Assessment on the expectation for built environment usage and its influencing factors during the pandemic

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Abstract. A vital question of how citizens expect to use the built environment is not fully addressed. This study aims to contribute to this question from the indoor and outdoor usage expectation. The potential influencing factors are examined via survey along with the meteorological data obtained from weather bureau. This study provides that the current location and the duration of indoor-stay serve as the influencing factors of the indoor and outdoor usage expectation. The indoor and outdoor usage expectation has an obvious influence on the thermal sensitivity of thermal environment. People who expect to use the outdoor environment showed the least thermal sensitivity, 42.3% weaker than those who do not expect to use. These findings help providing further understanding of the citizens' thermal expectation and their thermal responses during the post-pandemic period.

1 Introduction

Over the past two decades, the study of outdoor thermal comfort has been gaining attention. It is being more and more emphasized that the quality of built environment matters to users' responses. A literature finds that behavioural response to optimum thermal environment is different according to age and activity types [1]. Among all the users of outdoor space, the elderly group is observed as dominant user group compared with other age groups [2]. However, most existing studies address the outdoor thermal comfort issues based on the response of the young adults [3,4]. In addition, a study shows that affective responses relate to pleasant feelings and enjoyment in the outdoor environment [5]. Also, the willingness of using the outdoor space is now more commonly seen be measured by the attendance of specific built spaces in different regions and cities in global context [6]. However, these studies related to psychological factors are rarely conducted to quantify their effects on the willingness of using spaces and influences on thermal sensation and comfort. The mainstream of outdoor thermal comfort studies normally examine the influence of thermal factors by using thermal indices to assess the thermal environment, such as PET (Physiological Equivalent Temperature) and UTCI (Universal Thermal Climate Index). These studies fail to clarify that how the psychological factors affect the performances of PET and UTCI when they are used in the outdoor spaces is still unclear.

Therefore, how to quantify the effect of psychological factors on the willingness of using the built spaces and thermal sensation and comfort is worthy to be clarified, especially for the dominant middle-aged and the elderly citizens groups. This study examines how the expectation of indoor and outdoor usage changed with the type of current location, time-spent indoors, and how it influences thermal sensation. The availability of the data in this study is of important value and significance, because it helps to provide further understanding of the citizens' thermal expectation and their thermal responses during the post-pandemic period.

2 Methodology

The data was collected after the main breakout of the pandemic (from 14th March, 2020 to 9th April, 2020). This study used the method of passive observation and remote data collection to complete the study.

2.1 Online survey

In this study, 868 survey samples were collected from Jiangsu Province in total. The questionnaire was distributed and filled-in through internet. Over 60% of the participants were female. Most of the participants were middle-aged (aged from 36 to 50) and the elderly people (aged above 51). This study had been approved of the ethical check by the university academic ethics office.

The basic information of participant was collected at the beginning of the survey. The participant's mean clothing value was 1.32clo and mean metabolic rate was 1.22met. The participant's current thermal sensation vote was quantified in the nine-point scale and current thermal comfort vote was quantified in the five-point scale. The expectation of current environment was quantified in the five-point scale.

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2.2 Climate data acquisition and processing

The local climate data was acquired remotely. Dry bulb air temperature (T_a), wind speed at the height of 10m, and relative humidity were obtained from the closest local meteorological station from the China Meteorological Data Network (http://data.cma.cn). The local short-wave and long-wave radiation were collected from the ERA5 [7] and the ERA5-Land [8] databases. The mean radiant temperature (T_{mrt}) was calculated from the Equation (1).

$$T_{mrt} = \sqrt[4]{\frac{1}{\sigma}\left(\frac{\alpha_k\left[f_p \cdot I_{sw} + f_a \cdot D_{sw} + f_a \cdot R_{sw}\right]}{\varepsilon_p} + f_a \cdot (D_{lw} + U_{lw})\right)} - 273.15 \quad (1)$$

where, α_k is the absorption coefficient for short-wave radiation (standard value is 0.7); ε_p is the absorption coefficient for long-wave radiation (standard value is 0.970); σ is Stefan-Boltzmann constant ($5.67 \times 10^{-8} Wm^{-2}K^{-4}$); f_p is the projected area factor accounts for the directional dependence; f_a is the angular factor, 0.5; T_{mrt} is the mean radiant temperature (℃). 10m wind speed was converted to the wind speed at the pedestrian-level (1.1m height) by the Equation 2 [9].

