Outdoor thermal comfort and behaviour in urban area

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Abstract. Outdoor comfort is important due to the public spaces functions. Open spaces provide thermal comfort and a pleasant experience to improve the city life quality effectively. The influence of thermal comfort in outdoor activities is a complex problem. This paper presents a literature review and discussion of aspects of physical, psychology, and social behaviour toward outdoor thermal comfort. The valuation is determined not only by the "physical state" but also by the “state of mind”. The assessment is static and objective (i.e., physical and physiological characteristics) that it should be measured. Furthermore, an effective model to provide the knowledge of climatic conditions, as well as the dynamic and subjective aspects (i.e., psychological and social characteristics and behaviour), requires a comprehensive interview and observation. The model will be examined to describe the behaviour that is a reflection of perception and behaviour toward the environment. The adaptation process will constantly evolve so that it becomes a continuous cause between human behaviour and the spatial setting of the formation, which is eventually known as places and not just spaces. This evolutionary process is a civic art form.

Keywords: behaviour, perception, outdoor, thermal comfort, thermo-adaptive

1. Introduction

Regarding the thermal comfort in outdoor space, the role of microclimate is very dominant since users will experience an outdoor space directly in contact with elements of the microclimate such as temperature, humidity, solar radiation, and wind speed. Many studies revealed that the microclimate parameters greatly affect the thermal sensation, but approaches or methods used have been only accounted for around 50% of the statistics—a data variation between the objectively and subjectively comfort measurements [1]. There is barely an approach or method to obtain the thermal comfort value by considering all aspects, i.e., the physical, physiological, psychological, and social factors. The physical aspect that is considered as extremely influential is the environmental condition of the outdoor space itself, e.g., the configuration of the 'void', closing materials, building types, as well as other elements such as plants and others. Factors mentioned above affect microclimate conditions. The microclimate characteristics then influence the thermal comfort value, especially physiologically. The human body is quite sensitive to environmental conditions since there is a need to maintain body temperature.

Several studies revealed that physiological approach alone is not sufficient to be able to determine the exact value of outdoor thermal comfort since many other factors are affecting this value. Another researched thermal comfort using the physiological method, and the result turned out to be in contrary to previous theories [2]. Thus, it is required to assess the psychological aspect of individuals toward environmental conditions. In previous study stated that regards to the “thermal history” as well as
“memory and expectation” are recommended besides paying attention to physiological elements [1]. It was based on the assumption that there are other influential psychological factors such as naturalness, past experience, perceived control, time of exposure, environmental stimulation, and expectations. Researcher developed a network that connects the factors that psychologically affect the thermal adaptation [3]. The contradiction between behavioural aspects of psychological phenomena and the thermal physiology can be bridged by the environmental behaviour learning theory.

Based on results of earlier research, the psychological approach will provide answers to the contrary matters besides the physiological and microclimatic aspects. Various models to predict the thermal comfort are discussed in this article. The outcome can be developed to an accurate model as the criteria in determining the design of outdoor space that is functional, healthy, and comfortable to promote public activities. In the context of urban planning, how the thermal sensation affects human behaviour and the utilization of outdoor space is exciting stuff to be reviewed. Given the variety of literature concerning this subject, framework guidelines on assessing the behaviour of thermal comfort in outdoor space are highly useful for researchers and practitioners of planning and design. Such framework has not yet been the subject of many in-depth discussions [3], so it was further examined in this study. This research aims to find criteria or parameters which can serve as a manual on how to determine the thermal comfort value of outdoor space that is associated with the local microclimate as well as physical, psychological, social, and behavioural aspects.

2. Research Method
This paper discusses how far research has been carried out on obtaining the proper measurement instrument or methods to assess the thermal comfort, both quantitatively and qualitatively, related to the microclimate and subjectively appraised social behaviour. The measurement methods must be able to process the information of environmental conditions in detail based on the customized time and variation, as well as to generalize the analysis results to reveal the interconnectedness among variables. This study employed a descriptive theory of deductive method. According to [4], a logically argumentative research has a rationale that everything can be viewed as a system. The research objective of applying this method is to create a framework system based on logic.

3. Results and Discussion
3.1. Measurement of thermal comfort
Thermal comfort is defined as the condition of mind that expresses satisfaction with the thermal environment [5]. Thermal comfort is a subjective psychological perception based on the mechanism of physiological thermoregulation as well as when the human body is exposed to a combination of environmental factors including air temperature, air humidity, wind speed, and radiation [2]. It can be said that thermal comfort is the satisfaction level of the human condition in responding to the thermal environment, both physically and psychologically.

