The effect of personal and microclimatic variables on outdoor thermal comfort: A field study in Tehran in cold season

Sanaz Amindeldar², Shahin Heidari², Mitra Khalili²,∗

² School of Architecture, The University of Tehran, Tehran, Iran

A R T I C L E   I N F O

Keywords:
Outdoor thermal sensation and comfort
Personal variables
Climatic variables
Psychological adaptation
Indoor/outdoor acceptable thermal range difference

A B S T R A C T

Outdoor thermal comfort condition is examined through field surveys in Tehran, Iran, during five days of winter. Environmental monitoring has been carried out in parallel to human surveys using interviews and questionnaires with space users. Examining the climatic data in relation to subjective thermal sensation, this study confirms the significant effect of personal (age and gender) and climatic (air temperature, solar radiation, and air velocity) variables. It also determines the outdoor acceptable thermal range utilizing the index Ta, with the neutral air temperature of 14.2 °C for cold season, which is then compared and justified with its indoor associated study. Finally, this research endorses environmental stimulation and expectations as two major parameters of psychological adaptation influencing thermal perception in this study.

1. Introduction

Outdoor thermal comfort issues have recently gained a considerable attention in context of urban microclimate studies for a variety of reasons. Initially, microclimate is an important issue in determining the quality of outdoor spaces, since people’s sensation of thermal comfort is critically affected by local microclimate. Also, microclimate influences decisions on whether or not to use the space. Different studies have confirmed that thermal, and by implication, comfort conditions, affect people’s use of outdoor spaces and its frequency (Chen & Ng, 2012; Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Givoni et al., 2003; Katzecker, 2006; Mayer, 2008; Nikolopoulou, Baker, & Steemers, 2001; Zacharias, Stathopoulous, & Wu, 2001). Furthermore, indoor thermal condition of the buildings is affected by the surrounding outdoor environment. Thus, modifying outdoor conditions can improve indoor thermal condition and affect building energy consumption by reducing the energy demands for creating comfortable indoors (He, Hoyano, & Takashi, 2009; Hoppe & Seidl, 1991; Zhu et al., 2007). Finally, climate is one of the key factors influencing development in the tourism sector, and different studies have shown that climate is a pervasive factor in tourism decision-making (de Freitas, 2003; Lin & Matzarakis, 2007; Matzarakis, de Freitas, & Scott, 2004). A study by Murphy, Pritchard and Smith (2000) indicates that the destination environment – the climate of which is a major factor- is a highly significant predictor of destination quality. Likewise, trips to summer and winter resorts – in order to avoid the unpleasant climatic situation confirm this notion (Tsutsumi, Nakamatsu, & Arakawa, 2005).

Accordingly, extensive research on outdoor thermal comfort issues in various climates around the world have been conducted in recent decade. A comprehensive review of these studies has been conducted by Chen and Ng (2012) and Nikolopoulou (2011). Some aimed to study outdoor thermal comfort zone in different climates in order to investigate people thermal sensation in different outdoor spaces under different climatic conditions (Ahmed, 2003; Givoni et al., 2003; Hwang & Lin, 2007; Krüger, 2011; Lin, 2009; Moreno, Labaki, & Noguchi, 2008; Spagnolo & de Dear, 2003; Thorsson, Honjo, Lindberg, Eliasson, & Lim, 2007; Thorsson, Lindberg, Eliasson, & Holmer, 2007), with different adaptive behaviors (Lin, 2009; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007). These studies and some other (Zhao, Zhou, Li, He, & Chen, 2016) revealed that outdoor thermal comfort zones and levels of perception vary according to geographical, characteristic, and cultural differences. This fact elucidates the need to investigate outdoor thermal comfort (and key microclimatic and personal variables) within different climates and geographical regions independently. Personal variables studied so far are mainly focused on psychological aspects of the issue (Lin, 2009; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007). While various studies have investigated effect of gender on indoor thermal comfort, a comprehensive review of which has been provided by Karjalainen (2012), few studies have focused on age and gender as effective variables on outdoor thermal sensation (Krüger & Rossi, 2011;
Outdoor thermal comfort in urban spaces has not been an issue in Iran; and the few research studies have been limited to urban parks, in warm season of the year (Monam, 2011). Therefore, this study investigates how microclimate and personal variables affect human thermal sensation in geographical, cultural, and climatic context of Tehran, Iran. Among microclimate variables, the effect of air temperature, solar radiation, and air velocity on human thermal perception is studied, which is combined with age and gender as personal variables. The latter two factors are among those personal variable which need more investigation in various climates and cultures, which is the reason this study addresses the issue. A research study has been carried out in Tehran—the capital city of Iran—in winter. It mainly consists of a fieldwork involving objective measurement (through key climatic parameters) along with subjective assessment, which examines the thermal sensation of individuals present in the urban area.