$$v = \frac{v_{10.0} \log \frac{1.1}{0.01}}{\log \frac{10.0}{0.01}} \quad (2)$$

where, $v_{10.0}$ is the 10m wind speed provided by the local climate station; v is the wind speed at the pedestrian-level height (1.1m).

2.3 Calculation of the thermo-physiological indices

Two thermo-physiological indices were selected in this study for the data analysis, including the UTCI and the PET. The values of PET were calculated using the software package RayMan pro [10] and the values of UTCI were calculated using the desktop version downloaded from http://www.utci.org/.

3 Equations and mathematics

3.1 Meteorological data analysis

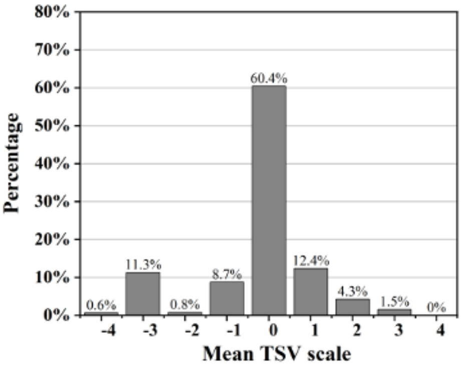
Table 1 shows the general information of the meteorological parameters. The mean T_a was 15.3 ℃ and the mean wind speed in pedestrian height (v) was 2.4 m/s. The minimum and maximum T_{mrt} were 5.5 and 33.0 ℃ respectively. The mean relative humidity was 58.8% and the maximum RH reached 100%.

Table 1. The general meteorological information for the measurement.

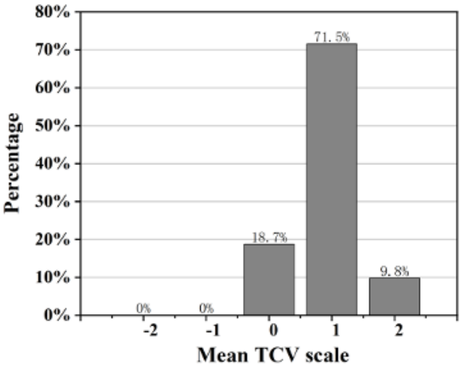
Index	Air temperature (T_a, ℃)	Mean radiant temperature (T_{mrt}, ℃)	Wind speed (v, m/s)	Relative humidity (RH, %)
MEAN	15.3	20.5	2.4	58.8
MAX	28.6	33.0	5.9	100.0
MIN	3.5	5.5	0.4	20.0
STANDARD DEVIATION	4.8	7.2	1.2	23.1

3.2 Thermal sensation and thermal comfort

Fig. 1 shows the overall thermal sensation and thermal comfort distribution. 60.4% of the participants voted for thermal neutral (TSV = 0).81.5% of the voting is in the range of slightly cool to slightly warm from Fig.1 (a). “TCV = 0” here stands for slightly comfortable or slightly uncomfortable; in other words, neutral. Fig.1 (b) shows that the lowest thermal comfort vote is “neutral” and the largest portion of voting is “comfortable”.



(a)



(b)

Fig. 1. Thermal sensation distribution (a) the overall thermal sensation; (b) the overall thermal comfort.

3.3 The built environment usage expectation

3.3.1 *The general expectation for using built spaces*

The general expectation for using built spaces is asked in the questionnaire. 91.9% of the participants express that they will use the built spaces in the near future (Fig.

2(a)). The purpose of built spaces usage is surveyed (Fig. 2(b)). The other options, belong to the recreational-related affairs, which account for 63.77% of the total voting. This result might attribute to the aged citizens being the major group of participants. Fig.3 shows that 41.6% of the participants vote for "expect" to "strongly expect", while 49.2% of them vote for "no preference". Very few of them vote in the negative side (9.2%).

