



Adaptive Outdoor Thermal Comfort at an Urban Park in Malaysia

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Abstract

This paper clarifies the perceptive and adaptive mechanisms involved in an outdoor thermal comfort in hot, and humid condition. The method of the study was through microclimate measurement coupled with structured interviews of urban park users. The objective of this study is to identify the impacts of weather and personal factors on respondents' perceptual and sensation estimations. The findings on the significant influences of microclimate parameters and personal factors on the participants' perceptions of outdoor urban places are discussed. This study shows the respondents' thermal adaptation from physiological and psychological perspectives. The significance of the findings showed the importance of a sustainable urban park for continued use by future communities.

Keywords: Outdoor Thermal Comfort; Urban Park; Microclimate; Hot and Humid

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1.0 Introduction

Outdoor green spaces are important for a community's wellbeing. Parks and green spaces play a vital role to improve the health of the community and also mitigate the effects of climate change. Parks and green spaces should not only provide a place to recreate, but create the opportunity for psychological revitalization of daily life.

As green space should provide a healthy and comfortable environment for its users, it is reasonable to consider how people adapt to that environment. For instance, one of the most important ergonomic factor is thermal comfort, which is defined by, "the state of mind that expresses satisfaction with the surrounding environment" (ANSI/ASHRAE Standard 55, 2004). When designing an urban park, it is crucial to design it to be thermally comfortable for the users' satisfaction.

Adaptive thermal behaviours can be patterned by the user's behaviour towards thermal comfort; such as changing posture and clothes, using air-conditioner or avoiding the heat sources. When thermal stress or dissatisfaction still occurred despite attempted adaptations, the situation could become harmful to the users. Hence, the study of outdoor thermal comfort becomes crucial.

When designing sustainable green space, addressing outdoor thermal comfort and heat stress have become more a prevalent focus. Therefore, the physiological and psychological impact should have been taken into account when designing green spaces. Previous studies described thermal comfort as a fundamental parameter, as well as how heat stress/thermal discomfort affects these outdoor activities (Vanos, Warland, Gillespie, & Kenny, 2010). These studies explained the consequences, implication and outcomes of how heat stress affected human life.

This study aims to clarify the perceptive and adaptive mechanisms involved in outdoor thermal comfort and weather assessment. The objective of this study is to identify the people's adaptation towards the hot and humid outdoor condition.

1.1. Outdoor thermal comfort

Thermal comfort can be defined as a condition in which individuals prefer neither warmer nor cooler temperatures i.e., the preferred temperature. While neutrality temperature is the temperature at which people feel comfortable, preferred temperature is the temperature people want (Staiger et al., 2012). The concept of thermal comfort is closely related to thermal stress. Many researchers have explored ways to predict the thermal sensation of people in their environment based on the personal, environmental and physiological variables that influence thermal comfort. As a result, several mathematical models that simulate occupants' thermal response to their environment have been developed.

The general energy balance equation is as follows (ANSI/ASHRAE Standard 55, 2004);

$$M - W = C + R + E + C_{res} + E_{res} + S \quad (1)$$

where, M is metabolic rate (W/m^2), W is mechanical power (W/m^2), C is convective heat loss

from skin (W/m^2), R is radiation heat loss from skin (W/m^2), E is evaporative heat loss from skin (W/m^2), E_{res} is evaporative heat loss from respiration (W/m^2), C_{res} is convective heat loss from respiration (W/m^2) and S is the rate of body heat storage (W/m^2).

1.2. Psychological and physiological adaptation

The thermal comfort adaptation encompassed on physical and physiological process (Huizenga, Hui, & Arens, 2001). Therefore, the physiological and psychological impact needed to be taken into account when designing green spaces. Previous studies described thermal comfort as a crucial parameter, and thermal discomfort affected these outdoor activities (Hartig, 2008; Nikolopoulou et al., 2001; Stathopoulos et al. 2004). These studies explained the consequences, implication and outcomes of how heat stress affected human life. Moreover, some studies confirmed the importance of shaded areas when designing outdoor spaces (Hwang et al., 2010; Makaremi et al., 2012). Previous studies also confirmed that people adapted to varying outdoor conditions through behavioural and postural changes, acclimatization and their perception of the outdoor conditions (de Dear & Brager, 2001; de Dear & Brager, 1998). Psychological adaptation towards environmental ergonomic is necessary to encourage better usage of outdoor space. Human responses to the outdoor environment and actual thermal sensation experienced by individuals are vital to determine the people's level of understanding of the condition.

