Photographic comparison: a method for qualitative outdoor thermal perception surveys

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Abstract

This article addresses the use of photographic comparison as a complementary visual appraisal method in an outdoor thermal perception survey. This survey was carried out during a Ph.D. research exploring how materials and vegetation influence thermal comfort in outdoor public spaces. Objective and subjective thermal perception parameters were combined and quantitative and qualitative research methods were used. The quantitative methods included microclimatic measurements, whilst the qualitative methods comprised observations and spatially localised interviews based on a questionnaire and the photographic comparison. This article explores how such visual research method allowed triangulating findings of this field survey. Three non-edited photographs of outdoor public spaces, under similar summer meteorological conditions but with contrasting spatial features, were shown to respondents to the questionnaire. The photographs depicted undisclosed locations for preventing biased emotional appreciations. Respondents were asked to select the potentially most comfortable and uncomfortable environments depicted. The choice of photographs matched the previous answers on the thermal sensation and evaluation judgement scales. Hence, we discuss the way the visual interpretations by respondents allowed the triangulation of in situ thermal perception data. The extent to which thermal comfort can be interpreted from thermal environments depicted in photographs containing clear visual signs is further discussed. The article concludes on how such a visual appraisal method can be valuable for enriching future qualitative outdoor thermal perception surveys with subjective interpretation of visual data.

Keywords Thermal perception · Field survey · Outdoor · Qualitative methods · Photographic comparison · Visual semiotics

Introduction

Providing the necessary conditions for outdoor thermal comfort, ‘that condition of mind which expresses satisfaction with the thermal environment’ (ISO 2005), is a challenge for urban designers over the coming decades. The degree and intensity of people’s activities in outdoor spaces ‘depends on the level of satisfaction or dissatisfaction under the prevailing climatic conditions’ (Gaitani et al. 2007). There is therefore an agreement on providing people the means to cope with the prevailing outdoor microclimatic conditions by assessing the human perception of thermal comfort and by climate-responsive

urban design (Givoni 1998; Nikolopoulou 2004; Lenzholzer and Wulp 2010; Hirashima et al. 2016; Eliasson et al. 2007).

Whilst earlier research on human perception of thermal comfort focused on the physiological dimensions of thermal comfort, recent research has been increasingly giving its psychological aspects more importance (Nikolopoulou et al. 2001; Knez and Thorsson 2006; Oliveira and Andrade 2007; Nicol 2008; Lenzholzer and Koh 2010; Lin et al. 2011; Hirashima et al. 2016; Shooshtarian and Ridley 2017). Due to the large physiological and psychological differences amongst individual people, empirical data on the subjective human parameter can provide a broader perspective from which to view thermal comfort in outdoor public spaces (Nikolopoulou and Lykoudis 2006).

Qualitative research methods dealing with subjective parameters provide insights on the relationship between spatial features and conditions offered for thermal comfort. Valuable information for climate-responsive urban design can thus be retrieved, since this is a discipline committed to finding the best mediation between man, climate and environment (Cortesão et al. 2016). This does not neglect the importance

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of quantitative methods. Indeed, understanding ‘the functional physical environment and how people subjectively experience it demands for appropriate representation of both’ quantitative and qualitative methods (Lenzholzer et al. 2016). Different outdoor thermal perception studies have been combining such methods (Knez and Thorsson 2006; Eliasson et al. 2007; Lenzholzer 2009; Zeng and Dong 2015; Wang et al. 2016).

Within the qualitative sphere, verbal and textual methods seem to be predominant whilst visual methods occur less frequently. Visual appraisal methods can however be greatly important to help supporting textual methods and/or overcoming misunderstandings from verbal communication. If on one hand focusing on the visual aspect of landscape provides only a partial ‘view’ of our environment (Lange 2011; Downes and Lange 2015), on the other hand, vision is a powerful sense for perceiving an outdoor thermal environment (Rosso et al. 2016). In visually oriented disciplines, such as urban design, images help engaging with a particular topic (Pettit et al. 2011; Lovett et al. 2015).

As a visual appraisal method, photography has been used in different fields for building up methodologies and understanding phenomena with the subjective interpretation of visual data. For example, Gardner (2008) makes an extensive and systematic use of photographs for building up her research and to get to grips with the subjective experiences of older people in their neighbourhoods. Goltara and Mendonça (2015) address photography as a landscape analysis method, arguing that photographic documentation of environmental behaviour can inform the development of indoor and outdoor environments best suited to their purpose.

Photographic comparison has been used by Rodiek and Fried (2005) as a method for assessing the preferences of assisted living residents in accessing outdoor spaces. The authors explore the match between the preferences for key spatial features respondents expressed in a previous verbal study and the choice for a preferred image. To this end, pairs of photographs of the same scene depicting and lacking such features were shown. The authors conclude that the results of the photographic comparison supported the findings of the previous verbal survey.

