Building and Environment 205 (2021) 108246

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Perceptions of human thermal comfort in an urban tourism destination – A case study of Porto (Portugal)

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A R T I C L E I N F O

Keywords:
Tourism
Urban areas
Perceptions
Thermal comfort
City of Porto

A B S T R A C T

Tourism is one of the fastest growing economic sectors on an international scale. Based on this growth, it became necessary to consider climatic-meteorological conditions as determinants for boosting tourism in some geographical areas. The main objective of this paper is to characterize the perception of bioclimatic comfort of tourists who visited the city of Porto in the summer seasons of 2019 and 2020 (in the on-going pandemic). Primary data were obtained from a questionnaire on perceptions of bioclimatic comfort and microclimatic measurements applied to 207 tourists in the summer of 2019, 146 in the winter of 2019–2020 and 210 in the summer of 2020. It took place in one of the main places of passage for tourists visiting the city of Porto. Based on statistical analysis, responses were parameterized according to the environmental and sociodemographic characteristics of the tourists. In addition, summary indicators (Physiological Equivalent Temperature – PET, Thermal Sensation Vote – TSV, Thermal Preference Vote – TPV) were used to characterize the profile of visiting tourists. The influence of microclimate conditions on the thermal comfort of tourists was evident, showing, however, that they still felt comfortable regardless of the situation. The results demonstrated a good effort to reduce thermal discomfort through adapted behavior. Air temperature and relative humidity seem to be more directly related to mean thermal sensation votes in the summer of 2019 ($r^2 = 0.86$ and $r^2 = 0.68$, respectively). In the winters of 2019–2020 and summer of 2020, these indicators do not show such a strong correlation. Anyway, it is verified that there is a greater tolerance for higher and lower temperatures than those that are verified for the residents, when compared to previous studies. The consideration of average thresholds for thermal comfort in tourism is crucial. In future studies and planning proposals, it will be necessary to consider the optimal climatic conditions of local climate change adaptation and mitigation policies.

1. Introduction

Although climate has a significant importance in tourism activity, influencing the spatiotemporal distribution of tourists, methods that include the relationship between this component and its effects on decisions in tourism planning and management are rarely applied. The fact that urban areas continue to grow on a global scale causes significant changes in (micro)climate. Consequently, the increase in waterproofed surfaces, the anthropogenic heat generated by cities and the change in air circulation, may contribute to a greater or lesser pleasantness of the public space for tourism practice [1–3].

Tourism is one of the main economic activities worldwide. The diffusion of tourism on a global scale as a strategic sector for socio-economic and territorial development has highlighted the need for a more sustainable tourism planning. Its development limit has not yet been reached, so its relevance has increased in recent decades, having become, until 2019, a major contributor for several local and national economies. Europe was the most visited region in 2019 [4]. It should be noted that, since March 2020, the situation has worsened, with a significant drop in expected revenue in the tourism sector due to the

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https://doi.org/10.1016/j.buildenv.2021.108246
Received 13 June 2021; Received in revised form 30 July 2021; Accepted 9 August 2021
Available online 13 August 2021
0360-1323/

COVID-19 pandemic [5]. The European Commission (EC) estimates for 2020 point to a 6.8% drop in Gross Domestic Product (GDP) growth in the Eurozone [6]. The World Tourism Organization (UNWTO) announced the pandemic's negative impacts in the tourism industry with a decrease of 74% in international tourism in the year 2020 [5].

The climate and weather, and in particular the temperature, which is often a decisive factor when choosing a tourism destination, also contribute to this [7–15]. It is also considered a key element in most tourism products defined by Turismo de Portugal [16] while assuming itself as the main motivation of those who visit Portugal (47% of tourists in 2014) [17].

The present study focuses on an estimation of thermal comfort by 563 tourists, between the years 2019 and 2020 in the city of Porto. This study is applied to its main bustling area - Avenida dos Aliados (Aliados Avenue) and Praça da Liberdade (Liberdade Square). The main objectives were: (i) to explore the relationship between bioclimatic comfort (expressed through the perceived temperature (PT), the thermal sensation vote - TSV and the thermal preferred vote - TPD) and climatic and environmental conditions, and (ii) to identify the personal parameters that influence climatic preferences, namely the temperature in an outdoor environment.

After this brief introduction, the two following sections are dedicated to the dissection of the relevance of using tourist-based inquiry instruments (Tourism Based Response - TBR) to determine the quality of both the experience and the so-called image. Next, the methodology underlying the study is presented, followed by its major findings. Finally, there is the study's discussion and its main conclusions.

2. Tourist based response (TBR) approach in the assessment of thermal comfort

One of the approaches used to assess the influence of thermal comfort on the destination image is based on stated preferences – designated in this study as *Tourist Based Responses* (TBR). This approach consists of consulting tourists directly about their climate preferences through surveys or interviews. These preferences are compared to measurements of climatic parameters in real-time.

Studies aimed at ascertaining the conditions of climate preferences based on the opinions of tourists hold a relevant place in scientific literature. Fewer are those that are designed to ascertain thermal comfort at the destination with measurements taken in situ. These studies are almost always applied to residents, although it is essential to assess the level of comfort of tourists during their stay.

In an international longitudinal literature analysis carried out by us (889 tourism and climate studies in Scopus and WoS databases analyzed between 1940 and 2020), seven studies were found that investigated these conditions, and none of these studies were conducted in Southern Europe (Table 1).

Based only on surveys, and without making momentary in place measurements of the survey, some authors have pointed out the most relevant variables to consider in the context of tourists' climate preferences. Several international studies highlight air temperature, insolation, precipitation and wind speed (climate variables) as the most relevant factors for tourism practice [9,15,18–20]. In urban environment, air temperature is the most important parameter [21–24]. A part of these conclusions differs according to the segment of the tourism

Table 1
Microscale bioclimatic comfort studies applied to tourists.

Reference	Study area	Koppen classification	Sample (number)	Data analysis	Analysis factors	Thermal Comfort analysis (parameters and indexes)[a]	Tourist segmentation	Temporal analysis
Lindner-Cendrowska (2013)	Warsaw, Poland	*Cfb*	553 tourists	Frequency, distribution, Regression	Physical parameters	AT, Clo, PET, TPV, TSV, UTCI	Urban	July 2010, February 2011, April, and October 2011
Rutty & Scott (2015)	Caribbean (tourists from Canada)	*Am*	216 tourists	Regression, frequency, ANOVA test,	Physical parameters	AT, TPV, TSV, UTCI, WS	Sun & Beach	March–April 2012
Kariminia et al. (2016a, b)	Isfahan, Iran	*Bsk*	504 tourists	Nonlinear model (autoregressive neural networks with exogenous input (NN-ARX)	Physical parameters, Location in the square, age, gender, activity, nationality	AT, GT, i, MRT, PET, PMV, RH, SET, TSV,WS	Urban	12–24 July 2014
Kovács et al. (2016)	Szeged, Hungary	*Dfb*	5128 tourists	Frequency, description, regression	Physical parameters	CTIS, PET, TCI, TPV, TSV,	Urban	Summer, Autumn, Winter 2011 and 2012
Nasrollahi et al. (2017)	Isfahan, Iran	*Bsk*	281 tourists	Frequency, description, regression, spatial modeling	Physical parameters, time of exposure, psychological conditions of tourists	AT, ET, i, MRT, n, PET, PMV,RH, SET, SET*, TPV, TSV, UTCI, WS	Urban	July 2016
Lindner-Cendrowska & Blazejczyk (2018)	Warsaw, Poland	*Cfb*	662 tourists	Frequency, description, Regression	Physical parameters, gender, age, air conditioning (air conditioning or not), nationality, climatic origin according to Koppen	AT, i (globe), MRT, PET, RH, TSV, TPV, WS	Urban	July 2010, February 2011, April, and October 2011
Xi et al. (2020)	Harbin, China	*Dwa*	1740 tourists	Frequency, description, Regression	Physical parameters, physical activity, clothing	AT, clo, i (globe), RH, WS,	Urban	Winter and Summer, between December 2017 and January 2019

[a] AT = Air Temperature; Clo = Clothing insulation; CTIS = Climate Tourism Information Scheme; ET = Effective Temperature; i = global radiation; MRT = Mean Radiant Temperature; n = nebulosity; PET = Physiological Equivalent Temperature; RH = Relative Humidity; SET = Standard Effective Temperature; SET* = New Standard Effective Temperature; TCI = Tourism Comfort Index; TPV = Thermal Preference Vote; TSV = Thermal Sensation Vote; UTCI = Universal Thermal Comfort Index; WS = Wind Speed.
Source: Own elaboration.

Table 2
Participants' responses on demographic, physiological and psychological variables included in the questionnaire used in the field surveys.

