Immersed in Microclimatic Space- Microclimate Experience and Perception of Spatial Configurations in Dutch Squares

1. Introduction

Public urban squares have become places of increasing importance in Dutch cities. Through the revival of urban centers many squares now accommodate leisure-oriented functions. To create urban places suitable for leisure it is vital to achieve sojourn quality for a substantial period of time throughout the outdoor seasons. This sojourn quality is affected by several parameters and microclimate and thermal comfort were identified as influential (Gehl, 1987; Eliasson et al., 2007; Zacharias, et al., 2001).

The concept of “thermal comfort” was described by the American Society of Heating, Refrigeration and Air Conditioning (ASHRAE) to be “that condition of mind which expresses satisfaction with the thermal environment” (1966). That implies that thermal perception is determined not only by physical and physiological factors, but also by psychological influences. This requires a thorough study of the “mental” thermal comfort aspects, next to the physical and physiological aspects of human biometeorology. The latter have already gained much attention in research. For example, a broad range of sophisticated physical models for thermal comfort have been developed. This includes, for instance, the studies of Fanger (1970) on the Predicted Mean Vote, the studies of Mayer and Höppe on the Physiologically Equivalent Temperature (1987), the COMFA-formula by Brown and Gillespie (1995) or the latest research on a Universal Thermal Climate Index.

Only recently the concept of thermal comfort in outdoor space was also studied from a more psychologically oriented perspective. A broad study on thermal comfort experience was conducted by Nikolopoulou and others. The main attention on the “Actual sensation vote” (ASV) of thermal comfort where information on the momentary thermal comfort experience of people in outdoor places was obtained and compared to “factual” measurement data that were taken parallel with the interviews.
It resulted in the conclusion that classical thermal comfort indices might often be too “strict” in their evaluation and that people in the outdoors show a greater tolerance to different thermal impacts than these indices suggest (Nikolopoulou and Steemers, 2003; Nikolopoulou and Lykoudis, 2006). Researchers like Knez and Thorsson investigated other psychological and cultural factors influencing outdoor thermal experience, such as the origin of people from different climate zones or their autobiography (Knez, 2005; Knez and Thorsson, 2006; Knez et al., 2009; Thorsson et al., 2007).

These studies, however, brought about findings that are not immediately useful for the urban designer. They focus on factors such as clothing degrees, length of outdoor stay, thermal history (the sequence of exposure to different thermal in- and outdoor conditions), personal origin, weather conditions, etc., that are not influenced by urban design interventions. Also, the concept of the momentary experience represented in the studies on the ASV cannot easily be translated into urban design due to its “transient” nature and the fact that it does not relate to the spatial surroundings. Urban design interventions are by their nature spatial, generally rather permanent and can not easily respond to “transient” conditions. Therefore, our research project, of which a part is presented in this manuscript, was launched to generate more usable design guidelines for the design of urban squares for microclimate and thermal comfort. The following part deals with one of the main questions: how do people’s longer-term microclimate perceptions relate to the spatial configuration of urban outdoor spaces?

There is some Dutch literature pointing towards the existence of such relations (Coeterier, 2000), but this was not researched systematically. Deduced from this we assume that people have microclimate “images” or “schemata” about urban places that relate to the spatial layout of place. Research on human environmental perception has shown that people develop these “schemata” on a plethora of environmental circumstances. Schemata are a means to structure and quickly assess these environmental circumstances (Eysenck, 2006; Lee, 1973; Neisser, 1976a). Schemata are based on learning processes (Neisser, 1976a) and on the interpretation of a
plethora of stimuli. In the case of environmental perception this can be certain situations, spatial configurations, or spatial elements being “environmental cues” (Brunswik, 1957; Gibson, 1979). Schemata that have once been developed can have the tendency to show mismatches with the situation they are applied to because they tend to remain in people’s minds for a long time even when the actual real situation has changed. This can lead to “illusionary” misjudgments, distortions (Eysenck, 2006) and sometimes behavioral maladaptation (Bechtel, 1997).

The fact that interpretations of environmental cues influence schemata is essential for this study, because we think that it is not only the microclimate itself that people perceive but also the spatial settings in which it happens. The phenomena of microclimate are not easily intelligible for people who are not familiar with the dynamic physics of microclimate and we assume that interpretation and schematization of visible environmental cues with respect to microclimate might therefore be a commonsense solution to get to grips with the complex invisible phenomenon of microclimate. Secondly, these spatial cues giving “hints” on the expected microclimate can consist of physical environments or objects which can serve as modifiers in urban design.

