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Visitors' perception of thermal comfort during extreme heat events at the Royal Botanic Garden Melbourne

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Abstract Outdoor thermal comfort studies have mainly examined the perception of local residents, and there has been little work on how those conditions are perceived differently by tourists, especially tourists of diverse origins. This issue is important because it will improve the application of thermal indices in predicting the thermal perception of tourists. This study aims to compare the differences in thermal perception and preferences between local and overseas visitors to the Royal Botanic Garden (RBG) in Melbourne during summer. An 8-day survey was conducted in February 2014 at four sites in the garden ($n = 2198$), including 2 days with maximum temperature exceeding 40 °C. The survey results were compared with data from four weather stations adjacent to the survey locations. One survey location, 'Fern Gully', has a misting system and visitors perceived the Fern Gully to be cooler than other survey locations. As the apparent temperature exceeded 32.4 °C, visitors perceived the environment as being 'warm' or 'hot'. At 'hot' conditions, 36.8 % of European visitors voted for no change to the thermal conditions, which is considerably higher than the response from Australian visitors (12.2 %) and Chinese visitors (7.5 %). Study results suggest that overseas tourists have different comfort perception and preferences compared to local Australians in hot weather based at least in part on expectations. Understanding the differences in visitors' thermal perception is important to improve the garden design. It can also lead to better tour planning and marketing to potential visitors from different countries.

Keywords Thermal comfort · Thermal perception · Botanic gardens · Tourism · Landscape design · Climate change

Introduction

Past studies on outdoor thermal comfort have mainly focused on the thermal perception of local residents (Spagnolo and de Dear 2003; Thorsson et al. 2004; Knez and Thorsson 2006; Oliveira and Andrade 2007; Oliveira et al. 2011; Andrade et al. 2011; Lin 2009; Lin et al. 2011). However, compared with local visitors, overseas visitors tend to have a different expectation and perception of the climate of tourist destinations (de Freitas 2003). This study examines the thermal comfort perception of visitors from different countries and local Australian visitors. Understanding this information is useful for tour planning, marketing to potential tourists, as well as landscape design to improve the tourists' satisfaction with outdoor experiences (de Freitas 2003).

Understanding the thermally acceptable temperature range of visitors is important for garden planning and management in order to make a public garden a pleasant place to visit throughout the year. It is well-known that weather affects a tourist's decision to visit tourism destinations (Scott and Lemieux 2010). Studies suggest that climate change is likely to increase the frequency of hotter days (Alexander and Arblaster 2009), which will affect the thermal comfort of visitors to outdoor areas (de Freitas 2003). Botanic gardens are important tourist destinations and play an important role in the health and well-being of people in the community. Increasing

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the number of garden visitations is important for justifying the public funding for gardens (Murray et al. 2007).

Climate influences urban land-use and affects human thermal comfort. Despite the importance of climatic factors, Eliasson (2000) suggests that urban planners appear to have limited knowledge of climate in urban areas, due to a lack of easily accessible literature. Incorporating the knowledge of how urban parks and gardens contribute to cooling is useful for managing issues such as Urban Heat Island. In addition, urban green space has previously been shown to reduce the perception of thermal discomfort under hot conditions (Lafortezza et al. 2009). Previous studies demonstrated that various tree species differed in their ability in lowering temperature compared with open space with no trees (Irmak et al. 2013; Streiling and Matzarakis 2003; Schiller 2001). The size, shape and permeability of tree crowns, as well as tree clusters, were shown to affect the mean radiant temperature and wind speed, and subsequently thermal comfort (de Abreu-Harbich et al. 2015). This study addresses this issue by using weather stations to examine the microclimate of different landscapes and compare it with the thermal comfort surveys of local citizens and overseas visitors to an urban botanic garden in Australia. A botanic garden is an ideal site for conducting this study as various types of vegetation are planted in close proximity, providing the opportunity to compare the cooling effects of different vegetation (Primack and Miller-Rushing 2009).

Physical, physiological and psychological factors interact with each other to affect the time of exposure, environmental stimulation and expectation (Nikolopoulou and Steemers 2003). All three factors contribute to human thermal comfort. First, physical factors include architecture, physical environment and microclimate such as temperature, humidity, wind speed and solar radiation (Chen and Ng 2012). They influence people's exposure to sun and wind in urban environment. Second, physiological factors refer to thermoregulation and human energy balance (Chen and Ng 2012), which responds to environmental stimulation. Third, psychological factors concern the perception of naturalness, past experiences and perceived control over their experiences (Nikolopoulou and Steemers 2003). Expectation influences people's clothing choice and their interpretation of discomfort (Nikolopoulou et al. 2001).

Perceived control affects how well people tolerate uncomfortable thermal conditions. When people have a high degree of control over sources of discomfort, they tend to tolerate uncomfortable environment more and show fewer negative emotional responses (Nikolopoulou and Lykoudis 2006). For an outdoor context, it can mean the choice to sit in the sun or shade, as well as choosing to leave when the environment becomes unbearable. When visitors were free to choose the time they visited and left an outdoor location, they demonstrated a higher thermal satisfaction than people with low autonomy in making those decisions (Lin 2009; Lin et al. 2013). Other behavioural adjustments include changes in clothing, wearing a hat or carrying an umbrella (Lin et al. 2013). Transient exposure and thermal expectations appear to affect a person's assessment and satisfaction of the thermal environment (Thorsson et al. 2004). When the environment lies within the acceptable thermal comfort zone, Thorsson et al. (2007) found that people are more willing to stay longer in outdoor environments.

Acclimatization and cultural preference leads to differences in thermal perception in various climate zones. Lin (2009) conducted a thermal perception study in Taichung City, Taiwan, which is a hot subtropical city. The results by Lin (2009) show a different pattern from the results in temperate cities in European studies (Nikolopoulou et al. 2001; Eliasson et al. 2007). For example, the Taiwanese in particular tend to prefer cool temperatures and weak sunlight. In addition, the acceptable thermal range is higher in Taichung city than the European cities. In particular, Taichung's thermal comfort range (27–29.4 °C physiological equivalent temperature, PET) (Lin et al. 2013) is significantly higher than that found in Central Western Europe (18–23 °C PET) (Matzarakis and Mayer 1996). In a Melbourne study, Kenawy and Elkadi (2013) stated that people from America, NW Europe and Australia had a higher mean thermal sensation vote than Asians in summer, meaning the former group of visitors felt hotter than the latter group.

Many outdoor thermal studies worldwide are conducted for several sites in a single city (Bowler et al. 2010). The majority of studies are from Europe (Bacci et al. 2003; Zoulia et al. 2009; Oliveira et al. 2011; Upmanis et al. 1998) and North America (Spronken-Smith and Oke 1998; Barradas 1991), with some studies in Asia (Chang et al. 2007; Thorsson et al. 2007), the Middle East (Potchter et al. 2006) and Africa (Jonsson 2004). In comparison, Australian field studies on outdoor thermal comfort are very limited. In Australia, Spagnolo and de Dear (2003) conducted a thermal comfort study in outdoor and semi-outdoor environments in Sydney such as parks. They obtained a thermal neutral temperature of 26.2 °C standard effective temperature (OUT_SET*), which was significantly higher than what they found for indoor environment (SET* of 24.0 °C). In addition, they did not find gender difference in their data. Loughnan et al. (2012) have shown that the thermally comfortable range is different for the residents in Mawson Lake, Adelaide (25 to 30.6 °C) and Melbourne (19.9 to 23.2 °C). Different population who are acclimatized to different climate may be partly responsible for the difference. Given the distinct climate of Melbourne in summer, it is uncertain whether people's thermal perception differs between an urban outdoor environment and a botanic garden, which has various microclimates. The purpose of this study is to address this lack of specific research by investigating the perceived human thermal comfort of visitors from different countries and Australians in the Royal Botanic Garden Melbourne. The study has the following objectives: (1) to examine the relationship between the microclimate in various parts of the garden and the thermal perception of visitors; and (2) to identify the personal characteristics that influence local and overseas visitors' perception of thermal comfort.