Variables	Summer 2019 (n = 207)		Winter 2019–20 (n = 146)		Summer 2020 (n = 210)		ANOVA		Overall (n = 563)	
	N°.	%	N°.	%	N°.	%	F	p-value	N°.	%
Gender										
Male	107	51,7	72	49,3	99	47,1	0.430	0.651	278	49,4
Female	100	48,3	74	50,7	111	52,9			285	50,6
Age										
15-24	22	10,6	17	11,6	20	9,5	0.807	0.447	59	10,5
25-44	146	70,5	94	64,4	141	67,1			381	67,7
45-64	31	15,0	30	20,5	44	21,0			105	18,7
65 and more	8	3,9	5	3,4	5	2,4			18	3,2
Trip planning										
More than 1 year	7	3,4	3	2,1	8	3,8	1.455	0.234	18	3,2
Between 12 and 6 months	15	7,2	6	4,1	8	3,8			29	5,2
Between 5 and 2 months	61	20,4	40	27,4	73	34,8			174	30,9
1 month before	21	10,1	21	14,4	31	14,8			73	13,0
15 days	29	14,0	22	15,1	31	14,8			82	14,6
A week before	40	19,3	28	19,2	33	15,7			101	17,9
The day before	34	16,4	26	17,8	26	12,4			86	15,3
Trip duration										
1 day	29	14,0	25	17,1	27	12,9	0.483	0.617	81	14,4
2–3 days	98	47,3	80	54,8	106	50,5			284	50,4
4–6 days	61	29,5	24	16,4	47	22,4			134	23,8
7–14 days	17	8,2	13	8,9	27	12,9			57	10,1
15 and more days	2	1,0	4	2,7	3	1,4			9	1,6
Travel group size										
Alone	37	17,9	7	4,8	16	7,6	5.121	0.006*	60	10,7
1 person	55	26,6	39	26,7	59	28,1			153	27,2
Between 2 and 3 people	66	31,9	61	41,8	93	44,3			220	39,1
Between 4 and 6 people	41	19,8	23	15,8	22	10,5			86	15,3
Between 7 and 10 people	7	3,4	15	10,3	16	7,6			38	6,7
>10 people	1	0,5	1	0,7	4	1,9			6	1,1
Country of residence										
Portugal	35	16,9	22	15,1	43	20,5	12.346	0.000**	100	17,8
Other European country	106	51,2	74	50,7	144	68,6			324	57,5
America	20	9,7	19	13,0	1	0,5			40	7,1
Other continent	46	22,2	31	21,2	22	10,5			99	17,6
Diseases										
With diseases	58	28,0	42	28,8	50	23,8	0.571	0.567	150	26,6
Respiratory disease	19	9,2	12	8,2	15	7,1			46	8,2
Hypertension	23	11,1	15	10,3	15	7,1			53	9,4
Rheumatic disease	11	5,3	8	5,5	14	6,7			33	5,9
Heart disease	3	1,4	4	2,7	6	2,9			13	2,3
Chronic gastric disease	1	0,5	0	0,0	0	0,0			1	0,2
Other diseases	1	0,5	3	2,1	0	0,0			4	0,7
Without diseases	149	72,0	104	71,2	160	76,2			413	73,4
Feeling about the health condition										
Very uncomfortable, aggravated symptoms	0	0,0[a]	0	0,0[a]	1	2,0[a]	1.372	0.257	1	0,7[a]
Uncomfortable, slight manifestation	13	22,4[a]	10	23,8[a]	17	34,0[a]			40	26,7[a]
Well, comfortable	45	77,6[a]	32	76,2[a]	32	64,0[a]			109	72,7[a]
Education										
Less than 6 years	7	3,4	4	2,7	3	1,4	1.117	0.328	14	2,5
7th - 9th year	20	9,7	13	8,9	16	7,6			49	8,7
10th – 12th year	70	33,8	50	34,2	64	30,5			184	32,7
Graduation	81	39,1	62	42,5	100	47,6			243	43,2
Master and PhD	29	14,0	17	11,6	27	12,9			73	13,0

*p-value < 0.01; **p-value < 0.001.
[a] Only individuals with diseases were considered.
Source: Own elaboration, based on 563 respondents.

market under analysis. Kotler's marketing theory (1999) appears to be fundamental in this study, showing that markets are made up of groups with unequal characteristics and needs [25]. In addition to climatic parameters, sociodemographic characteristics can contribute to significant differences in preferences or tolerance to certain thermal conditions [15]. In a study carried out in the city of Tel-Aviv, in Israel, Mansfeld et al. (2004) found that national tourists were more sensitive to thermal conditions than international tourists, and that this sensitivity was higher when the destination was Sun & Sea [19].

Engineers conducted investigations, of a more empirical nature, on human thermal comfort and with definition of optimal and critical thresholds, in particular about the international standard accepted by the American Society of Refrigeration and Air Conditioning (ASHRAE). Based almost exclusively on data from climatic in-chambers experiments carried out in medium latitude climatic regions and in the northern hemisphere, researchers have sought to validate the recommended 'ideal temperature' of 21–23 °C (with relative humidity between 40 and 60%). The results may vary according to people's sensitivity. Apparently, and according to some studies on stated preferences, people are much more sensitive to variations in outdoor environments. Knez & Thorsson (2006) revealed that the air temperature in public spaces was perceived as colder by the Swedish people than by the Japanese, suggesting that different cultures perceive temperatures differently [26].

These differences can also translate into different climatic preferences during the holidays. In these cases, studies reveal slightly more significant differences in thermal preferences, with climatic optimum

Table 3
Characteristics of the activities carried out by respondents in Avenida dos Aliados and Praça da Liberdade.

Variables	Summer 2019 (n = 207)		Winter 2019–20 (n = 146)		Summer 2020 (n = 210)		ANOVA (Survey periods)		Total (n = 563)	
	N°.	%	N°.	%	N°.	%	F	p-value	N°.	%
Length of stay in the surrounding area										
<5 min.	47	22,7	41	28,1	24	11,4	32.567	0.000**	112	19,9
5–15 min.	77	37,2	47	32,2	42	20,0			166	29,5
16–30 min.	59	28,5	50	34,2	74	35,2			183	32,5
>30 min.	24	11,6	8	5,5	70	33,3			102	18,1
Activity performed in the last 30 min.										
Sitting	41	19,8	26	17,8	36	17,1	1.021	0.234	103	18,3
Standing	38	18,4	17	11,6	28	13,3			83	14,7
Walking	123	59,4	99	67,8	141	67,1			363	64,5
Running	1	0,5	0	0,0	2	1,0			3	0,5
Lying	4	1,9	4	2,7	3	1,4			11	2,0
Location of the activities in the last 30 min.										
Outdoor (in the sun)	98	47,3	67	45,9	77	36,7	4.976	0.007*	242	43,0
Outdoor (in the shade), including shade of trees	77	37,2	62	42,5	95	45,2			234	41,6
Indoor (with air conditioning)	28	13,5	15	10,3	27	12,9			70	12,4
Indoor (without air conditioning)	4	1,9	2	1,4	6	2,9			12	2,1
In own vehicle (with air conditioning)	0	0,0	0	0,0	0	0,0			0	0,0
In own vehicle (without air conditioning)	0	0,0	0	0,0	2	1,0			2	0,4
By public transport (with air conditioning)	0	0,0	0	0,0	0	0.0			3	0,5
By public transport (without air conditioning)	0	0,0	0	0,0	3	1.4			0	0,0

*p-value < 0.01; **p-value < 0.001.
Source: Own elaboration, based on 563 respondents.

tending to expand much more, because tourists are willing to have greater climatic variability than residents engaged in common daily activities [15,27,28].

Although limited, TBR begins to reveal differences for specific tourism segments or activities, as well as sociodemographic differences, confirming and contradicting aspects of revealed preference studies. What tourists consider to be optimal or unacceptable climatic conditions depend on several factors, and studies that have attempted to generalize this complex relationship across universal boundaries (for example, climate indices, macro scale models) may be too simplistic [7,29,30].

Psychology-based investigations have also contributed to the study of tourism climate assessments, revealing that thermal perceptions and preferences cannot be fully explained by the energy balance of the human body (e.g., Physiologically Equivalent Temperature – PET and Predicted Mean Vote – PMV). Human beings are also affected by behavioral factors, including their thermal experience, comfort expectations, duration of exposure and their culture [28,31–34]. Other factors such as clothing can influence the experience in the destination [35], although they can always decide to add or remove a certain layer.

A problem currently associated to the COVID-19 pandemic is the use of the face mask, whose thermal specifications are not yet included in any standard scientific literature. The use of the face mask became widespread with COVID-19, significantly altering the comfort level at travel destinations. When people are exposed to warmer environments, breathing frequency tends to increase (also depending on the level of activity) and thermal discomfort will not be only local (limited to the facial surface affected by the mask or the surrounding areas), but will spread throughout the body, which can condition activity [36].

A long time ago this aspect was highlighted by several authors [37,38] who revealed that the use of a face mask represented an additional factor for thermal stress and that facial skin temperature significantly influenced whole-body thermal sensations. Despite this, a recent study with 8 participants, in conditions of 40 °C and 20% relative humidity, showed that only the perceived dyspnea was aggravated by prolonged use of a face mask, with no other differences in motor-cognitive performance, physiological tension or thermal discomfort [39].

Although COVID-19 has changed tourism activity, more studies are still needed in the field of urban thermal comfort, namely as regards the return to a 'new normal'. Since climate is evaluated based on personal perceptions, expectations, and experiences, it will be necessary to calibrate measures to account for psychological adaptation. Currently, a large percentage of climate-tourism rapport assessments is focused exclusively on tourists' responses to macroscale, based on a top-down perspective (for example, preference revealed), thus excluding subjective perceptions of tourists' climatic preferences responses. In this sense, it is essential to increase the research on declared preference approaches (bottom-up perspective), which will make it possible to ensure the validation and psychological assessment among tourists in relation to the visited places, this way establishing a connection between both objective and subjective dimensions.

3. Research methodology

3.1. Geographic context

The study was conducted in Avenida dos Aliados (Aliados Avenue) and Praça da Liberdade (Liberdade Square), one of the most visited areas of Porto (Fig. 1). The municipality of Porto, with an area of 41.42 km^2, is integrated in the Porto Metropolitan Area and located in the northwest of mainland Portugal. In Portugal, it is the second territory with the greatest economic dynamism and the nuclear area of the second most populous Portuguese Metropolitan Area. Porto has a privileged geographical location along the coast, with the Atlantic Ocean to the west, being bordered in the south by the Douro River. It is installed on a small slope platform facing the Atlantic Ocean, with an altimetric amplitude of 160 m [40–42]. It presents a temperate maritime climate, with average air temperatures ranging from 15 °C to 25 °C. Summers can occasionally reach 35 °C, while winters are usually rainy and cool, with air temperatures between 5 °C and 14 °C. According to Köppen-Geiger's climate classification system, Porto is in a *Csb* zone [43].

