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Thermal environment and thermal sensations of occupants of nursing homes: a field study

Federico Tartarini[a,]*, Paul Cooper[a], Richard Fleming[a]

[a]*University of Wollongong, Northfields Ave, Wollongong NSW, 2522, Australia*

Abstract

A demographic shift is underway in Australia; the number of people aged 65 and over is rapidly increasing. Regulations have been implemented to enhance the quality of care being provided in nursing homes; however, in the aged care sector there is little by way of guidance addressing design and performance issues in regards to Indoor Environmental Quality (IEQ), and there is still uncertainty as to the perceptions of residents on specific IEQ factors. The objectives of this study are to determine: how accredited facilities are performing in regards to thermal comfort conditions; how indoor environmental factors can be assessed in a non-intrusive way; and how occupants perceive their thermal environment. Air temperature and relative humidity were monitored over ten months in six nursing homes located in southeast NSW using 305 loggers. Subjective perception of the thermal environment was gathered from 157 residents, 31 family members and 64 staff who completed a questionnaire at the same time that local environmental parameters were monitored. Results show how accredited nursing homes performed in regards to thermal comfort, along with a detailed description of the non-intrusive methodology adopted to assess IEQ factors. Subjective responses of occupants, along with adaptive behaviour strategies employed by participants to counter unsatisfactory thermal conditions, were also examined. This study has practical implications for the aged care sector and provides quantitative evidence on how nursing homes should be designed and operated to enhance satisfaction and well-being of occupants.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: thermal comfort; residential aged care facility; older people; field survey; IEQ monitoring device

* Federico Tartarini. Tel.: +61-4-239-2109.
E-mail address: ft674@uowmail.edu.au

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1. Introduction

Australian population is ageing, in 2015, about 15% of the total population was aged 65 years and over [4] and this age group is projected to increase to 22% in 2061 [3]. Due to this demographic shift, the demand for aged care services is also projected to grow in the coming years and new facilities will need to be built. In 2014, approximately 270,600 people resided in Australian nursing homes [8]; and the aged care sector consumed around 7.8 million gigajoules of energy [27]. A report from the NSW Office of Environment and Heritage showed that on average heating and cooling systems accounted for 30% of the whole energy consumption in nursing homes, and 15% of the total electricity and 18% of the total gas consumption could be saved by implementing energy efficient solutions [27]. Inefficiencies in heating and cooling systems, especially when caused by malfunctioning and misuse of control systems, and poor building fabric not only increase energy bills but also have an impact on thermal comfort.

Evidence from nursing literature studies indicates that Indoor Environmental Quality (IEQ) not only plays a central role in providing comfort but could also be seen as a non-pharmacological method to reduce the occurrence of unwanted behaviours and to enhance the well-being of occupants of nursing homes [18]. Therefore, several 'design guides' have been published to help architects, building designers and care providers to better understand how to improve interior design (e.g. safety, mobility) of facilities [10]. However, in the literature regarding nursing homes there is very limited guidance on how facilities should be designed/operated to enhance thermal comfort [18]. Uncertainty still remains about perceptions of residents on specific IEQ factors (e.g. lighting, noise and thermal comfort) [19,21], and the specific impact that thermal environment may have on quality of life of occupants has not been fully understood [17,30,32]. Evidence from architectural and engineering studies has shown that the thermal environment has a central role in enhancing productivity and well-being of building occupants [11,14,17]. However, to date, only a limited number of field studies have been conducted in nursing homes [18]. Nursing homes represent something of a hybrid category of buildings: part residential, part offices and part commercial [30]; and different types of occupants (e.g. staff versus residents), who might have different thermal requirements due to variations in types of activity, clothing insulation, time spent indoors and health status, share the same environment.

The most commonly used general purpose thermal comfort standards, ASHRAE Standard 55 [1] and ISO 7730:2005 [24], do provide comprehensive/quantitative guidance as to thermal sensation as a function of age; in other words, the neutral temperature is taken to be constant among different age groups. This assumption is based on Fanger's findings, since he observed that healthy people aged around 65 years and college-age subjects showed no significant difference in their preferred temperature [12]. Fanger argued that older adults have a lower basal metabolic rate (approximately 4 kcal/m^{2}hr) than college-age subjects; however, the decrement of metabolic rate is compensated by the decrement of insensible perspiration [12]. In June 2012, the median age of Australian nursing homes residents was 86 years old [7]. Arguably, a person aged 86 may have a different thermal comfort sensation than a person aged 65 [33].