As a means of visual communication, photographs can be interpreted based on different aspects. The process of interpretation, or meaning-making, through photography can be studied using a framework based on visual semiotics (Jappy 2013). Semiotics is a theory of meaning and of how meaning is attributed to the world (Eco 1976). There are several strains of semiotic theory as there are several types of meaning. Yet, the most appropriate framework for studying the process of interpretation of visual materials in relation to spatial design can be derived from the semiotic theory of the pragmatist philosopher and semiotician Charles Saunders Peirce (Raaphorst et al. 2017). According to the theory of semiotics the world has meaning because it is constituted by *signs* (Eco

1976). For Peirce, anything can be a sign as long as it has some sort of significance for someone (Peirce 1958). A sign has a sign-function: it can be a sound, an emotion or a physical sensation that refers to a real-world phenomenon, which is then interpreted by someone. In relation to thermal perception, for example, the feeling of a soft breeze and the sound of rustling leaves are signs that can evoke sensations of certain microclimatic conditions which are subsequently interpreted as positive or negative. Likewise, signs of thermal comfort can be visual: the presence or absence of vegetation, the type of paving materials, the predominant colours or the brightness or shading of a scene.

Taking these examples of the use of photography as a visual appraisal method and based on the argument that the interpretation of visible environmental cues related to microclimate can be a common sense solution for better understanding ‘the complex invisible phenomenon of microclimate’ (Lenzholzer and Koh 2010), the following question is formulated: to what extent can photographic comparison be a valuable visual research method for complementing the verbal methods typically used in qualitative outdoor thermal perception surveys?

To answer this question, this article addresses a thermal perception survey making use of photographic comparison (Cortês 2013). The match between the respondents’ preference for a photograph and the votes on thermal comfort judgement scales is investigated. The discussion on the use of photographic comparison is expanded through a visual semiotic analysis to explore the relation between the visual characteristics of the scenes depicted in the photographs and the spatial characteristics (in particular, materials and vegetation) of two sites in which the survey was conducted. We investigate how outdoor urban thermal environments depicted in photographs were interpreted by the survey respondents by decoding the visual signs present in each photograph through a semiotic logic. From here, we explore how photographic comparison can enrich future qualitative outdoor thermal perception surveys with the interpretation of visual data.

In the ‘**Materials and methods**’ section, we present an overview of the field survey. The ‘**Results**’ section consists of a to-the-point presentation of the outcomes of this exercise. The bulk of the article is the discussion section, where we provide an interpretative analysis of these outcomes and discuss the extent to which thermal comfort can be interpreted from photographs containing specific types of visual signs. The article concludes by addressing the importance of this visual appraisal method for qualitative outdoor thermal perception surveys.

Materials and methods

To the end of exploring the extent to which the combination of materials and vegetation could influence the micrometeorological performance of public spaces, an outdoor thermal

perception survey was carried out at two contiguous outdoor public spaces in Porto, Portugal: a soft non-paved garden with mature vegetation providing shelter from all climatic variables and a hard-paved square with little vegetation, fully exposed to climatic variables (Fig. 1). The aim of the survey was to explore the eventual link between the sharply different spatial features with the microclimates and, thus, thermal comfort conditions, of the two spaces.

The survey

The survey combined objective and subjective thermal perception parameters. The objective parameters were collected through quantitative and qualitative research methods. The quantitative methods included microclimatic measurements with a portable micrometeorological station (data on physical parameters, i.e. air temperature, relative humidity, direct solar radiation, wind speed and mean radiant temperature) prepared with consideration to ISO 7726 (2001a) standard. The qualitative methods comprised first-person observations documented through datasheets (data on personal and physiological parameters, i.e. type of user, position, exposure to sun, company, food/drink consumption, clothing level, activity, age and gender). The subjective parameters were collected by qualitative research methods, namely spatially localised interviews based on a structured thermal comfort questionnaire and a photographic comparison (data on psychological parameters).

The survey was undertaken during the heat peak hours, between 11 a.m. and 2 p.m., during a 15-day period in July 2011. The target group was all users or potential users. No further criteria were considered in order to include as many people as possible. However, the sample was pre-defined according to age groups: children (0–14), adolescents (15–17), young adults (18–24), adults (25–64) and elderly (> 65). The interviewees were randomly

selected as available in situ. Consequently, the representation of age groups or, for example, gender or clothing level was impossible to predefine. In the end, the sample was characterised by 80% adults; 14% elderly and a little number of children, adolescents and young adults; and 38% male and 68% female; the clothing level (ASHRAE 2010) for women was Clo 0.32 and, for man, Clo 0.45 (values corresponding to local typical values for summer).

A total of 110 interviews were conducted by a team of two researchers previously contextualised with the aim of the survey and instructed by the principal researcher on how to proceed. The interviews were held in different locations within each space. The locations were predetermined by combining main crossing routes and sojourn locations with relevance for collecting micrometeorological data, i.e. locations where the microclimate of one the other space could be better characterised. The white dots in Fig. 1 specify these locations which, in the square, correspond to sunlit areas whilst, in the garden, to shaded areas.