A stacked histogram in Fig. 4 shows the distribution of the built environment usage expectation corresponded to different indoor-stay durations. It is obvious that the percentage of the positive side of the expectation for using the built environment grows with the length of indoor-stay duration.

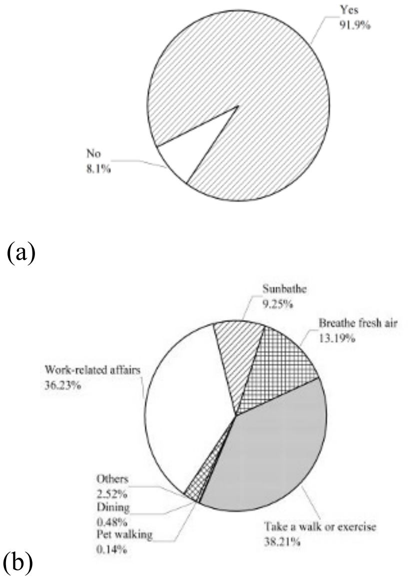


Fig. 2. The willingness and purpose for built environment usage (a) the willingness of using spaces in the near future; (b) the purpose of using spaces.

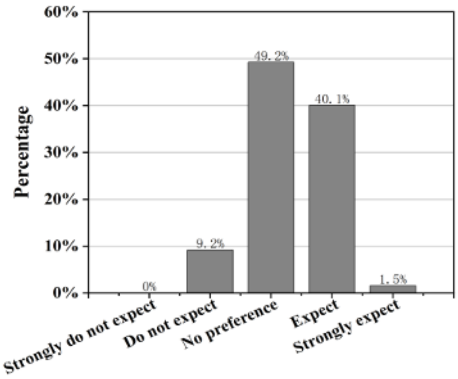


Fig. 3. The distribution of the expectation for using spaces.

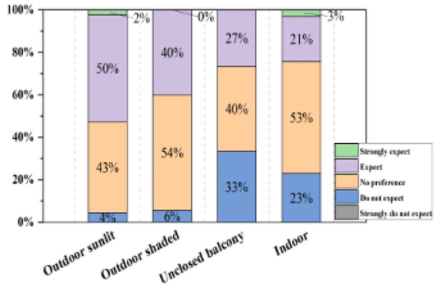
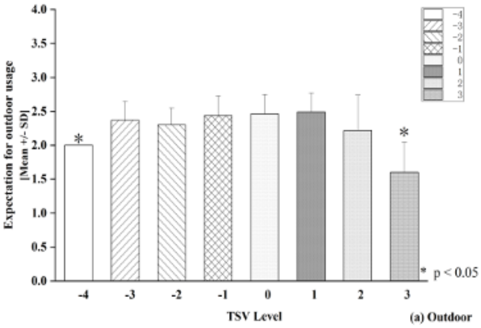


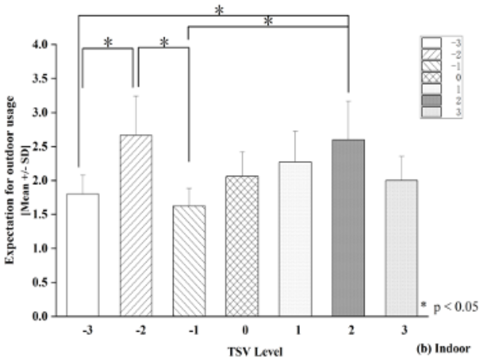
Fig. 4. The stacked histogram of site-specific expectation for using spaces.

3.3.2 Thermal sensation and built environment usage expectation

The relation between thermal sensation levels and the built environment usage expectation is presented in Fig.5 in the category of locations. In Fig. 5(a), there is no difference exist between the groups from "cold" (TSV = -3) to "warm" (TSV = +2) regarding the expectation level. But when people feel hot (TSV = +3) or very cold (TSV = -4), the expectation for going out decrease significantly. It is interesting to find out from this analysis that thermal sensation level does not have an influence on the expectation level in quite a wide range when people are already outdoors. However, the thermal sensations from "slightly warm" to "warm" (TSV=1~2) are significantly higher than the other categories when people stay indoors (Fig.5 (b)).