The underlying conceptual model of our research project is shown in fig. 1 and is based on the theory on schemata and environmental cues that was discussed above. It differentiates the “real” environment from the perceived environment and indicates that the “real” urban environment influences local microclimate. It is assumed in this model that people in their perception of places also develop a “schema” on how certain urban configurations influence microclimate. This “schema” of the environment is represented in dashed lines. In the larger context of the research project the relation of real and perceived microclimate
was also analyzed, indicated as “microclimate interpretation” in the diagram. The results of that corresponding analysis suggested that long-term microclimate schemata are influenced by rather salient microclimate situations (especially windy ones in the Dutch situation) that get engrained in a person’s memory (article in press). The analysis presented in this manuscript focuses on the spatial cues (highlighted in grey color in the conceptual model) in relation to the real microclimate.

Many potential cues exist in the urban realm that might influence microclimate perception. Especially the permanent spatial configurations of the built environment with their dimensions and proportions and objects might serve as visual cues for microclimate. These elements serving as cues are usually created or changed by urban design interventions. If it is possible to discover spatial cues that influence people’s microclimate schemata for a place, then operable design guidelines can be identified to change the cues and eventually the schemata people have developed. For such design guidelines it is also important to know if people’s perceptions are accurate or rather imagined because the urban design response would be different. In the first case, the true microclimate problems should be solved whereas in the second case measures that influence people’s perceptions should be taken into consideration. To identify the existence of these cues (being spatial configurations) and examine their relationship with microclimate reality two questions were to be answered:
1. Are there spatial configurations that function as spatial cues for microclimate?
2. How are these spatial cues or configurations related to the real microclimate in these configurations?

2. The Research

The two research questions were investigated with different methods. The first question on the spatial configurations functioning as cues was investigated through the analysis of cognitive maps based on user interviews. The second question was inquired through comparison of the spatial configurations (including the analysis of geometric properties) that were assigned certain microclimate properties with measurement results and microclimate literature.

The study was conducted on three Dutch squares (Spuiplein in Den Haag, Neckerspoel in Eindhoven and Grote Markt in Groningen). The squares share some similar characteristics such as their size in plan which ranges roughly around 100 x 100 m (Fig. 2). But in terms of surrounding building structure and function the squares differ substantially.

Fig. 2 maps of sizes and structure of the case study squares

1. Spuiplein in Den Haag (52°04’ N and 4°19’ E, fig. 3 and 4)

Den Haag (475,580 inhabitants) is the administrative centre of the country. The Spuiplein square is situated in the city centre in a place where several pedestrian routes converge. It is also flanked by a main traffic artery. The square is restricted to
pedestrian and bicycle traffic and well connected to public transport. The square’s central area has an eye-catcher in the summer: a field of about a hundred little fountain jets. Occasionally used for events such as music and sport festivals, most of the time throughout the year it is just an open surface without significant activities.

Fig. 3 Spuiplein, Den Haag

Fig. 4 map of functions and building entrances, Spuiplein

2. Neckerspoel in Eindhoven (51°25’N and 5°28’ E, fig. 5 and 6)

Eindhoven (210.860 inhabitants) is known as a centre of technological knowledge with the main branch of Philips and the Technical University of Eindhoven. The Neckerspoel square serves as the main bus terminal of the city and lies on the northern flank of the central railway station building. The main waiting area for the passengers lies on the northern side of the station building where also some snack- and flower shops can be found. The square allows limited automobile traffic to serve for “kiss and
ride” and taxis on the eastern side and the rest of the square is reserved for buses. It has to be mentioned that just when the field-work had started a broad canopy was built to cover large parts of the waiting which is very relevant to thermal comfort of passengers.

Fig. 5 Neckerspoel, Eindhoven

Fig. 6 map of functions and building entrances, Neckerspoel

3. Grote Markt in Groningen (53°13’ N and 6°34’ E, fig. 7 and 8)

Groningen (180.908 inhabitants, of which 42.000 are students) is the administrative and cultural centre of the Northeast of The Netherlands. The Grote Markt is the historical main market square of the city and lies in the centre of the city as a part of a sequence of squares. The square features a landmark, the Martini church tower, on the North Eastern corner. Motor traffic (buses and taxis only) is limited to the eastern side. The rest of the square is open for pedestrian and bicycle traffic and loading activities.
related to the market. The market is held on two mornings per week and fun-fairs or events take place a few times per year. But for the majority of the time the square is an open, rather unused place.