Materials and methods

Study area

The Royal Botanic Garden (RBG) Melbourne is situated near the central business district of Melbourne, Australia. It is located at 37° 50′ S, 144° 58 E, bordering the Yarra River and the Melbourne and Olympic Parks to the north. The RBG Melbourne covers 38 ha, and it includes a mixture of native and exotic vegetation. The RBG Melbourne was selected because of its wide range of microclimates within the garden and its reputation as a popular tourist destination. A description of the survey sites is presented in Table 1. Further details are provided in Figs. 1 and 2, which show the survey locations within the garden.

Micrometeorological measurements

The temperature and relative humidity at O Gate and the Terrace were measured using a Vaisala HMP155 Probe in a radiation shield. Wind speeds were measured by Met One 014A-L anemometers. Globe temperatures were measured using a 150-mm-diameter black globe thermometer. Solar radiation values were recorded by an Apogee SP-212 Amplified Pyranometer. The data were block averaged into 10-min intervals and recorded by a data logger (CR211X, Campbell Scientific). These two Campbell Scientific weather stations were mounted on existing poles. For the Fern Gully and Guilfoyle's Volcano, a Kestrel 4400 heat stress tracker was used to measure air temperature, globe temperature, relative humidity and wind speed at 1-min intervals. All logging equipment was positioned at approximately 1.3 m above the ground, except for the Terrace site (2.3 m). Calibration was done in a climate laboratory between the Campbell Scientific and Kestrel weather stations. Campbell CR3000 was used to connect with four Vaisala HMP155 temperature and relative humidity probes. After that, two Kestrel 4400 Heat Stress trackers were attached to the HMP155 probes. There was no statistically significant difference between the sensors in terms of temperature. The range of differences was up to 0.3 °C. For relative humidity, there was statistically significant difference between different stations of up to 3 %. However, as the accuracy Kestrel station is ±3 %, the 3 % difference is still acceptable in the readings.

Field survey

Approvals for this research were obtained from the Monash University Human Research Ethics Committee and from the RBG Melbourne. A group of volunteers was recruited to conduct surveys with visitors over the age of 18 years about their thermal comfort. The survey used in this study is shown in the Appendix of this paper. A total of 2198 valid surveys were conducted at the RBG Melbourne. The survey was conducted from 10 am to 3 pm on Wednesdays, Fridays and weekends between 5 February and 16 February 2014. For the period 7–9 February, the survey ended at 12 pm because of heat-health concerns for the volunteers, with the temperatures reaching well over 40 °C. In addition, Fridays and weekends were chosen because of higher visitor numbers. During the survey period, there were many tour groups from China to the RBG Melbourne. Therefore, the survey was translated into Chinese to study a population that would otherwise remain unsurveyed. In total, 148 surveys were conducted in

Table 1 Descriptions of the survey sites in the RBG Melbourne

Study area	Descriptions	Surface of the survey site	Under shade?
O Gate	One of the main entrances in the western part of the garden towards the visitor centre, with some trees and grass.	Asphalt/paving	Sometimes
Fern Gully	A natural gully with ferns located at the centre of the garden, with a misting irrigation system.	Asphalt/paving	Yes
Terrace (tea room)	Grassland with limited tree shade in the north part of the garden, next to an ornamental lake and a tea room.	Mostly grass, sometimes asphalt	Sometimes
Guilfoyle's Volcano	An exposed site in the eastern part and the highest elevation point of the garden. The main plant species are low-water use plants such as cactus.	Asphalt/paving	No

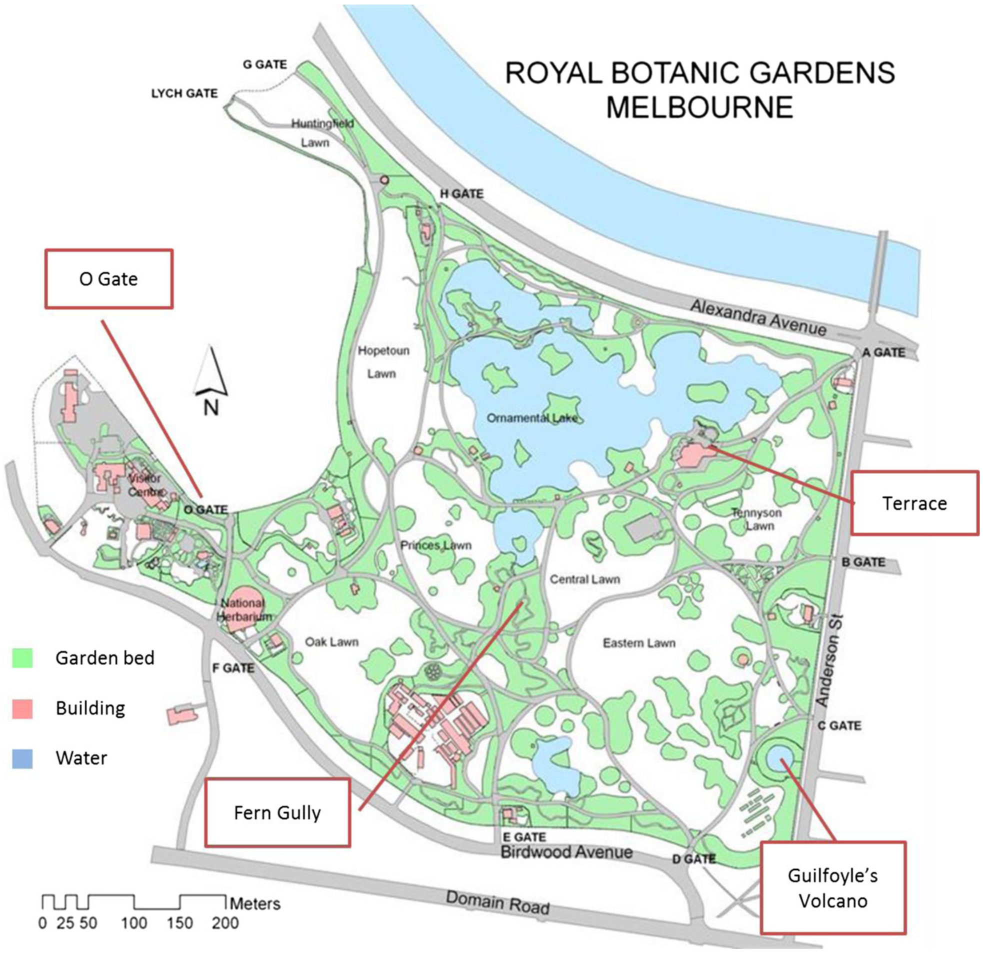

Fig. 1 The study area (reproduced with the permission of RBG Victoria)

Chinese. The translated survey provided a unique understanding of how Chinese tourists perceive thermal comfort in Australia.

