperature extremes and health: impacts of climate variability and change in the United States, J. Occup. Environ. Med. 51 (1) (2009) 13–25, https://doi.org/10.1097/JOM.0b013e318173e122.
[7] C.M. Blatteis, Age-dependent changes in temperature regulation - a mini review, Gerontology 58 (4) (2012) 289–295, https://doi.org/10.1159/000333148.
[8] J. van Hoof, L. Schellen, V. Soebarto, J.K.W. Wong, J.K. Kazak, Ten questions concerning thermal comfort and ageing, Build. Environ. 120 (2017) 123–133.
[9] G. Havenith, Temperature regulation and technology, Gerontechnology 1 (2001) 41–49.
[10] A. Hansen, M. Nitschke, P. Bi, D. Pisaniello, et al., Heat-health behaviours of older people in two Australian states, Austr. J. Ageing 34 (1) (2014) 19–25 https://doi.org/10.1111/ajag.12134.
[11] J.K. Rosenthal, P.L. Kinney, K.B. Metzger, Intra-urban vulnerability to heat-related mortality in New York City, Health Place 30 (2014) 45–60 https://doi.org/10.1016/j.healthplace.2014.07.014.
[12] P. Ebersole, P. Hess, A. Schmidt Luggen (Eds.), Toward Healthy Aging, sixth ed., Mosby, St. Louis, MO: USA, 2004.
[13] M.M. Huynen, P. Martens, D. Schram, M.P. Weijenberg, A.E. Kunst, The impact of heat waves and cold spells on mortality rates in the Dutch population, Environ. Health Perspect. 109 (5) (2001) 463–470, https://doi.org/10.1289/ehp.01109463.
[14] J. Garssen, C. Harmsen, J. de Beer, The effect of the summer 2003 heat wave on mortality in The Netherlands, Euro Surveill. 10 (7) (2005) 165–168.
[15] PwC, Protecting Human Health and Safety during Severe and Extreme Heat Events: a National Framework, Report Prepared by PriceWaterhouse Coopers Australia, (2011).
[16] DEWHA, Energy Use in the Australian Residential Sector 1986 – 2020, Department of the Environment, Water, Heritage and the Arts, Commonwealth of Australia, Canberra, 2008.
[17] ABC, SA Storms: Thousands Still without Power as Businesses Suffer Losses in Blackout, Australian Broadcasting Commission, 2016, http://www.abc.net.au/news/2016-12-29/sa-weather-ses-crews-brace-for-more-severe-storms/8151846.
[18] L. Chester, The Impacts and Consequences for Low-Income Australian Homes of Rising Energy Prices. Report to Consumer Advocacy Panel, University of Sydney, Sydney, 2013.
[19] A. Hansen, P. Bi, M. Nitschke, D. Pisaniello, J. Newbury, A. Kitson, Older persons and heat-susceptibility: the role of health promotion in a changing climate, Health Promot. J. Aust. 22 (2011) 17–20.
[20] R. Bills, V. Soebarto, T. Williamson, Thermal experiences of older people during hot conditions in Adelaide, Paper Presented at 50th International Conference of the Architectural Science Association, 2016, pp. 657–664.
[21] L. Daniel, T. Williamson, V. Soebarto, D. Chen, Learning from thermal mavericks in Australia: comfort studies in Melbourne and Darwin, Architect. Sci. Rev. 58 (1) (2015) 57–66.
[22] ABS, Household Use of Information Technology, Cat. No. 8146.0 Australia, 2012-13, Australian Bureau of Statistics, Canberra, 2014.
[23] ABS, Population by Age and Sex, Regions of Australia. Cat. No. 3235.0, Australian Bureau of Statistics, Canberra, 2015.
[24] ABS, Reflecting a Nation: Stories from the 2011 Census, 2012–2013, Cat. No. 2071, 0 Australian Bureau of Statistics, Canberra, 2012.