These conditions have come to be recognized internationally through awards that guarantee the quality of Portuguese tourism, revealing itself by increasing the attractiveness of certain geographical areas, namely PMA, with particular emphasis on the city of Porto (e.g., European Best Destination, 2012, 2014 and 2017). In this territory, the increase in the number of tourists occurred until the year 2020, where the media played a relevant role in attracting interest to certain places and activities already consolidated [15,44], but also due to the valorization of new urban spaces resulting from a continuous growth by extension-aggregation [45]. In 2019, Porto was ranked 96th position

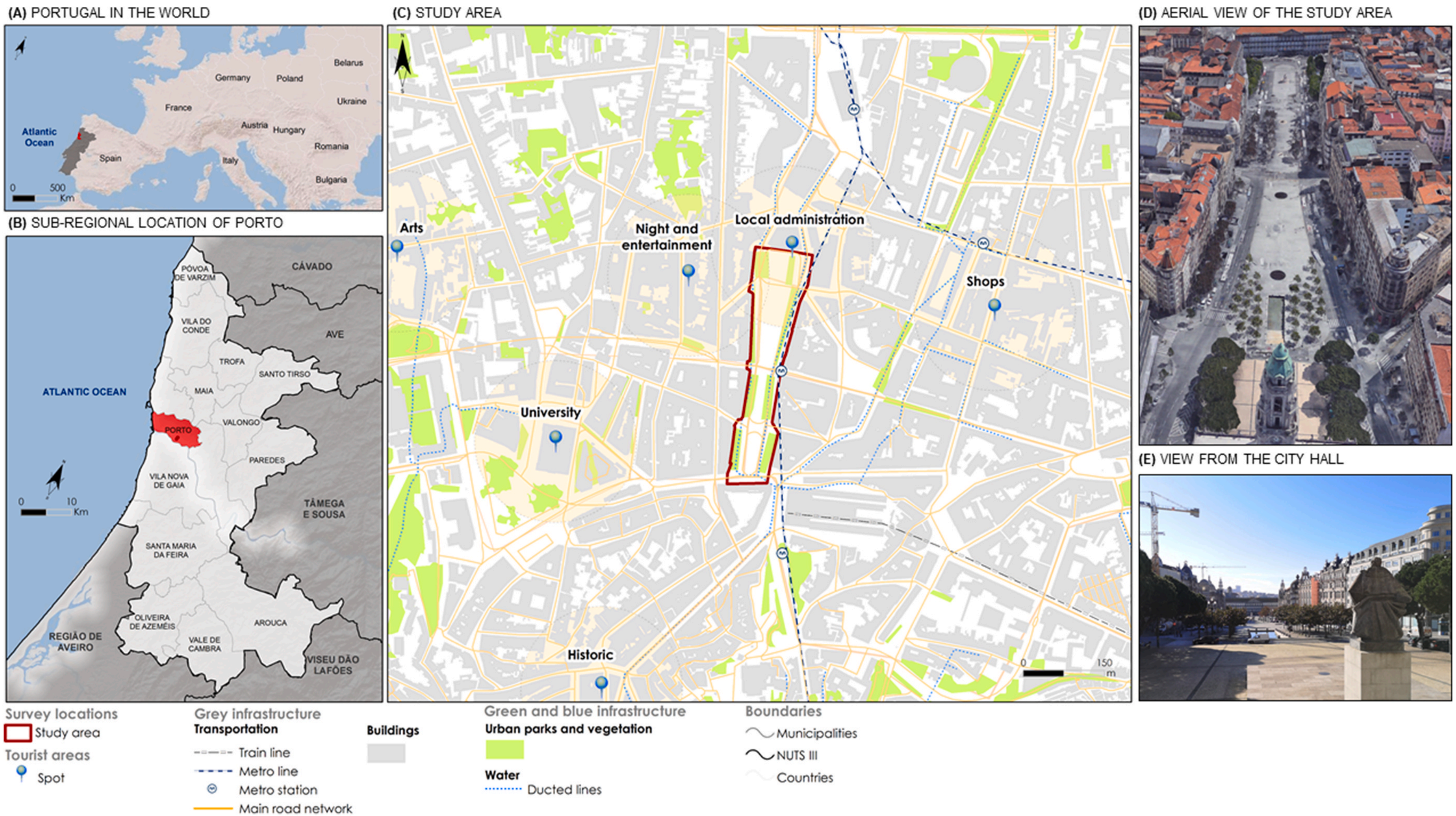

Fig. 1. Porto and the study area. (A) Portugal in the world; (B) Sub-regional location of Porto; (C) Study area; (D) Aerial view of the study area; (E) Study area view from the city hall. Source: Own elaboration. [D] View from Google Earth; [E] Photo by the authors at the City Council (December 21, 2020).

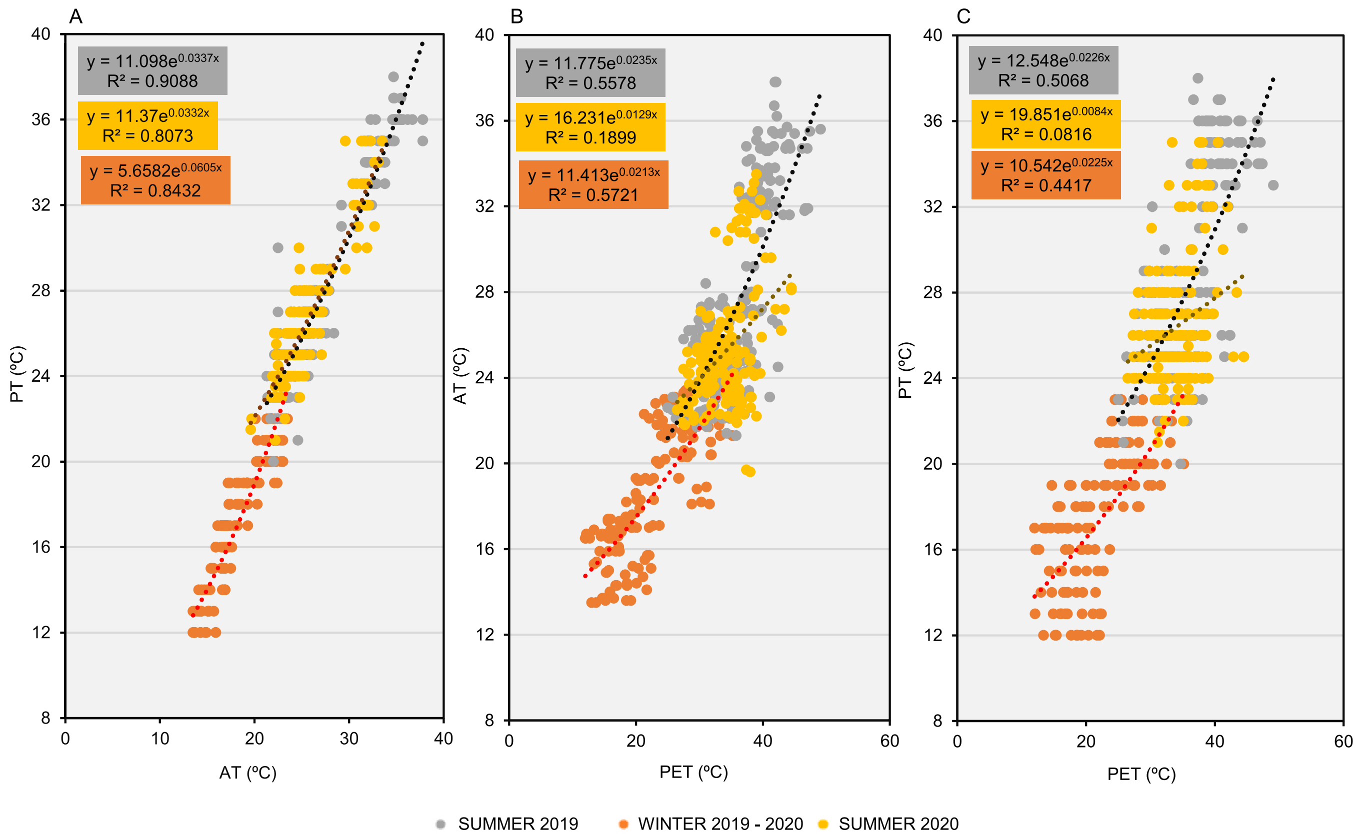

Fig. 2. Relationship between climatic variables during the measurement and application of surveys. Relationship between air temperature (AT) and perceived temperature (PT) (A); between PET and air temperature (AT) (B) and between PET and perceived temperature (PT) (C).
Source: Own elaboration.

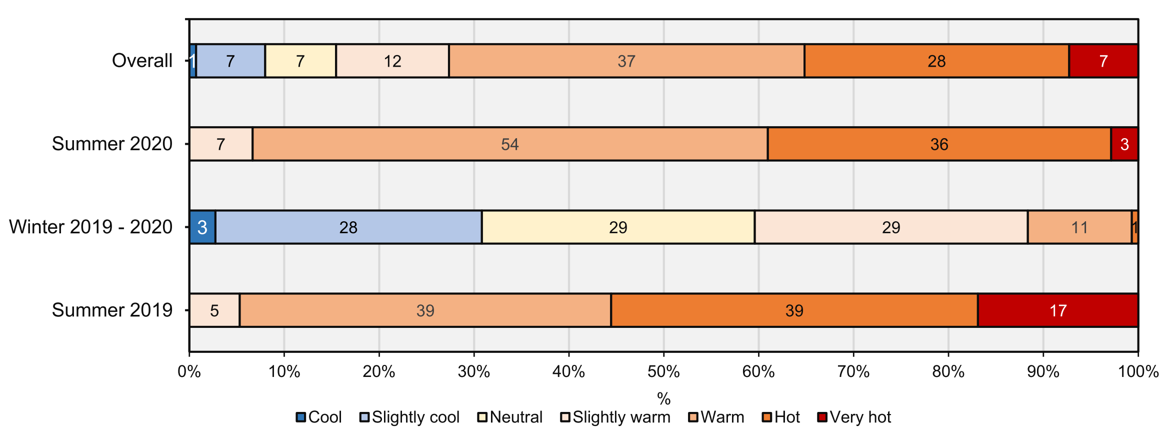

Fig. 3. Classification of thermal sensation situations, according to PET based on microclimatic and personal parameters, in summer 2019, winter 2019–2020 and summer 2020.
Source: Own elaboration.

among the 100 cities with the largest number of visitors in the world, according to Euromonitor International [46].

The city of Porto, as it is known today, has physical, economic, and social characteristics that contribute to the definition of 'Tourist Historic City' [47,48]. The municipality of Porto invested in tourism promotion in 2014, assuming a brand image used to promote it in international tourism markets, as well as to contribute to its affirmation. Many programs have also been developed over the past three decades to make the city of Porto one of the most notable destinations on the international arena. Part of these programs and policies sought to adapt the city to the urgency of climate change, but also to schedule specific interventions to increase thermal comfort in different urban spaces. More recently, COVID-19 brought some additional measures that have been implemented and which coincided with the upgrading of the urban space to the new needs and the provision of more sustainable strategies for the development of the tourism sector in the post-pandemic period.

The global warming trend makes it essential to change urban strategies, which includes programming the future based on current conditions. The climatological records of the secular meteorological station Porto - Serra do Pilar allow to identify a tendency of air temperature increase in the last 108 years, which follows the estimates launched for this latitude in the various models of climate forecast (cf. Appendix – Fig. A.1.). Note that this evidence is very clear with oscillations between average and maximum air temperature being registered since the 1980s.

Despite the benefits and losses that tourism development entails, it should be noted that the intense artificialization of the territory introduces profound changes in air temperature and in the direction of the winds. The latter can be mitigated or increase depending on the influence of the regional climate, which is constantly changing.

These conditions have repercussions on thermal discomfort in dense urban areas during the summer, caused by an Urban Heat Island and aggravated in some cases by extreme heat waves [49–52].

3.2. Field survey

The field examinations were carried out in three study periods: summer of 2019, winter of 2019–2020 and summer of 2020. Measurements were taken for a period of twelve days (view their characteristics and weather patterns in Appendix.). We opted for days with stable conditions and under the effect of the Anticyclone located in the region of the Azores archipelago. As it is recurrent, the prevailing winds were mainly from NNW, although in the days of the inquiry, in winter, the wind direction was more irregular (predominantly ESE – E).