The questionnaire was prepared based on previous studies such as from Ahmed (2003), Spagnolo and de Dear (2003), Nikolopoulou (2004), Nikolopoulou and Lykoudis (2006), Eliasson et al. (2007) or Oliveira and Andrade (2007). Each questionnaire comprised 18 closed-ended questions and took around 8 min to complete. Portuguese language was used and attention was given to wording in order to comply with the ISO 10551 (2001b). In particular, professional jargon was avoided.

The questionnaire was divided into three sections. The first section included the five most common thermal comfort judgement scales (thermal sensation, evaluation, preference, acceptability and tolerance) and was based on the ISO 10551 standard (2001b). For thermal sensation, the ASHRAE seven-point scale was used. This section also included six questions on additional parameters for interpreting the votes on the judgement scales (motivation, time of exposure, frequency

Fig. 1 The analysed spaces with indication of the locations where the interviews were held (source of background image: GoogleEarth, 2009)

of use, long-term thermal experience, short-term thermal experience and health conditions).

The second section comprised three questions addressing which role people would attribute to materials and vegetation in the microclimates they were experiencing. People were asked their opinion on three fundamental topics: ground permeability to water, surfaces' albedo/glare and shading from vegetation. The first topic comprised the question 'do you think this ground is...' and the answer options 'too soft', 'soft', 'mixed', 'hard' and 'too hard'. The second topic was addressed by the question 'do you usually feel glare in this space?'; the answer options being 'yes, by the ground', 'yes, by the buildings facades' and 'no'. The last topic was addressed with the question 'does this space's vegetation make you feel more comfortable?' and the answer options were 'yes, because it protects me from sun' and 'no, because it does not protect me'.

The photographic comparison

Aim and framework

The third section of the questionnaire was the photographic comparison. This visual method was used for complementing the findings for the in situ thermal experience (thermal sensation and evaluation judgement scales / verbal method) with long-term experience (photographic comparison / visual method), i.e. the information people have about a particular thermal situation or space (Nikolopoulou 1998). In other words, the aim was to evaluate the significance of the immediate appreciations people made about the thermal environment they were immersed in by opposing those appreciations to people's mental images of comfort and discomfort in a typical summer day. Widening the two fundamental questions of the questionnaire to people's broad outdoor summer thermal experiences whilst showing images would help to identify amongst respondents eventual misinterpretations concerning the questions made earlier and assist the researchers in interpreting people's votes and in understanding how 'real'/reliable they were. Hence, the photographic comparison was planned as a means to gather insights complementing the answers to the verbal methods and, thereby, inform and enrich the interpretation of their meanings.

Since often pictures are more efficient in communicating an idea than words — particularly in a field, such as outdoor thermal comfort, dealing with non-visible phenomena that people cannot easily relate to and where professional jargon is abundant — it was conjectured that selecting an image depicting common outdoor summer thermal conditions could help respondents to more easily relate to their empirical long-term experiences. However, the interpretation of an image is often subjective. Bearing this in mind, the photographs were prepared to be as clear as possible with regard to specific thermal environments. Also, it was defined that the use of

photographs as a means to complement objective data would only have significance should predominant trends of votes be found and should these trends match the votes given in the judgement scales. Large agreements were sought whilst scattered occurrences were considered meaningless.

It should be noted that the photographic comparison was not the main nor the sole method used in this field survey. Photographic comparison was not used as a comprehensive research method but only to verify particular assumptions gathered through other methods comprised in this survey.

Since no studies were found using photographic comparison as a systematic method for collecting subjective data during qualitative outdoor thermal perception surveys, this photographic comparison was built by reference to the method used by Rodiek and Fried (2005). Although with a different scope, the method developed by these authors fulfilled its goal which, such as for the case addressed in this article, was assessing the findings of a previous verbal survey. The present photographic comparison was drawn on the fundamentals of the method used by these authors: its purpose; the use of photographs depicting different spatial alternatives around the subject of study; the choice for compelling yet realistic pictures; the direct interaction with respondents.

The photographs

The photographs depicted three existing outdoor urban public spaces (Fig. 2). The locations were yet undisclosed in order to prevent biased appreciations based on, for instance, personal memories. No contextualisation was provided even when asked for. The photographs were taken under similar environmental conditions to those expected to be observed ahead during the interviews and micrometeorological simulations. The whole survey addressed the heat peak hours of the warmest month for the location under consideration. For coherence, the photographs should refer to the same period.

A compact photographic camera was used from standing eye level. The viewing angles excluded landmarks and included as many relevant signs as possible on spatial and behavioural features. Visual clarity, i.e. the clear communication of the details, components and overall content of the image (Sheppard 2001), was a fundamental principle for making the photographs. It was aimed to induce to perceptions consistent with the likely experiences at the depicted environments — the photographs should depict environments where interviewees could place themselves and recall their thermal experiences. Therefore, no post-edition was made.