Over the past fifty years, several studies have been conducted on older adults to determine whether age affects thermal sensation; however, some found quantitative evidence to support to Fanger's model, while others have found differences in the subjective perception of thermal environment between older and younger adults [21,33]. Therefore, uncertainty remains and, as a result, little by way of guidance exists to help the aged care sector in understanding how to design and operate heating ventilation and air conditioning systems in nursing homes. Furthermore, about 50% of permanent residents of nursing homes have dementia [6]. Dementia may alter how people, affected by this pathology, perceive the environment and their thermoregulation [18]. Until specific guidelines are provided, caregivers are likely to continue to attempt to modify the indoor environment relying on trial and error adjustments [18] and facilities that may not offer optimal thermal conditions for occupants may continue to be built. Extended exposure to hot and cold temperatures may not only cause a sensation of thermal discomfort but may also have repercussions on health, well-being and manifestation of unwanted behaviours (e.g. agitation) [17,19,30]. More research is needed to investigate thermal sensation of people aged 65 years and over living in nursing homes [17,21].

Along with inconsistent views on how age influences perceptions of thermal comfort, we found little in the literature on how IEQ factors could be assessed in a non-intrusive way in care centres. A wide range of sensors and logging devices are currently available; however, to the authors' knowledge, only a limited range of portable equipment can be used to monitor IEQ factors in accordance with the requirements of the thermal comfort standards.

Finding accurate and easy-to-use equipment is one of the major challenges in IEQ monitoring [16]. Furthermore, the majority of multi-parameter IEQ measurement devices are bulky and intrusive, making it difficult to accurately assess all IEQ factors simultaneously using a single auditing tool. Hence, researchers have used carts to move multiple sensors around the indoor environment and to keep the sensor steady at a defined height during the measurement period. However, since the majority of the studies have been conducted in offices or in commercial buildings the impact that the equipment may have had on occupants was not a primary concern. In contrast, assessment of IEQ in nursing homes poses major challenges, including: data acquisition needs to meet the requirements imposed by the standards; the equipment needs to have a minimal impact on residents, especially on those with dementia who may manifest unwanted behaviours when exposed to unfamiliar objects [13]; and data collection must not interfere with the provision of care.

2. Methodology

This study was approved by the University of Wollongong Human Research Ethics Committee.

2.1. Building characterization

This research phase was conducted in six homes, all located in southeast NSW. Four facilities were located in the near proximity of the coast in a warm temperate climate (National construction code (NCC) climate Zone 5), one facility was located in a cool temperate zone (NCC climatic zone 7) and one home was located in a mild temperate zone (NCC climatic zone 6) [2]. Table 1 contains information about: climate zone, lowest and highest monthly mean minimum and maximum temperatures recorded outdoor between September 2015 and May 2016, thermal features of the building, and number of data-loggers installed. Building characteristics data were collected via walk-through surveys of the sites.

Table 1. Aged care facility characteristics. National Construction Code (NCC); direct expansion air conditioning unit (DX); Variable Refrigerant Flow (VRF) air conditioning unit.

Nursing home	NCC climatic zone [2]	Outdoor temperature [a]	*N* of beds (*N* beds dementia section)	Building features	*N* data loggers installed
NH1	Zone 5	8.7 - 27.4 °C	150 (13)	Built: first section1993; second section 1997; third section 2008. Double bricks external walls, no insulation; single glazed windows, ceiling insulation. Heating: bedrooms combination of electric heaters, DX, hot water wall radiators; common areas ducted system and DX. Cooling: DX in some bedrooms, DX and ducted system in common areas.	45
NH2	Zone 6	4.7 - 25.7 °C	90 (25)	Built in 2007. Double bricks external walls, no insulation; single glazed windows, ceiling insulation. Heating and cooling: DX bedrooms and ducted system common areas.	42
NH3	Zone 5	8.7 - 27.4 °C	62 (14)	Built in 1955. Double bricks external walls, no insulation; single glazed windows, ceiling insulation. Ducted gas heating, DX common areas.	23
NH4	Zone 7	4.0 - 28.5 °C	160 (25)	Built in 2008. Double bricks external walls, no insulation; single glazed windows, ceiling insulation. Heating and cooling: DX bedrooms and ducted system common areas.	64
NH5	Zone 5	8.7 - 27.4 °C	40 (0)	Built: first section 1968; 1985 were added 40 beds. Double bricks external walls, no insulation; single glazed windows, ceiling insulation. Bedrooms: electric heaters and wall radiators, DX dining room.	30
NH6	Zone 5	8.7 - 27.4 °C	101 (55)	Built in 1984. Double bricks external walls, no insulation; single glazed windows; one section ceiling insulation. Heating wall radiators, DX common areas and corridors (installed 02/2016).	101

[a] lowest and highest monthly mean minimum and maximum temperatures recorded outdoor between September 2015 and May 2016 [5].