Information about the visitors' demographic background, the perception and preference of current thermal and shading conditions, clothing, activities and purpose of visit were

Fig. 2 Overview of the study area. **a** O Gate, **b** Terrace, **c** Fern Gully, and **d** Guilfoyle's Volcano

obtained in the survey (see Appendix). The thermal perception was evaluated using the seven-point actual sensation votes (ASV), ranging from hot (+3) to cold (−3), with 0 being neutral. Personal characteristics such as gender, age, country of origin, clothing and activity were also obtained. Table 2 shows the assumed clothing insulation values (clo) of various garments worn by visitors to the botanic garden. Clothing insulation is the thermal insulation provided by clothing (Parsons 2003). One clo refers to the amount of clothing required to keep a person sitting comfortably at 21 °C (Parsons 2003).

Data analysis

The analysis focused on the ASV in which visitors indicated their thermal sensation. ASV can be considered as a dependent variable whereas weather, personal and psychological factors are the independent variables that influence ASV. One-way analysis of variance (ANOVA) was used in SPSS 21 (IBM Corp. 2012) to determine whether there were any significant differences between the thermal perception of visitors from various origins. Similarly, ANOVA was used to compare thermal perception at various garden locations. As clothing affects thermal perception, ANOVA was used to determine the differences of clothing behaviour of visitors from different origins in the RBG Melbourne. Independent *t* tests were used to compare the differences of thermal perception stratified by gender and age (≤65 and >65 years) in the RBG Melbourne. A *p* value of less than 0.05 was considered significant.

Apparent temperature (AT) incorporates wind speed and moisture characteristics to calculate the human perceived air temperature in terms of discomfort (Steadman 1994). AT was chosen over more sophisticated thermal indices (for example, PET and UTCI) because it is easier for the garden management to understand and use. Upon further analysis, it was found that the underlying results and conclusion are insensitive to whether AT or UTCI was used. The following equation in Bröde et al. (2012) was used to upscale the wind speed data from the original weather station height to 10 m above ground, since 10 m is what the Steadman equation requires.

$$\mathrm{ws}_{10\mathrm{m}} = \mathrm{ws}_{x\mathrm{m}} \mathrm{x\ LOG}\ (10/0.01)/\mathrm{LOG}\ (x/0.01)$$

where *x* is the original weather station height

Table 2 Individual clothing garments: dry thermal insulation values (Parsons 2003). The clo values for underwear are derived from Spagnolo and de Dear (2003)

Garment description	Thermal insulation clo (I_{clo})
Underwear (male—men's brief)	0.04
Underwear (female—bra and panties)	0.04
Shorts	0.06
Short skirt	0.15
Jeans/long pants/long skirt	0.25
Jumper	0.28
Jacket	0.25
Shoes	0.04
Socks	0.02
Vest	0.20
Singlet top	0.12
Shirt (long sleeves)	0.25
Shirt (short sleeves)	0.15
Sandals/thongs	0.02

Results

Recorded meteorological conditions

Table 3 summarizes the recorded meteorological conditions during the days when the surveys were conducted (5 February 2014 to 16 February 2014). O Gate was chosen as the representative site for meteorological conditions because it is the main entrance to the RBG Melbourne. There was no rainfall throughout the survey period except for 16 February (4.2 mm).

Respondent characteristics

Table 4 presents the respondent characteristics. Although the overseas visitors were fewer than local Australian visitors, they had a large enough sample size for meaningful comparison.

Table 5 shows the survey location, daily total visitors and survey sample size on each of the fieldwork days in the RBG Melbourne. The sites were selected to represent a wide range of vegetation and microclimate environments. Daily total visitors were obtained from the Visitor Monitoring Report from the Royal Botanic Garden (Smith 2014).

Cooling and shade preference

There was a bell curve distribution with neutral having the highest percentage of visitors preferring no change in cooling or shade (Fig. 3). Visitors who preferred to be warmer decreased from 23.8 % when they felt cool to 1.1 % for when they felt hot. There were two visitors who voted cold (ASV = 3) during the survey period, and both of them preferred to be warmer. Visitors who preferred no change in shading decreased with an increase in temperature (Fig. 4). The percentage of visitors preferring no change in shading decreased rapidly after temperature exceeded 28.3 °C.

Table 3 Meteorological conditions during the survey days. The data is based on the weather station at the O Gate

Date (2014)	Air temp (°C)			Relative humidity (%)			Wind speed (m/s)			Solar radiation (W/m^2)	
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Max
5 Feb	21.0	11.7	31.2	61.7	30.1	81.5	1.0	0.0	2.3	297.5	993.0
7 Feb	25.5	18.5	36.7	55.1	22.8	83.8	0.8	0.0	1.8	276.4	1009.7
8 Feb	27.1	17.0	41.0	58.8	20.2	92.6	0.3	0.0	1.2	290.9	985.0
9 Feb	27.4	18.2	40.6	40.4	14.1	70.4	1.5	0.0	2.6	262.2	973.8
12 Feb	21.3	15.5	26.4	75.7	57.3	94.5	0.4	0.0	1.4	222.9	900.2
14 Feb	22.4	17.5	25.7	76.4	57.1	92.9	0.2	0.0	0.7	135.1	508.2
15 Feb	23.0	19.9	29.0	75.9	55.2	88.9	0.4	0.0	1.1	164.4	1012.5
16 Feb	19.1	16.3	22.9	76.4	56.1	94.8	1.1	0.5	1.8	201.1	1033.4

Visitors' origin affected their thermal preference and clothing behaviour. Figure 5 shows that 36.8 % of European ($n=87$) and 25 % of North American ($n=8$) visitors preferred no change in temperature when they felt hot, compared with only 12.2 % of Australian ($n=180$) and 7.5 % for Chinese ($n=53$) visitors. It is noteworthy that the number of North American tourists that were surveyed dropped substantially after the temperature exceeded 28.4 °C. Figure 6 shows that Chinese visitors and Australians wore significantly more clothing than European visitors (higher mean clo). Wearing more clothes might explain the higher percentage of Chinese who wanted to be cooler when they felt hot.

Table 4 Survey respondent characteristics at the RBG Melbourne

Characteristics		*n*	Percentage
Gender	Female	1246	57.7
	Male	915	42.3
Age	18–24	262	12.1
	25–44	815	37.7
	45–64	699	32.3
	65+	388	17.9
Area of origin	Australia	1376	63.1
	China	189	8.7
	Europe	428	19.6
	North America	93	4.3
	Other area	96	4.4
Activity 5–10 min prior to survey	Lying down	17	0.8
	Sitting	391	17.9
	Standing	103	4.7
	Walking	1632	74.9
	Running	23	1.1
	Other	13	0.6
Exposure 5–10 min prior to survey	Outdoor, exposed	1081	49.6
	Outdoor, shaded	916	42.0
	Indoor (no air-conditioning)	65	3.0
	Air-conditioned	119	5.5

Interestingly, visitors' purpose for visiting the RBG Melbourne appeared to influence their thermal preference when they felt hot (Fig. 7). When the tourist's purpose was to relax and admire the garden's scenery ($n=141$), 21.3 % preferred no change in temperature. In contrast, only 10.2 % of visitors preferred no temperature change if their purpose was spending time with family and friends ($n=87$). These results indicate that people who came to admire the garden's scenery appear to have a higher heat tolerance than visitors who came to spend time with family and friends.