The number of photographs was determined by consideration to three basic summer thermal environments: 'cool' (photograph C), 'hot' (photograph B) and 'in-between' (photograph A). The features depicted in the photographs are conceptualised as signs connoting a perception of thermal comfort. Visual signs can relate to both the *form* of the image,

Fig. 2 The three photographs of the photographic comparison

e.g. the composition, contrasts and colour palette; and the *content* of the image, i.e. the scene that is depicted. A visual deconstruction of the photographs is now used to identify these signs. Form and content are taken as the main categories of signs in this deconstruction.

Photograph A The *form* of this photograph shows a high degree of contrast between the top, right and bottom area and the left area of the image. The centre of the image is dominated by a row of dark-grey objects dividing the scene diagonally between the dark and green colours on the left and bottom and the light-grey and blue colours on the right and top. The *content* is depicted in a pale blue sky with some distant clouds. The pavement is grey and includes a beige strip of tiles leading to the shallow ponds at the centre of the space. These ponds include a set of small fountains. Beige or brown tiles link the water surface visually with the tiles leading up to it. The lighting pillars in the centre are round and faced with a highly reflective grey metal. The vegetation on the left-hand side has a reasonably dense canopy whereas on the right-hand side, the canopy is less dense. Bigger trees are visible in the background. The buildings on the right-hand side have predominantly grey colours whilst the buildings on the left have both light and dark colours. There are highly reflective metal litter bins and benches at the centre of the space. A somewhat even distribution of warm, neutral and cool colours creates a predominantly mixed pallet. The majority of people are in motion, looking straight. People are wearing jackets and there are no people sitting nor relaxing.

Photograph B The *form* of this photograph shows a high degree of contrast between the dark middle area and the bright top and bottom areas of the image. The majority of the top half of the image is bright yellow whilst the bottom half is mostly a light grey. The *content* contains a section of clear blue sky. The space is hard-paved with a geometrical pattern of cobblestones with cement mortar. There are no water bodies or vegetation. The image depicts highly reflective aluminium tables and chairs with aluminium frames and seating surfaces made of woven reed painted dark red, light brown or black. There is a high bright-dark contrast between the peripheral light-grey round pillars and the shaded galleries behind. Despite the strong presence of the yellow plastered building facades and dark metal frames of balconies in the background, the predominant colours are mixed. People are mostly found sheltered in the galleries. In the foreground, people seating exposed to sun are hunching forwards in an active posture, wearing sunglasses or squinting their eyes, and showing a somewhat tense/serious facial expression. The centre of the space is empty, with the exception of some people crossing it.

Photograph C The *form* of this photograph shows a low degree of contrast. The top of the image accounts for a soft and dark green whilst the middle with white and light brown. A light-grey object, a fountain, frames the scene on the top right and bottom. The *content* of the image consists of dense green canopy of different light intensities, from a large number of medium aged trees. Directly underneath, a collection of white parasols, most of them shaded, with brown wooden poles that

cover brown wooden terrace furniture. Shade from trees is casted on the clothing of some individuals. The bottom of the image is dominated by an elevated water reservoir where water is subtly moving. The water is coloured green by the reflection of the canopy overhead. The predominant colours are cool. People in the background terraces are seated in sunlit instead of shaded areas and show a relaxed body posture. The foreground shows an individual sitting at the border of the water reservoir, reading the newspaper in a relaxed posture. Another individual is passing by in a relaxed posture as well.

Procedure

The high-resolution (300 dpi) photographs were printed on satin A4 photographic paper and adhered to a rigid support. As the interviews were held standing outdoors and eventually in sunlit areas, the satin paper prevented glare. The rigid support allowed better handling the three photographs and enabled respondents to hold the photographs for careful inspection when they wished so. The photographs were shown at the end of the questionnaire. The three photographs were shown side to side in order to enable people's interpretation of one environment by direct comparison to another (Fig. 3). However, the photographs were not shown sequentially to prevent any sort of coolest-to-warmest or warmest-to-coolest interpretations.

Fig. 3 Photographic comparison—the process of showing (top) and choosing (bottom) the photographs

People were invited to simply point out one photograph better matching their feeling about each of two questions: for a typical summer day, ‘which of these spaces do you think it might be the most thermally comfortable?’ and ‘which of these spaces do you think it might be the less thermally comfortable?’ People's votes were manually recorded on paper and, later, plotted into Microsoft Excel. A simple comparative analysis of the dataset was made for two variables only: votes on the judgement scales (in situ appreciation of thermal comfort conditions) and choice of photographs (preference for a represented thermal environment). The goal was a simple and straightforward verification of the match between the two variables.