[25] D.A. Dillman, J.D. Smyth, L.M. Christian, Internet, Phone, Mail, and Mixed-Mode Surveys: the Tailored Design Method, John Wiley & Sons, Hoboken, New Jersey, 2014 (Chapter 3).
[26] ABS, Census of Population and Housing Data, Australian Bureau of Statistics, Canberra, 2016.
[27] ABCB, Climate Zone Map: Australia Wide, Australian Building Codes Board, Canberra, 2015.
[28] BOM, Key Climate Groups of the Objective Classification of Australian Climates Using Koppen Scheme. Bioregional Assessment Source Dataset, Bureau of Meteorology, 2014 Viewed 21 August 2018 http://data.bioregionalassessments.gov.au/dataset/01089f5d-33ef-4fc4-b044-6e1e1f72d698.
[29] M. van Reenen, B. Janssen, EQ-5D-5L User Guide Basic Information on How to Use the EQ-5D-5L Instrument, EuroQol Research Foundation, 2015.
[30] ISO, Market, Opinion and Social Research (ISO 20252:2012), International Organization for Standardization, 2012.
[31] IBM Corp, IBM SPSS Statistics for Windows, Version 25.0, IBM Corp, Armonk, NY, 2017.
[32] United Nations, Department of Economic, Social Affairs, Population Division, World Population Prospects: the 2017 Revision, (2017) https://esa.un.org/unpd/wpp/Download/Standard/Population/.
[33] ABS, Australian Social Trends, Cat. No. 4102.0 Canberra, Australian Bureau of Statistics, 2002.
[34] V. Soebarto, H. Bennetts, Thermal comfort and occupant responses during summer in a low to middle income housing development in South Australia, Build. Environ. 75 (2014) 19–29 https://doi.org/10.1016/j.buildenv.2014.01.013.

[35] T. van Hooff, B. Blocken, H.J.P. Timmermans, J.L.M. Hensen, Analysis of the predicted effect of passive climate adaptation measures on energy demand for cooling and heating in a residential building, Energy 94 (2016) 811–820 https://doi.org/10.1016/j.energy.2015.11.036.
[36] T. Moore, J. Morrissey, Lifecycle costing sensitivities for zero energy housing in Melbourne, Australia, Energy Build. 79 (2014) 1–11 https://doi.org/10.1016/j.enbuild.2014.04.050.
[37] ABS, Environmental Issues: Energy Use and Conservation Cat. No. 4602.0.55.001, Australian Bureau of Statistics, Canberra, 2008.
[38] ABS, Environmental Issues: Energy Use and Conservation Cat. No. 4602.0.55.001, Australian Bureau of Statistics, Canberra, 2014.
[39] J. van Hoof, J.L.M. Hensen, Thermal comfort and older adults, Gerontechnology 4 (4) (2006) 223–228, https://doi.org/10.4017/gt.2006.04.04.006.00.
[40] N. Willand, R. Horne, "They are grinding us into the ground" – the lived experience of (in)energy justice amongst low-income older households, Appl. Energy 226 (2018) 61–70 https://doi.org/10.1016/j.apenergy.2018.05.079.
[41] R. Hitchings, G. Waitt, K. Roggeveen, C. Chisholm, Winter cold in a summer place: perceived norms of seasonal adaptation and cultures of home heating in Australia, Energy Res. Soc. Sci. 8 (2015) 162–172 https://doi.org/10.1016/j.erss.2015.05.007.
[42] J. van Hoof, H.S.M. Kort, J.M. Hensen, M.S.H. Duijnstee, P.G.S. Rutten, Thermal comfort and integrated building design for older people with dementia, Build. Environ. 45 (2) (2010) 358–370 https://doi.org/10.1016/j.buildenv.2009.06.013.
[43] A. Hansen, P. Bi, M. Nitschke, D. Pisaniello, J. Newbury, A. Kitson, Perceptions of heat-susceptibility in older persons: barriers to adaptation, Int. J. Environ. Res. Public Health 8 (2011) 4714–4728, https://doi.org/10.3390/ijerph8124714.