![Fig. 7 Grote Markt, Groningen](image)

![Fig. 8 map of functions and building entrances, Grote Markt](image)

### 2.1 Generation of Cognitive Maps and Analysis

To answer the first research question, “are there spatial configurations that function as spatial cues for microclimate?”, we used cognitive maps.

As discussed in the introduction, the interpretation of cues that get embedded in mental schemata, seems to be influential on microclimate experience. Neisser carried the concept of mental schemata further into the concept of cognitive maps. He describes a cognitive map as a spatially configured collection of schemata (Neisser,
Since then, this idea has been broadly used by researchers in the field of cognitive mapping (Golledge and Stimson, 1997; Kitchin, 1994; Kitchin, 1996; Mark et al., 1999; Tversky, 2003). Because we were interested in the relation of the mental schemata that people had about a space, we considered cognitive mapping a promising research tool.

Many cognitive map researches focused on visual orientation, way-finding, mental representation of geographical maps and distance estimation, such as the landmark research of Kevin Lynch (1960) that has boosted research in the field (Kitchin, 1996; Mark et al., 1999). But other, non-visual cues perceived through other senses are also described to be part of cognitive maps (Kitchin, 1996; Mark et al., 1999; McDonald and Pellegrino, 1993). Therefore we think that a cognitive map method is also usable to depict thermal or microclimate experience.

Probably, much of the research on visual orientation, way-finding, mental representation of geographical maps and distance estimation was conducted because this was easily comparable with measurable reality and therefore distortions can easily be revealed. In our case, it is also possible to use more objective criteria derived from measurements and scientific knowledge to compare these cognitive maps with reality.

Several authors have identified cognitive maps as a helpful tool for planners and designers (Golledge and Stimson, 1997, p 239; Kitchin, 1994; Kitchin et al. 1997) who normally have to address both with their interventions: the physical reality and people’s perceptions of it. Since we were trying to generate design recommendations for climate- responsive design we too consider the cognitive map as an aid to generate this basic design knowledge. For the reasons stated above we decided to use cognitive maps based on interviews with people in the study squares as a main tool in our research.

Given our interest in long-term experience or schemata of people we had to limit the sample group to the long-term users. Hence, the interviewees were asked if they know the square for a longer time already and come there on a regular basis. This way
groups such as tourists that visit the place only occasionally could be excluded from the sample group.

The series of interviews were taken during the outdoor seasons (spring, summer and autumn in 2005 and 2006) on 4 days per season. Winter was left out because people in The Netherlands generally do not use public space for sojourn during winter. There was an average amount of 232 interviews per square (Spuiplein, Den Haag: 218, Neckerspoel Eindhoven: 254, Grote Markt, Groningen: 223).

The method to generate the cognitive maps was a combination of two methods described in Golledge and Stimson (1997): a “base map with overlays” with a “word list”. We wanted to inquire people’s fine-grained microclimate experience of sub-zones in the squares rather than their impressions of the entire squares. This was because we knew that within the squares different microclimates existed and we were interested in how far people perceive these differences. Therefore we asked people to identify the zones within the respective square that they perceived microclimatically comfortable or uncomfortable for sojourn from their long-term experience. This was recorded on a base map. Sometimes people marked the areas on the maps on the questionnaire sheet themselves. But the majority of people preferred to point out the areas on the squares and have the researcher draw them into the map. The fact that a square is rather easy to overlook was of great advantage for this. The place-related microclimate knowledge was only aired about the places which interviewees knew and about which they had an opinion. So the cognitive map generated from one interview was normally not covering all parts of the square. Additionally, people were asked to specify their comfort or discomfort experiences in the respective areas: were these experiences caused by wind speed, shadow, sun, rain protection or others (tab. 1)? A combined application of the two methods can be seen in an example derived from an individual interview in fig. 9.
The individual cognitive maps showing the different zones and microclimate experiences were accumulated and overlaid in GIS. Generally, this was not problematic because borders of these zones mentioned were mostly quite distinct. This is because the areas that people pointed out had clear limitations due to spatial markers such as vertical delineations, height differences, roads or changes in the pavement. All the assessments by the users were subdivided according to the different reasons for the experiences (tab. 1). They were added up in a database per zone per square and depicted in GIS (appendices 1-3, upper two rows).