Thermal sensation vote (perception)

Gender difference in thermal perception was observed for visitors under 65 years, but not for those over 65 years. Female visitors generally felt hotter than male visitors (higher mean ASV) between 24.2 and 40.6 °C (Fig. 8). When temperature was above 24.2 °C, female's ASV (1.79 ± 1.03, $n=716$) was significantly higher than male's ASV (1.60 ± 1.04, $n=544$) across all age groups, $t\,(1258)=-3.356$, $p=0.001$. The gender difference also varied between age groups. Considering visitors ≤65 years, the ASV of female visitors (2.44 ± 0.76, $n=140$) was also significantly higher than male visitors (2.22 ± 0.79, $n=102$) when temperature exceeded 32.4 °C, $t\,(240)=-2.254$, $p=0.025$ (Fig. 8). In the same temperature range, there were no statistically significant differences between male and female visitors ≥65 years ($p=0.128$). Female visitors started to feel warm (ASV = 2) between 28.4 and 32.4 °C, whereas male visitors started to feel warm between 32.5 and 36.5 °C (Fig. 8).

In terms of clothing insulation value (clo), there was a sharp decrease after the temperature exceeded 20 °C. Clo values reduced to around 0.35 between 24.2 and 40.6 °C (Fig. 9). These clo values correspond to a person wearing a T-shirt with shorts and shoes. Overall, there was no significant difference between the clothing worn by women and men in the garden.

Cultural difference in thermal perception was found in different groups of visitors. Chinese and European tourists were selected and compared with local Australian visitors. Overall,

Table 5 RBG Melbourne survey summary

Survey date	Survey locations	Daily total visitors	Survey sample size
5/2/14 (Wed)	O Gate, FG, T, Volcano	5704	366
7/2/14 (Fri)	O Gate, FG, T, Volcano	6878	249[a]
8/2/14 (Sat)	O Gate, FG, Volcano	5027	115[a]
9/2/14 (Sun)	O Gate, FG, T, Volcano	7067	192[a]
12/2/14 (Wed)	O Gate, FG, T, Volcano	4960	321
14/2/14 (Fri)	O Gate, FG, T, Volcano	6750	270
15/2/14 (Sat)	O Gate, FG, T, Volcano	6532	326
16/2/14 (Sun)	O Gate, FG, T, Volcano	7108	359
Total			2198

FG Fern Gully, *T* Terrace (tea room), *Volcano* Guilfoyle's Volcano

[a] Volunteers went home at 12 pm because of high temperature (>40 °C) and occupational health and safety concerns

European visitors felt significantly hotter across most AT ranges, whereas Chinese visitors felt significantly cooler than other visitors (Fig. 10). The downward trend for North American tourists after 32.4 °C is due to a very small sample size ($n = 8$) and cannot therefore be considered a representative sample.

There was a subtle difference in visitors' thermal perception for the four survey locations (Fig. 11). Visitors felt the hottest at the O Gate and coolest in Fern Gully. Visitors generally felt neutral (ASV = 0) when AT was between 16.3 and 20.3 °C. Visitors also reported a higher ASV in the O Gate when AT was between 24.4 and 32.3 °C. For Guilfoyle's Volcano, visitors felt slightly warm consistently when AT was between 20.4 °C and 32.3 °C ($n = 238$). After 32.4 °C, visitors generally started to feel warm to hot ($n = 20$). The same magnitude of increase in ASV between 32.4 and 36.3 °C was also observed for all other survey locations. When AT was between 32.4 and 36.3 °C, the mean ASV reported at Fern Gully was significantly lower than the other three survey locations.

Discussion

In terms of people's preference for shading and cooling, the response from the visitors agrees with the findings of

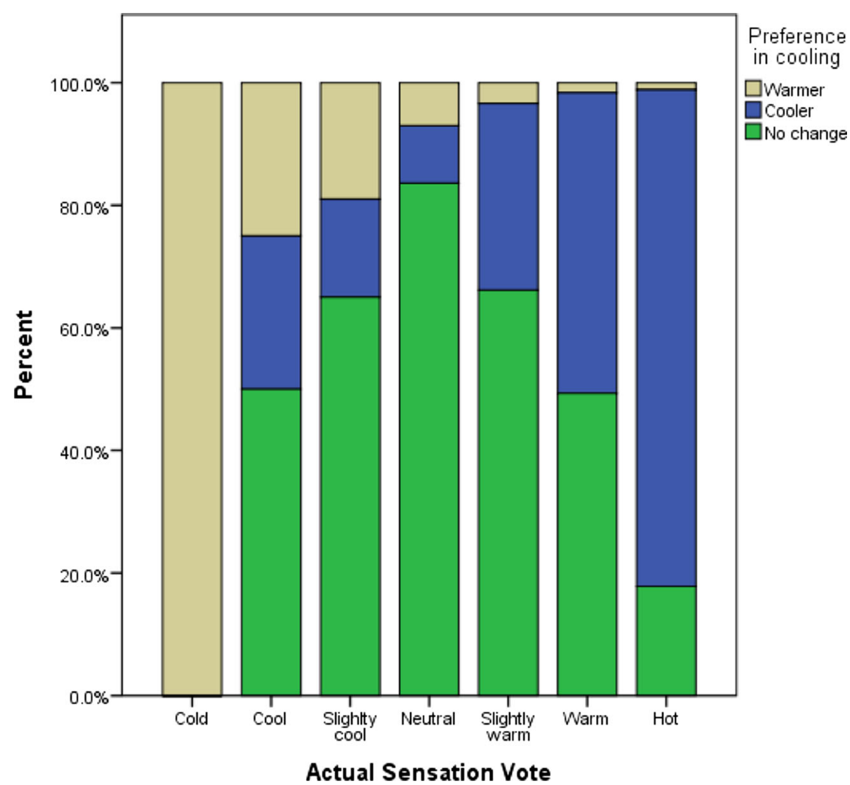

Fig. 3 Thermal preference votes based on perceived thermal sensation

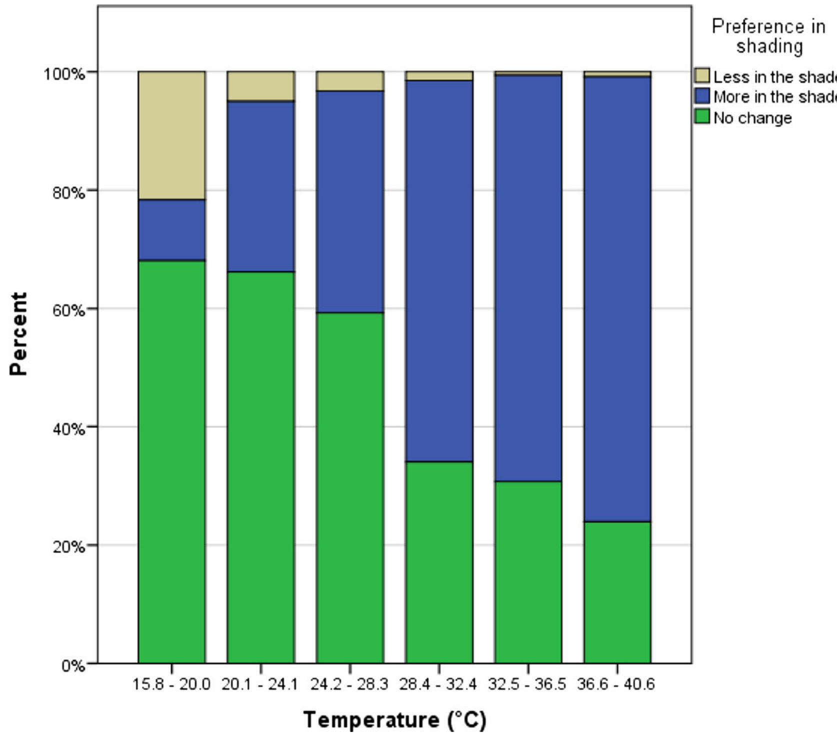

Fig. 4 Preference in shading for recorded temperature

Pantavou et al. (2013). Most visitors were satisfied with the thermal environment when they felt neutral. About half of the visitors (49.1 %) still preferred no change in the thermal sensation when they felt cool or warm (Fig. 3). When visitors felt hot, substantially more respondents (81.1 %) indicated that they wanted the environment to be cooler (Fig. 3). Comparing ASV of −1 and −2 to +1 and +2, the percentage of preferring no change was similar. However, more visitors wanted to be cooler in the warmer thermal sensation (+1, +2) than those who wanted to be warmer in the cooler thermal sensation