2. Field study

The study site is located in the city of Tehran, for the longitude 51°19’ E and latitude of 35°41’ N. Tehran features a semi-arid climate (Köppen climate classification: Bsk), and can be generally described as mild in the spring and autumn, hot and dry in the summer, and cold in the winter. Average annual temperature in Mehrabad station reaches 17.5 °C, which ranges from 3.8 °C in January to 29.5 °C in August. Minimum and maximum temperatures of −15 °C and 44 °C have been recorded in this station for last sixty years. The annual precipitation in Tehran is around 220 mm, with the highest amount in January, and summers without precipitation. Average relative humidity varies from 25 to 46 percent in different months of the year. Fig. 1 indicates a 60-year record of meteorological data of Tehran, which is achieved through data archives of Islamic Republic of Iran Meteorological Organization (IRIMO). The fieldwork was carried out in five days of January, between the hours 9:00 in the morning to 5:00 in the evening. A section of Valieasr Avenue (Fig. 2), a south-north street—the longest street in Tehran—was chosen for data record and interview. Due to its diversity of use and significant role in communication network, a wide range of people with different aims of presence in the street were interviewed.

2.1. Physical measurements

The objective climatic parameters investigated in the fieldwork were air temperature in shade (Ta, °C), relative humidity (RH, %) and air velocity (WS, m/s). The climatic measurements were recorded in 37 test area using a mobile system. The devices were installed on a tripod at the height of 1 m (corresponding to the average height of centre of gravity for adults); but in order not to be affected by people’s movements, the anemometer was installed at the height of 2 m (Mayer, & Höppe, 1987; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007; Yang at al., 2017). Air temperature, relative humidity and air velocity were recorded at intervals of 2 min automatically (corresponding to the 4 min interview period). The characteristics of applied measurement devices are illustrated in Table 1.

2.2. Questionnaire survey

Along with climatic measurements, a questionnaire survey was administered in order to record the corresponding subjective responses simultaneously. The questionnaire collected information in two separate parts; the first part collected information such as time, type of exposure to the sun, activity level, and clothing which was completed by the interviewers, while the second part was performed by the interviewee. The latter included demographic data (e.g. age and sex) and information such as reason and duration of presence in the street; however, it mainly asked subjects to rate their current thermal comfort and also preference (Table 2). Thermal experience was rated on ASHRAE 7-point thermal sensation vote (TSV) scale (including cold, cool, slightly cool, neutral, slightly warm, warm, and hot).

Records of subjective perception of thermal condition, wind, and sun exposure together with some additional questions of this section provided the subjective data needed. The whole questionnaire process was designed to take less than 5 min to complete, and the only personal information about the subjects recorded was gender and age. Both features were intended to reduce the rejection rate.

The subjects’ group consisted of 410 persons randomly picked out, while trying to maintain an almost equal portion between male and female subjects (206–204 respectively), ranging from 13 to 76 years old. Yet, the majority of subjects (96%) are 20–65 years old.

3. Results and discussion

3.1. Summary table

Summary of the recorded climatic data in their means, ranges and standard deviation are depicted in Table 3 for the period of work. It should be noted that air temperature values recorded are quite higher than the climatological data for Tehran. Values of clothing value – as physical data with a great effect on thermal comfort—can be also seen in the table.

Outdoor air temperatures ranged from a low of 9 °C to a high of 15 °C. Mean of air velocity was 0.28 (m/s) and the mean of relative humidity was around 51%. Mean clothing value of subjects was 1.10 clo, ranging from the low of 0.50 to the high of 1.76.

3.2. Thermal sensation vote: data and analysis

As previously stated, thermal experience was rated on ASHRAE 7-point thermal sensation vote (TSV) scale (i.e., 3— as cold; 2 —as cool; 1— as slightly cool; 0 as neutral; 1 as slightly warm; 2 as warm; and 3 as hot). Table 4 displays the distribution percentage of number of TSVs of all subjects in the study, while mean of TSV equals −0.48 and standard deviation is 0.65.