<table>
<thead>
<tr>
<th>comfort</th>
<th>discomfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind comfortable</td>
<td>Too windy</td>
</tr>
<tr>
<td>Shade comfortable</td>
<td>Too shady</td>
</tr>
<tr>
<td>Sun comfortable</td>
<td>Too sunny</td>
</tr>
<tr>
<td>Good rain-protection</td>
<td>Bad rain-protection</td>
</tr>
<tr>
<td>Others comfortable</td>
<td>Others uncomfortable</td>
</tr>
</tbody>
</table>

Tab. 1 reasons for microclimate long-term experience

Fig. 9 example of an individual cognitive map derived from an interview
Since some areas showed zones that were perceived both comfortable and uncomfortable for certain reasons we needed to get a more generalized picture for further analyses. Therefore, we balanced all positive (“comfort”) and negative (“discomfort”) votes of the different microclimate experiences (wind, shade, sun, rain protection and “other reasons”) per sub-zone. This was done by assigning the sum of experiences causing discomfort (subdivided according to the reasons wind, shade, sun, rain protection and “other reasons”) with negative values and experiences causing comfort with positive values. After this balancing, the sub-zones that were perceived predominantly comfortable showed positive values and the ones perceived predominantly uncomfortable showed negative values (see examples fig. 10 and 11, complete set of maps in appendices 1-3, lower row).

Fig. 10 general cognitive map after balancing comfort and discomfort perceptions on “wind” for Spuiplein, Den Haag.
For further investigation we excluded sub-zones that got votes due to sub-zone specific incidental reasons. Hence, we selected only the sub-zones that got values > 5% or < – 5% of the balanced votes for the different microclimate parameters (wind, shade, sun, rain protection and “other reasons”).

During the interviews certain spatial configurations were mentioned quite often (e.g. “here in the central area of the square”, “there in that street entrance”, “here under the canopy”) in relation to certain microclimate properties. Further visual assessment of the balance maps revealed that indeed certain types of areas, sometimes consisting of only one sub-zone, sometimes consisting of a cluster of them, were assigned rather similar microclimate characteristics. Since this might reveal regularities in the ways how people interpret these spatial patterns in relation to microclimate, we analyzed these patterns further and identified a range of spatial types. These spatial types were identified for all the squares (overview in appendix 4).

For a subsequent analysis of the spatial configuration types and their role as cues for microclimate the selection of spatial types was narrowed further because we believed that singular occurrence of a spatial configuration type of one square might be caused
by local incidences. So the spatial configuration types that were selected for further analysis were the types reoccurring in the spatial type overview, either within one and the same square or in different squares (see appendix 4).

From results of this selection we found answers to the first research question. There was indeed a range of spatial configuration types that were often assigned certain microclimate conditions in different places. The types were:

1. Places perceived to be “too windy”:
   a) Central open square area
   b) Foot of a tall building
   c) Entrance of street canyon
   d) Passage

2. Places perceived to be “comfortable in terms of wind”
   a) Semi-enclosed area
   b) Foot of a low building

3. Places perceived to be “comfortably sunny”
   a) Semi-enclosed areas
   b) Foot of a low building

This list indicates that there were certain spatial configurations that serve as cues with respect to microclimate. It was interesting to notice that the question of scale was influential here and that the spatial types with some sense of enclosure were rated more positive than the spatial types like large open squares. The “semi-enclosed places” for example scored with only positive balances. This preference for spatial enclosure, smaller scale places and avoidance of large open space is consistent with findings from other studies (Carr et al., 1992; Gehl, 1987). Reasons for such preference were predominantly sought in “proxemics”- the body of knowledge on spatial patterns based on people’s social interaction and the minimum distances related to those interactions (Gehl, 1987; Hall, 1966). Those studies, however, did not focus on the microclimate aspect.
2.2 Microclimate Measurements

To acquire comparison data for validation of people’s long-term experiences, microclimate measurements were conducted parallel with the interview series. For each square we selected a range of points to depict different microclimate situations. The measurements were carried out on 4 days for each of the three outdoor seasons at 9, 11, 13, 15 and 17 hrs. At these times measurements were taken at five spots in the square in Den Haag, and six spots in the squares in Eindhoven and Groningen (fig. 12-14). Spot no. 6 in Eindhoven was eventually excluded from evaluations because too many measurements were taken between waiting buses that strongly distorted the microclimate in terms of shadows cast and wind deflected.