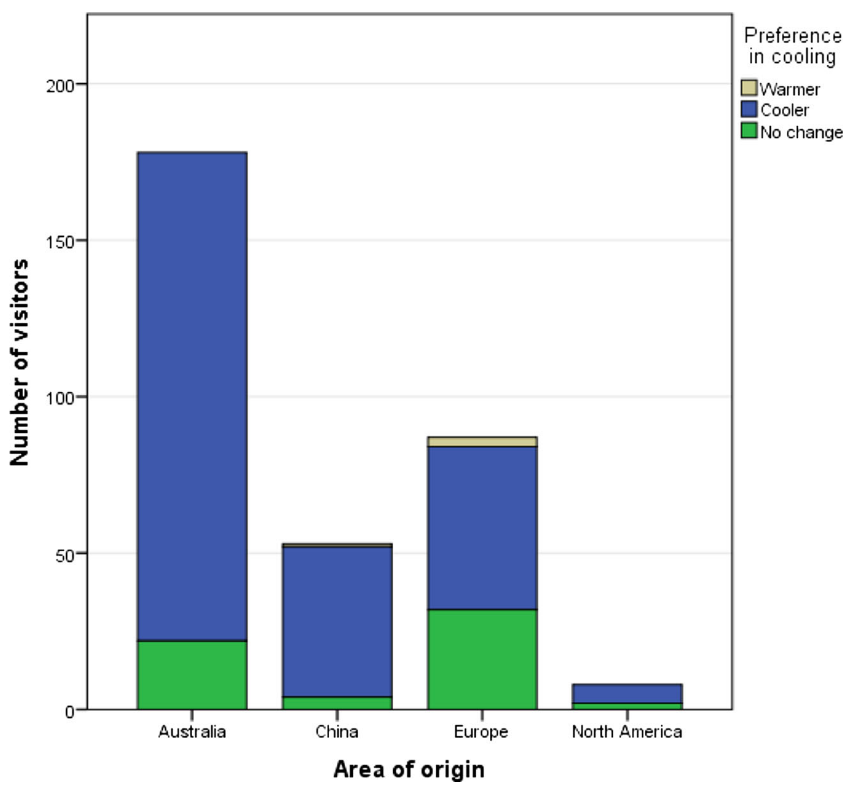

Fig. 5 Preference in cooling when visitors felt hot (ASV = 3), divided by visitors' origin

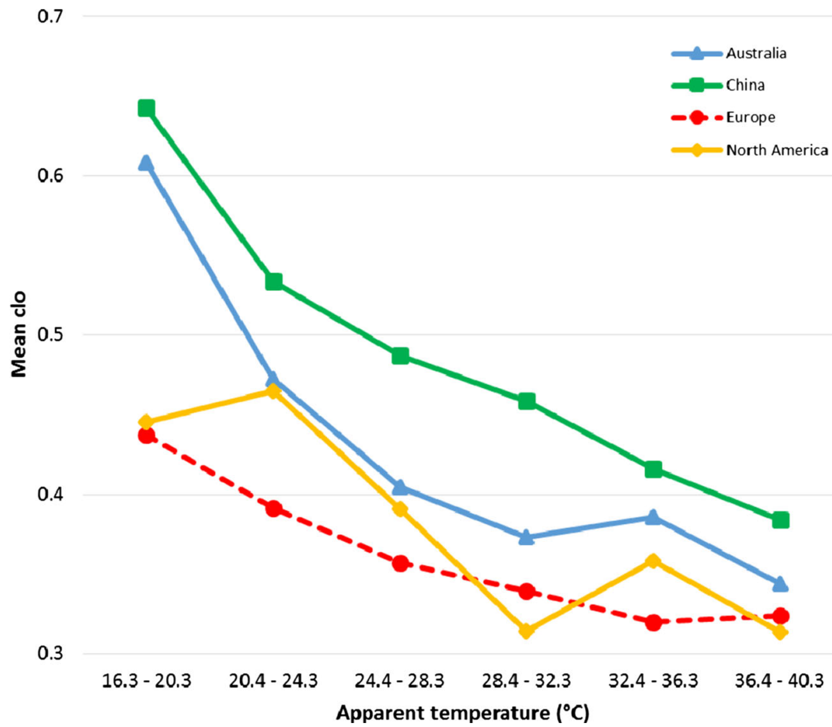

Fig. 6 Clothing insulation (clo units) worn by visitors from different origins for each AT range

(−1, −2) (Fig. 3). These results suggest that visitors are more sensitive to heat and desire to be cooler rather than warmer in summer conditions. In terms of preference for shading, visitors who voted for 'no change' dropped substantially from 59.1 % (temperature 24.2–28.3 °C) to 33.8 % (temperature 28.4–32.4 °C) (Fig. 4). This reduction shows that there is a threshold temperature where people prefer more shading in the garden environment. As ASV increases, people prefer more shading and cooling.

Our results indicate that the country of origin affects the thermal preference of visitors. Previous studies identified 'slightly cool', 'neutral' and 'slightly warm' as the thermally

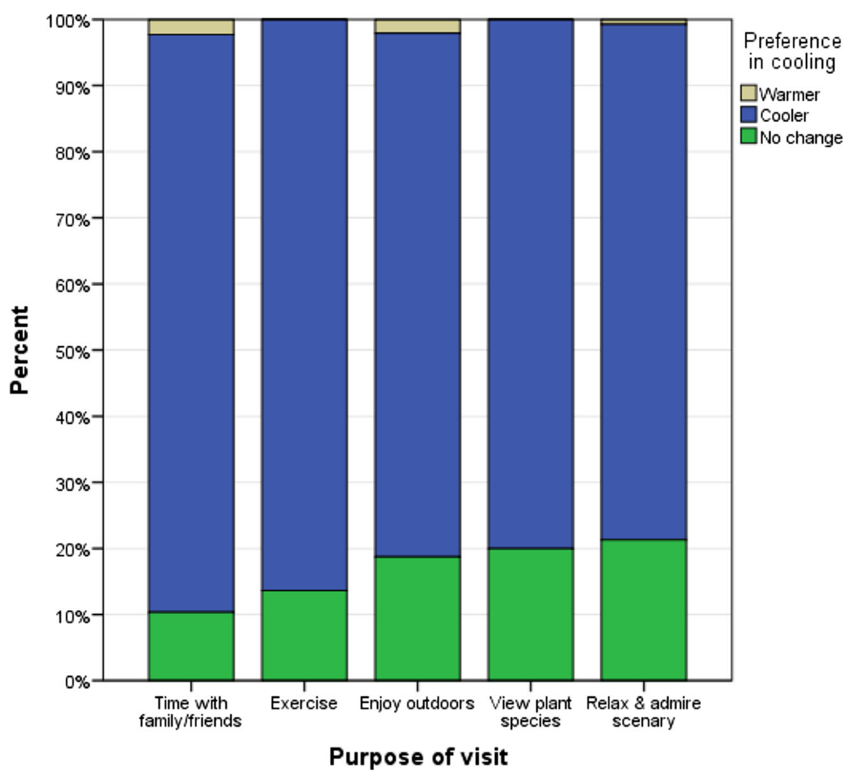

Fig. 7 Thermal preference when visitors felt hot (+3), stratified by purpose of visit

