The impact of urban green spaces on residents’ outdoor thermal comfort – a psychological and physical approach

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Green infrastructure has the ability to improve thermal comfort in outdoor urban spaces in moderate climates. Up to now, the impact of greenery on thermal comfort, however, was only studied in physical terms, using meteorological variables and human-biometeorological indices.

The main objective was to get comprehensive insights into the impact of green spaces on outdoor thermal comfort from both a psychological and a physical perspective. We answered the following research questions:
1. How do people generally perceive green places in urban environments during warm summer days with respect to thermal conditions?
2. What are the physical thermal comfort conditions related to air temperature (Tmrt), mean radiant temperature (Tmrd) and physiological equivalent temperature (PET) in urban green areas (during daytime on warm summer days)?
3. Is the impact of green spaces on perceived thermal comfort consistent with the physical thermal environment?

Little is known about the role of green spaces on people’s behaviour and generally perceived thermal comfort. Furthermore, physical thermal conditions of various parks within one city have not yet been investigated in the Netherlands.

Study 1 - Psychological approach (Surveys with passers-by)

- Interviews with passers-by during summer days, in 2011 and 2012 in three cities in The Netherlands: Arnhem, Utrecht and Rotterdam
- Response of 559 questionnaires (184 in Arnhem, 181 in Utrecht, and 194 in Rotterdam), response rate 31%
- Investigating relationship between green environments and thermal comfort compared to built and water environments on the basis of recurring patterns in people’s experiences
- Analyses: descriptive statistics, reliability analyses, SPSS 19 (more details see 1)

People generally perceived urban green spaces as thermally comfortable during warm summer days (Fig. 3).

Fig. 1: Interviews with passers-by in the city centre of Utrecht

Study 2 - Physical approach (Micrometeorological measurements)

- Mobile micrometeorological measurements on two summer days in 2012 in the city of Utrecht, The Netherlands
- Cargo-bicycles equipped with sensors for air temperature, wind, humidity, solar and thermal radiation and a GPS device (more details see 2)
- Loops covered 13 parks (1 - 22 ha), the city centre and an open grassland outside the north-eastern side of the city (Fig 2)
- Analyses: calculation of Tmrt and PET (Rayman), comparison of the average values and the variance of all Tmrt, Tmrd and PET measurements (more details see 2)

There was a wide variation in ambient thermal conditions, both between different parks and inside individual parks (Fig. 5). The variance is related to tree canopy cover inside parks and up-wind vegetation cover outside parks (see 2).

Measurement results demonstrate that the 13 examined parks were cool islands within the urban area (Table 2).


Fig. 3: Generally perceived thermal comfort in three different urban environments - Responses coded on a five-point scale from very uncomfortable (-2) to very comfortable (+2)

The experienced thermal comfort in green environments was significantly (p < 0.001) larger than in water and built environments (Table 1).

Table 1: Differences of generally perceived thermal comfort between urban environment types

<table>
<thead>
<tr>
<th>Control</th>
<th>Mean difference</th>
<th>T-test statistics</th>
<th>P-value</th>
<th>Significance</th>
<th>effect size</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green versus built</td>
<td>1.84</td>
<td>49.3</td>
<td>0.001</td>
<td>1.78 b (0.66)</td>
<td></td>
<td></td>
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<td>Green versus water</td>
<td>0.34</td>
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<td>0.001</td>
<td>1.78 b (0.66)</td>
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<td></td>
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<tr>
<td>Water versus built</td>
<td>1.01</td>
<td>36.2</td>
<td>0.001</td>
<td>1.78 b (0.66)</td>
<td></td>
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</tr>
</tbody>
</table>

59.4% of the 672 specific places that were indicated as thermally comfortable on warm summer days was a green environment (Fig. 4). All findings were stable across the cities of Arnhem, Utrecht and Rotterdam.

Fig. 4: Preferred thermal comfort places in three cities on warm summer days (times mentioned/ response frequency)

1. Green places within cities are perceived as thermally comfortable during warm summer days. Green environments are perceived even more thermally comfortable than built and water environments. This implies that peoples’ generally perceived thermal comfort is related to spatial characteristics of the environment (green, built, water).
2. Green spaces, like parks, are cool islands within the city. On average green spaces were characterized by PET values 1.9 K lower than the city centre and 5 K lower than the open grassland outside the city indicating the best physical thermal comfort conditions.
3. The psychological impact of green spaces on generally perceived thermal comfort is consistent with the physical thermal conditions related to Tmrt, Tmrd and PET. Therefore, we recommend to use ample green spaces within urban environments in moderate climates as urban green does improve perceived and objective thermal comfort.

Fig. 2: Location of bicycle loops in Utrecht in The Netherlands (yellow, blue and red = bicycle route, green=ridge of parks, with/rde of city centre) (aerial photograph by Google Earth)