Fig. 13 map with measure point numbers, Spuiplein, Den Haag

Fig. 12 map with measure point numbers, Neckerspoel, Eindhoven
The factors measured for thermal comfort were air temperature, globe temperature, short-wave radiation, wind speed and wind direction. The instruments used were a cup-anemometer with vane and a combined thermometer and hygrometer by Thies company, a globe-thermometer consisting of a black plastic ball with Pt100 and a pyranometer for short-wave radiation measurements by Kipp und Zonen company. Not all of these measured parameters proved to be of importance to serve as a reference for microclimate experience. Wind speed was clearly the most important parameter in terms of people’s experiences. For the analysis in this regard, the wind speeds of all the measurements taken were averaged per measurement point. This average provides a picture of wind speeds over time which we consider most suitable to be compared with people’s long term wind experience. Also the parameter “sun” was important. Since the measurements did not show the very fine-grained and continuous changes of sun and shadow clearly enough, we decided to use shadow simulations. The patterns of sun and shadow were simulated through the 3D-software SketchUp for three days in the middle of the three outdoor seasons (15th of April, July and October). The evaluation of shadow patterns were based on percentages of time that show in how many cases the places are indeed sunny. The results of these measurements and shadow simulations will be shown and discussed in the following in direct relation to people’s spatial microclimate schemata.
2.3 Relating Spatial Cues for Microclimate to Microclimate Reality

To address the second research question, “how are these spatial cues or configurations related to the microclimate in these configurations?”, two steps were taken. Firstly, the microclimate schemata related to different configurations were compared with the results from the measurements in points that represent these configurations, respectively with the shadow simulations. The overview in tab. 2 shows the average wind speeds in the different points that represent the spatial configuration types. In Eindhoven two measurement spots occurred to be situated either within an area that was not mentioned by people (point 3) or in a spatial type that occurred in Eindhoven only (under an overhang, point 2). Thus we decided that measurements from these points could not be considered for the comparisons.

The shadow simulations (appendix 5) were used to be compared with the impression that a place is “comfortably sunny”. Here we investigated if it is indeed “sunny” in the places all the time, knowing that the shadow patterns change over the day. This is evaluated by counting the “matches” for the different spatial types on the shadow-maps. That is, when a place lies in the sun the entire day, the match is 100% and when it is in the shade the entire day it is 0%. The results are shown in table 3.

<table>
<thead>
<tr>
<th>spatial configuration type</th>
<th>Den Haag meas. pt. numbers</th>
<th>Den Haag average wind speeds per type (m/s)</th>
<th>Eindhoven meas. pt. numbers</th>
<th>Eindhoven average wind speeds per type (m/s)</th>
<th>Groningen meas. pt. numbers</th>
<th>Groningen average wind speeds per type (m/s)</th>
<th>Total average wind speeds per type (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>too windy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) central open square</td>
<td>1 and 5</td>
<td>1.65</td>
<td>5</td>
<td>1.16</td>
<td>6</td>
<td>1.78</td>
<td>1.53</td>
</tr>
<tr>
<td>b) foot of a tall building</td>
<td>\</td>
<td>\</td>
<td>4</td>
<td>1.11</td>
<td>1</td>
<td>2.15</td>
<td>1.63</td>
</tr>
<tr>
<td>c) entrance of street canyon</td>
<td>\</td>
<td>\</td>
<td>1</td>
<td>2</td>
<td>4 and 5</td>
<td>1.9</td>
<td>1.95</td>
</tr>
<tr>
<td>d) passage</td>
<td>4</td>
<td>1.5</td>
<td>\</td>
<td>\</td>
<td>\</td>
<td>\</td>
<td>1.5</td>
</tr>
<tr>
<td>comfortable in terms of wind</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) semi-enclosed</td>
<td>3</td>
<td>1.1</td>
<td>\</td>
<td>\</td>
<td>\</td>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td>b) foot of a lower building</td>
<td>2</td>
<td>1.3</td>
<td>\</td>
<td>\</td>
<td>2</td>
<td>1.47</td>
<td>1.39</td>
</tr>
</tbody>
</table>

Tab. 2 results of wind speed measurements
Additionally, an analysis of the geometric properties of the spatial configuration types was conducted because we consider this as crucial for the physical microclimate. The sizes of the spatial types on the ground as well as the heights of surrounding or adjacent buildings and resulting proportions (when applicable) were measured. Figures 15 and 16 show two examples. For the complete overview of geometries, see appendix 4. The resulting geometric properties were then analyzed on their probability to bring about the microclimate effects that people ascribe to them. This was done with help of existing literature on microclimate and microclimate modifiers.