Stand-alone iButton® data loggers [26] were used to monitor dry-bulb air temperature and relative humidity. iButtons® are small, cylindrical data loggers 17.5 mm in diameter and 6 mm deep which were able to measure temperature with an accuracy of ±0.5 °C (operation range from -40 °C to 85 °C) and relative humidity with an accuracy of ±5%, thus, meeting the accuracy requirements of the ISO 7726:1998 standard [23]. Data was collected at hourly intervals from 1st of September 2015 and to 30th of June 2016. Data loggers were installed on internal walls using thick adhesive tape, at the approximate abdomen height of the occupants (0.6 m sitting/reclining, 1.1 m standing) as suggested by ISO 7726:1998. The specific height of each sensor was selected based on type of activity and body position of the participants. Location of each sensor was selected to avoid direct exposure to solar radiation and direct radiation/convection from neighbouring heat sources. Only data monitored between 5.00 and 23.00 in dining rooms and lounges was included in the analysis, since those rooms were unoccupied at other times.

2.2. Development of a non-intrusive methodology to assess indoor environment parameters – the IEQ Cart

A four-wheeled 'walker' was used as the supporting structure for sensors and logging equipment. A walker was chosen since: aged care residents are familiar and used to seeing these devices in the facility; they have a light and strong structure; have a good degree of mobility; they can be easily transported to different locations; and can be safely used by residents, if need be. Air temperature and air velocity were measured at four different heights as recommended in the ASHRAE 55 and ISO 7730:2005 standards [1,24]. Average air temperature (T_a) and average air velocity (V_a) were calculated based on the body position of occupants. For seated occupants T_a and V_a were calculated averaging the readings at 0.1, 0.6 and 1.1 m, for standing occupants T_a and V_a were calculated averaging the readings at 0.1, 1.1 and 1.7 m, while for reclined occupants T_a and V_a and were measured at 0.6 m. Black globe temperature was measured at 0.6 m for seated and reclining occupants, and at 1.1 m for standing occupants. A 40 mm diameter globe thermometer was used since this is held by many to be the optimum size to measure globe temperature in human comfort studies [20,29]. Mean radiant temperatures and operative temperatures were calculated using equations provided in the Annex B of the ISO 7726:1988 standard [23]. All the indoor environmental parameters were sampled at 1-second intervals and saved on the internal memory of the Graphtec-GL820® data logger. Table 2 summarises the sensors that were installed on the walker, while figure 1 shows two images of the portable equipment, or 'IEQ Cart', which was used in this study.

To determine any specific effects that the IEQ Cart had on the manifestation of agitation, a field study was conducted in the dementia section of one aged care facility. During each observation, agitation was assessed for three minutes using the Wisconsin Agitation Inventory (WAI) [25]. The WAI is an observational tool used to rate agitation on a 5-point scale ranging in 25-point intervals from 0 (*the person was entirely calm*) to 100 (*high motor, verbal, or vocal behaviour*). The three consecutive stages of the observation were as follows:

- Pre-intervention: a trained research assistant entered the room, and after 12 minutes assessed agitation for 3 minutes. The aim was to determine the baseline agitation level of the resident.
- Intervention: a second researcher entered the room and placed the IEQ Cart next to the resident (maximum distance 1 m) and then left the room, agitation was then assessed after 12 minutes (by the first research assistant). The aim was to determine whether the cart could cause agitation.
- Post intervention: the cart was removed from the room and after 12 minutes agitation was assessed for the third time (by the first research assistant). The aim was to determine whether the cart could have had an effect on behaviours even after removing it from the room.

Each stage lasted for 15 minutes, which was the approximate duration of the thermal sensation survey. Twelve individuals with dementia were observed, all receiving the same intervention; they acted as their own controls. Proxy consent was obtained in writing from legal guardians of each resident. Observations took place between 9.00 and 17.00. Multi-level analysis was used since data had a hierarchical structure, the same resident was observed several times and therefore observations were not independent. Data analysis was performed with the generalized linear mixed model procedure in IBM SPSS Statistics 21; data analysis included descriptive statistics, and the database was tested to check the assumptions of the statistical test.

