The comparison of thermal sensation and acceptable range for outdoor occupants between Mediterranean and subtropical climates

Tzu-Ping Lin[1*] Henrique Andrade[2] Ruey-Lung Hwang[3]
Sandra Oliveira[2] and Andreas Matzarakis[4]

[1]Department of Leisure Planning, National Formosa University, 64 Wen-hua Rd, Huwei, Yunlin 632, Taiwan.
[2]Centre of Geographical Studies, University of Lisbon, Faculdade de Letras, Alameda da Universidade, 1600-214, Lisboa, Portugal
[3]Department of Occupational Safety and Health, China Medical University, 91 Huseh-Shin Rd, Taichung 404, Taiwan
[4]Meteorological Institute, University of Freiburg, Werthmannstr. 10, D-79085 Freiburg, Germany.

1. INTRODUCTION

For multi-functional public places, activities are not confined to indoor spaces, with semi-outdoor and outdoor spaces also being utilized. Providing thermally comfortable outdoor environments is essential to urban parks, squares and open spaces in urban areas (Hwang and Lin, 2007). Nikolopoulou et al. (2001) found that the thermal environment conditions outdoors influenced significantly their usage rate. Given the difficulty of controlling the thermal conditions, individuals may have low expectations regarding the outdoor thermal comfort. Furthermore, people in different areas may have different thermal sensations or preferences even under the same climate conditions.

Although some detailed thermal comfortable prescriptions, such as ASHRAE Standard 55 (ASHRAE, 2004), ISO 7730 (1994) have been established for indoor environments, no prescriptions have yet been established regarding thermal comfort in outdoor environments. Furthermore, since people spend most of their time indoors, research concerned with thermal comfort has generally focused on indoor environments. Thermal comfort is the perception which expresses satisfaction with the thermal environment and should be assessed subjectively. Thermal comfort involves physiological and non-physiological factors. For example, thermal perception range may be wider in outdoor environments because the difficulty of modeling thermal conditions in these environments in order to make them as comfortable as indoor environments is recognized. Instead of the rational heat balance model, an adaptation model of thermal comfort, developed by de Dear and Brager (2002), which relates acceptable temperature ranges to meteorological parameters, is more appropriate for situations where non-physiological factors are important. Owing to the difficulty of quantifying non-physiological factors, field survey is recognized as the most appropriate investigative method. To understand the thermal comfort requirements in semi-outdoor and outdoor environments, this study carried out extensive field surveys and presents the findings.

Some researchers have investigated thermal comfort in semi-outdoor or outdoor environments. Spagnolo and de Dear (2003) found that the neutral standard effective temperature (SET*) for semi-outdoor and outdoor environments significantly exceeds the recommended value for indoor environments. Nakano and Tanabe (2004) examined thermal comfort requirements for semi-outdoor environments and demonstrated that occupants of semi-outdoor environments could tolerate a wider temperature range than indoors. Ahmed (2003) performed a comfort survey in an urban space and defined the boundaries of outdoor thermal comfort for tropical urban environments. Givoni et al. (2003) conducted the field experiments in outdoor environments and discussed the relationship of air temperature, solar radiation and wind speed with thermal sensation. Cheng and Ng (2006) developed the guideline of thermal comfort for urban Hong Kong based on the previous thermal comfort predicted formulas.

People in different areas may have different thermal sensations or preferences even under the same climate conditions. Lin and Matzarakis (2007; 2008) found that neutral temperature scale of Taiwan is higher than that of Western/central Europe. Furthermore, the PET range of Taiwan is larger than that of Western/central Europe for each thermal sensation scale.

In this research, two different climate regions have been chosen for the comparison: Portugal for the Mediterranean and Taiwan for the subtropics. Taiwan, located at 23º latitude N with hot-humid climate and Portugal, located at 40º latitude N with hot-dry summer and mild winter,

* Correspondence to: Tzu-Ping Lin, National Formosa University, 64 Wen-Hua Road, Yunlin 632, Taiwan

are the analyzed subjects. This research aims to compare thermal sensation/preference votes between these two regions, which have different climatic and cultural characteristics.

2. METHODS

2.1 PHYSICAL MEASUREMENTS

In Taiwan, micro-meteorological instruments, positioned on a tripod at a height of 1.1 m above the floor, were used for measurements and automatically collected data on thermal comfort parameters, including ambient air temperature, globe temperature, relative humidity, air velocity and global radiation. In Lisbon, measurements of air temperature, relative humidity, wind speed, solar and infra red radiation were taken in a very similar way to Taiwan. Mean radiant temperature was calculated from solar and infra red radiation, using the method described in Jendritzky and Nübler (1981); PET and SET* were also calculated.