The percentage of people feeling neutral (TSV = 0) was highest (56%), while the percentage of people who felt slightly cool (TSV = −1) was the next high vote (38%). Assuming the TSV range of (-1, +1) as the thermal acceptable range— which will be further discussed in section 3.5— and according to Tables 2 and 3, it could be suggested that with total mean value of air temperature of 11.87 °C (ranging between 9.0 °C and 15.0 °C), more than 90% of reported votes lie in thermal comfort conditions.

Fig. 3 illustrates the number of TSVs in ASHRAE scale along with mean value of Ta in each set. As could be predicted, the mean value of
In order to assess the thermal conditions people experience, the bulk of TSVs falls in cold side of the scale ("slightly cool", "cool", "cold"), and just 1% of slightly warm condition has been reported, which are in accordance with field study time of the year. However, the value of mean TSV also lies between the categories “neutral” and “slightly cool”.

In order to assess the thermal conditions people experience, the climatic parameters were then compared with subjective responses (resulted from structured interviews and observations). Such a correlation can be clearly distinguished between the recorded Ta and reported TSVs by interviewees (Fig. 4). It can be interpreted that by the increase in Ta, people feel warmer; thus, the TSVs reach out higher values.

### 3.3. Effects of personal variables on thermal sensation

#### 3.3.1. Gender effect: data and analysis

As a personal variable modifying thermal sensation and also sensitivity to cold, gender effect can be evaluated from subjective thermal sensation votes- which is a combined effect of all climatic parameters. Fig. 5 depicts the graph of thermal sensation votes for both male and female subjects individually. It can be interpreted that under the cold conditions of winter, the comfort zone of women seems to be smaller, which suggests a higher sensitivity of female subjects to uncomfortable conditions of winter. This is in accordance with Krüger and Rossi (2011), and also similar study regarding indoors (Karjalainen, 2012).

#### 3.3.2. Age effect: data and analysis

Likewise, age could be a decisive personal parameter affecting subjective thermal sensation. Age effect on sensitivity of male and female subjects to cold was investigated for range of ages of surveyed people, from 13 to 76 years old, with 96% within the range 18–65. In order to be able compare the results, the splits between the age groups were defined exactly identical to those stated in the study by Krüger and Rossi (2011), including 13–24, 25–64 and more than 65.

Figs. 6 and 7 show thermal sensations of the age groups of female and male subjects respectively. As illustrated in figures, under the cold conditions of experimental days, the difference between the age groups is obvious and there is a clear pattern of age affect in group of women: as the group is younger, it is more sensitive to cold. The age effect of male group functions similarly; however, there is no clear difference for the age group of more than 65, which could be a result of the few numbers of subjects in this age group. All in all, the resulted age effect by the current study complies with the study by Krüger and Rossi (2011).

### 3.4. Effects of climatic variables on thermal sensation

#### 3.4.1. Solar radiation: data and analysis

Since measurements in this study did not include mean radiant temperature- that is the uniform surface temperature of an imaginary

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**Table 1**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Device</th>
<th>Error rate</th>
<th>Log</th>
<th>Calibration Co.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Temperature (°C)</td>
<td>Skye; DataHog2 rht+ sensor; SDL 5060</td>
<td>± 0.2 °C</td>
<td>Automatic</td>
<td>Skye Instruments Ltd.</td>
</tr>
<tr>
<td>Relative Humidity(%)</td>
<td>Skye; DataHog2 rht+ sensor; SDL 5060</td>
<td>± 1%</td>
<td>Automatic</td>
<td>Skye Instruments Ltd.</td>
</tr>
<tr>
<td>Air velocity(m/s)</td>
<td>Tes; 1341 (Hot Wire Anemometer)</td>
<td>± 3% of reading</td>
<td>Manual</td>
<td>TES Electrical Electronic Crop. No:100805458</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Question Topic</th>
<th>Time/Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject’s thermal sensation</td>
<td>at the moment</td>
</tr>
<tr>
<td>Subject’s thermal preference</td>
<td>at the moment; any reason</td>
</tr>
<tr>
<td>Subject’s perception of air movement</td>
<td>at the moment</td>
</tr>
<tr>
<td>Subject’s perception of solar radiation</td>
<td>at the moment; any reason</td>
</tr>
<tr>
<td>Subject’s preference of solar radiation</td>
<td>at the moment; any reason</td>
</tr>
<tr>
<td>Subject’s history of eating/drinking</td>
<td>in last 30 min</td>
</tr>
<tr>
<td>Subject’s purpose of presence in the space</td>
<td>–</td>
</tr>
<tr>
<td>Subject’s history of leaving the last closed/conditioned space</td>
<td>when/where</td>
</tr>
<tr>
<td>Subject’s history of living in Tehran</td>
<td>–</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Air temperature (T&lt;sub&gt;a&lt;/sub&gt;)</th>
<th>Relative Humidity (RH)</th>
<th>Air Velocity</th>
<th>Clothing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>11.87</td>
<td>51.15</td>
<td>0.28</td>
</tr>
<tr>
<td>St. Dev.</td>
<td>1.60</td>
<td>9.23</td>
<td>0.40</td>
</tr>
<tr>
<td>Min.</td>
<td>9.00</td>
<td>29.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Max</td>
<td>15.00</td>
<td>68.87</td>
<td>2.66</td>
</tr>
</tbody>
</table>