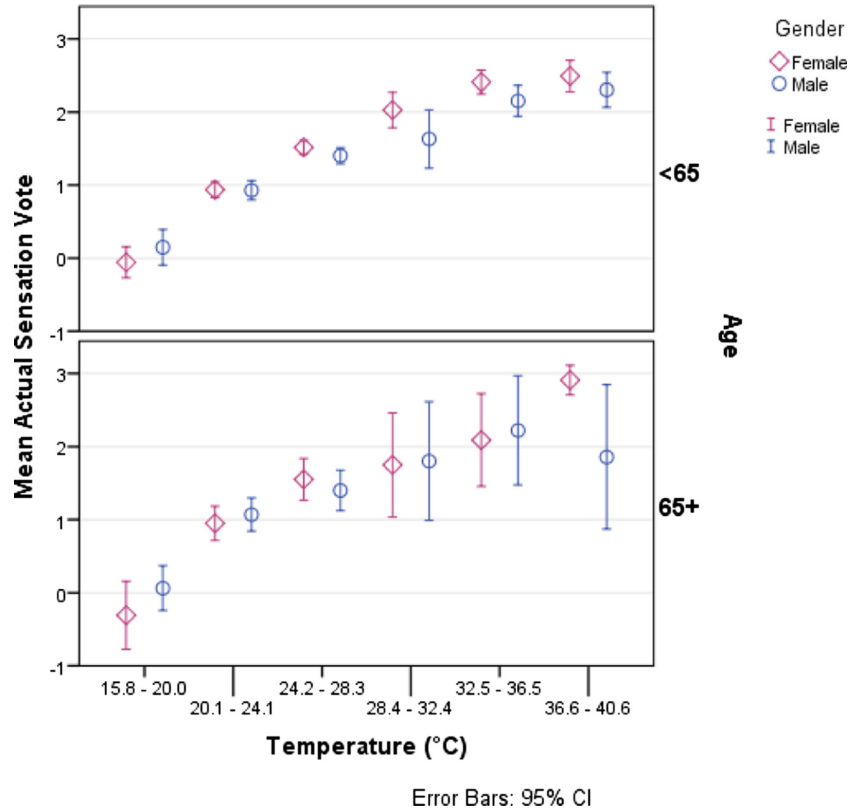

Fig. 8 The relationship between the mean actual sensation vote and air temperature in the cases of male and female visitors with different age group

comfortable range for tourists (de Dear and Fountain 1994; Lin 2009). Rutty and Scott (2015) showed that the thermal preference of visitors to the beaches in the Caribbean is very different from the thermal comfortable range in the literature.

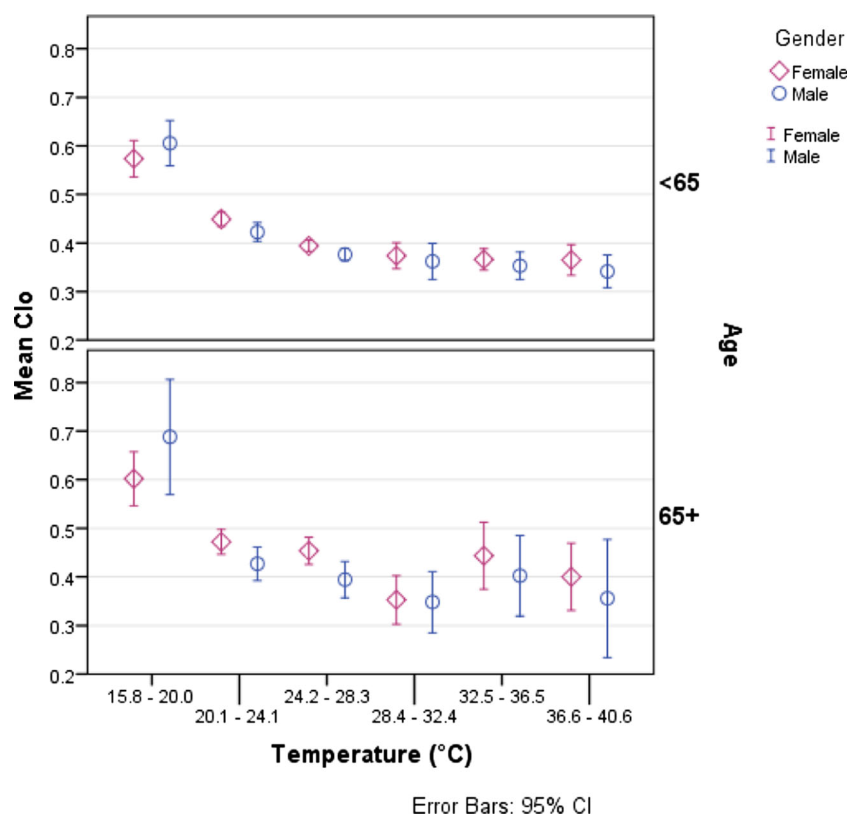

Fig. 9 The relationship between the clothing insulation (clo) and temperature in the cases of male and female visitors with different age groups

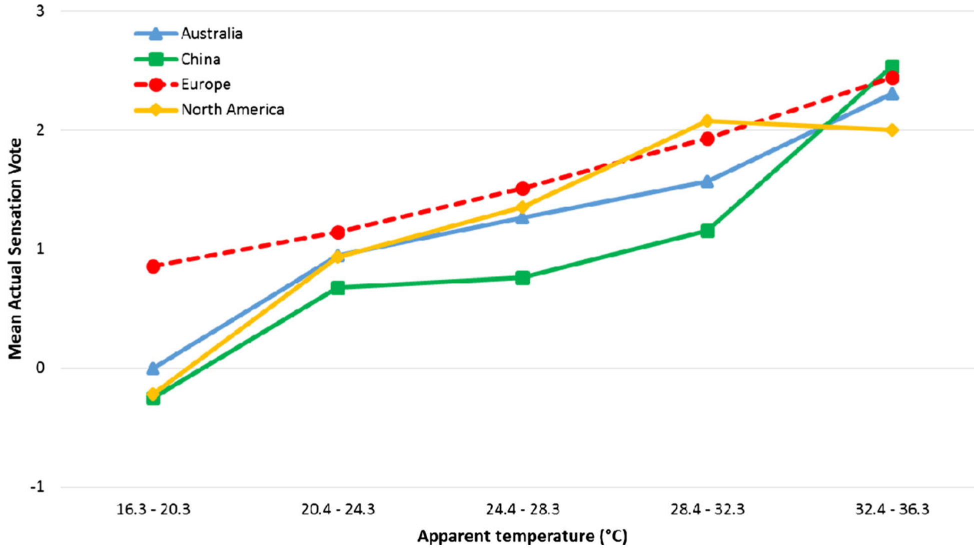

Fig. 10 Visitor's thermal sensation from selected country of origin

In particular, even when the beach tourists felt hot, the majority of tourist voted no change (Rutty and Scott 2015). Similarly, some European and North American visitors to the RBG Melbourne voted no change in terms of cooling preference even when they felt hot (Fig. 5). These visitors also wore less clothing compared with Australian visitors (Fig. 6). This response reveals the differences in the expectation of local and overseas visitors, who mostly came from a Northern Hemisphere winter (USA, Europe) during the survey period.