After checking the daily forecast concerning Porto's meteorological station – Pedras Rubras (located at Francisco Sá Carneiro Airport) and assessing ECMWF's weather charts with predictions based on numerical models, available in IPMA – Portuguese Institute for Sea and Atmosphere, and the respective vertical profile, we started our fieldwork. The four instruments were used to perform analysis of wind speed (WS), ambient temperature (AT), relative humidity (RH), global radiation (GRAD) and surface temperature (ST) (view Appendix Table A.2.).

Data collection was based on a set of assumptions:

(1) instrumental configuration, measurement range and accuracy - the recommendations of ISO 7726 (1998) and the ASHRAE manual were followed, with the sensors standing at 1.1 m [53,54];
(2) air temperature and humidity - the sensors must not be exposed to the sun, as it may cause the air temperature to be overestimated. This time, when using protection for the sensors against radioactive exchanges between the instrument and the surroundings, it was sought that the equipment was protected to maximize convection and avoid the formation of hot air and the provision of about 1 and a half minutes for the response time of the sensor, before starting the measurement, considering the thermal inertia of the instrument [55];
(3) Wind speed and direction - the instrument complies with ISO 7726 [53] and the time interval between measurements was sufficient to cover the difference between low and high wind speeds. As according to Andrade et al. (2011) and Oliveira & Andrade (2007) [56,57], the wind speed considered resulted from the combination of two parameters: the maximum wind speed recorded during the survey (MWS) and the standard deviation (SD) of the wind recorded in the same period; this factor is pondered by the following formula: $Wx = MWS + SD$;
(4) MRT (mean radiant temperature) was calculated based on modeling, using RayMan. The calculations used are based on the proposal of several studies [58–61] and result from the combination of data collected and recorded in the software. RayMan-based simulation requires the introduction of some variables, namely day and time information; geographic location; urban structure and environmental morphology; visibility factor (Sky View Factor - SVF) based on the use of the fisheye image and the meteorological data. The information of the procedures is summarized in the annex – Table A.3.

The distribution of measurements during summer and winter between 2019 and 2020 was aimed at: (i) obtaining a global climate assessment during the various winter and summer months; (ii) allowing the establishment of a constant interval between visits (≈15 days); and (iii) enabling the data collected from each fieldwork to be processed subsequently.

Alongside this analysis, it was decided, as in similar studies (namely in Ref. [62]), to analyze the psychological aspects, which can complement the thermophysiological analysis, thus contributing to the provision of guidelines and clues for the strategy to be implemented within this investigation. This analysis is also complementary to that carried out through questionnaire surveys to tourists, to obtain TBR, as well as by mapping the behavior of some tourists who were in the areas under study.

3.3. Questionnaire survey

The questionnaire used was prepared based on the multidisciplinary perspective of several areas that are working towards a similar goal (e.g., tourism, geography, biometeorology, climatology, medicine, psychology, engineering and architecture and urbanism), and to assess tourists' climatic-meteorological preferences and thresholds.

It was structured in 3 sections (A-C), with a total of 27 questions, subdivided into sub-items. We chose to use closed questions and only one open-ended question (optional). The questionnaire presents a conventional structure (top-down structure – global to particular scope) and was created based on different investigations carried out in other territorial contexts [15,24,27,28,56,63,64].

This investigation focuses on climatic-meteorological conditions, namely on the evaluation of the continuum between what tourists consider 'ideal' and 'unacceptable', from a thermal viewpoint, during their stay in public spaces. The questionnaire starts with a presentation, in which the scope and purpose of the investigation are clarified, identifying who is conducting the investigation and how it is being carried out.

The questionnaire focuses on three main sections: (1) the travel experience at Porto Metropolitan Area, (2) the climatic-meteorological experience in Porto and (3) general personal characteristics. In 2020, an additional section dedicated to the role played by COVID-19 in the tourism experience was added.

Section 1 aimed to understand which PMA destinations tourists considered in their visitation decision. Section 2 identifies what visitors have defined as their ideals and climatic limits based on four climatic parameters: (i) air temperature; (ii) precipitation; (iii) wind and (iv) cloudiness. In this section, respondents were asked to rate their current thermal comfort. Based on the ASHRAE 55 and ISO 10551 standards [65,66], a thermal sensation test (TSV - Thermal Sensation Vote) was performed according to a 7-point Likert scale [very cold (−3), cold (−2), slightly cold (−1), neutral (0), slightly hot (1), hot (2) and very hot (3)]. A scale between very low (−3) and very high (3) was used to measure the tourist's perception of wind speed (WSV – Wind Sensation Vote) [65,66]. When it came to humidity (HSV – Humidity Sensation Vote) a 7-point scale was also used. In addition, respondents were asked to indicate their opinion on thermal preferences on a 5-point scale, for each of the 4 variables (air temperature, wind, solar radiation, and air humidity). In addition, tourists were also asked about their preference about cloudiness at that time.

For overall comfort, a 7-point Bedford scale was used, denominated Thermal Comfort Vote (TCV) test [very uncomfortable (−3), moderately uncomfortable (−2), slightly uncomfortable (−1), neutral (0), slightly comfortable (+1), moderately comfortable (+2) and very comfortable (+3)] [67].

In the third section, the questionnaire aims to assess the socio-demographic context of the surveyed visitors. This information was obtained through questions related to age, gender, weight, and height. In addition, to assess the metabolic rate and clothing insulation, the respondents' activity level and clothing were analyzed, in accordance with ISO 9920 and ISO 8996 [68,69], respectively. For each survey, the AT, RH, and WS were recorded momentarily for measurement and noted in questionnaire. The GRAD and ST were registered on datasheet associated with each questionnaire. Microclimatic measurements were made every 90 s, concurrently with the interviews. Between 3 and 4 measurements were made during each interview.

3.3.1. Sample

The first task for defining the sample size is to specify the 'population' and 'element' that will underlie the investigation [70–72]. In this case, the population is tourists and visitors to Porto and the element consists of their perception of thermal comfort during their visit to the city. It is impossible to survey all individuals who visit it in the period defined for the completion of this study, for financial reasons and time constraints. Therefore, it is necessary to select a sample of the universe to participate in the study. To define an ideal sampling base, representative of all perspectives of tourists in Porto and aged 15 years or over, it was necessary to think of a model to obtain the largest number of responses, based on the comparison of the number of guests in Porto. In this sense, we opted for the use of data regarding guests in the city in 2018.

We chose to use a simple random sampling method [73,74]. In the present investigation, the decision on the sample size was related to the following factors: (i) the number of visitors/guests and (ii) the best solution in terms of time and cost necessary to carry out the investigation [70,75].

To obtain valid results, a sample of 385 individuals was considered, which would represent 0.02% of the registered guests in Porto in 2018. Consider, therefore, that this is an excellent number when comparing tourists' perspective with momentary measurements of meteorological parameters.

3.3.2. Pre-test and administration of the questionnaire survey

During this pre-test period, Avenida dos Aliados (Aliados Avenue) and Rua das Flores (Flores Street) (both areas located in the center of Porto) were chosen. They are usually frequented by individuals of various ages, most visited by tourists, and associated with transport, cafés, restaurants, and supermarkets. Individuals who agreed to answer the survey questionnaire were asked a series of questions, which were associated with the surveyor's measurement of certain meteorological elements (air temperature, relative humidity, and wind speed). These participants were invited to evaluate the adequacy and clarity of the adopted items, as well as to suggest some additional items. The pre-test was conducted on July 6, 2019 (Saturday), between 10:30 a.m. and 4 p.m. GTM + 00. Ten questionnaires were carried out and the average length was 15 min. After the questionnaire was applied, some problems arose: (i) a large part of the respondents considered that the questionnaire was extensive; and (ii) two of the questions were considered difficult to answer. Still, the comments on the layout, instructions and topics covered were very positive. After this phase, the opinion and validation by some specialists in the areas of Tourism, Climate and Meteorology were also collected. This survey was also made available to sectoral and regional entities in order to assess the relevance of its continuation. Hence, the questions to be included in the questionnaire were significantly reduced to facilitate data collection and reduce dropouts.

3.4. Data analysis and procedures

3.4.1. Thermal index

A quantitative index was selected to assess outdoor thermal comfort in this study: Physiological Equivalent Temperature (PET). The use of PET is due to its generalization in several studies, being the most used index, and the fact that it allows the use of personal variables associated with the metabolic profile and clothes used [76–79]. The index was calculated using WinComf [80] and RayMan [58] software. Subsequently, these values were used to compare with the measured and predicted parameters (namely, AT and PT).

3.4.2. Thermal comfort limits, neutral and preferred index values

The thermal comfort ranges were calculated based on different thermal comfort limits, neutral and preferred index values. In this study, neutral temperature was determined through different methods. First, bins were created for thermal indices in a range of 1 °C. Then, the regression equations resulting from votes of average thermal sensation and thermal index values were also used to determine the neutral temperature (mTSV = 0).

We also used the Probit method to determine the temperature of the neutral index [64,81]. The use of polynomial quadratic regression allowed us to establish a thermal comfort range. Theoretically, this coincides with a temperature with 90% of thermal acceptability [82]. For this classification, the TSV values proposed by Lin et al. (2013) (TSV≤ -2 or TSV $\geq +2$) were considered unacceptable [82]. These thresholds were used in other studies on perceptions of outdoor thermal comfort [28,79,83–85]. 1 °C bins were used to determine the regression curve and the two points of intersection of 10% unacceptability.

In addition, a binning method was later used to determine the relationship between meteorological variables and mTSV. Then, the adjusted regression equations resulting from votes of average thermal sensation and microclimate variables were made. It should be noted that considering this work was developed in the light of tourism activity, its last stage was dedicated to comparing mTSV and mTPV values compared with the climatic origin (according to the Koppen-Geiger classification) and to distinguishing national from foreign tourists.

3.4.3. Statistical tests

Main statistical tests were performed. In both statistical tests, the 95% confidence thresholds ($p < 0.05$) were followed. In this sense, the statistical analysis software SPSS (Statistical Package for the Social Sciences), version 26.0 was used.

4. Results

4.1. Participants' characteristics and thermal environment

This study includes 563 valid surveys, of which 278 were applied to men (49.4%) and 285 to women (50.6%). These were collected in three time periods: summer of 2019 (n = 207; 36.8%), winters of 2019–20 (n = 146; 25.9%) and summer of 2020 (n = 210; 37.3%) (Table 2).