**Table 4**

<table>
<thead>
<tr>
<th>TSV</th>
<th>Percentage of distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>–3</td>
<td>1%</td>
</tr>
<tr>
<td>–2</td>
<td>4%</td>
</tr>
<tr>
<td>–1</td>
<td>38%</td>
</tr>
<tr>
<td>0</td>
<td>56%</td>
</tr>
<tr>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>0%</td>
</tr>
</tbody>
</table>

Ta has an upward trend as the amount of TSV increases, that is to say –3 to 3.

As indicated, the bulk of TSVs falls in cold side of the scale (“slightly cool”, “cool”, “cold”), and just 1% of slightly warm condition has been reported, which are in accordance with field study time of the year. However, the value of mean TSV also lies between the categories “neutral” and “slightly cool”.

Fig. 2. Pictures of Valieasr Avenue (Photos taken at 5:00 in the evening).
black enclosure with which man exchanges the same heat by radiation as in the actual environment (Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007)- solar radiation situation was divided into two parts: passers-by in shade or solar exposure. Distribution of the data into these two batches (Fig. 8) suggests little difference between these two parts.

Regression curves of TSV according to Ts in both groups of “in shade” and “solar exposure” are indicated in Fig. 9. It is revealed that neutral temperature is lower for solar exposure conditions; however, the slopes of curves are not equal, suggesting various ranges of thermal comfort zone. Assessment of neutral temperatures and other regression properties can be seen in Table 5.

3.4.2. Air velocity: data and analysis

In order to study the simultaneous effect of wind and air temperature on perceived thermal sensation of subjects, air velocity values were categorized according to Beaufort wind force (Huler, 2007). The recorded air velocities varied from 0 to 2.6 m/s. Therefore, the first group of data (less than 0.3 m/s) was defined as “calm air”, the second batch (from 0.3 to 1.5 m/s) “light air” and the third batch (from 1.6 to 2.6 m/s) “light breeze”. As illustrated in Fig. 10, most of air velocity
Table 5: Regression equations for thermal sensation.

<table>
<thead>
<tr>
<th>Climatic variable</th>
<th>Regression equation for thermal sensation</th>
<th>R²</th>
<th>Coefficient (slope)</th>
<th>Tn°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Still air: $TS = 0.230^* T_a - 3.187$</td>
<td>0.279</td>
<td>0.23</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Light air: $TS = 0.192^* T_a - 2.825$</td>
<td>0.211</td>
<td>0.192</td>
<td>14.7</td>
</tr>
<tr>
<td>Solar radiation</td>
<td>Sun: $TS = 0.254^* T_a - 3.493$</td>
<td>0.251</td>
<td>0.254</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>Shade: $TS = 0.172^* T_a - 2.490$</td>
<td>0.216</td>
<td>0.172</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Fig. 9. Correlation between thermal sensation TS and air temperature Ta for shaded and solar exposure conditions.

Fig. 10. Histograms for air velocity.

values lie in the category “calm air” firstly, and then “light air”.

Fig. 11 indicates the correlation between thermal sensation votes and air temperature for the two first classes of air velocity, as the “light breeze” class included too little distribution percent. Although the bulk of data lies in the first category (fig. 10), it can be seen that there is an obvious pattern between these classes regarding comfort condition and thermal neutrality. As the air velocity increases, an increase in neutral temperature can be seen, which could be predicted. Assessment of neutral temperatures and other regression properties can be seen in Table 5.