Results

The data analysis showed that the sharp differences in materials and vegetation between the analysed spaces were indeed leading to substantially different microclimates and, thus, thermal comfort conditions. In turn, this led to quite different usage patterns: an intense sojourn usage of the garden and the near absence of people in the square. The observations showed that in the garden, 64% of respondents were sitting, 27% strolling and 9% walking moderately, and that in the square, 64% were walking moderately, 18% strolling, 14% standing and only 4% sitting. The observed activities assign the garden a predominantly long-term usage pattern (15' to $\geq 60'$) and the square a short-term usage ($\leq 5'$ to 15').

The comparison between these observations and the votes on the thermal comfort judgement scales keeps pointing out fundamental distinctions between the two spaces: for thermal sensation, 82% of respondents at the garden were feeling neutral, whereas at the square, 40% were feeling warm and 53% hot (93% of votes on the warm side of the scale). With respect to thermal evaluation, 91% of interviewees at the garden referred to feel comfortable, whilst at the square, 93% were feeling uncomfortable. It is also relevant to mention that for thermal preference, 91% of respondents at the garden voted for ‘neither warmer nor cooler’ whilst at the square, 93% would prefer a ‘cooler’ environment. Thermal acceptability accounted for 91% of people at the garden stating it as ‘clearly acceptable’ and 93% at the square voting for ‘clearly unacceptable’. Regarding thermal tolerance, the garden was stated by all respondents to be ‘perfectly tolerable’ and 73% of respondents at the square voted for ‘intolerable’ and 27% ‘very difficult to tolerate’.

Regarding the second section of the questionnaire, 87% of respondents considered the paving of the square as ‘hard’ and 13% ‘too hard’, whereas in the garden, 96% described its ground surface as soft and permeable and 4% as ‘mixed’. Seventy-three percent of respondents at the square stated to feel glare by the ground and 18% by the buildings, whilst in the garden, 98% of respondents felt no glare. In the square, all

respondents stated that they could not count on vegetation to meet their comfort requirements, whilst for the garden, nearly all (96%) expressed the reverse opinion.

The contrasting values recorded with the micrometeorological measurements for all climatic variables substantiate the evidence that the votes on the thermal comfort judgement scales are a consequence of the microclimatic conditions in situ. These values assign a balanced microclimate to the garden and a harsh microclimate to the square. The average differences in the values recorded for the direct solar radiation and mean radiant temperature between the two spaces provide the clearest picture here: 771 W/m^2 for direct solar radiation and $11.81 \text{ }^\circ\text{C}$ for mean radiant temperature. Taking into account that all spatial features were basically the same in one and the other space except paving materials and vegetation, such sharp microclimatic differences were likely to result from the different combinations of these two features.

The outcomes of the photographic comparison are in line with the outcomes of the micrometeorological measurements and the votes on the judgement scales. For the potentially most comfortable space, 89% of respondents voted for the environment depicted in photograph C. Photograph A and B accounted respectively for 8 and 3% of votes. With regard to the potentially most uncomfortable space, photograph B received 83% of votes. Photograph A was chosen by 14% of respondents and C by 3%. The choices made for the potentially most comfortable and uncomfortable environments have in common a large gap between the main and minor trends of votes.

Discussion

A consistency between in situ and long-term experiences

In general, the outcomes of the visual appraisal method, i.e. the photographic comparison, supported those of the verbal method, i.e. the outdoor thermal perception survey. This match was also substantiated by the micrometeorological data recorded.

In the square, the 93% of respondents voting for a 'warm' or 'hot' sensation is matched by 93% voting for 'uncomfortable' on the thermal evaluation scale. In the garden, there is a slight discrepancy between the votes on these scales since 82% of respondents voted for 'neutral' in the thermal sensation scale and 91% for 'comfortable' in the thermal evaluation scale. For both scales, the few votes falling out of the main trends are likely to be explained by age. Age leads to different appreciations of a thermal environment. For example, for the same thermal environment, the elderly is likely to feel colder than youngsters (Novieto and Zhang 2010) and youngsters more easily tolerate thermal conditions that the elderly would consider intolerable. At this respect, it is noteworthy that the 18% of respondents feeling 'slightly cool' at the garden

belong to the '> 65' years of age group and that the 7% feeling 'neutral' at the square belong to the 'child' and '18–24' years of age groups.

The choices made for the photographic comparison were more levelled: 89% of respondents selected photograph C as depicting the potentially most comfortable space, and 83% photograph B as the most uncomfortable.

The match between in situ evaluations and choice of photographs is rather significant. Even though the percentages of votes for the photographic comparison do not match those for the in situ evaluations in absolute terms, the main trends of votes for the photographic comparison (long-term experience) match the main trends of votes for the thermal sensation and evaluation judgement scales (in situ experience). The large majority of respondents chose a photograph depicting an environment alike to the space where the thermal sensation judgements scored the best (garden) as the potentially most comfortable, and an environment alike to the space where those judgements scored the worst (square) as the potentially most uncomfortable. The spaces with a 'cool' ambience (low contrast, predominantly cold colours, presence of water, shading devices and a dense green canopy), i.e. the garden and photograph C, were regarded as comfortable; the spaces with a 'hot' ambience (high contrast, predominantly warm colours, absence of water, shading devices or vegetation), i.e. the square and photograph B, were regarded as uncomfortable. As anticipated, although the layouts are different, the two analysed spaces and the environments depicted in the photographs B and C present, respectively for the most comfortable and uncomfortable situations, similar spatial features (Fig. 4).