Table 2. Instrumentation installed on the IEQ Cart.

Parameter	Measurement Range	Accuracy	Sensor type/ Model	Height sensors
Air temperature	0 … + 50 °C[a]	20 °C ± 0.04 °C 30 °C ± 0.05 °C[a]	RTD PT100	0.1 m / 0.6 m / 1.1 m / 1.7 m[a]
Relative humidity	0 … 95 %RH[a]	0 … 60 %RH ± 2.5%RH 60 … 80 %RH ± 3.0%RH[a]	HUMICAP	0.75 m
Black globe temperature, T_g	0 … + 100 °C[a]	± 0.5 °C or ± 0.4% reading [a]	Type T thermocouple placed inside a 40 mm in diameter matt black copper sphere	0.6 m / 1.1 m[a]
Air velocity	0.05 … + 2.5 m/s[a]	± 3.0% reading, ± 1.0% full scale range [a]	Omnidirectional probe tip	0.1 m / 0.6 m / 1.1 m / 1.7 m[a]
Illuminance	0 … 10,000 lux	± 3.0% reading		0.85 m
CO_2	0 … 2000 ppm	20 … 30 °C ± (30 ppm + 2.0% reading) - 30 … 40 °C ± (35 ppm + 2.7% reading)	Micro electro mechanical system	0.75 m
Sound level	30 … 130 dB	± 1.4 dB [b]		0.3 m

[a] meets ASHRAE 55 and ISO 7726:1988 standards

[b] meets ANSI and IEC 61672-1 Type 2 standards

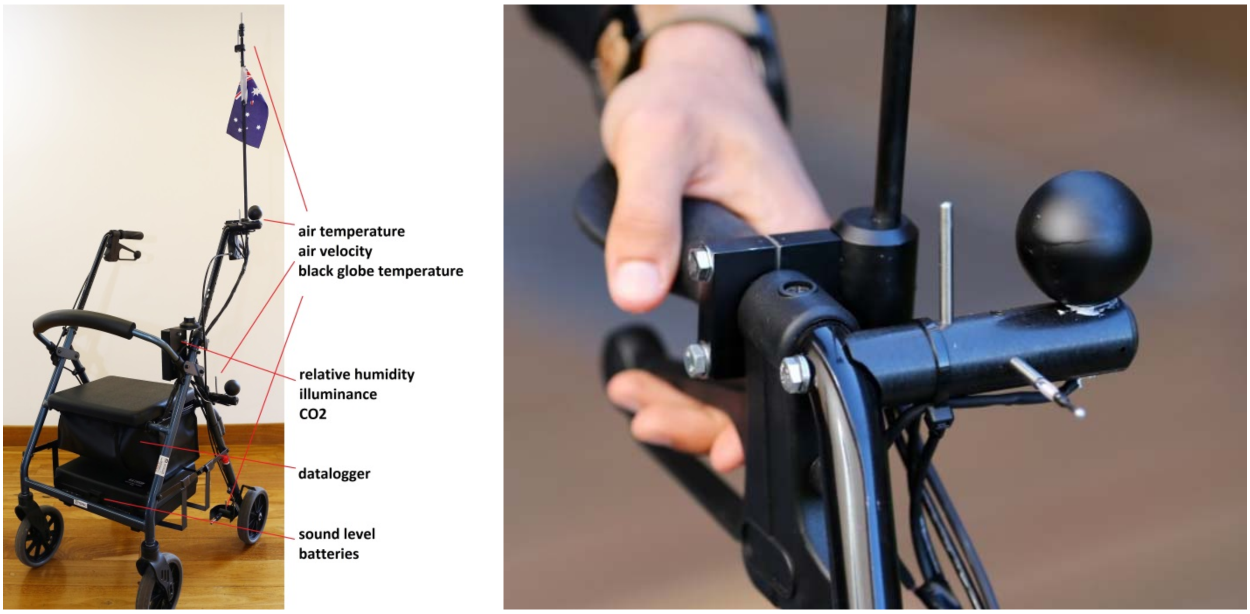

Fig. 1. IEQ Cart used to monitor and log IEQ parameters.