2.0 Methodology

2.1 Study area

The study area for the microclimate measurement was at the Shah Alam Lake Garden, Malaysia, positioned at $3^{\circ}5'00''N$, $101^{\circ}32'00''E$, which is the main public park for Shah Alam residents. There were an abundance of *Samanea saman* (rain tree) and *Pterocarpus indicus* (Angsana) that shaded the area and the ground was covered with graminoid like *Axonopus compressus* (common grass) (Figure 1). There was also a playground within the perimeter with sitting and resting places for picnicking and leisure activities.

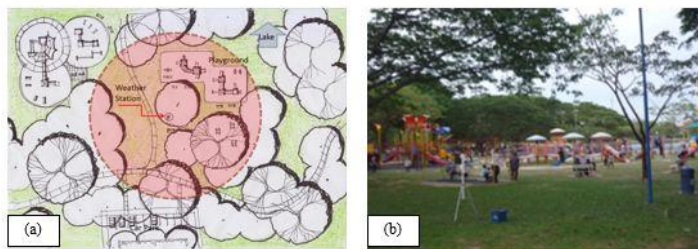


Figure 1. a) Sketches plan of the study area (not to scale) b) View of the studied area showing position of portable weather station

The main attraction of the 43ha Shah Alam Lake Garden is the beautifully landscaped green areas. There are also cafes, playgrounds, jogging tracks, lakeside promenades, and gazebos, resting area, water features and massive lakes. The study area was accessible to pedestrians and access limited to bicycles. The section of the study area is shown in Figure

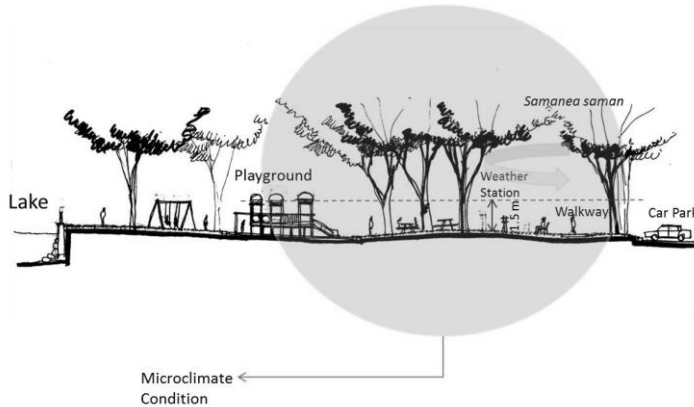


Figure 2. Section of the microclimate study site (not to scale)

2.2 Microclimate condition

The climate of Shah Alam (Subang Jaya station) is classified as hot and humid. The local climate is characterised by the annual southwest (April to October) and northeast (October to February) monsoons. The relative humidity was also high which was between 50% and 99%. The trends of the climate condition in Shah Alam are shown in Figure 3.

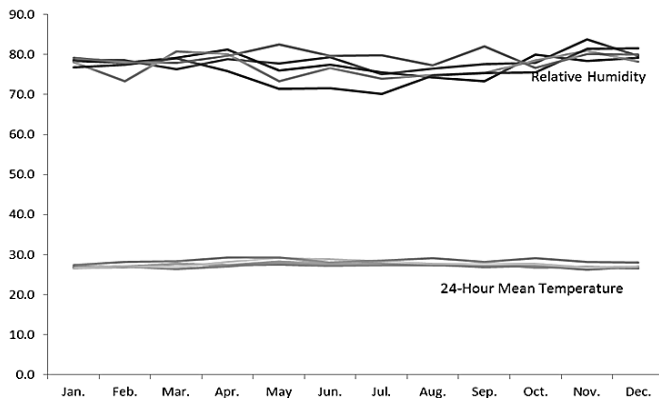


Figure 3. Meteorological Trends in Shah Alam in 2006-2010 (source: Malaysian Meteorological Department)

The measured microclimate parameters were Air Temperature (T_a), Relative Humidity (RH), Wind Velocity (v), Solar Radiation (I), Apparent Temperature (AT), Mean Radiant Temperature (T_{mrt}) and calculated PET as shown in Table 3. A portable weather station positioned 1.5 m from the ground was used for data collection (Figure 1b). The measurements were taken on days 70, 99, 134, and 161 of the year. The measurement days were selected by referring to the weather forecast published by the Malaysian Meteorological Department website. The selected days excluded rainy days. The data was collected between 0700 and 1900 h each day at 10-min intervals with the total N of 292.