2.2 QUESTIONNAIRE SURVEYS

People were asked to complete questionnaires while physical measurements were taken. The scope of the questionnaires was based on Appendix E: the Thermal Environment Survey in ASHRAE Standard 55 (ASHRAE, 2004). The questionnaire comprised three sections. The first section dealt with demographic information such as age, gender, activity level and the clothes the individuals were wearing. The second section then questioned people regarding their current thermal comfort status. The ASHRAE 7-point scales for thermal sensation vote (TSV, -3: cold, -2: cool, -1: slightly cool, 0: neutrality, 1: slightly warm, 2: warm and 3: hot), the 3-point McIntyre preference scales (Right now I “want cooler”, “want no change” or “want warmer”), and direct assessments of thermal dissatisfaction (“satisfied” or “dissatisfied”) were used to help respondents to rate their thermal sensations considering their current environment. Respondents were also asked to indicate their present sensations and general preferences regarding air movement and global radiation.

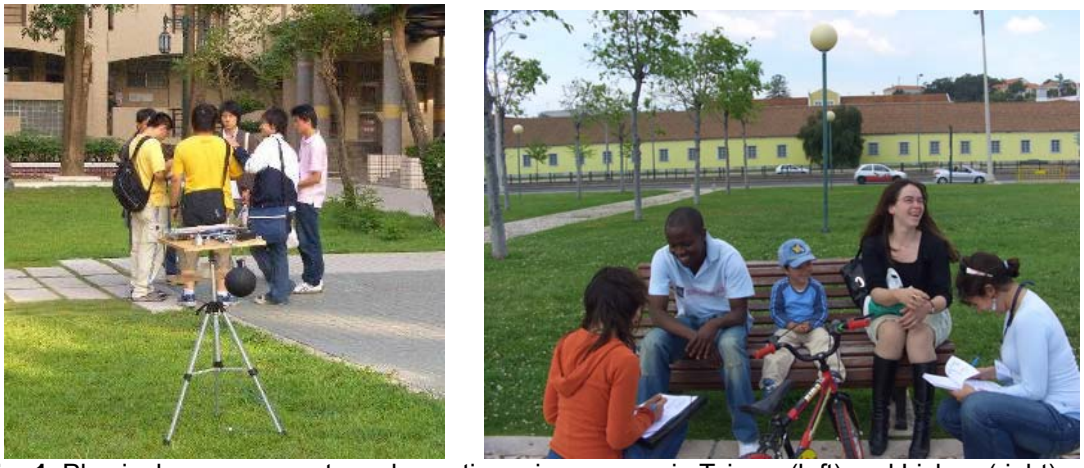

Fig. 1. Physical measurements and questionnaire surveys in Taiwan (left) and Lisbon (right)

3. RESULTS

In the field experiment, 1644 people are investigated in Taiwan during 2004-2006, while 1000 people are investigated in Lisbon during 2006-2007. The detail analysis of both places and their comparison are listed below.

3.1 THERMAL PREFERENCE BETWEEN DIFFERENT AGE GROUPS

Figure 2 displays thermal dissatisfaction in relation to temperature preference between different age groups in Taiwan and Lisbon. In Taiwan, similar conditions on “prefer higher temperature” for each age group were found, while more young people prefer lower temperature. In Lisbon, on the contrary, no significant difference for “prefer lower temperature” among different age groups, while young people “prefer higher temperature”.

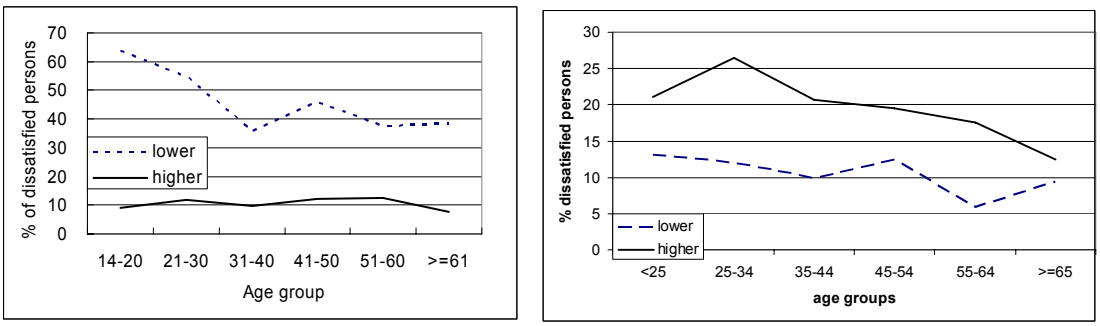

Fig. 2. Thermal dissatisfaction and preference between different age groups in Taiwan (left) and Lisbon (right)

3.2 PREFERENCES OF SOLAR RADIATION

Figure 3 shows the logistic model of Tmrt on solar radiation preference. Compared to people in Taiwan, this figure reveals that people in Lisbon can tolerate higher solar radiation.