Physiological Equivalent Temperature (PET) is a way of measuring the thermal comfort developed by Mayer and Hoppe in 1987 from the Munich energy-balance model for individuals [3]. PET is the “temperature dimension index” which is expressed in Celsius unit (°C). It is used in-depth for certain settings to determine the skin and body temperature as well as the sweat rate balance. Index of Thermal Stress (ITS), Fuzzy-PMV, OUT-SET, and the model of COMFA thermal outdoor space are the analysis tools to assess the thermal environmental response of the outdoor space users [3]. Research studied thermal comfort using OUT-SET and PET indexes as the primarily designed instrument for outdoor use [2].

3.2. Physiological aspect of thermal comfort
The basic concept of the physiological thermal comfort is the occurrence of heat balance. The process of metabolism yields by products in the form of body heat. The heat wave is then continuously released to the environment. Body heat production rate should be balanced to prevent heat exhaustion [5]. Heat dissipation is present in the form of radiation, conduction, convection, and evaporation [5]. The human body is quite sensitive to environmental conditions since it has to maintain the body
Temperature even though the surrounding temperature has changed much. The adaptation process will occur by relying on the mechanism of physiological thermoregulation as described by [2].

Thermal comfort in the psychological point of view is a state of mind that represents satisfaction with the thermal environment. In the thermo-adaptive (psychological) approach, the achievement of a comfortable thermal condition is related to the thermal neutrality—a condition that causes a person to prefer neither a warmer nor cooler circumstances to the present one [6]. The assessment of thermal comfort is demonstrated by the human response to the thermal environment. Thus, this response is a form of a relationship between the human psychologies with the surroundings, implying that the psychological approach is capable of studying the thermal comfort.

As already known, the relationship between the human psychologies with the environment has initiated by the conceiving of perception. It occurs along with the process of sensing the environment. Concerning thermal comfort, the sensing begins with the presence of physical stimuli which are perceived by individuals with their own distinct characteristics. The individual characteristics include the ability or level of adaptation, psychological control, personal factors related to social connections with the community, exposure duration to the stimulus, and so on. It is in line with the statement of previous study [1] that the psychological approach consists of six parameters, i.e., naturalness, expectations, experience (short or long term), time of exposure, perceived control and environmental simulation. Understanding the parameters as well as their interconnectedness and effects on the thermal comfort is crucial in determining the role of design besides promoting its innovation.

3.3. Social and behavioural aspects
Human behaviour is a form of coping with environmental stress, including the open and closed behaviour. Open behaviour is behaviour that can be observed visually, while the closed behaviour is the opposite—cannot be examined visually—such as attitudes, tendencies, and preferences that can be assessed through direct or indirect inquiries. In this context, ‘coping’ is a human process of dealing with stress [6]. Social and behavioural aspects are crucial in determining the level of thermal comfort. Research established that the psychological approach alone is not sufficient to describe the conditions of thermal comfort in outdoor space [1]. They advised paying attention to the “thermal history” and “memory and expectation”, with three levels of adjustment to formulate thermal adaptations: physical, physiological, and psychological extents. According to other study [3], though the concept is quite interesting, the relationships between these parameters have not been considerably affected the design alternatives because of the complexity of the interconnectedness among parameters. Hence, they developed a model that can be used as a generic framework which describes valuations of outdoor thermal comfort based on the behavioural aspect (Figure 1).

3.4. Assessment of thermal perception from behavioural and social perspectives
Based on the above statements, determining the individual level of thermal comfort relies heavily on various parameters whose relations are complicated as well. Factors such as gender are variables that can influence the thermal comfort [2]. Previous research asserted that women have a low tolerance for the conditions of heat and sunlight exposure. On the contrary, the results of this study indicate that physiologically, women have a higher thermal tolerance than men. This finding can be conceded by looking at it from the psychological point of view. In the theory of environmental behaviour, this phenomenon is indeed a contradiction between the psychological behaviour and the physiological aspect of autonomously thermal functions. Women’s desire of radiant skin tone is induced by social learning processes, such as observation and education, which are then reflected in their perceptions of psychological factors (fear of heat and sun exposure) and behavioural adjustments (bringing an umbrella or seeking shade). Therefore, the phenomenon of a unique psychological and behaviour cannot be directly explained by the autonomous mechanism of physiological thermoregulation.