Table 3. Measured microclimate parameter

Parameters	Min	Max	Mean \pm Std. Error		Std. Dev.
T_a ($^{\circ}\text{C}$)	24.4	32.2	28.5	± 0.1	1.8
RH (%)	52.0	96.0	70.8	± 0.6	9.9
v (ms^{-1})	0.0	3.1	1.3	± 0.0	0.8
T_{apparent} ($^{\circ}\text{C}$)	27.2	36.7	32.3	± 1.3	2.2
T_{mrt} ($^{\circ}\text{C}$)*	24.5	50.5	33.3	± 0.3	4.9

Apparent Temperature was calculated using Equation 2 (Steadman, 1984). The following formula is applied in the calculation as follows:

$$AT = T_a + 0.33 \times e - 0.70 \times v - 4.00 \quad (2)$$

where T_a is air temperature ($^{\circ}\text{C}$), e is water vapour pressure or humidity (hPa), and v is wind speed (m s^{-1}). The vapour pressure, e is calculated from air temperature and relative humidity using the Equation 3 (Steadman, 1984).

$$e = RH/100 \times 6.105 \times \text{EXP}(17.27 \times T_a/(237.7 + T_a)) \quad (3)$$

where RH is Relative Humidity (%).

2.3 Interview sheets and observation

The interviews were conducted simultaneously with the microclimatic measurements. The questions consisted of demography (age, gender, activities, and origins) clothing, the reason(s) for being at the park and time spent outdoors. The respondents were requested to express their feeling regarding wind, air temperature, humidity, brightness, and the overall condition suitability with the microclimate. Each interview took an average of 5 minutes to complete. On average, 73 interviews were conducted daily during the measurement within the four different days. The park's physical features and users' behavioural pattern were observed.

3.0 Findings and Analysis

3.1 Thermal Comfort level

The Physiological Equivalent Temperature (PET) was estimated using the RayMan model (Matzarakis et al., 2007) which calculated the radiation fluxes within urban settings based on certain parameters, including T_a , Wind Velocity (v), Solar Radiation (I) and surrounding surfaces. The results of calculated PET for the measured days using Rayman application are shown in Figure 4. The results showed that 11.6% of the PET were comfortable, 66.4% slightly warm, 19.9% warm and 2.1% hot. The range of PET was between 20.8 and 39.70°C which belonged to the warm zone.

Another way to clarify the thermal comfort level is by employing apparent temperature (AT). AT (calculated of T_a and h) showed better understanding of the value of how Malaysians adapt to the hot and humid outdoor condition. Figure 5 shows the apparent temperature captured in this study. The range of AT was between 27.2 and 36.7°C. The AT comfortable range was between 20 and 29°C. Therefore, this study showed that the condition during measurement days was in the “some discomfort” range which when occurred in hot weather, will induce sweating, which cooled the body as it evaporated and created some discomfort condition.

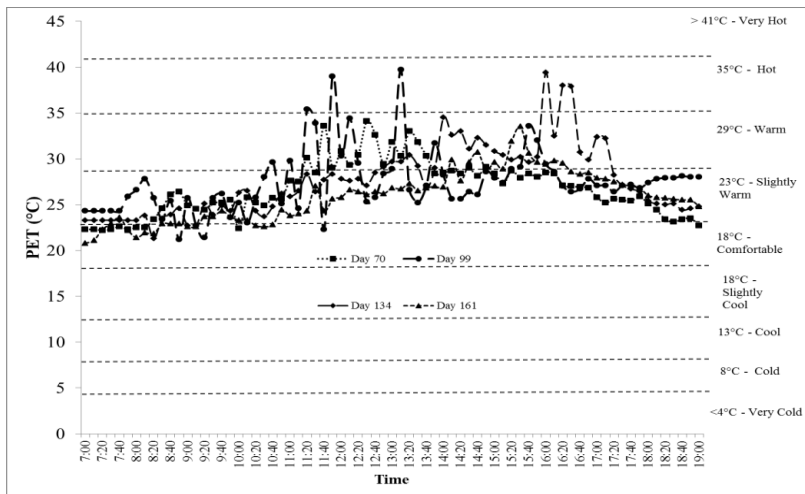


Figure 4. Calculated Physiological Equivalent Temperature (PET)