2.3. Thermal perceptions of occupants

There are several factors that affect people's perceptions and expectations of their indoor environment. These can be grouped in two main categories: thermal environmental factors and personal factors [1]. Indoor environmental factors were monitored using the IEQ Cart, simultaneously a given participant was invited to complete a *point-in-time* paper based questionnaire [1] designed to assess subjective perceptions and personal factors. The questionnaire was divided in three main sections: i) personal information (e.g. age group, gender, job type, height, weight); ii) personal parameters (e.g. activity level, metabolic rate); and iii) subjective perception of the environment, which was assessed using the 7-point thermal sensation ASHRAE scale [1], i.e. -3 *cold*; -2 *cool*; -1 *slightly cool*; 0 *neutral*; +1 *slightly warm*; +2 *warm*; +3 *hot*. All surveys were conducted indoors between 9.00 and 17.00. Researchers waited for a minimum of 12 minutes prior measuring thermal environmental parameters, since that is the average time required for the black globe sensor to reach thermal stability with the environment. The cart was always positioned in within 1.0 m of the participant. A total of 252 questionnaires were collected between the 25th of November 2015 and the 16th of February 2016; each participant completed the questionnaire only once.

3. Results

3.1. Building characterization

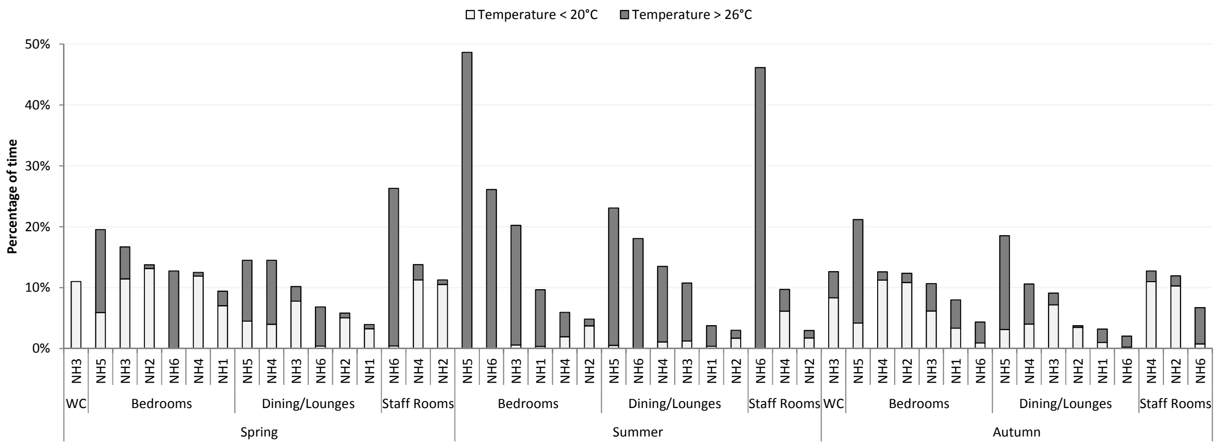

Fig. 2. Percentage of time at which temperatures higher than 26 °C and lower than 20 °C were recorded during spring, summer and autumn in different rooms in the six nursing homes. Only data monitored between 5.00 and 23.00 in dining rooms and lounges was included in the analysis, since those rooms were considered to be unoccupied at night time.

Figure 2 shows the percentage of time that temperatures occurred outside the comfort temperature range, 20 to 26 °C, as recorded across different room types in the six facilities. The temperature range was selected based on the recommendations provided in Annex A of the ISO 7730:2005 Standard [24]; since no minimum provisions in regards to thermal comfort were provided by the Australian residential aged care Accreditation Standards. Temperatures higher than 26 °C were recorded for more than 20% of the summer time in those rooms without air conditioning units (e.g. bedrooms at NH5, NH6 and NH3, and staff rooms at NH6). Temperatures higher than 26 °C were also recorded in spring when the heating was turned on, in those rooms that were equipped with water radiators without thermostatic valves (e.g. bedrooms NH6 and NH5). Temperatures higher than 26 °C were recorded for 65% of the summer period in the medication room at NH6; medication should be stored in a dry and cool location and extreme temperature should be avoided [28].

Temperatures lower that 20 °C were found to occur in all the facilities (except NH6) during spring and autumn. However, in newer facilities the majority of the residents lived in single bedrooms equipped with a split-system air conditioning unit. Therefore, temperatures lower than 20 °C were not necessarily synonymous with discomfort since residents had nominal control of the temperature set-point in their bedrooms (e.g. set the air conditioning unit at 20 °C or lower at night or switch off the heating while in outside their bedrooms). In older facilities residents did not have the opportunity to adjust the temperature set-point, and many of them lived in shared bedrooms; therefore, temperatures lower than 20 °C should be avoided.