Although Chinese tourists also travelled from the Northern Hemisphere, it appears that they have different expectation compared with European and North American tourists. In particular, when Chinese tourists felt hot, 90 % of them preferred to be cooler and the Chinese survey respondents were mainly below 65 years old (91.1 %). As overseas visitors mainly receive the information about holiday destinations from sources such as travel agents and websites, their expectation of what is considered to be comfortable can be different from local Australians (Gómez Martín 2005). In particular, many tourists from temperate regions travel to warmer places to seek sunny, warm weather (Gómez Martín 2005; Rutty and Scott 2015) and are likely disappointed if their expectations are not met. It is also interesting to note that only eight North American tourists were surveyed in hotter weather (AT ≥32.4 °C), compared with European ($n = 60$), Chinese ($n = 42$) and Australian visitors ($n = 159$). It is possible that visitors from North America avoided coming to the garden in extreme heat conditions due to their greater knowledge of heat warnings in the USA (Sheridan 2007). A heat warning system was already in place in Melbourne during the time of this study. When North Americans receive heat warnings, they are used to staying indoors with air-conditioning (Sheridan 2007). Emphasizing cooler places to visit in the garden such

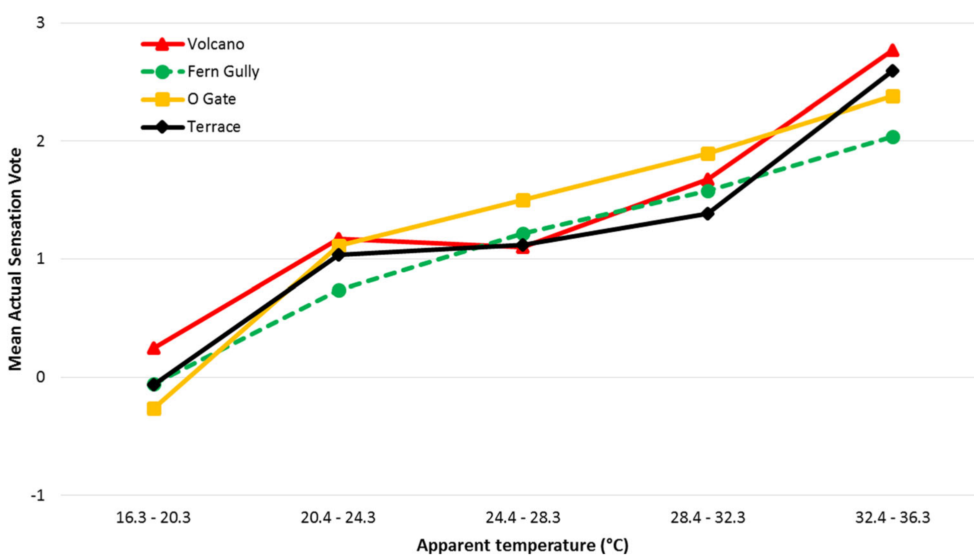

Fig. 11 Mean actual sensation vote (ASV) in different garden locations

as the Fern Gully could potentially attract more visitors from North America.

Clothing is another major factor in visitors' thermal sensation in the garden. When the temperature was greater than 32.4 °C, there also appears to be a threshold for how much clothing people wear (Fig 9). As the temperature increases, the clothing level reaches a minimal socially acceptable limit and clothing thus remains at a similar level. This phenomenon is known as 'adaptive saturation' (Mishra and Ramgopal 2013, p. 102). Adaptive saturation can explain why women wear more clothing than men at higher temperatures and possibly feeling hotter. Gender difference in clothing was not observed, which is similar to the finding of Spagnolo and de Dear (2003).

Chinese tourists generally wore more clothes than visitors from other countries (Fig. 6). From the observation during fieldwork, most Chinese tourists came in tour groups. It is speculated that the temperature was likely to be cooler in the morning when they left the hotel, and the Chinese tourists wore more clothing. During the survey, some of the Chinese tourists might be reluctant to remove their extra clothing to avoid getting a darker skin tone and solar UV radiation, especially for females (Tung et al. 2014). On the contrary, European tourists wore less clothing than visitors from other countries (Fig. 6). It is possible that they prefer to develop a suntan (Bränström et al. 2001) or want to cool off. After more than 30 years of education campaigns around sun protection in Australia, there were fewer Australians who prefer suntanned skin (Makin et al. 2013; Dobbinson et al. 2015). In the last decade, the percentage of Australians who prefer to get a suntan has reduced by 20–30 %, mainly due to education and advertisement campaign such as the SunSmart program (Volkov et al. 2013; Dobbinson et al. 2015). However, according to recent studies, the percentage of Australians desiring suntanned skin was still about 30 % (Volkov et al. 2013; Cancer Council Victoria 2015). The figure was even higher (45 %) among Australian adolescents (aged 12–17 years) (Volkov et al. 2013). This public attitude towards sun exposure might explain why certain Australians wore less clothing at higher AT. Normally people who wear less clothing feel cooler (Liu et al. 2013), but this is not the case for the Europeans in this study. For instance, when AT was between 24.4 and 28.3 °C, the mean ASV of European, North American and Australian visitors was significantly higher than that of Chinese visitors. This finding is in agreement with a Melbourne study conducted by Kenawy and Elkadi (2013). It is likely that Europeans, North Americans and Australians have greater body and muscle mass, which lead to higher metabolism (de Boer et al. 1988) and subsequently higher ASV.

It is interesting that the purpose of visit affects the thermal preference of visitors when they feel hot. Activity prior to the survey was similar across different reasons to visit the garden. Previous studies have showed that visitors with a greater autonomy in deciding to visit a public place have a greater tolerance for heat (Chen and Ng 2012; Lin 2009). Visitors who visited the garden with family or friends might have less autonomy in their decision to visit the garden, because the individual might prefer going to somewhere else on a hot day. It is probable that this group of visitors was less tolerant of hot conditions. In contrast, visitors with the purpose of relaxing and admiring the garden's scenery were more tolerant to heat, as indicated by 21.3 % of people who voted 'no change' (Fig. 7). These visitors decided to visit the garden even on a hot day, showing that they felt they were more prepared for hot weather and hence were more tolerant of heat. This result agrees with the findings of Lin (2009), who suggested that people coming to rest have the highest autonomy. Different visitors carry various expectations to the garden, especially when they decide to visit the garden on a hot summer day. With this in mind, the garden manager could modify the design of the garden to make visitors who come to spend time with family feel more comfortable (Fig. 7). Moreover, the garden can also provide advice to the visitors regarding outdoor exposure time and activity level on hot days. This could mean providing more shading or advice to tourists to visit certain cooler spots in the garden (de Freitas 2003). The garden can also work with tour agencies to design routes that allow visitors to pass through the Fern Gully and other rest houses for resting purposes on extremely hot days.