The age groups varied between 15 and 24 years old (10.5%) and 65 and over (3.2%), with the majority being in the age group between 25 and 44 years (67.7%). A good part of the sample planned the trip 1–5 months before its completion (43.9%) and the duration of the visit was on average between 2 and 3 days (50.4%), with a predominance of city breaks, already identified in previous studies on Porto [86–88].

Most visitors reported a healthy clinical status (73.4%), even though in the summer of 2020, 0.2% of respondents said they had already had COVID-19. Most of the respondents came from a European country (57.5%), namely in the summer of 2020 (68.6%), which is a testament to the number of countries that had to close their borders due to the pandemic.

In addition to the predominance of individuals in the sample with a normoponderal body mass index (71.0%), the profile of respondents in terms of education is associated with undergraduate and secondary education degrees (75.9%).

Non-parametric tests did not reveal any major differences between respondents during the three periods under analysis, maybe except for the variables *travel group size* (H = 8.050; *p*-value = 0.018) and *country of residence* (H = 26.719; *p*-value = 0.000). Tourists' geographical origin changes markedly between seasons. It can significantly influence their thermal perception, namely because there may be situations of greater differences in air temperature or relative humidity between the country of origin and the country of destination. In addition, an analysis of the Köppen-Geiger classification seems essential to determine if these differences are found between respondents in the summers of 2019 and 2020, and in the winter of 2019–2020 (view Appendix Fig. A.2).

Despite the different patterns between nationalities, according to the Köppen-Geiger classification climatic origins were not distinct. Temperate climates predominate in all seasons, with only a slight inflection between the Cfb and Csa classes during the periods of analysis. There were fewer tourists from the Cfb division (27.6%) in the summer of 2020, largely due to COVID-19 and the absence of tourists from certain typical emission markets.

Table 3 summarizes the activities carried out in their last 30 min in the study area. Tourists stayed on average between 16 and 30 min in the area. Most respondents were walking (64.5%). Although most tourists find themselves doing activities in the sun during the last 30 min (43.0%), it should be noted that, in the summer of 2020, there was a preference for staying in the shade – including the shade of trees (45.2%). The differences were very relevant both regarding the stay in the surrounding area (on average, with an increase in the stay in the study area) and the location of the activities carried out in the last half-hour. One of the reasons for this could be related to the COVID-19 pandemic and the consequent use of face masks in public spaces. Thus, the use of facial masks during the visits, seemed to have significantly different effects both on the trips and on choosing to stay or not in the same place, and on whether the activities should take place in the shade or in the sun (with *p*-value = 0.000 and 0.008 in the Mann-Whitney test, respectively).

Incidentally, in terms of weather, the summer of 2020 was more pleasant than that of 2019 (cf. Table A.1. and details on microclimate conditions below).

The correlation between destination choice and climate is crucial. According to the survey results, it does not matter whether it is any type of foreseen travel or actual ongoing tourism practice (Appendix . Fig. A.3). In general terms, 73.2% of the respondents consider that climate influences the choice of destination, 71.0% the choice of season and 80.3% planned activities. Just over half of the surveyed tourists planned their trip according to the climate/weather in Porto (58.4%). It should be noted that during the summer of 2020 there is a slight decrease in the relevance attributed to the climate factor compared to the summer of 2019 and the winters of 2019–2020, especially when it comes to destination choice (−6.3%) and duration of the visit (−6.6%). The main reason may be long lockdown periods, which led to the consideration of other factors besides climate.

4.2. Experimental results

Table 4 summarizes field measurements of meteorological parameters collected during the surveys in the summer of 2019, in the winters of 2019–2020 and in the summer of 2020. During the winter the average air temperature (average AT) was 18.4 °C, while in the summers of 2019 and 2020 was around 27.8 °C and 25.3 °C, respectively.

Regarding the calibrated wind parameter (W*x*), expressed in m/s, it was found that the days presented, in general, light breezes or calm situations (average of 1.0 m/s). However, the highest wind speed occurred on December 28, 2019 (winter season) - 6.0 m/s during this investigation. Wind speeds were very low when measurements were made in both seasons; this may be due to the nature of urban areas where buildings' volumetry is very high. The survey periods showed relative humidity values between 33.0% and 84.0%.

The relationship between air temperature, PET and the perceived temperature is shown in Fig. 2. In all periods of data collection, the perceived temperature reported by respondents showed a statistically significant relationship with air temperature. Note that the relationship between air temperature and PET, and the perceived temperature (PT) and PET was quite low ($R^2 < 0.6$).

Table 4
Mean weather conditions verified during the questionnaires.

Period of study		AT (°C)	W*x* (m/s)	RH (%)	GRAD (W/m^2)	MRT (°C)
SUMMER 2019	Mean	27.8	0.9	56.1	598.8	49.8
	Median	26.2	0.8	54.3	601.4	50.5
	Minimum	21.3	0	34.5	31.3	34
	Maximum	37.8	3.85	81.3	896.5	64.7
WINTER 2019–2020	Mean	18.4	0.88	46.2	249.5	28.1
	Median	17.8	0.65	42.9	243.6	27
	Minimum	13.5	0	34.3	21.2	8.1
	Maximum	23.5	6.04	69.3	556.8	48.4
SUMMER 2020	Mean	25.3	1.07	62.8	594.1	48.5
	Median	24.8	0.83	64.8	598.3	49.9
	Minimum	19.6	0	33.6	31.9	34.9
	Maximum	33.5	4.1	84.2	845.4	60.4
OVERALL	Mean	24.4	0.96	56	482.3	43.7
	Median	24.3	0.78	56.1	483.5	48.2
	Minimum	13.5	0	33.6	28.3	8.1
	Maximum	37.8	6.04	84.2	765.4	64.7

Source: Own elaboration.

During the survey periods in Porto, the respondents' profiles made it possible to identify potential thermal sensation situations, from cold to extremely hot, for simulated PET based on RayMan Pro. In the summer, the hot to extremely hot class prevailed (Fig. 3). The summer of 2019, in particular, presented a preponderance of situations in which respondents would be in extremely hot situations (17.0%).

4.3. Thermal sensation votes and meteorological parameters

Thermal sensation votes for the hot and cold seasons in Porto were also analyzed based on the ASHRAE seven-point scale [54].

The influence of meteorological variables on respondents' thermal sensation was assessed using meteorological measurements and comparison with mTSV. AT and RH show a stronger relationship with mTSV in the summer of 2019 ($r^2 = 0.86$ and $r^2 = 0.68$, respectively; *p*-value <0.05), when compared to the summer of 2020 ($r^2 = 0.67$ and $r^2 = 0.65$, respectively; p-value < 0.05). The most extreme wind speed in the winter season concerns the thermal sensation vote categories of −2 (cold) and −3 (very cold). Nevertheless, there was no significant relationship between respondents' mTSV and W*x* ($r^2 = 0.15$; *p*-value <0.05). In fact, no relationship was found between tourists' thermal sensation and wind speed during the survey period.

These conditions contribute to the fact that most respondents present a high level of adaptation to the weather conditions present at the touristic destination. 41.0% of respondents expressed a feeling of neutral thermal sensation (n = 231). It should be noted that the interquartile range and the minimum and maximum AT values recorded between each thermal sensation class is very large, especially in neutral TSV (0) (18.6 °C) and slightly warm TSV (+1) (18.2 °C) (Table 5).

These variations are more significant between the seasons, comprising, for the period under analysis, significant differences between the winter of 2019 and the summers of 2019 and 2020 when it comes to the distribution of neutral thermal sensation votes. 59.6% of respondents in the winter of 2019 expressed a neutral thermal sensation (TSV = 0).

The summer of 2019 corresponds to the period when respondents felt most uncomfortable due to heat (TSV> 0 = 59.9%). Note, moreover, that the summer of 2020 can be considered a little atypical. If most individuals considered that their thermal sensation was neutral (TSV 0 = 39.5%), the classes of TSV> 0 and TSV <0 also showed very expressive values (33.8% and 26.7%, respectively). Despite this, respondents also reveal that neutral TSV presents notable differences in the different days

Table 5
General conditions of Thermal sensation votes during the survey period.

Statistical parameters	TSV (Thermal Sensation Vote)						
	Cold (−3)	Cool (−2)	Slightly cool (−1)	Neutral (0)	Slightly warm (1)	Warm (2)	Hot (3)
No.	4.0	43.0	83.0	231.0	86,0	78.0	38.0
Per cent (%)	0.7	7.6	14.7	41.0	15.3	13.9	6.75
Minimum	13.5	13.5	13.6	14.1	17.2	21.3	22.6
Maximum	23.4	25.6	28.4	32.7	35.4	37.8	37.8
1st Quartile	13.6	15.9	16.8	21.2	24.2	24.8	32.3
Median	18.0	22.3	22.3	23.5	25.3	28.0	34.0
3rd Quartile	22.6	23.7	24.6	25.2	27.4	32.4	34.8
Mean	18.2	20.8	20.8	23.0	26.1	28.9	33.1
Variance (n-1)	29.0	17.5	16.8	11.6	12.5	19.1	10.2
Standard deviation (n-1)	5.4	4.2	4.1	3.4	3.5	4.4	3.2

Source: Own elaboration.

of analysis.

Fig. 4 shows the relationship between mTSV and PET, with values based on 1 °C bins. PET showed a higher correlation with mTSV in all seasons, a situation also found in other studies [2,89,90]. Even so, it should be noted that the summer of 2019 presents a stronger correlation between PET and mTSV than the summer of 2020. PET reveals less explanatory capacity for tourists' thermal sensations. In all situations, the perceived temperature (PT) showed a high correlation with mTSV ($r^2 > 0.8$). Neutral conditions and thermal preferences can favor the understanding of the limits to tourist practice, which tend to be much wider than for the local resident population.

4.4. Neutral temperature and preferences

In this study, the neutral temperature in the summers of 2019 and 2020 and winter of 2019 either individually, or all three periods combined, was determined using the Probit technique [81].

Fig. 5 presents the Probit technique results for the summers of 2019 and 2020 and winter of 2019, as well as a combined model. There is a difference of more than 1.5 °C in the neutral temperature between the summers of 2019 and 2020. In the winter of 2019, the neutral temperature is 17.9 °C. In general terms, the neutral temperature of the visitors is situated at 23.8 °C.