Fig. 15 example of geometric analysis of “open square surface” type
The results of the two analyses— the local measurements and the descriptions from microclimate literature for each spatial type are discussed in the following.

1. Places perceived to be “too windy”
   a) Central open square surface (example fig. 17)

In all three squares these places are considered to be too windy. The measurement data also support for all three squares that these areas indeed show higher wind speeds than the areas considered comfortable in terms of wind (also see tab. 2).

In order to assess further if the central areas of squares are prone to be windy in general, we analyzed their spatial properties in detail. The proportions of a square are often expressed through the height/width ratio (H/W), as shown in fig. 18. This ratio sets the height of the surrounding buildings in relation to the square’s
depth from “wall to wall” of the square. That is, the lower the H/W ratio-value the wider are a square’s proportions. We calculated this ratio for each square, also taking the different

![Fig. 18 diagram of height and width relation in a square](image)

Fig. 18 diagram of height and width relation in a square

heights of surrounding boundaries into consideration. For the Spuiplein, Den Haag this results in the H/W ratio of 0.14, the Neckerspoel, Eindhoven in 0.11 and Grote Markt, Groningen in 0.10. When we compare this H/W ratio with the threshold value of H/W ratio 0.25 in other researches on urban wind dynamics (Bottema, 1993a; Oke, 1987) we see that all three central areas of the squares are well below that threshold of 0.25. Squares that have a H/W ratio lower than 0.25 show typical wind flow patterns that bring flows of wind higher speeds (“isolated roughness flows”) to the central areas of a central square area (fig. 19).

![Fig. 19 typical wind pattern of “isolated roughness flow” on squares with h/w ratio smaller than 0.25, adapted from Oke 1987, p. 267 with wind flows of higher speeds touching the square surface](image)

Fig. 19 typical wind pattern of “isolated roughness flow” on squares with h/w ratio smaller than 0.25, adapted from Oke 1987, p. 267 with wind flows of higher speeds touching the square surface

Considering the measurement results and the wind pattern research knowledge together we conclude that user’s assessments of the open square areas to be
“windy” matched well and that people have developed a good comprehension of the wind climate in these types of places.

b) Foot of a tall building (example fig.20)

Here measurement data for two such places supported that these areas indeed had higher wind speeds than the areas considered comfortable in terms of wind (also see tab. 2). The measurements in place no. 4 in Eindhoven, however, showed only marginally higher wind speeds than places that were considered comfortable in terms of wind. This might have to do with the wake of trees that suppress winds from the prevailing wind directions in that spot.

But other studies give a clear support of people’s impressions. The buildings described to be “tall” in this case are at least 20 m high. The threshold of 20 m in height used here relates to the Dutch building recommendation (NEN-norm 8100, 2006), calling for a special wind- assessment procedure for building projects exceeding a total height of 20 m. Other research on wind- patterns confirms that the areas around the feet of tall buildings are generally windy due to downwash effects (Bottema, 1993b; Littlefair et al., 2000).

So we conclude that in this case the perception of people about these places being “windy” is justified, both by the measurement results and other research. But the
appropriateness of these evaluations can also be a function of the orientation of the buildings. The fact that these taller, tower-shaped buildings are often free-standing (due to building regulations) causes a wind exposition to many sides. So the chance that at one of their bases downwash effects occur is quite high.

c) Entrance of street canyon (example fig. 21)

Fig. 21 impression of spatial cue type “entrance of street canyon”, Neckerspoel, Eindhoven

The street entrance areas clearly show higher wind speeds in our measurements than areas that are perceived comfortable in terms of wind. These places are prone to higher wind speeds due to two causes. Firstly street canyons can work as wind funnels increasing wind speeds due to higher pressure “venturi” effects (Bottema, 1999; Johnson and Hunter, 1999). Secondly, since a street canyon is normally open to two sides there is a great chance that winds are caught and channeled, especially when the street lies parallel with the predominant wind directions. Furthermore, angular building corners -as opposed to buildings with corners rounded off- are often more gusty due to corner pressure effects (see fig. 22; Bottema, 1993a, Bottema 1999). In this case people often correctly read the cues for wind climate in these types of spaces.
Fig. 22  Plan view of corner pressure wind effects under different wind directions with indication of wind speed isolines, Bottema 1993, p. 85

d) Passage (example fig. 23)

Our measurements had only one point that is situated at the end of a passage-type of space, but the measurement results here were once more higher than the ones in the places considered comfortable in terms of wind. The geometry of this spatial type depends on the size of the overarching buildings. This configuration type’s air flow physics show a clear tendency to act as strong wind funnels (Bottema, 1993a; Littlefair et al., 2000). Again, in this case people’s interpretations are quite appropriate.
It might be worth while to remark that respondents often used a special term to describe the latter two kinds of configurations (entrance of street canyon and passage). They call these places “tochtgaten”, literally translated: “draught holes”. This word indicates that a climatic phenomenon (“draft”) is associated to a spatial configuration (“hole”).