The role of gender is important to determine the efficiency of heat dissipation. Females appear to be less tolerant to the thermal environment than males at higher temperatures. This finding agrees with the meta-analysis of indoor studies by Karjalainen (2012) and an outdoor study in Taiwan by Tung et al. (2014). Lundgren et al. (2013) state that men can sustain exercise in extreme dry heat conditions due to their higher aerobic capacity. Males have higher maximal sweat rates and therefore dissipate heat more effectively (International Labour Organization 1998). This phenomenon means that males can tolerate extremely hot and dry environments better than females.

In contrast, females appear to be better at suppressing excess sweating and conserving body water, so they are more tolerant of humid heat (Lundgren et al. 2013). In agreement with Lundgren et al. (2013), Havenith (2001) states that women have lower heat stress due to their higher surface to mass ratio, which can explain why females tolerate humid heat better than males. The menstrual cycle and menopause may also affect the females' thermoregulation (Havenith 2005). For example, postmenopausal women have been observed to have a higher core temperature than younger women at equal stress and fitness levels (Havenith 2005). In short, our study indicates that women tend to feel hotter in a hot and dry summer in Melbourne due to their physiological differences from men and greater clothing levels.

Age adds another interesting dimension to the gender difference of thermal perception. In our study, this gender difference is observed for visitors below 65 years but not for those over 65 years. When temperature exceeded 32.4 °C, the mean

ASV of female visitors 65+ years (2.50) was higher than male visitors 65+ years (2.06), although the differences were not statistically significant due to the small sample size ($n = 39$). With a larger sample size for visitors 65+ years, it may reach statistically significant differences. This issue warrants further study because female visitors 65+ years might require more adaptive actions to heat than male visitors 65+ years. If female visitors 65+ years are satisfied with the garden environment at high temperatures, then it is very likely that male visitors 65+ years are also satisfied.

Acclimatization plays a major role in affecting the range of thermal perception. Chinese tourists appear to feel cooler than Australian, European and North American tourists at a lower AT range (20.4 to 28.3 °C) (Fig. 10). However, Australian visitors felt cooler than Chinese and European tourists when AT was between 28.4 and 32.3 °C (Fig. 10). This is possibly due to acclimatization and its associated reduced strain from heat exposure (Nikolopoulou and Steemers 2003). This difference shows that the foreign tourists are less acclimatized to the extreme heat conditions in Melbourne during summer. Visitors who are unacclimatized have a higher risk of developing heat illnesses. It is important for gardens to recognize this heat-health issue and employ measures to protect visitors from heat stress. For example, gardens can provide temporary shading at exposed locations and provide water fountain to prevent dehydration.

The garden's different site characteristics and microclimate also influence the perceived thermal comfort of visitors. This is possibly due to the differences in vegetation in various sites, as noted by Irmak et al. (2013). At a higher AT range (32.4 to 36.3 °C), Guilfoyle's Volcano was perceived to be hotter than other locations and Fern Gully was perceived to be the coolest (Fig. 11). Over the entire observation period, Guilfoyle's Volcano had the highest maximum temperature (44.4 °C), whereas the lowest maximum temperature was recorded at Fern Gully (41.2 °C). The difference in visitors' thermal perception is likely to be explained by the differences in vegetation and moisture availability, and prior exposure and activity. Guilfoyle's Volcano is located at the highest point and one of the most exposed locations in the garden. Visitors need to walk up the slope to reach the Guilfoyle's Volcano, resulting in a higher metabolic rate compared with other locations. At the higher AT range (32.4 to 36.3 °C), the mean ASV appears to be similar in every survey location except for Fern Gully (Fig. 11). Since Fern Gully has a misting irrigation system, it cools the temperature in hot weather. In addition, it is a well-shaded environment compared with the other survey locations. This setting demonstrates that Fern Gully provides cooling benefits for visitors during hot weather. The mean ASV of the O Gate was generally higher than the other survey locations when AT was between 24.4 and 32.3 °C (Fig. 11). Visitors who exited the O Gate ($n = 694$) might have had a longer exposure to the sun in the garden compared with other locations, so they probably perceive the temperature to be higher. Twenty visitors at the O Gate mentioned they came to visit the children's garden. In addition, 218 visitors at the O Gate said they came to spend time with family and friends. Based on question 6 of the survey, we speculated that about 30 % of visitors surveyed at the O Gate had recently exited the children's garden. It is also possible that those visitors had a prolonged exposure to sun at the children's garden, which has limited shading. Overall, the differences in microclimate in the garden affect visitors' thermal perception.

Conclusion

This study provides empirical evidence of the relative thermal comfort perception of visitors from different countries. As the Royal Botanic Garden Melbourne has a diverse microclimate, this study offers new insight into the roles of various factors that affect overseas visitors' thermal comfort perception. Since the garden visitors travelled from various climate zones, their clothing behaviour differs. It is important to appreciate how cultural and ethnic differences in dress affect the thermal comfort of visitors in the garden. Our study results indicate that foreign visitors have fundamentally different thermal preferences and sensations compared with Australian visitors, especially during hot weather.

Understanding the variability of temperature and thermal comfort in the botanic garden can improve the garden design, and it allows the garden management to prepare for future changes in climate. It is necessary for microclimate and thermal comfort to play a bigger role in landscape and urban planning. In light of the future rising temperature, this study can be used to inform garden landscape planning and ultimately improve visitor comfort levels in hot weather, which in turn will improve the garden's long-term sustainability.

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Appendix 1

MONASH University

Outdoor human thermal comfort survey

Date: ___/___/____ **Time:** ____:____am/pm **Survey location:**______________________

Gender: ☐₁ Male ☐₀ Female **Age** ☐₁ 18-24 / ☐₂ 25-44 / ☐₃ 45-64 / ☐₄ 65+

Country /Postcode: ________________________

Question 1: please circle how you feel now

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
-3	-2	-1	0	1	2	3

Question 1b: Would you like to be

☐1 Warmer ☐0 No change ☐-1 Cooler

Question 2: For today, would you like to be

☐1 More in the shade ☐0 No change ☐-1 Less in the shade

Question 2b: Which garden location would you like more shade?

Question 3: please tick ALL clothing of the person

Upper body:	☐ Hat ☐ Vest ☐ Singlet top	☐ Jumper ☐ Jacket ☐ Long sleeved shirt ☐ Short sleeved shirt / T-shirt
Lower body:	☐ Shorts ☐ Short skirt	☐ Jeans ☐ Other long pants ☐ Long skirt
Footwear:	☐ Shoes ☐ Socks	☐ Sandals ☐ Thongs

*DRESS = SHORT/LONG SLEEVED SHIRT/SINGLET TOP + SHORT/LONG SKIRT

Question 4: Activity 5-10 minutes prior

For the last 5-10 minutes have you been mainly

☐1 Lying down ☐2 Sitting ☐3 Standing ☐4 Walking ☐5 Running ☐6 Other (please specify):

Question 5: Exposure 5-10 minutes prior

For the last 5-10 minutes were you mainly in

☐1 Outdoor, exposed (in the sun) ☐2 Outdoor, shaded (including tree shade)

☐3 Indoor (no air conditioning) ☐4 Air-conditioned

Question 6: What is your main reason of visiting the garden? (Choose one option)

☐1 relaxation ☐2 garden's scenery ☐3 time with family/friends ☐4 enjoy outdoors ☐5 exercise

☐6 view plant species ☐7 Other reasons (please specify):__________________________

The questionnaire used in this study (modified from Spagnolo and de Dear 2003)

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