3.5. Acceptable thermal range: different ranges for indoors and outdoors in Tehran

3.5.1. Acceptable thermal range: outdoor spaces of Tehran

In order to account for subject thermal perceptions under different thermal situations based on air temperature (Ta), the Ta ranges where the subjects feel comfortable should be defined. The result is the “acceptable thermal range” for Ta. By means of the conventional method regarding thermal sensation votes within the three central points of the seven-point ASHRAE sensation scale and at least 80% of the subjects satisfied by their environment, thermal acceptability of present subjects can be recognized (de Dear & Fountain, 1994; Kariminia, Ahmad, Ibrahim, & Omar, 2010; Kim et al., 2016; Yang, Olofsson, Nair, & Kabanshi, 2017). For this purpose, a quadratic equation expressing the correlation between TSVs and Ta (Fig. 4) was applied to estimate the linear regression curves, the results of which is illustrated in Table 6. It can be seen that acceptable thermal range of air temperature is 9.4 °C to 19.1 °C for the given range of relative humidity stated in Table 4; and neutral temperature equals 14.2 °C.

3.5.2. Acceptable thermal range: indoor spaces of Tehran

Compared to the current study, similar study regarding indoor thermal comfort was performed in Tehran by Heidari (2009, 2010). This research was performed by applying the identical methodology and ASHRAE 7-point thermal sensation vote (TSV) scale, so can be totally in accordance with the current study concerning outdoors in order to draw a conclusion regarding the discrepancy between indoor and outdoor acceptable thermal range. The corresponding results of Heidari’s indoor thermal comfort study for the cold season of the year are illustrated in Table 6. As indicated, the air temperature of 18.2 °C and 26.7 °C is suggested as the minimum and maximum boundaries of acceptable conditions indoors in Tehran, with the neutral temperature of 22.5 °C.

3.5.3. Acceptable thermal range: a comparison between ranges indoors and outdoors

A few studies have verified the dominant discrepancy between indoor and outdoor acceptable thermal range, seeking to find out the reasons (Hoppe, 2002; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b; Spagnolo & de Dear, 2003). Determining the difference of acceptable thermal ranges of indoor and outdoor spaces of Tehran has been one of the main objectives of this study; thus, a comparison between the two associate studies has been drawn, the summary of which is indicated in Table 6.

As indicated, the outdoor neutral temperature is around 8 °C less than its associate study of indoors. This difference arises from various factors, including higher values of clothing insulation, activity level, wind velocity, solar radiation, and also significant psychological adaptation elements-among which this study has examined the two factors of expectation and environmental stimulation and found them to be imperative.

In order to compare the results of these two research studies, the indoor neutral air temperature (i.e. $T_{neutral} = 22.5$) was assumed as the basis, on which differential values of the above mentioned factors were implemented. The equivalent temperature drop/rise (as a function of the difference in mentioned factors) was mainly obtained through the study by Arens et al. (2010). It is noteworthy that the difference in metabolic rate is caused by subjects’ varied activities in the indoor and outdoor settings.

According to Table 7, the cumulative effect of clothing insulation and metabolic rate yields the decreased neutral air temperature of 16.5. Furthermore, the difference in mean value of air velocity results in an
owing to the negligible number of votes in TSV categories of 1, with preference vote of "warmer". Table 8 may be due to the small range of air temperature in the following. 

mean radiant temperature and psychological adaptation factors, explained in the following.

4.3 °C is left, which could be attributed to the covering just likely to happen generally.

people will feel comfortable in higher temperatures, which are not thermal comfort range that is of more importance in cold season, as decreases, the number of individuals with preference vote of thermal preferences votes reported by subjects. As expected, as the TSV

situation—though they were feeling neutral, slightly cool, or cool.

providing to the closed space, and the statements a majority of the subjects had why

question in thermal preference of colder

Thermal preference votes of people along with their thermal sensation reveals importance of psychological adaptation, which affects thermal perception of the space. A three-point preference scale including votes of "Cooler", "No change" and "Warmer" was applied in order to record people's preferences. Table 8 illustrates the distribution of thermal preferences votes reported by subjects. As expected, as the TSV decreases, the number of individuals with preference vote of "cooler" and "no change" declines accordingly, while the number of individuals with preference vote of "warmer" has an upward trend. However, owing to the negligible number of votes in TSV categories of 1, −2, and −3 (as the bulk of data lies in two categories of TSV = 0 and TSV = −1) the pattern is not clear.