The outcomes of the second section of the questionnaire substantiate these findings. People were able to recognise the spatial features influencing the thermal environment they were immersed in. In this case, the ground surface and amount of vegetation of one and the other space were 'perceived' by respondents simultaneously as their main spatial characteristics and sources of thermal discomfort. People were more satisfied with a soft-paved and densely vegetated space, presenting a high level of protection from direct solar radiation and reflected light (similar to photograph C). Opposed to this was an extensively hard-paved space with the little or no vegetation/shade (similar to photograph B). These appreciations are therefore in line with the match found between thermal evaluation scales and photographic comparison to the extent that they relate to the sort of 'cool' and 'hot' ambiances mentioned above.

Signs of thermal comfort

In view of the above considerations, the consistency between in situ and long-term experiences was explored and shown through the combination of a verbal (thermal comfort judgement scales) and a visual (photographic comparison) research

Fig. 4 The most comfortable space — garden (Ga) and the potentially most comfortable environment — photograph C (C); the most uncomfortable space — square (Sq) and the potentially most uncomfortable environment — photograph B (B)

method, where the findings of the latter support the findings of the former.

Whilst the exceptions to the main trends of votes reflect the subjectivity of thermal comfort evaluations and illustrate how in these studies ‘the average response of a group is more significant than the individual response’ (Givoni 1998), it is noteworthy that the largest difference between main and minor trends of votes was found in the verbal method. This suggests that the visual media might have been more efficient in communicating to respondents than the verbal judgement scales. These findings develop the evidence of the strong influence spatial features have over people’s actual thermal comfort but also over people’s mental images of thermal comfort. There are spatial features that can work as visual triggers of thermal comfort. Therefore, opportunities are open for interpreting outdoor thermal comfort from environments depicted on photographs containing clear visual signs. This sheds light on the possibilities of using photographic comparison as a complementary research method during qualitative outdoor thermal perception surveys.

Concurrent with the view that ‘representations are a form of visual communication that involve a collection of visual signs’ (Raaphorst et al. 2017), the interpretations people made of the photographs are linked to the visual signs depicted in the photographs and, with particular relevance, their combinations. An image is never viewed immediately but ‘reconstructed via a scanning sequence in which the eye continuously flits from point to point to complete an almost instantaneous visual reconnaissance of the situation’ (Porter 2000). The significance of these combinations is likely to be dependent on people’s long-term thermal experience. The clearly demarked

trends of votes for the photographic comparison suggests that people have mental images of outdoor thermal comfort shaped by their empirical experiences and that these can be recalled through visual media. Consciously or unconsciously, people seem to recognise spatial features triggering a perception of comfort—stimuli. This is in line with findings from previous studies (Nikolopoulou 2004; Lenzholzer and Koh 2010; Lenzholzer et al. 2016).

Based on the visual deconstruction of the photographs made above, 15 signs could convey a thermal comfort message for the photograph chosen as the potentially most comfortable environment, and 12 signs could convey a message of thermal discomfort for the potentially most uncomfortable environment (Fig. 5). Photograph A is excluded from this exercise since it gathers signs from photograph B and C and due to its little relevance in the votes for the photographic comparison. Table 1 allocates the signs depicted in photographs B and C into categories in order to understand to which dimensions of outdoor public spaces analysis does each sign relate to: spatial or behavioural. For the spatial dimension, the signs are distributed amongst sub-categories related to design elements. The sub-categories in the behavioural dimension relate to ‘non-designable’ parameters.

In order to explore which signs are relevant for informing photographic comparison methods, we explore which signs depicted in photograph B and C can be found as spatial features and behavioural patterns in the analysed spaces. This exercise shows that 12 out of the 15 signs of photograph C can be found at the most comfortable space (Fig. 5). ‘Shaded parasols’ (spatial dimension), ‘sitting in the sun’ and ‘slow crossing’ (behavioural dimension) are the exceptions. In turn,

Fig. 5 The key signs conveying a thermal message for the garden (Ga) and photograph C (C), for the square (Sq) and photograph B (B)

8 out of the 12 signs of photograph B were identified at the most uncomfortable space (Fig. 5). The exceptions are ‘tense facial expressions’, ‘squinting’, ‘active posture’ and ‘sunglasses’ (behavioural dimension).