(a) * The paired columns without markings of significant level refer to significant level >0.05

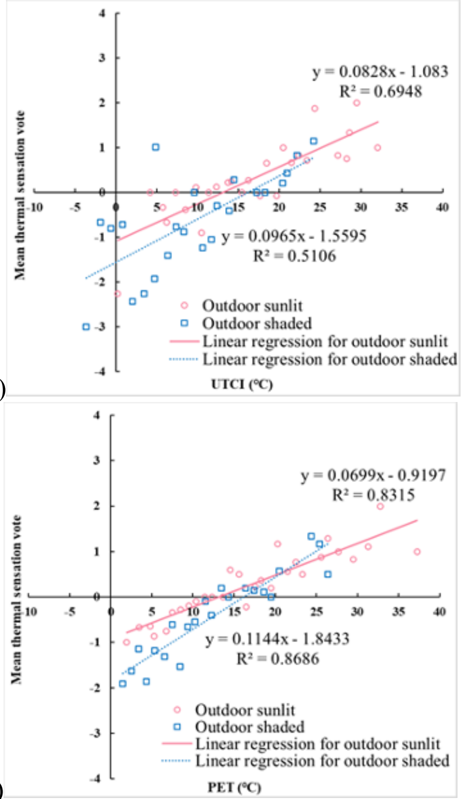


(b) * The paired columns without markings of significant level refer to significant level >0.05

Fig. 5. The expectation of using built environment corresponding to different thermal sensation levels of the following spaces: (a) outdoor; (b) indoor.

3.4 Evaluating the thermal environment using thermo-physiological indices

UTCI and PET values are both calculated to compare their performance as thermal indicators in such a special period after the pandemic. From the regression results in Fig. 6, it is obvious that the average gap of the PET for different locations is smaller than that for the UTCI. Thus, it is preferred to choose PET as the thermo-physiological indicator for further analysis.



(a)

(b)

Fig. 6. Comparison of the UTCI (left) and the PET (right) as indicators of thermal environment.

The results in Fig. 7 show that the expectation for built environment usage is a factor influencing people's thermal sensitivity. The slops of each regression line reveal the sensitivity of thermal sensation with the change of thermal environment. The "do not expect" group has the largest slop among all three groups, followed by the group of "no preference". The "expect" group has the smallest slop, representing the smallest sensitivity of thermal sensation to the change of thermal environment. In other words, if people were expected to use a certain built space, they would have less concern of its thermal environment.

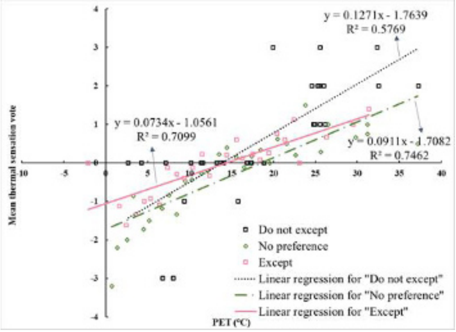


Fig. 7. The relationship between expectation level and PET.

4 Equations and mathematics

In this preliminary study, the expectation of using built environment, its influencing factors and its impact to thermal evaluation were examined. The following conclusions can be drawn from the aforementioned analysis.

(1) More than 60% of the participants tend to use the built environment for the recreational purpose, which represents the need of the middle-aged and the elderly group of people.

(2) Both the current location and the duration of indoor-stay serve as the influencing factors of the built environment usage expectation. But the thermal sensation level does not have influence on the expectation level when people are already outdoors. The expectation of using the built environment increases along with the indoor-stay duration.

(3) The PET serves as a better equivalent temperature for the representative of thermal sensation than the UTCI during the late-period for the main breakout of the pandemic.

(4) Different expectation levels have impact on people's sensitivity to the built environment. Those who "expect" to use the built environment have the lowest sensitivity to the current thermal environment.

References

More information and further discussions can be found in the article of Liu et al. (2022) on *Urban climate*.

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