The neutral zone (i.e., between TSV <0 and TSV> 0) represents here thermal conditions with which at least half of the subjects are satisfied, and which they will possibly not want to change, using 50% probability

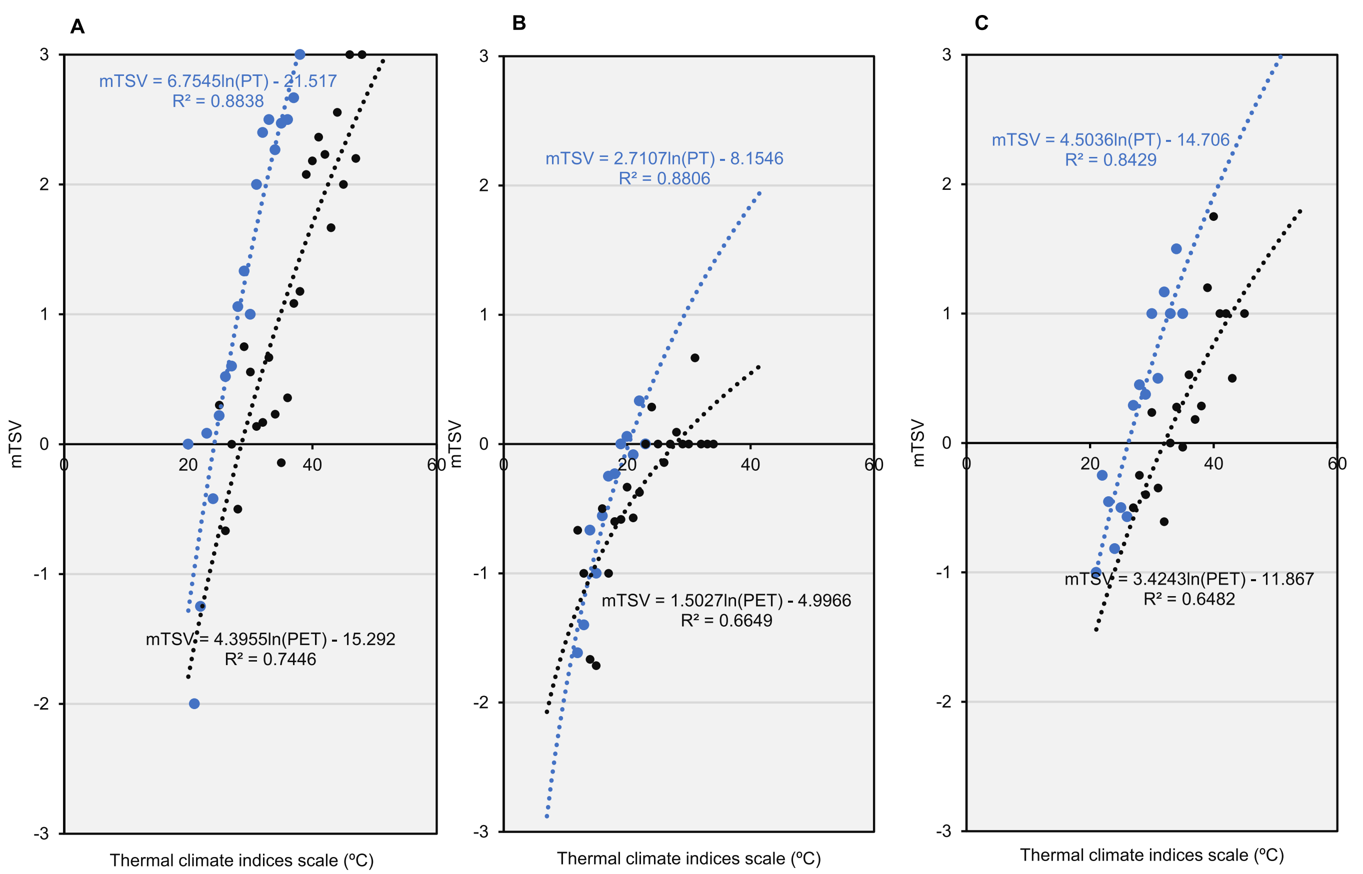

Fig. 4. Comparison of thermophysiological index (PET) and perceived temperature (PT) with mTSV by the respondents. Summer 2019 (A), winter 2019–2020 (B) and summer 2020 (C).
Source: Own elaboration, based on 563 respondents.

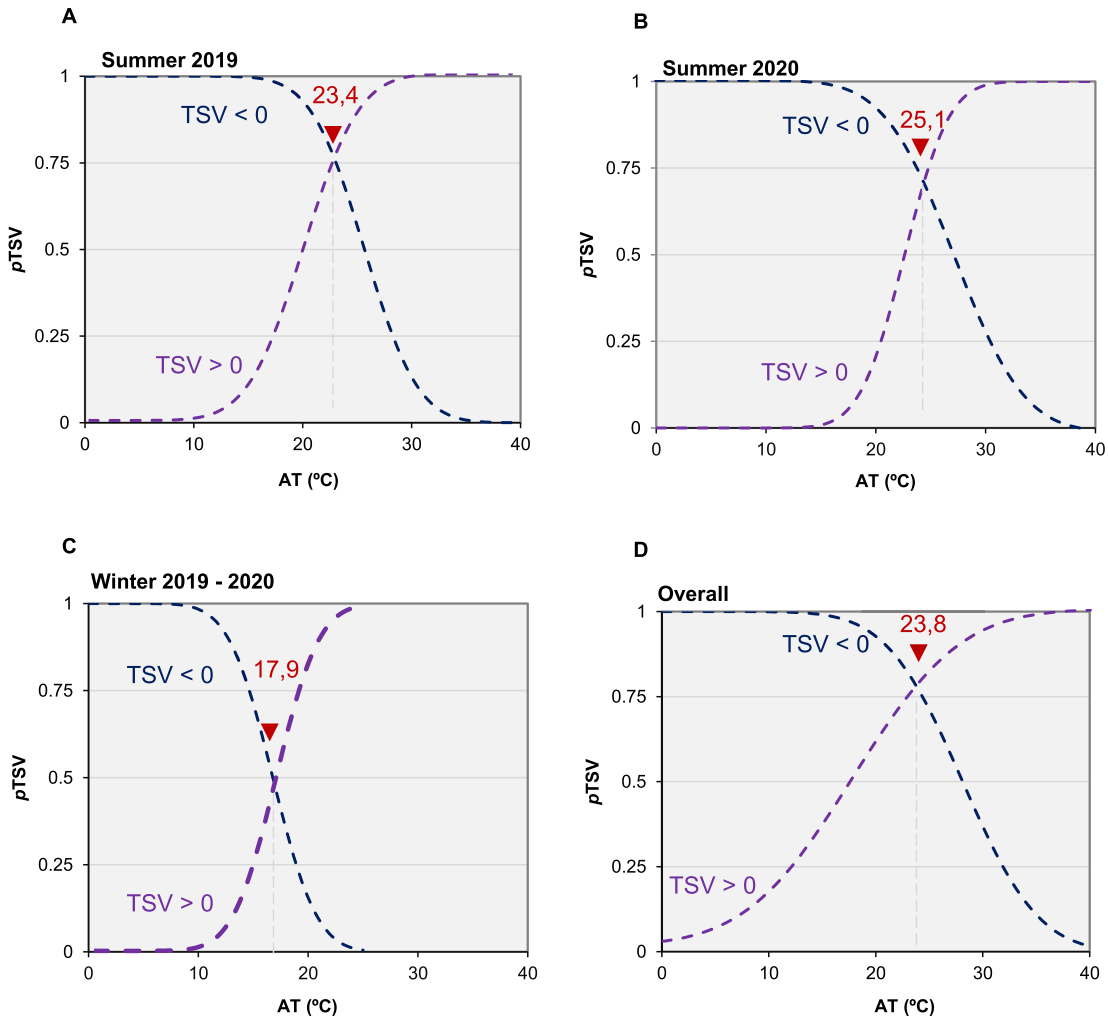

Fig. 5. Establishment of the optimal neutral temperature for tourism based on the probit regression technique. Summer 2019 (A), winter 2019–2020 (B), summer 2020 (C) and overall (D).
Source: Own elaboration, based on 563 respondents.

as a dividing line. This range is much more significant in the summer of 2020, when tourists have neutral temperatures between 22.6 °C and 27.0 °C.

The use of the quadratic regression method allows us to assess meteorological situations in Porto is more pleasant for tourists. It reveals that tourists have a wide range of thermal comfort given the weather conditions in Porto (between 20.0 °C and 25.3 °C - range of 5.3 °C) (Fig. 6). This range of values shows that colder conditions in winter and very hot conditions in summer (especially during heat waves) are less pleasant for tourism.

This study observed that there is a significant difference between the temperatures that the interviewees want and the temperature felt.

It was also observed that the difference between neutral and preferential temperature is greater for the winter season than for the combined season. This difference may be due to variations in respondents' experience and expectations; this trend has also been observed in other studies [64,91]. It is common for people in hot climates to want lower temperatures, and the urgency of expectation in relation to comfortable thermal conditions increases with the difference between neutral and preferential or expected temperature [64,92,93]. Nonetheless, the same is not necessarily the case in temperate climate areas, such as the city of Porto.

The identification of the optimal thermal limits for urban tourism and recreation during the year uses the binomial regression model for average thermal preference votes – mean Thermal Preference Vote (mTPV) in AT intervals of 1 °C (Fig. 7). AT values corresponding to the mTPV ±0.125 range are considered comfortable.

The use of the same approach allows the identification of the preferred range of thermal conditions for tourism and recreation in Porto associated with AT between 18.0 °C and 30.0 °C. These values represent well the lower and upper limits of the thermal sensations determined in the neutral thermal range for all seasons.

Subsequently, we compared the respondents' thermal sensations with their thermal preferences. Spearman's correlation between TPV and TSV turned out to be negative and moderately strong throughout the year ($\rho = -0.624$, N = 563, $p < 0.0001$). When analyzing the respondents' mTPV with their corresponding mTSV at appropriate AT intervals of 1 °C, in most cases the preference for slightly warmer conditions than the real ones prevailed (Fig. 8). For mTSV less than or equal to 0 (neutral), mTPV generally set themselves between 0.0 and 0.5, which indicates a moderate desire for a higher AT than the current one.