The percentage of individuals preferring to be colder while they are feeling neutral (TSV = 0) reaches 50%. Likewise, those feeling "slightly cool" or "cool" (TSV = −1 and TSV = −2) and prefer no change constitute 53% and 12% respectively. Moreover, there are even 14% and 19% of subjects in the two latter groups willing to be colder. All these together, reveals that people appreciate the environmental stimulation offered outdoors. This totally abides by Nikolopoulou & Steemers' statement declaring that in such conditions, people show greater tolerances to extreme circumstances than they would under average conditions — provided that they are not threatening (2003).

An argument could be introduced concerning the issue, that the subjects may have been exposed to the cold conditions outdoors for only a short time after leaving an air-conditioned building. Nevertheless, the history of exposure of subjects discloses that 78 percent of them have been to outdoor conditions for at least 30 min before the interview. Only 10 percent of the interviewees reported not being in outdoor spaces for less than 15 min before the interview took place.

Besides environmental stimulation, expectations — that is what the environment should be like, rather than what it actually is—greatly influence people's perceptions. The findings of the current study comply with Nikolopoulou & Steemers' argument concerning expectations as an effective factor (Nikolopoulou & Steemers, 2003a, 2003b), since the very same responses concerning the influential factor of expectations have been given by people.

Statements meaning "it is winter and it is meant to be cold" declared by 68 percent of people who have reported TSVs of cold side of the scale, and also "it's OK for this time of year" or "for this time of year I would prefer it even colder" claimed by 74 percent of people reporting TSV = 0 and preference votes of "colder" or "no change" denote the effect of expectation on thermal perception outdoors. As mentioned, this study examined only two ways of psychological adaptation which were already considered in the questionnaires. Other psychological adaptation factors might also be contributing to the difference in neutral air temperature indoors and outdoors.

increase of two in neutral air temperature, which is equivalent to 18.5 °C. On that account, 4.3 °C is left, which could be attributed to mean radiant temperature and psychological adaptation factors, explained in the following.

It should be noted that the smaller range of outdoor thermal comfort may be due to the small range of air temperature in field study days, covering just five days during the coldest period of the year with the maximum Ts of 15 °C. In other words, it is the lower boundary of the thermal comfort range that is of more importance in cold season, as people will feel comfortable in higher temperatures, which are not likely to happen generally.

Among various psychological adaptation factors affecting people's thermal perception (Aljwabara & Nikolopoulou, 2010; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b), this study examined expectation and environmental stimulation, and found them to be affecting the people thermal sensation and preference. It resulted from the subjective responses to the questions on both thermal sensation and preference. It is also settled from history of presence in a closed space, and the statements a majority of the subjects had provided to the "why" question in thermal preference of colder situation—though they were feeling neutral, slightly cool, or cool. Among these responses, almost 56% mentioned that this is winter, and so it must be cold.

Thermal preference votes of people along with their thermal sensation reveals importance of psychological adaptation, which affects thermal perception of the space. A three-point preference scale including votes of "Cooler", "No change" and "Warmer" was applied in order to record people's preferences. Table 8 illustrates the distribution of thermal preferences votes reported by subjects. As expected, as the TSV decreases, the number of individuals with preference vote of "cooler" and "no change" declines accordingly, while the number of individuals with preference vote of "warmer" has an upward trend. However, owing to the negligible number of votes in TSV categories of 1, −2, and −3 (as the bulk of data lies in two categories of TSV = 0 and TSV = −1) the pattern is not clear.

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ture in the same context of climate and culture discloses the importance of psychological aspects in outdoor thermal comfort studies. Among those, two main parameters of psychological adaptation (environmental stimulation and expectations) were found to modify subjective thermal perception and comfort by the current research.

This study also identifies a paucity of empirical thermal comfort research conducted in outdoor settings of Tehran, Iran. Due to limited resources, the field study was only conducted on five days of the coldest month of the year, so more such work is clearly needed to provide a comprehensive evaluation of outdoor thermal comfort issues of the whole year. In addition, physical measurements can be improved, including the crucial factor of mean radiant temperature and leading to other authentic thermal indices to consider the effects of short and long-wave radiation fluxes in outdoor environments on the human energy balance. Also, other psychological and behavioral aspects of outdoor thermal comfort perceptions in Tehran are some essential issues required to be considered. This can consequently provide new approaches to understanding the pervasive influences of outdoor thermal comfort on people’s use of outdoor space and activities, and finally planning and design implications.

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