2. Places perceived to be “comfortable in terms of wind”

a) Semi-enclosed area (example fig. 24)
All the measurements taken in these areas showed indeed lower wind speeds than the ones taken in places considered to be “windy”. Semi-enclosed areas are usually surrounded by buildings or other vertical structures like wind-screens, walls or vegetation. A typical configuration for instance is the café terrace that is bounded by a building along one long side and laterally by wind screens. These areas can offer wind protection from three sides. For example, in case of the typical windscreens of

Fig. 25 Dimensionless, proportional size of wake and wind speeds around a wind obstacle, adapted from Oke, T. 1987, p. 243 and Robinette, G. O., and McClennon, C., 1983, p. 36

~1,5 m height that usually flank the café terraces a wake area is approximately 10 -15 m (fig. 25; Oke, 1987; Robinette and McClennon, 1983). Most café terraces do not exceed this width. So there is only a small probability that the semi-enclosed areas get exposed to wind when it comes right from the front. So people’s interpretation of this spatial cue “semi-enclosed area” has a high probability to be suitable.

b) Foot of lower buildings (example fig. 26)
The averaged measurements taken in two typical spots also show lower wind speeds than the places perceived “windy”. However, point nr. 2 in Groningen
shows values that are somewhat higher than some points in areas that are perceived to be “windy” (points 4 and 5 in Eindhoven).

Fig. 26 impression of spatial cue type “foot of lower building”, Spuiplein, Den Haag

This type of place lies at the foot of buildings, without vertical screening elements on the side. The low buildings discussed here generally do not exceed 20 m in height. People’s perception of a “foot of a lower building being comfortable in terms of wind” can be supported by other researches, particularly for the cases where wind directions are perpendicular to the building. Generally, at the foot of lower buildings downwash effects that are associated with taller buildings do not occur. Also the buildings provide wind protection for two directions as a part of the cavity area on the windward side or a wake area on the lee-side (also see fig.25; Oke, 1987; Robinette and McClennon,1983). However, this strongly depends on the exposure of a building. Also our measurement data show that there can be bigger differences. So we assume that people’s assessment might be based more on the reading of the spatial cues than the wind microclimate.

3. Places perceived to be “comfortably sunny”

a) Semi- enclosed areas

The analysis of shadow simulations showed that matches of the perception “sunny” over time varies between 50 and 80% for the different areas. The total match of 62% indicated that people’s perceptions of sun tend to be only partly
appropriate, with still a large percentage unexplained. Semi-enclosed areas are often surrounded by buildings or other vertical structures like wind-screens, walls or vegetation. These elements all cast shadows and it depends on the orientation of the surrounding vertical structures for this type to actually receive sun. People’s perceptions do not seem to take this sufficiently into account in their judgments. It seems that in this case people’s perception of “comfort in terms of sun” is based more on the spatial setting than the real sun/ shadow climate.

b) Foot of lower buildings

The analysis of shadow- simulations showed that matches of the perception “sunny” were between 40 and 80% for the different areas. The total match of 66% shows that people’s perceptions of sun tend to be rather appropriate, with still quite a large percentage unexplained. This type of place is generally a longer strip along the foot of buildings that generally do not exceed 20 m in height. This type of space might sometimes have a good sun- exposure, and sometimes not, depending on the building orientations. However, the places that were pointed out by the interviewees were in most cases indeed spots with a relatively good sun-orientation. These types are often café terraces or some benches or other sittable elements are situated in these areas. In these places the perception of “comfortable in terms of sun” might also have to do with the fact that people enjoy a friendly atmosphere and relate this to their overall feeling of comfort. Or people unconsciously choose sunny places to stay and thus base their experience on the time they spend in these sunny spots.