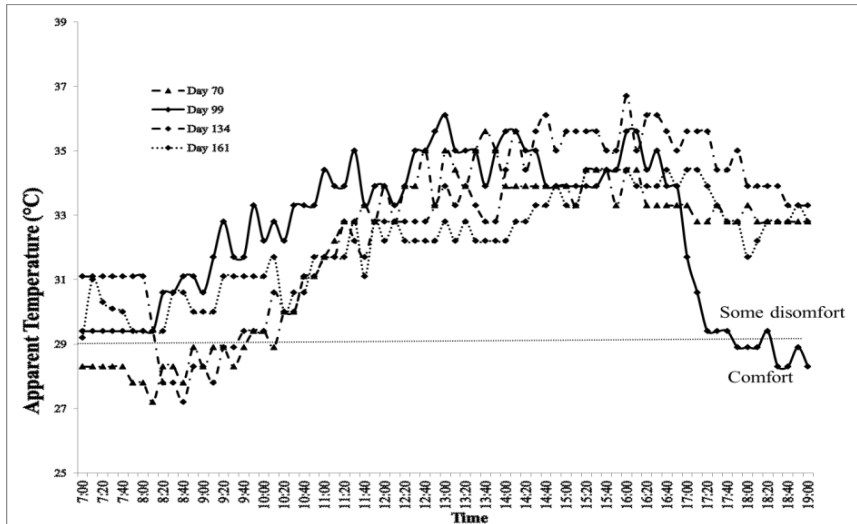


Figure 5. Apparent Temperature (AT)

3.2 Psychological Adaptation

Outdoor thermal comfort for the tropical climate is a positive attribute as it ensures better tolerance to outdoor conditions, which in turn, encourages better usage of outdoor recreational areas.

The respondents (N=292) were requested to express their thermal sensation, according to a 9-point scale. The majority of the respondents expressed their thermal sensation as comfortable.

The varieties of the respondents' answers were cold (0.7%), cool (4.1%), slightly cool (8.2%), comfortable (69.5%), slightly warm (12.7%), warm (3.1%) and hot (1.7%).

The results proved that the respondents adapted to a higher range of thermal conditions (21.1 - 39.4 °C of PET) compared with the comfortable range of PET (18 – 23 °C) in Europe (Matzarakis, Mayer, & Iziomon, 1999).

3.2.1 Meteorological indices and Respondents' Vote comparison

The respondents were inquired about their perception towards the actual microclimate conditions; wind, heat and humidity. The microclimate data was then classified into standard rating. Then, the counts of the level were compared.

Figures 7, 8 and 9 show the frequency percentage on the perception of respondents and the actual measured data classified by specified indices.

Figure 7 shows the comparisons between the wind speed level and the perception of the respondents towards wind flow. The x-axis of this graph shows the classified level of wind speed (Bedford scale) and respondents perception on wind while frequency percentages (%)

appear on the y-axis. The wind speed (m s^{-1}) level is classified into five categories; <0.3 is Calm, $0.3-1.5$ is Light Air, $1.5-8.0$ is Breeze, $8.0-10.8$ is Strong Breeze and >10.8 is Windy. It may be seen clearly that the wind condition mostly fell into "light air", yet, the respondents sensed it as the "breeze". The measured wind speed showed that there were light winds dominating the area, yet, the respondents felt more breeze than light wind.

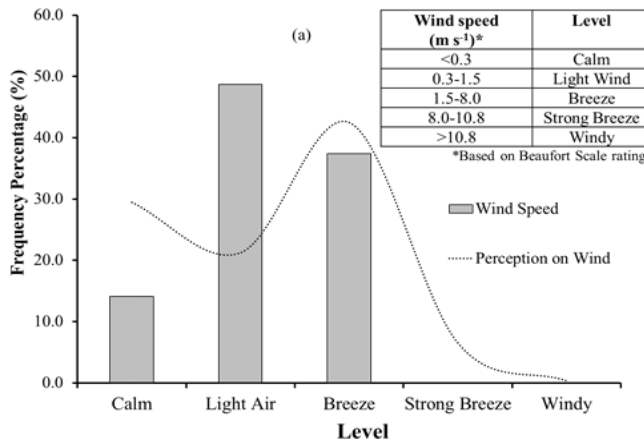


Figure 7. Frequency Percentage (%) of Respondents' Perception and Microclimate measured data on Wind Speed