3.2. Evaluation of the non-intrusive methodology to assess IEQ

A total of 46 observations were made (agitation was assessed 138 times). Eight residents, out of a total of 12 participants, did not manifest agitated behaviours during the observations. WAI scores occurred as follows: “0” - 129 times; “25” - 6 times; “50” - 2 times; “75” - once. None of the participants scored “100”. Twice the WAI score increased and twice decreased after the IEQ Cart was entered into the room; while, in two occasions, agitation increased after the cart was removed from the room. Results from the statistical analysis showed that there is no statistically significant correlation between the introduction of the cart into the room and higher WAI score; suggesting that the specific design used for the IEQ Cart had negligible impact on agitation in residents with dementia.

3.3. Thermal perceptions of the occupants

Table 3 summarizes the characteristics of the sample surveyed during the present study and shows mean and standard deviations for each of the six main thermal comfort factors which influence thermal sensation of the occupants. Among 95 non-residents that participated in the study: 64 were staff members or volunteers, and 31 were family members. Participants were excluded from the analysis if family members completed the survey on their behalf. Data was collected between the 25th of November 2015 and the 16th of February 2016.

Table 3. Sample characteristics of the indoor environment survey; data is presented for residents and non-residents. Total clothing insulation (I_{cl}); metabolic rate (M); relative humidity (RH); average dry-bulb air temperature (T_a); mean radiant air temperature (T_r); average air velocity (V_a).

	Respondent	Gender			Age group[a]				M (met)		I_{cl} (clo)		T_a (°C)		RH (%)		V_a (ms^{-1})		T_r (°C)	
Site	Resident	N	F	M	<65	66-75	76-85	>85	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
NH1	No	25	20	5	13	2	3		1.2	0.3	0.49	0.15	23.2	1.5	56.2	6.5	0.11	0.03	24.3	1.1
NH1	Yes	66	51	15	2	5	26	28	1.0	0.1	0.85	0.57	23.5	1.4	57.5	5.9	0.14	0.11	24.0	1.0
NH2	No	16	12	4	7	4	3		1.2	0.3	0.53	0.11	21.9	0.9	52.0	2.9	0.09	0.03	22.5	0.7
NH2	Yes	33	18	15	2	3	9	16	1.0	0.3	0.94	0.51	21.9	0.7	50.5	3.1	0.08	0.05	22.4	0.7
NH3	No	12	9	3	7	2	2		1.3	0.4	0.47	0.09	27.2	2.1	42.8	5.3	0.23	0.17	28.0	1.3
NH3	Yes	14	4	10	2	5	1	3	0.9	0.1	0.63	0.60	28.0	2.5	43.7	9.2	0.26	0.14	28.0	1.4
NH4	No	5	3	2	2	1			1.3	0.4	0.40	0.09	26.1	2.8	59.6	5.0	0.19	0.18	27.1	1.7
NH4	Yes	23	12	11		4	8	11	0.9	0.1	0.72	0.35	26.9	2.3	56.7	5.7	0.21	0.13	27.4	1.8
NH5	No	37	31	6	24	5	4	2	1.2	0.4	0.47	0.11	26.1	2.2	51.8	11.2	0.31	0.19	26.6	1.8
NH5	Yes	21	12	9	1	1	10	8	1.0	0.1	0.58	0.33	25.8	1.6	50.4	10.3	0.29	0.22	26.7	1.2
Total		252	172	80	60	32	66	68	1.1	0.3	0.68	0.44	24.5	2.58	53.2	8.39	0.18	0.15	25.2	2.3

[a] a total of 26 participants did not disclose their age.