3. Conclusions

From this research we can conclude that there are significant correlations between people’s interpretation of spatial configurations and microclimate perception and that people have developed schemata on microclimatic space.
Concerning the first research question, “are there spatial configurations that function as spatial cues for microclimate?”, we can answer with yes. There are spatial configuration types that are associated with certain microclimate properties and this was in general supported by measured microclimate data. To summarize them again:
1. Places perceived to be “too windy” are the central open square surfaces, foot areas of tall buildings, entrances of street canyons and passages.
2. Places perceived to be “comfortable in terms of wind” and “comfortably sunny” are semi-enclosed areas and areas at the foot of low buildings.

Concerning the second research question, “how are these spatial cues or configurations related to the microclimate in these configurations?”, we conclude that many people have developed acuity for the general microclimate reality for most of the places. The cues seem to be a tool to “quick-scan” spaces on most probable microclimate properties. However, there are exceptions. Not in all cases the interpretation of the spatial configuration on their expected microclimate was right. Especially the data on sun-exposure showed this. But these incidental misinterpretations are typical for the way that mental schemata work. They form a probabilistic approximation tool to assess the environment, risking that they do not always work appropriately. Yet, generally speaking, people’s interpretations of spatial/visual cues for microclimate, most of the time, have a good relation to reality and misinterpretations of cues are more exception than rule. For design recommendations this means that design should focus on the real microclimate situations and that it would only in exceptional cases be recommendable to respond to “imagined” microclimates.

Some practical recommendations can be derived from this study for the Dutch situation and for similar climate contexts in temperate maritime North Western Europe. We summarize them in the following by restating the conclusions for the spatial configurations and adding implications for urban design.
1. Open squares with a height/width ratio lower than 0.25 often are perceived windy and indeed tend to be windswept. Open places of this proportion should rather be avoided in urban design because higher wind speeds are likely to touch the square’s floor area. When these square proportions are not avoidable, remedies should be provided: spatial objects such as screens, vegetation, larger sized furniture or pieces of art. These elements can at the same time help to mitigate wind impact and can act, for example, also as shadow devices. They break the scale of the open squares and offer the diversity of smaller scaled spots (e.g. the semi-enclosed areas) which tend to be preferred by the interviewees.

2. The foot areas of tall buildings are perceived uncomfortably windy and also often prove to be windy, indeed. Here, measures should be taken to mitigate the downwash effects by either adding awnings or other wind deflecting devices or trying to keep the main public away from these zones.

3. Entrances of street canyons are perceived uncomfortably windy and can factually show strong wind effects. Here measures to mitigate wind impact can be difficult, because winds come from several sides, just as the main traffic movements. This problem can better be solved by avoiding sojourn functions in these areas.

4. Passages which often are perceived uncomfortably windy, are in fact very problematic in terms of wind properties. This situation is difficult to solve. Wind is pushed in from various directions and all movements have to go through the passages, too. The best remedy is to avoid sojourn functions here.

5. Semi-enclosed areas are perceived to be “comfortable in terms of wind” and this perception is often correct. So it is advisable to create sufficient semi-enclosed places to offer wind-protected spots through screens, walls, mounds, vegetation, etc.

6. The foot areas of lower buildings are also perceived “comfortable in terms of wind” but this depends on the building orientations. In urban refurbishment or public design projects the erection of more buildings to create these kinds of zones is generally not possible. However, making better use of well- oriented areas by situating sojourn functions at the foot of existing buildings is often feasible.
7. Semi-enclosed areas are often considered to be “comfortable in terms of sun” – even if they are factually not that sun-exposed over the day. If possible, more semi-enclosed areas that have an ideal south facing sun exposition should be provided.

8. The foot area of lower buildings is seen to be comfortably sunny, but that depends on the building exposure. Here goes that public design can generally not influence the erection of more buildings to create these kinds of zones. However, making better use of these areas at the foot of existing buildings, and especially the ones with a good sun-orientation, by situating sojourn functions there is often possible.

Our study has shown that there are relations between people’s spatial/visual and microclimate perceptions and based on this, we have given some hints for public space design. Our findings represent only a little fraction of the plethora of relations that are expected to exist between spatial and microclimate perceptions. It would be worthwhile, for instance, to conduct similar research as the one presented here in other places that have very different sizes or spatial setups. This might yield a refinement of our results or more spatial configuration types that are read as microclimate cues. Also, it would be interesting to study this in different climate zones because it is very likely that people develop different schemata and interpretations of spatial cues for microclimate depending on the regional climate. In general, more knowledge on people’s microclimate perceptions will help to create more precise urban design guidelines for climatically comfortable urban outdoor spaces.
List of References


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