Although limited to the spaces under consideration in this study, the remarkable correspondence between depicted and in situ signs suggests that there are key features of outdoor thermal comfort which may be generalised to different circumstances. Notwithstanding, the identified signs on both spatial and behavioural categories present different degrees of generalisation. Some signs (e.g. the clear sky vault, hard paving, or moving water) are generalisable since they refer to typical spatial attributes of urban public spaces. Other signs and, perhaps more importantly, combinations of signs are specific to the spaces addressed in this study. Furthermore, the precise meaning that signs have for survey respondents is difficult to ascertain as interpretations of signs are shaped by personal and professional backgrounds, experiences and preferences (Raaphorst et al. 2018).

For these reasons, the relevance of the presented semiotic deconstruction lies more in the categorisation of signs than in the inventory of signs per se. The listed signs were the ones this study dealt with which, for its purpose, were assumed to be relevant. Yet, these signs may not automatically suit

another survey due to the immense variability around the configuration and context of public spaces. Notwithstanding, the presented categories and sub-categories (Table 1) do entail a level of abstraction making them suitable for application in other surveys. These categories can comprise an array of particular signs conveying a thermal message and, thus, work as key features upon which outdoor thermal comfort can be expressed visually. The categories and sub-categories presented in Table 1 can provide a valuable framework for producing and selecting photographic scenes best depicting an outdoor thermal environment.

The findings from this survey suggest that the sub-categories related to direct solar radiation can be particularly relevant. This parameter is likely to have been the most decisive factor in regard to the votes on both judgement scales and photographic comparison: at the square, 67% of respondents mentioned direct solar radiation was the main cause for their discomfort during the interview, whilst at the garden, 85% mentioned no climatic variable was causing discomfort. For the photographic comparison, the presence and absence of signs belonging to sub-categories related to solar radiation is likely to have played a substantial role in the choices made.

The sharp differences between photograph B and C with regard to such signs are plain, e.g. the density of the tree

Table 1 Categorisation of the signs contained in photograph B and C

Category	Sub-category	Photograph C	Photograph B
Spatial	Vegetation	Trees	–
	Light, shade and colour	Dark trunks	High bright-dark contrast
		Bright canopy	Glare
		Dark canopy	Mixed colours
		Shaded parasols	
		Shade on clothing	
		Cool colours	
		Light-coloured elements	
	Water	‘Green’ water	–
		Moving water	
	Furniture	Wooden objects	Metal objects
Behavioural	Paving	–	Hard paving
	Sky view factor	No sky vault	Clear sky vault
	Posture and expression	Relaxed posture	Active posture
			Tense facial expressions
			Squinting
	Position	(People) sitting in the sun	People sheltering (from sun)
	Motion	Slow crossing (of people)	Fast crossing (of people)
	Accessories	–	Sunglasses

canopy versus the amount of visible sky vault (Fig. 5). This consideration is in line with previous studies showing that, during summer, outdoor thermal comfort is mainly affected by exposure to direct solar radiation and solar reflectance (Andreou 2013; Rosso et al. 2016).

Photographic comparison—possibilities of use

Although the interpretation of photographs does not attain an objective dimension, whenever depicting a clear ‘thermal comfort message’ through significant visual signs that people can relate to, photographs can help attributing meaning to objective data gathered in a space where the same or similar signs, now spatial features, can be encountered. The purpose of the photographic comparison is not to replace objective methods but to enrich the interpretation of objective data. A (nearly) consensual preference for a photograph can complement the interpretation of votes on thermal judgement scales by helping to clarify preferences, confirm trends or interpret conflicting information on different scales.

Through the interpretation of a photograph, the participant in a thermal perception survey can attribute meaning to a depicted thermal environment. Since thermal comfort evaluations are largely conditioned both physiologically and psychologically by the spatial characteristics of a site, it is important to understand these meanings, particularly, which spatial features influence people’s thermal comfort. Qualitative outdoor thermal perception surveys can benefit from this approach by characterising the relationship space-microclimate-thermal comfort in a more complete way and, thus, better informing designs aimed at improving outdoor thermal environments.

By endowing qualitative outdoor thermal perception surveys with the appreciation of outdoor thermal environments based on visual data, photographic comparison comprehends several possibilities of use in both academia and practice of climate-responsive urban design.

In research, photographic comparison can be included, at some point, in a thermal comfort questionnaire (such as in the research herewith presented) as to complement verbal data. This method can enable respondents to a thermal comfort questionnaire to better target their personal responses since images relate better to people’s empirical experience. Respondents can thus provide more realistic reactions during the formulation of subjective thermal judgements. Thereby, researchers can gain access to insights helping to interpret people’s votes on judgement scales.

The method can also be used per se, for instance, in students’ academic short-term studies as a means to quickly obtain insights on the relationship space-microclimate-thermal comfort. Whenever research teams do not possess the time and/or the means to undertake complex surveys, photographic comparison can be an alternative.

Photographic comparison can also help researchers to more effectively communicate with designers. Through the use of the appropriate visual signs, researchers can communicate the outcomes of a research as visual guidelines (a language designers are familiar with) informing designers about the range of climate-responsive design principles they should take into account whilst designing.