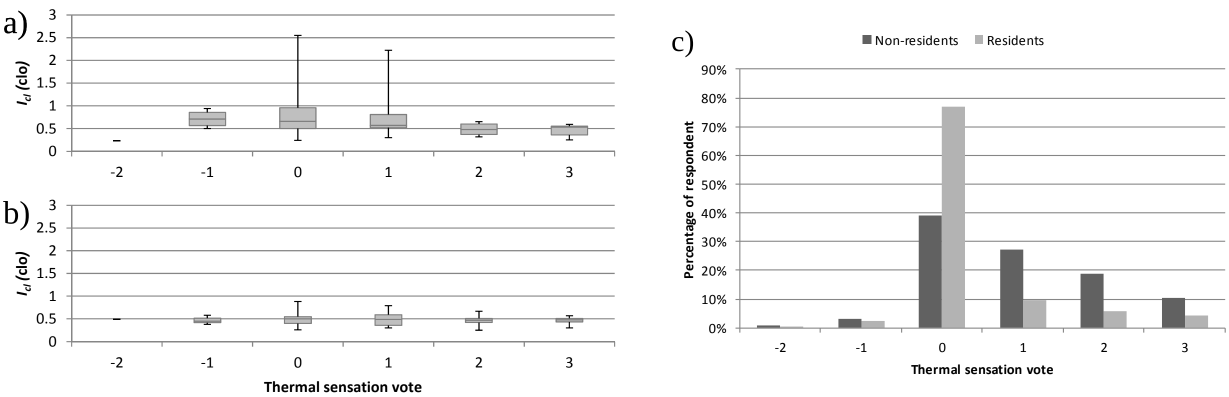

Fig. 3. a) and b) clothing insulation worn by residents and non-residents, respectively, plotted against thermal sensation vote. c) Percentage of occurrence of each thermal sensation vote relative to each group of participants. Data collected between the 25th of November 2015 and the 16th of February 2016.

Figure 3 c) shows that 77% of the residents voted “0” on the thermal sensation scale (i.e. comfortable/neutral); while, non-residents were less satisfied with the environment, only 39% voted *neutral*. Although, figure 3 shows that several residents who voted *neutral*, had to wear extra layers of clothing to compensate for unsatisfactory environmental conditions. Figure 3 also shows that both residents and non-residents who voted *warm* or *hot* attempted to reduce their clothing insulation to compensate for warm temperatures, however, that was not sufficient. Table 3 shows that participants increased local air speed using pedestal or ceiling fans when exposed to warm indoor air temperatures.

Figure 4 shows the thermal sensation votes plotted on the psychrometric chart where the winter (I_{cl} = 1.0 clo) and the summer (I_{cl} = 0.5 clo) comfort zones, as defined by the ASHRAE 55 2013 standard, have been highlighted. A total of 50 residents were surveyed when exposed to higher temperatures and/or humidity ratios than those recommended by the standard for summer clothing; however, 60% of them voted *neutral*. Out of 71 residents interviewed when the thermal environmental conditions were on the cold side of the summer clothing thermal comfort zone, only three reported to be *slightly cool* and one *slightly warm*. The remaining residents (36) were surveyed when exposed to environmental conditions within the summer comfort zone and 67% of these voted *neutral*. Non-residents were exposed to a similar range of temperatures as the non-residents, however, only 19% of them voted *neutral* when exposed to higher temperatures and/or humidity ratios than those recommended by the standard for summer clothing. Furthermore only 38% of those surveyed when the thermal environment was within the 0.5 clo ASHRAE summer comfort zone voted *neutral*. While, when temperatures were colder than those recommended for the summer period, a total of 62% of the non-residents voted “0” in the thermal sensation scale.

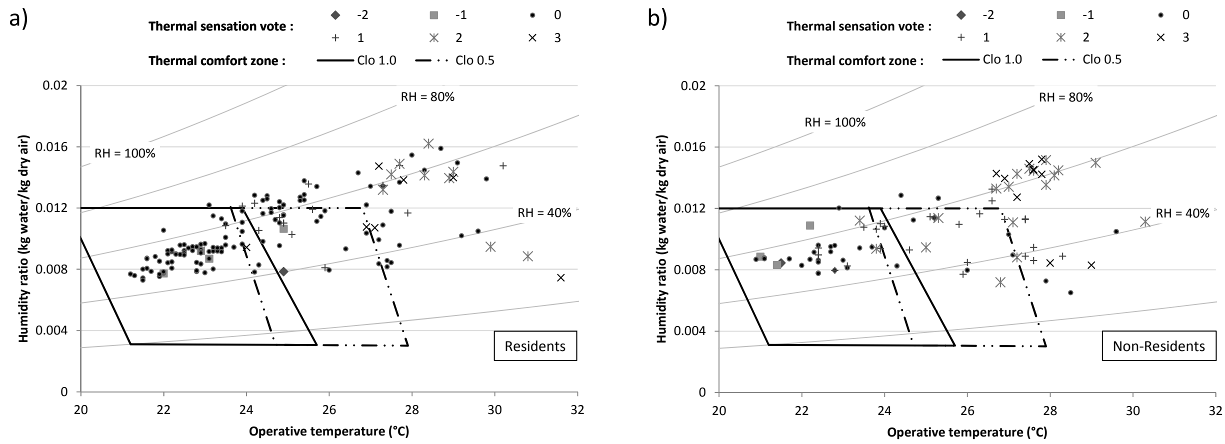

Fig. 4. Thermal sensation votes, collected between the 25th of November 2015 and the 16th of February 2016, plotted on the psychrometric chart, for a) residents and b) non-residents.