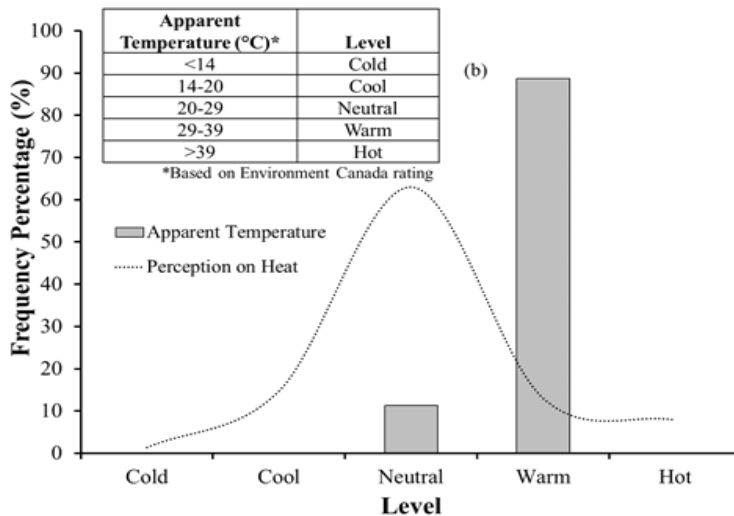


Figure 8. Frequency Percentage (%) of Respondents Perception and Microclimate measured data on Apparent Temperature (AT)

Figure 8 shows the classified level of Apparent Temperature (AT) and perception on heat sensation in frequency percentage (%). The Apparent Temperature (AT) (°C) are classified based on Environment Canada rating level in five categories; <14 Cold, 14-20 is Cool, 20-29 is Neutral, 29-39 is Warm and >39 is Hot. The findings showed that the respondents answered in symmetrically distributed, yet, the measured AT mostly fell into “Warm” category. The measured T_{apparent} showed that the actual condition of the study area was warm and should create some discomfort. However, most of the respondents rated the T_{apparent} as neutral.

Figure 9 shows the classified level of Relative Humidity (RH) and perception on the humidity in frequency percentage (%). The RH (%) are classified evenly into three categories; <30 is Dry, 30-60 is Neutral, and >60 is Damp. The findings show that the respondents answer in symmetrical distributed, yet, the measured RH mostly fall into “Damp”. Moreover, the measured RH fell into “damp” level, but the respondents felt neutral.

In conclusion, the results showed significant findings that agreed with the theory of adaptive comfort where people living in the tropical climate adapted to higher temperature, more humid and less breezy conditions.

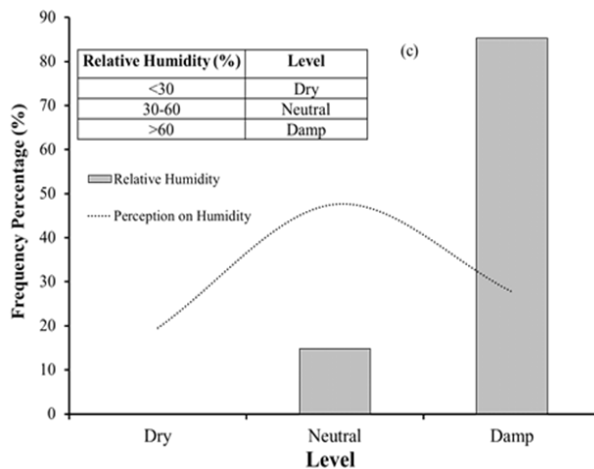


Figure 9. Frequency Percentage (%) of Respondents Perception and Microclimate measured data on Relative Humidity (RH)

Summary

This study explored the people's perception on the microclimate condition of a Malaysian urban recreational area. The results confirmed the existence of adaptive thermal comfort amongst the respondents whereby they perceived better microclimatic conditions than what was measured. It showed how Malaysian understood and perceived about microclimate. There is room for further research with wider sampling to determine the adaptations of subjects to the microclimate.

The findings on the significant influences of microclimate parameters (air temperature, wind velocity, Apparent Temperature (AT), Physiological Equivalent Temperature (PET)) and personal factors (demographic) on the participants' perceptual and emotional estimations of outdoor urban places were discussed. This study confirmed that the subjects adapted to the "warm" rather than the "comfortable" range of Physiological Equivalent Temperature (PET), which contradicted with their perception that responded positively to much warmer physical environment. Moreover, the Apparent Temperature (AT) showed how the Malaysian subjects adapted to the "discomfort" level of PET, yet still felt "comfortable". Furthermore, the respondents' perceptions on the microclimate condition varied according to factors such as age, gender, race, and the respondents' activities.

The objective of this study was to examine the thermal comfort levels of Malaysians in a recreational park, which had the condition of hot and humid, and even shaded area. This research proved that personal factors did not affect the comfortable level, and there are must be other factors impacting the preferences. Moreover, the respondents adapted into the microclimate condition which is hot and humid.

The findings showed that the Malaysian subject were physiologically and psychologically adapted to the shaded microclimate condition based on their experience and perception. The significance of the findings showed the importance of sustainable urban parks for continued use by future communities. The findings may contribute to the theory and design of sustainable urban parks for present and future communities.

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