In urban design practice, photographic comparison can help designers to more consciously represent a thermal environment in visual communication material, such as photorealistic

images. This can be useful, for instance, when producing illustrations of before and after situations, aimed at informing clients, stakeholders or local populations about the improvements a design scheme will bring to the microclimate of a site.

In this sense, photographic comparison can also be used for raising awareness to the importance of climate-responsive urban design. This represents an array of possibilities of use such as for lectures, workshops or training sessions within public and private entities.

Remarks

It was acknowledged that, since the interpretation of photographs is to great extent subjective, showing only one image for a particular environmental setting could condition people's reactions. However, showing different moments of the day for the depicted environments would make sense should the focus of the survey be the represented spaces and, thus, the aim of the photographic comparison be appreciating these environments per se. However, the aim of this photographic comparison was far simpler: to make a straightforward verification of the match between the in situ appreciation of a thermal environment and the preference for a represented thermal environment. In this article, we retrieve from this verification the in situ and represented visual signs likely to best convey a thermal message. Retrieving these signs implied making the two environments (real and depicted) comparable. In turn, this required working with similar environmental conditions.

Besides the age of respondents, other subjective psychological parameters might explain the exceptions observed to the main trends of votes for both judgement scales and photographic comparison. The votes on the thermal preference, acceptability and tolerance scales have partially helped explaining outliers in the data, but it was not possible to accurately determine the influence of these scales due to their high subjectivity and time constraints. The time people had available for answering the questionnaire was found to be determinant on their willingness to participate. When time was short, this might have led to quicker, less conscious answers.

The number of interviews was conditioned by people's willingness to participate, especially in the square, where the micrometeorological conditions were harsh at the time the interviews. The number of interviews was also conditioned by interviewees going beyond the time expected for completion due to a spontaneous incursion on personal subjects, especially amongst the elderly.

The deconstruction of the photographs from a semiotic perspective revealed that some signs on both spatial and behavioural categories had some discrepancies. In photograph C, an individual is wearing a jumper next to the relaxed individual in the foreground which is wearing a light shirt and, in photograph A, most users are wearing coats and jumpers. In photograph B, the shades at the centre of the space are shorter

than in photograph A. In photograph C, pavements and building plasters are barely visible whilst in photograph B, the situation is reverse. Considering the main and minor trends of votes, none of these discrepancies seem to have influenced people's answers. This is not meant to imply that such discrepancies are unimportant but rather that these were not relevant enough to make respondents hesitate in making a choice. Nevertheless, the photographs should have been as comparable as possible on methodological grounds.

Conclusions

This article offers a preliminary approach to the use of photographic comparison as a visual research method for enriching qualitative outdoor thermal perception surveys. Although the interpretation of photographs is subjective, the match found between the outcomes of the photographic comparison and the votes given on the thermal sensation and perception scales suggests that the appropriate visual signs can help attributing subjective meaning to objective data. Photographic comparison holds thus the potential to become a valid visual appraisal method during outdoor thermal perception surveys. However, photographic comparison does not replace any other method in this type of surveys and should be regarded as a complement to the typically used methods.

This article offers a preliminary approach to the use of photographic comparison during qualitative outdoor thermal perception surveys. Light was shed on the key visual features of outdoor thermal comfort, i.e. visual signs that can better inform space-microclimate-thermal comfort relationships on which design schemes targeted at improving outdoor urban microclimates ought to be based. However, visual signs can be object of subjectivity when interpreting a photograph. More important than the sign itself is how good a type, or category, of sign is in conveying a message of comfort. This is why, instead of pointing out which specific signs are relevant, this article states primarily the importance of certain categories of signs.

More intricate connections between thermal judgement scales and photographic depictions of microclimatic conditions can be made for increasing the possibilities of triangulating the outcomes of a survey. For example, the significance of specific microclimatic signs could be studied through the addition and elimination of categories and signs in a sequence of photographs by means of a survey experiment. Furthermore, a semiotic perspective for the analysis and selection of visual materials could help to improve the understanding of how visual signs work together to signify certain microclimatic conditions. The validity of such visual appraisal methods can be improved through studies approaching the statistical relevance of photographic comparison.

Although some inconsistencies in the photographs seem not to have influenced people's answers, future research should confirm how misleading these situations can be. It is important to ensure that photographs are as comparable as possible, but as behavioural-related signs are not likely to be controlled by the photographer, the challenge can be to reduce ambiguity to the utmost. Photo editing can be a powerful resource to overcome this problem as long as the overall thermal message is kept realistic.

This article does not exhaust all possibilities of using photographic comparison in thermal comfort studies. As a visual appraisal method, photographic comparison can be widened to different subjects of spatial perception. However, further research developing on the topics herewith outlined and other additional insights should be conducted before a statement can be made regarding the whole range of possibilities offered by this method.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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