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Perceptions of thermal comfort in heatwave and non-heatwave conditions in Melbourne, Australia

Cho Kwong Charlie Lam [a,b,*], Ailie J.E. Gallant [a,b], Nigel J. Tapper [a,b]

[a] School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia
[b] CRC for Water Sensitive Cities, Melbourne, Australia

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ABSTRACT

Heatwaves can cause discomfort and illnesses due to heat stress. However, how people perceive thermal comfort and adapt to extreme heat conditions on heatwave days is uncertain. Most outdoor thermal comfort studies have been conducted under non-extreme conditions and very few during heatwaves. For those studies that encountered a heatwave, sample size tends to be small or modelling approaches were used to assess thermal comfort. It is important to understand people's perceptions in relation to the physiological experience during extreme heat, as it would help practitioners apply the extreme heat range of thermal indices in outdoor settings. To understand people's thermal perception and clothing behaviour during a heatwave, we combined meteorological measurements and thermal comfort surveys at two botanic gardens in Melbourne, Australia. The variations in respondents' thermal comfort and clothing are assessed during heatwave and non-heatwave conditions, where temperatures during heatwave conditions exceeded 36°C. We observed that local visitors felt significantly hotter and wore less clothing for the same ranges of the Universal Thermal Climate Index (UTCI) during heatwave than non-heatwave conditions. Thus, we suggest that thermal expectation influences changes in thermal perceptions and clothing, even over the course of several days to a week.

* Corresponding author at: School of Earth, Atmosphere and Environment, Monash University, Clayton, Australia.
E-mail address: cklam10@student.monash.edu (C.K.C. Lam)

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1. Introduction

Prolonged heatwaves can be particularly stressing on the human body both physiologically (Tian et al., 2011) and psychologically (Tawatsupa et al., 2010). Human thermal comfort indices have been designed to measure the thermal stress in different thermal conditions (Kampmann et al., 2012). These indices predict that people feel most uncomfortable during extreme temperature conditions, including extreme heat and extreme cold, as shown in indices such as the Universal Thermal Climate Index (UTCI) (Błażejczyk et al., 2010) and the physiological equivalent temperature (PET) (Matzarakis et al., 1999).

However, the reliability of these thermal comfort indices is not clear during extreme hot and cold conditions. Specifically, it is unclear whether people perceive outdoor thermal comfort differently during heatwaves, as many outdoor, observational thermal comfort studies have only been conducted in non-heatwave conditions (see Table 1). For example, the Rediscovering the Urban Realm and Open Spaces (RUROS) project has one of the largest thermal comfort survey datasets from across seven European cities (Nikolopoulou and Lykoudis, 2006), but their study period (2001–2002) did not coincide with heatwaves.

Previous heatwave studies in Australia have mainly examined the impact of heatwaves on hospital admission (Hansen et al., 2008; Bi et al., 2011), mortality (Nicholls et al., 2008), and indoor thermal comfort for residents (Saman et al., 2013; Soebarto and Bennetts, 2014). For the purpose of this study, heatwaves are defined as 'periods of three or more consecutive days when each day exceeds the calendar-day 90th percentile' (Perkins and Alexander, 2013: 4512). This study addresses the lack of outdoor thermal comfort research during heatwave conditions in Australia and uses UTCI for its analysis. It is important to examine thermal comfort during heatwaves, as it reveals how suitable thermal indices are in predicting thermal comfort in extreme heat conditions.

This study is a validation study of UTCI during heatwave conditions and this validation is necessary for two reasons. First, previous UTCI validation studies have been mostly conducted in the Northern Hemisphere. A number of authors claim that UTCI can be used in all climates, seasons and scales (Błażejczyk et al., 2010; Jendritzky et al., 2012; Bröde et al., 2013a). However, most UTCI validation studies have been conducted in Europe (Błażejczyk et al., 2010; Nowosad et al., 2013; Pantavou et al., 2013; Błażejczyk et al., 2014), Brazil (Bröde et al., 2012b; Bröde et al., 2013b), Canada (Provençal et al., 2016), Japan (Watanabe et al., 2014) and South Korea (Park et al., 2014). UTCI could perform differently in other climates. Melbourne is located in a warm temperate climate zone of the Southern Hemisphere with occasional extreme heat days exceeding 40 °C, which contrasts the more temperate climate of northern Europe where most studies have been performed. How the UTCI performs as a thermal index in the warm temperate climate of Australia is uncertain, since it was previously developed in a European context (Jendritzky et al., 2012).

Second, very few studies have validated UTCI for extreme heat conditions, which is one of the primary uses of the index. Past UTCI validation studies seldom encountered heatwaves (Bröde et al., 2012b; Pantavou et al., 2013; Park et al., 2014). An example of UTCI studies that used surveys during heatwaves is that of Pantavou et al. (2013). They found that 80% of survey respondents were dissatisfied with the thermal environment once UTCI exceeded 37.7 °C. Without comparing the thermal indices with survey data during heatwave conditions,

Table 1
Selected studies on outdoor, observational thermal comfort studies that focused on local residents.

Study area	Outdoor locations
Sydney, Australia	Outdoor & semi-outdoor locations (Spagnolo and de Dear, 2003)
Adelaide & Melbourne, Australia	Outdoor urban space (Loughnan et al., 2012)
Melbourne, Australia	Federation Square (Kenawy and Elkadi, 2013)
Phoenix, Arizona, USA	Neighbourhood area (Harlan et al., 2006; Hartz, 2012)
Lisbon, Portugal	Riverside area (Oliveira and Andrade, 2007; Andrade et al., 2011)
Göteborg, Sweden	Urban park (Thorsson et al., 2004)
Göteborg, Sweden & Matsudo, Japan	Public square (Knez and Thorsson, 2006)
Taichung, Yunlin and Chiayi, Taiwan	Public square (Lin, 2009; Lin et al., 2011)
Tianjin, China	Urban park (Lai et al., 2014)
Mendoza, Argentina	Central pedestrian streets (Ruiz and Correa, 2015)
Cairo, Egypt	Urban park (Mahmoud, 2011)