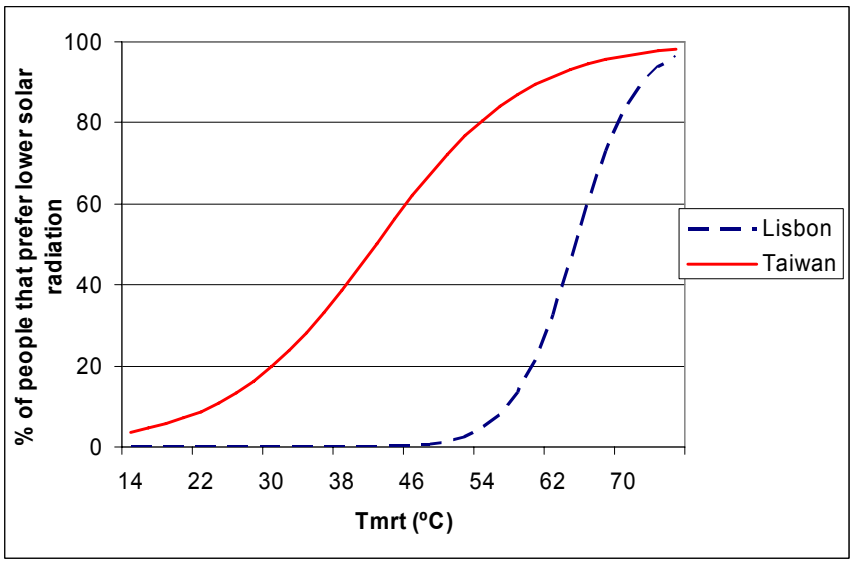

Fig. 3. Logistic model of Tmrt on solar radiation preference

3.4 PET ACCEPTABLE RAGE

Figure 4 shows the correlation of percentages of dissatisfaction and PET. The ASHRAE Standard 55 (ASHRAE, 2004) specifies the thermal environmental conditions which are acceptable to 80% or more of the occupants of a space. In Figure 4, the 80% acceptability limits are the intersections of the fitted curve and the 20% unacceptability line. It reveals that people in Taiwan have wider acceptable range than Lisbon.

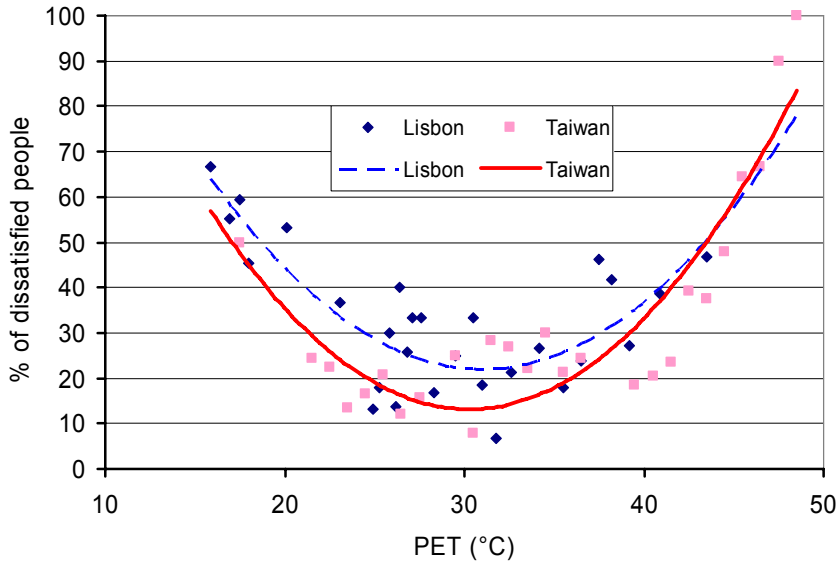

Fig. 4. Thermal acceptable range of PET in Taiwan and Lisbon

4. DISCUSSION

The results of the analysis of the thermal sensation, the thermal comfort range and the occupants' thermal preference reveal that significant differences exist between both climatic regions. Solar radiation is highly related to thermal sensation for Taiwan's people, while extreme wind speed plays an important role for Lisbon's people thermal perception. Furthermore, people in Taiwan can tolerate higher air temperature than Lisbon's people. The results display the thermal adaptation in different areas and demonstrate the importance of outdoor field survey data of the local people for the design of more comfortable outdoor spaces in urban areas.

5. CONCLUSION

While discussing the thermal environment in urban areas, it is important to offer the information of the user's thermal comfort range to understand their sensation and preference upon different thermal conditions. It is not proper to apply the criterion for one region to another one which has a different type of climate. The comparison of thermal sensation of people in Taiwan and Lisbon indicates that people have different thermal comfort ranges, maybe due to the climate, cultural aspects and experience.

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