Outdoor thermal comfort in urban environments is a complex issue involving many affecting aspects. Hence, the assessment to assess public perception of thermal comfort must be carried out on at least four levels of physical, physiological, psychological, and social/behavioural aspects. Social and behavioural aspects in outdoor space greatly influence the built environment, which personally presented on the physical environment.
Figure 1. A general framework for outdoor thermal comfort assessment based on the behavioral aspect [3].

Based on the framework guidelines developed by previous study [3], the assessment to determine a person’s thermal comfort starts on the physical level that defines the physical condition of the built environment as a consequence of microclimate. This physical condition will then influence the thermal comfort on the physiological level. Someone can respond and adapt to the surrounding thermal condition through balancing the body heat by relying on the thermoregulation mechanism. At this stage, a problem in determining the thermal comfort often emerges since its definition is not limited to the physical state only, but also by the state of mind that expresses one's satisfaction of the thermal environment. Thus, the response toward thermal comfort is a form of human psychological reaction to the environment based on the thermo-adaptive approach—psychology concerning the thermal neutrality. Research proved that there is a difference of thermal comfort perception between men and women, while contrariwise, the previous study employing a physiological approach stated that women have a lower heat tolerance than men [2].

Research defined that environmental perception is an interpretation of a setting by individuals. It is based on their cultural backgrounds and experiences [6]. This statement is in line with the research conducted by other study [7] explaining that cultural and climatic differences affect the thermal sensation. It can be said that the perception has a crucial role in the formation of space or physical settings, including the idea of outdoor thermal comfort.

According to [8] in the book of architectural environment and behaviour, conceptually, the approach accentuates that human behaviour is thinking being who has the perception and judgment of its interaction with the environment. Behavioural approaches emphasize the linkages between outdoor...
space and humans or societies utilizing or inhabiting the space. A setting of a life that is already formed will directly produce values. Those values will be the foundation of the relationship or be a reference to public behaviour [8]. Behaviour is a reflection of human perception and the behaviour toward the environment will experience adaptation and continuously evolve so that it becomes a continuous cause between the behaviour and the formation of its spatial setting which is eventually known as places instead of just space. This evolutionary process is a form of civic art. The success achieved by a place through the efforts of civic art is not only physically beautiful to be looking at but also work well for the present and the future [8]. Therefore, the assessment framework of thermal comfort perception developed by other study [3] can be modified into Figure 2.

| Approach                  | Level of Assessment | Influencing Factors                                      |
|---------------------------|---------------------|----------------------------------------------------------|
| Teasurement; Modeling     | Physical            | Form; Height and space between building, open space orientation (Nikolopoulou M, Steemers K. 2003) |
|                           |                     | Outdoor space                                             |
|                           |                     | Micro-climate and Bioklimatic (Vanos, 2010) suhu, kelembaban, angin. |
| Modeling; Monitoring      | Physiological       | Termoregulation: skin temp, core temp/inti, sweat moderate (Vanos, 2010). |
|                           |                     | Energy Balance: Physic activity                            |
| Survey; Interview         | Psychological       | Function of space                                          |
|                           |                     |                                                           |
| Observation; Interview;   | Social / Behavior   |                                                           |
| Prediction                |                     |                                                           |

**Figure 2.** A framework model of outdoor thermal comfort with the approach of physical, physiological, psychological, behavioral, and social aspects [3].
4. Conclusion

Outdoor thermal comfort in urban environments is a complex issue involving many affecting aspects. Environmental stimulus (e.g., the local microclimatic condition) is the most influential factor on the thermal sensation and individual convenience level. Thermal comfort is not only determined by the physical state but also by the state of mind. Hence, the assessment to describe the public perception of thermal comfort must work on at least four levels: physical, physiological, psychological, and social/behavioural extents. The perception begins to form when the environmental sensing process occurs. Concerning thermal comfort, the sensing starts with the presence of physical stimuli which are then perceived by individuals with their own distinct characteristics. Those individual characteristics include the ability or level of adaptation, psychological control, personal factors related to social connections with the community, and prolonged exposure to the stimulus. This adaptability can bridge the four aspects through the physiological thermoregulation with thermal neutrality as the adaptation process. The assessment of thermal comfort is dynamic and subjective: dynamic in the sense that the adjustment to the ambient thermal condition is naturally progressive, also subjective given that the thermal sensation is primarily determined by personal experiences and subjective evaluation that thermal comfort does not always refer to climatic conditions. In other words, the static and objective aspects (i.e., physical and physiological characteristics) should be measured to provide “knowledge on climate” through an effective model, while the dynamic and subjective aspects (i.e., psychological and social/behavioural characteristics) require a comprehensive interview and observation to provide “knowledge on human”.

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