If mTPV = 0 is related to the comfortable and desired thermal environment, the preferred thermal sensation for tourists and people who are outdoors enjoying the public space is equal to 0.4, which means

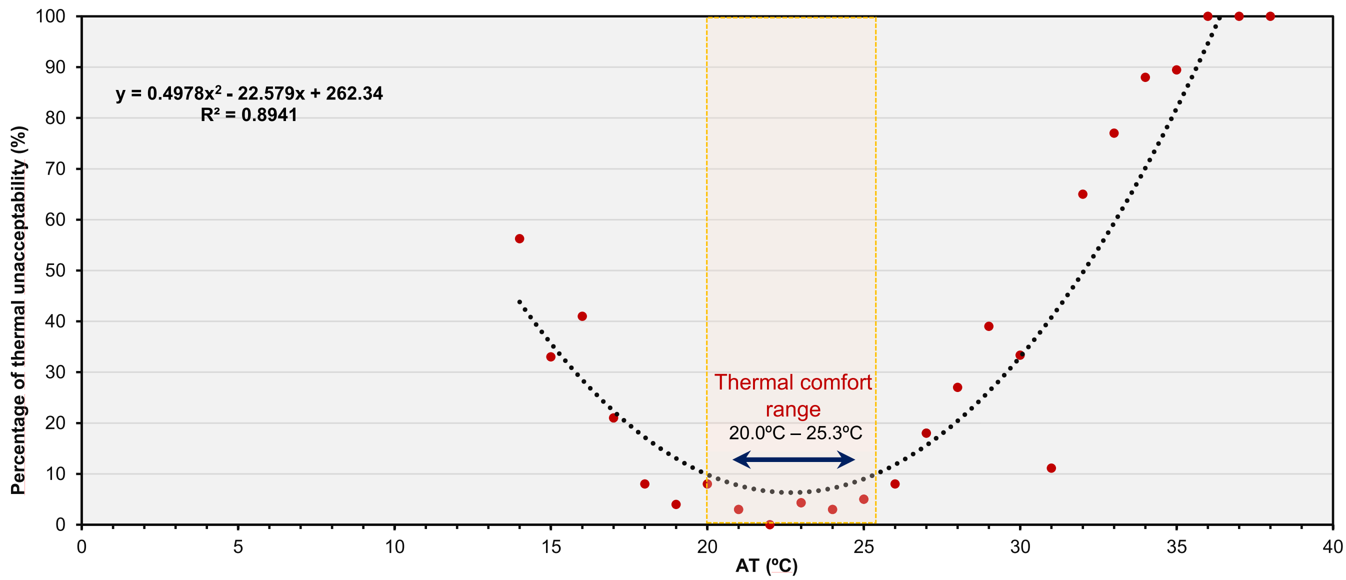

Fig. 6. Thermal comfort range between respondents' based on polynomial quadratic regression.
Source: Own elaboration, based on 563 respondents.

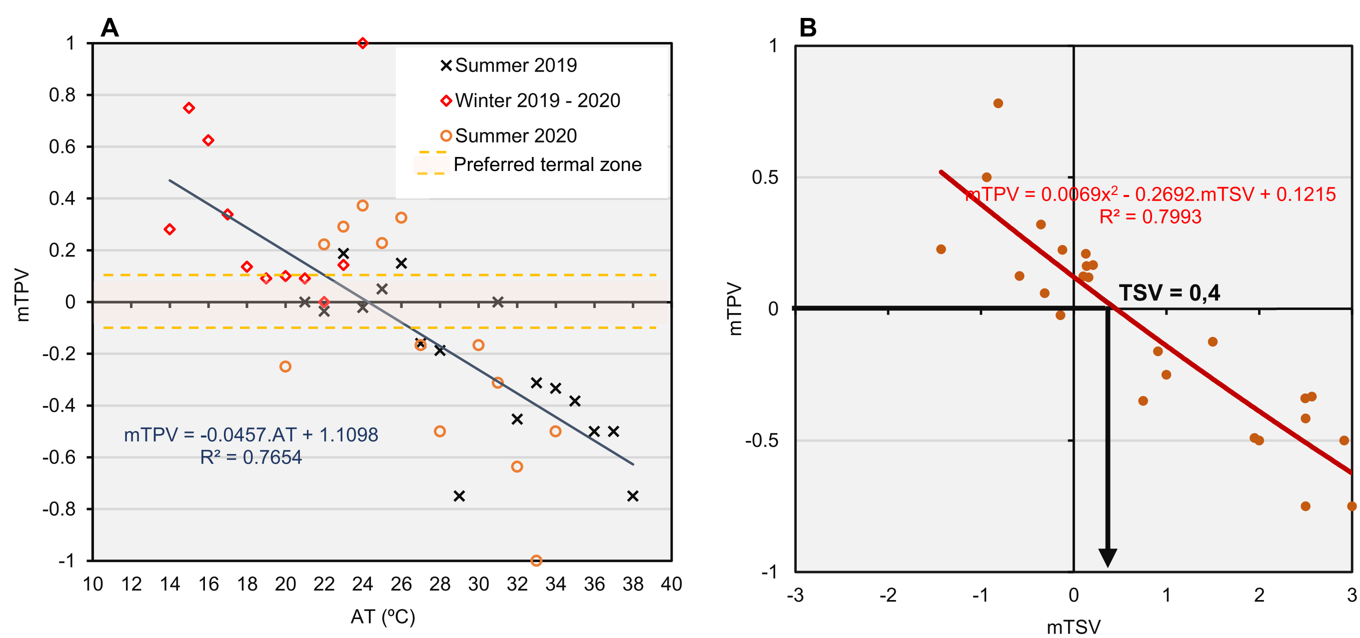

Fig. 7. Mean thermal preference vote (mTPV) and 1 °C AT values in the period of analysis (A) and respondents' mean thermal preference vote (mTPV) compared with the corresponding mean thermal sensation vote (mTSV) in 1 °C AT range (B).
Source: Own elaboration, based on 563 respondents.

a "slightly warm" feeling. This shows that thermal neutrality is not the same as thermal preference. Such evidence is supported by seasonal and even inter-annual differences between TSV and TPV.

In neutral TSV there are situations in which tourists would prefer it to be between a little warmer to warmer, despite the pleasant weather conditions they experience. There is a proportional reason between considering being under hot conditions and preferring it to be much cooler. Henceforth, the reverse also happens. It should be noted, in fact, that in cold TSV in the winter period, the preference is usually for it to be a little warmer. We sought to ascertain whether the respondents' TSV and TPV assumed values regarding the summer of 2020 were any different. Statistically, and according to a T-test, significant differences were found for the variable TSV ($t = -2.011$; p-value < 0.05), which came from using a mask. However, thermal sensation cannot be attributed exclusively to the use of the mask, and the variables related to nationality and climatic origin may be relevant factors.

The first study to assess the influence of the place of residence on thermal perceptions in an urban environment was conducted by Lindner-Cendrowska & Błażejczyk [28]. There seems to be a good ability to adapt to the meteorological situation at the destination, evidenced by sensation and thermal preference, regardless of the type of climate. However, note that the climatic similarity does not always determine levels of neutral sensation and preference for maintaining the thermal situation. This preference seemed to be more decisive in temperate

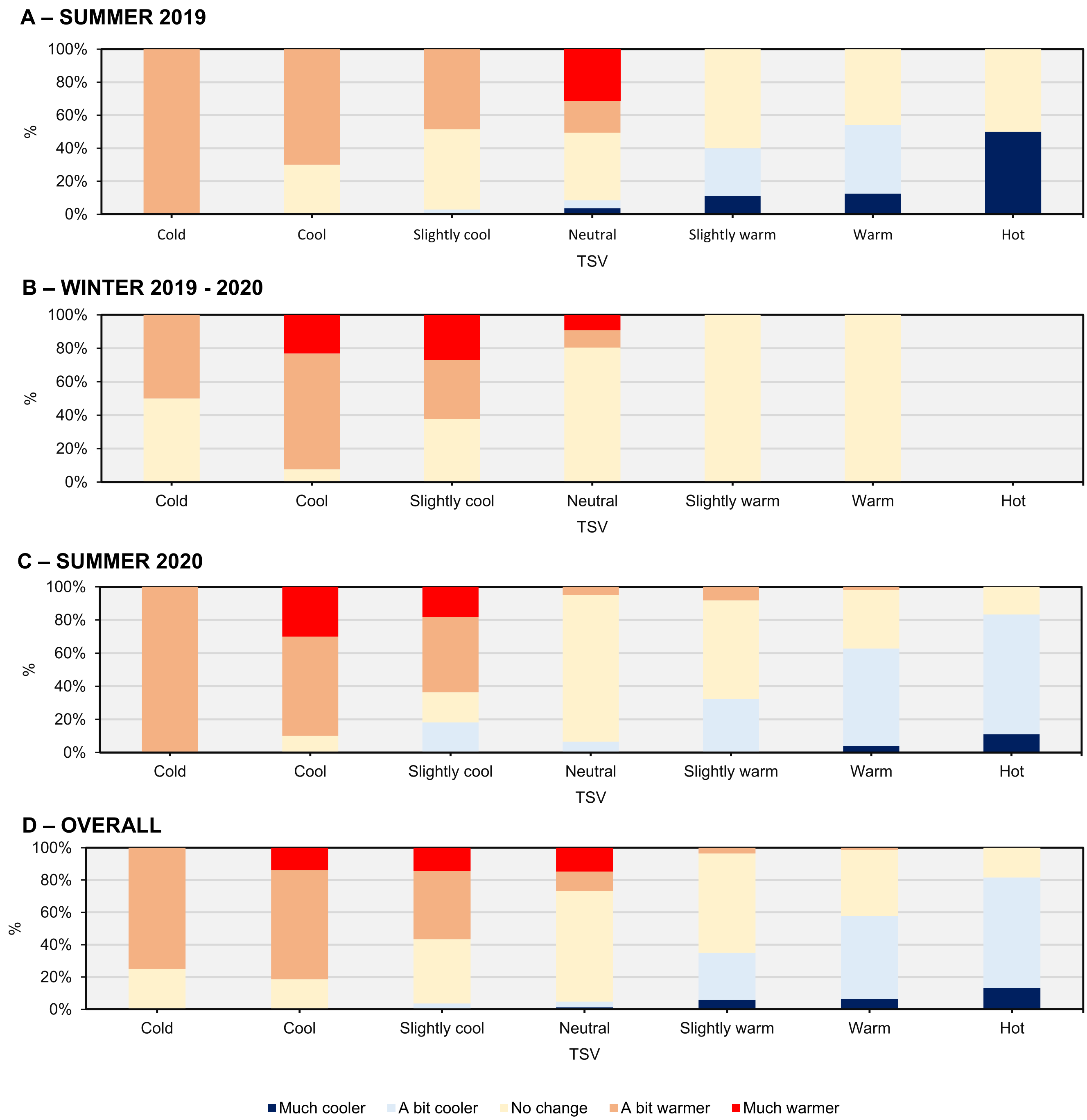

Fig. 8. Frequency (%) of thermal sensation votes (TSV) by period of analysis. Summer 2019 (A), winter 2019–2020 (B), summer 2020 (C) and overall (D). Source: Own elaboration, based on 563 respondents.

climates (C) during the winter of 2019 (Fig. 9). The tourists who manifest a greater affinity with the climatic situation are those from the continental climate group (D), with the highest percentage of votes in the TPV class = 0.