[44] V. Henshaw, S. Guy, Embodied thermal environments: an examination of older-people's sensory experiences in a variety of residential types, Energy Policy 84 (2015) 233–240 https://doi.org/10.1016/j.enpol.2014.11.018.
[45] L.T. Wong, K.N.K. Fong, K.W. Mui, W.W.Y. Wong, L.W. Lee, A field survey of the expected desirable thermal environment for older people, Indoor Built Environ. 18 (4) (2009) 336–345.
[46] N. Willand, C. Maller, I. Ridley, "It's not too bad" – the lived experience of energy saving practices of low-income older and frail people", Energy Procedia 121 (2017) 166–173.
[47] L. Romanach, N. Hall, S. Meikle, Energy consumption in an ageing population: exploring energy use and behaviour of low-income older Australians, Energy Procedia 121 (2017) 246–253.
[48] M. Giamalaki, D. Kolokotsa, Understanding the thermal experience of elderly people in their residences: study on thermal comfort and adaptive behaviors of senior citizens in Crete, Greece, Energy Build. 185 (2019) 76–87.
[49] L. Nicholls, H. McCann, Y. Strengers, K. Bosomworth, Electricity Pricing, Heatwaves and Household Vulnerability in Australia, Centre for Urban Research (CUR), Melbourne, 2017 June.
[50] ABS, National Health Survey: First Results, 2014–15 Australia, Cat. No. 4364.0, Australian Bureau of Statistics, Canberra, 2015.
[51] S. Vandentorren, P. Bretin, A. Zeghnoun, L. Mandereau-Bruno, et al., August 2003 heat wave in France: risk factors for death of elderly people living at home, Eur. J. Public Health 16 (6) (2006) 583–591 https://doi.org/10.1093/eurpub/ckl063.
[52] M. Nitschke, A. Hansen, P. Bi, D. Pisaniello, et al., Risk factors, health effects and behaviour in older people during extreme heat: a survey in South Australia, Int. J. Environ. Res. Public Health 10 (2013) 6721–6733 https://doi.org/10.3390/ijerph10126721.
[53] R.S. Kovats, S. Hajat, Heat stress and public health: a critical review, Annu. Rev. Public Health 29 (2008) 41–55 https://doi.org/10.1146/annurev.publhealth.29.020907.090843.
[54] F. Tartarini, P. Cooper, R. Fleming, Thermal perceptions, preferences and adaptive behaviours of occupants of nursing homes, Build. Environ. 132 (2018) 57–69.
[55] X. Hu, B. Xia, M. Skitmore, L. Buys, Providing a sustainable living environment in not-for-profit retirement villages: a case study in Australia, Facilities 36 (5–6) (2018) 272–290.
[56] J. van Hoof, H.S.M. Kort, H. van Waarde, Housing and care for older adults with dementia. A European perspective, J. Hous. Built Environ. 24 (3) (2009) 369–390, https://doi.org/10.1007/s10901-009-9143-3.
[57] A. Mendes, A.L. Papoila, P. Carreiro-Martins, ... N. Neuparth, J.P. Teixeira, The influence of thermal comfort on the quality of life of nursing home residents, J. Toxicol. Environ. Health A Curr. Issues 80 (13–15) (2017) 729–739.
[58] S. Ahrentzen, J. Erickson, E. Fonseca, Thermal and health outcomes of energy efficiency retrofits of homes of older adults, Indoor Air 26 (4) (2016) 582–593 https://doi.org/10/1111/ina.12239.
[59] A. Vilches, A.B. Padura, M.M. Huelva, Retrofitting of homes for people in fuel poverty: approach based on household thermal comfort, Energy Policy 100 (2017) 283–291 https://doi.org/10/1016/j.enpol.2016.10.016.
[60] J. van Hoof, H. Bennetts, A. Hansen, J. Kazak, V. Soebarto, The living environment and thermal behaviours of older South Australians: a multi focus group study, Int. J. Environ. Res. Public Health 16 (6) (13 March 2019) 935 https://doi.org/10.3390/ijerph16060935.