4. Discussion

As a result of the demographic shift towards an older population, the aged care sector in Australia is expected to grow, and in the coming years there will be an increasing demand for nursing home care. It is therefore important to assess how facilities are currently performing and how occupants perceive the indoor environment to ensure that a high standard of care is provided. This study investigated how accredited nursing homes performed in regards to thermal comfort and provided quantitative data regarding thermal perception of nursing homes occupants.

In newer facilities the heating, ventilating air conditioning (HVAC) units were able to finely control the temperature set-point regardless the outdoor conditions and all residents had the opportunity to adjust the temperature set-point in their bedrooms. However, not all of them were able to do so due to several constraints, such as: they were not taught how to use the air conditioning unit remote controls; they were not familiar with the technology; the screen of the remote had low contrast and hence reduced visibility/clarity. Furthermore, not all the staff members were trained in how operate the air conditioning units and there was neither a defined protocol nor guidelines to be followed to adjust the temperature set-point. Hence, temperatures lower than 20 °C were recorded in the shoulder seasons, autumn and spring. Moreover, windows were often found open while the air conditioning units were turned on, temperature variations during the day were observed, and often different air conditioning units across the facility had different temperature set-points.

In the majority of the older facilities the heating system was manually controlled and only relatively few common areas were equipped with air conditioning units. In addition, external walls were not insulated and windows were single glazed without draught sealing. As a result, indoor temperatures fluctuated as a function of the outdoor weather conditions. Temperatures higher than 26 °C were recorded for more than 20% of the time in summer in bedrooms at NH3, NH5 and NH6. The lack of an appropriate local air temperature control for the heating system, which was manually operated by the maintenance team in NH6, NH3 and NH5, resulted in temperatures higher than 26 °C being recorded in autumn and in spring when the heating was turned on. Occupants often mitigated this problem by opening the windows; however, this had repercussions on thermal comfort and on the energy bills. Cassette air conditioning units have been installed in some corridors to attempt to reduce the temperature variations by cooling the facility in summer and warming it during the shoulder seasons. However, these units when in operation are often the cause of local thermal discomfort such as drafts, vertical air temperature differences and cyclic temperature variations.

Several effective strategies could be implemented to enhance thermal comfort and maximize energy efficiency, such as: training staff members in how to better operate the building (e.g. use natural ventilation, close windows when cooling/heating is on) and how to provide *thermal care* (e.g. helping residents to adjust their clothing insulation, ensuring that they remain hydrated with hot/cold drinks) [30]; simplifying the temperature control in bedrooms (e.g. remote with two buttons red "warmer", blue "colder"); using occupancy sensors to detect whether rooms are occupied; having one reference person who is responsible for adjusting the temperature set-point in the common areas; upgrading the building fabric (e.g. external walls insulation, double glazed windows); installing centralized HVAC systems in older facilities or installing a control system for the existing heating system.

The IEQ Cart did not significantly affect agitated behaviours of residents with dementia, and was demonstrated to be a robust portable equipment that can be used to reliably and accurately monitor IEQ factors in nursing homes.

Results from the thermal comfort field study showed that residents were more tolerant than non-residents (67% of whom were staff members) of their thermal environment; 77% of them voted *neutral* in the thermal sensation survey. Residents effectively adjusted their clothing insulation when exposed to uncomfortable conditions. Only 39% of non-residents were satisfied with the environmental conditions, and despite the fact that they were wearing on average wearing summer clothes (mean I_{cl} = 0.48 clo, SD I_{cl} = 0.12 clo), and the majority of them was involved in sedentary or light activities (mean M = 1.23 met, SD M = 0.34 met), they preferred colder temperatures than those recommended by thermal comfort standards. Similar results were previously found in studies conducted in hot and humid climatic zones where occupants tend to prefer temperatures lower than neutral [22].

The findings suggest that more research in this area is needed to provide guidelines for aged care providers on how nursing homes should be operated to enhance thermal comfort and maximize energy efficiency. Research is also needed to investigate the possible impact that exposure to unsatisfactory thermal conditions may have on the well-being of the occupants, with special regard to those with dementia or those with physical restraints that prevent them from adopting adaptive behaviours to compensate for thermal discomfort.

Acknowledgments

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