The preferences about climatic parameters under different TSV, both from national and international tourists, were analyzed and compared, as shown in Fig. 10. Most national tourists seemed more pleased with the local climate, with 'neutral' TSV. This is not the case in the winter of 2019. This does not mean that respondents would prefer to experience higher or lower temperatures. It should be noted that foreign tourists expressed that they faced cooler conditions than residents and expected higher temperatures.

5. Discussion and conclusions

This paper aimed to evaluate the thermal comfort conditions of one of the most visited outdoor spaces by tourists and to identify the processes of thermal adaptation (sensation and thermal preference), analyzing their responses obtained from the triangulation of methods based on the questionnaire and microclimatic measurements carried out during summer and winter, between 2019 and 2020.

The study assumed that tourists when practicing outdoor activities, related to tourism and recreation – in the urban context – do it differently than passers-by or with outdoor jobs. In fact, this investigation shows that the thermal perception of individuals cannot be explained

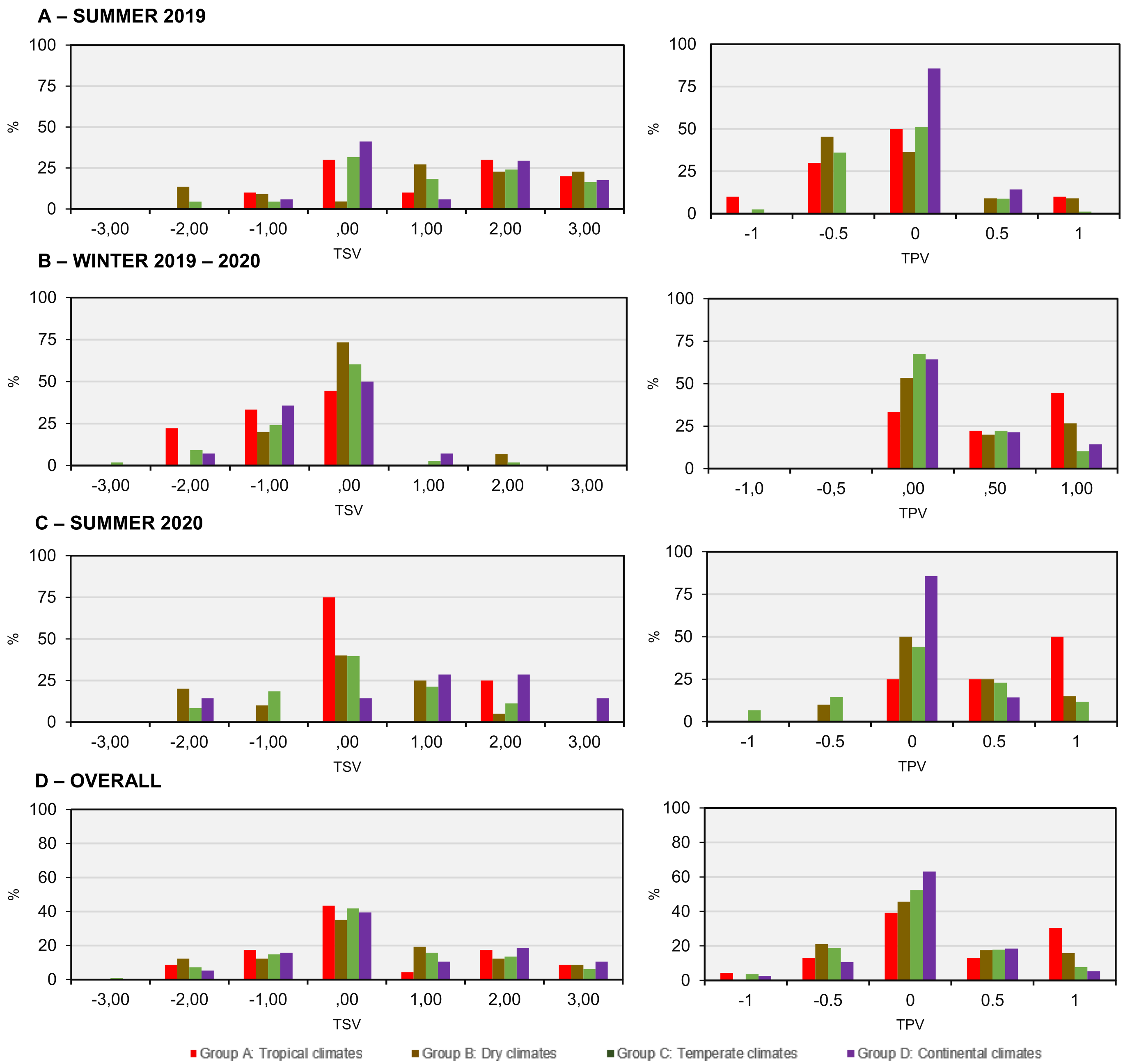

Fig. 9. Thermal sensation votes (TSV) and thermal preference votes (TPV) depending on the provenance climatic zone. Summer 2019 (A), winter 2019–2020 (B), summer 2020 (C) and overall (D).
Source: own elaboration, based on 563 respondents.

exclusively through the energy balance of the human body. Other psychological and functional factors determine TBR, namely thermal sensations and preferences in relation to climatic elements [64,94]. There is a condition that is relevant to the evaluation of the results obtained. The voluntary nature of tourism experience makes tourists more tolerant of various climatic-meteorological conditions, which they frequently evaluate as comfortable.

Consistently, our research has shown that in the urban environment, people who practice outdoor tourism and recreation activities prefer even warmer thermal conditions than the ones they usually experience, even in the summer when registered temperatures are high. Any of the thermophysiological indices (PET, UTCI, * SET) prove to be incapable of translating the range of sensations and preferences that a tourist may have during tourist practice. In this investigation, PET results were presented, but, despite being widely used in the literature, were not very significant. The remaining indices were also tested, but failed to translate the climatic-meteorological experiences, revealing in all cases a weak to very weak correlation ($r^2 \leq 0.35$; p-value <0.05). Also, in 2020, tourists found themselves involved in different travel situations (COVID-19 pandemic) that may have resulted in slightly more tenuous thermal perceptions when it came to thermal comfort:

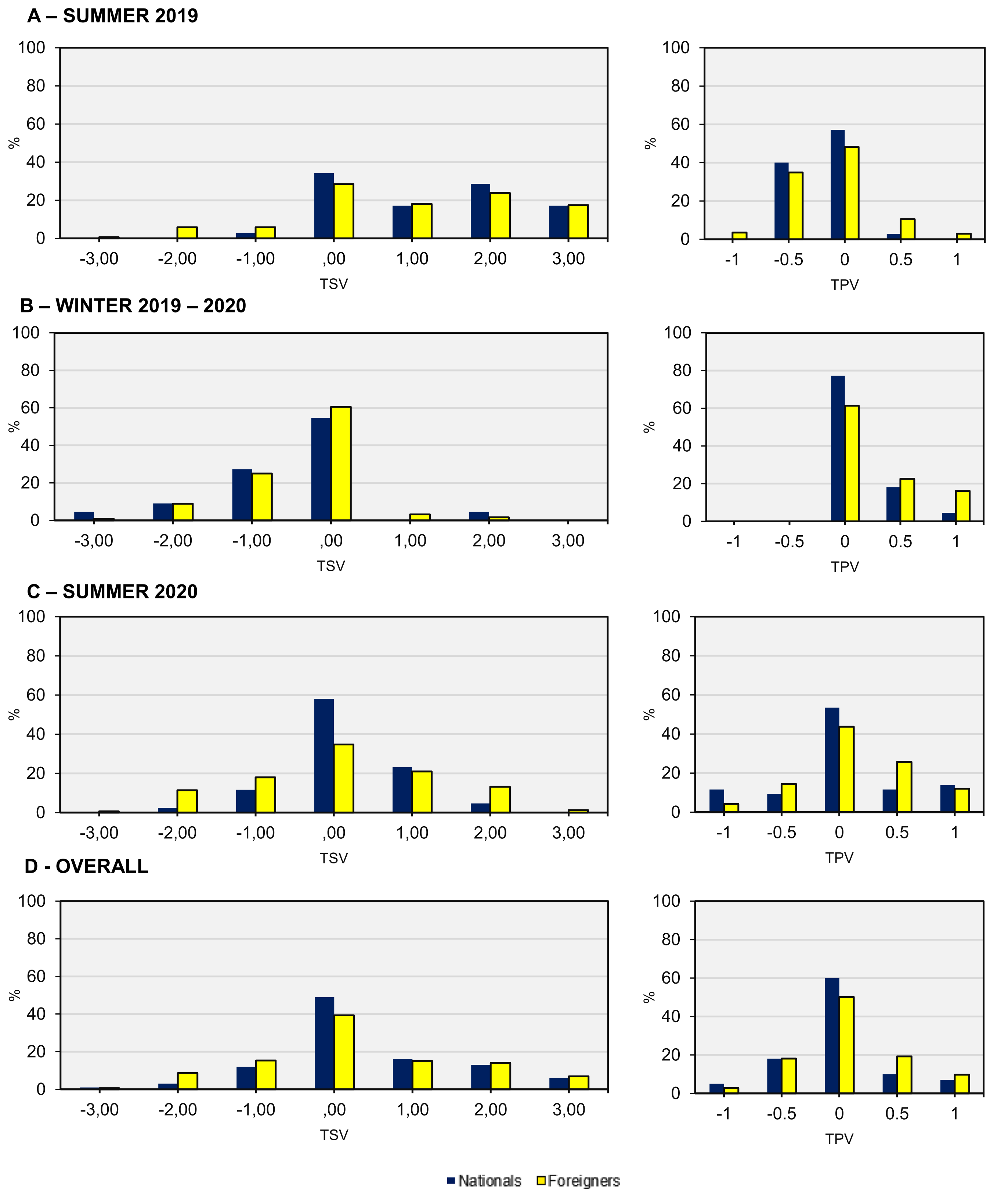

Fig. 10. Thermal sensation votes (TSV) and thermal preference votes (TPV) depending on origin (nationals vs. foreigners). Summer 2019 (A), winter 2019–2020 (B), summer 2020 (C) and overall (D).
Source: own elaboration, based on 563 respondents.

- The geographic characteristics of the place of origin of tourists are similar to those of destination Porto. The temporary closure of borders between countries for more than 3 months resulted in fewer visits than usual on the part of other international markets. During the first phase of the inquiries - on July 7, 2021 - Portugal had opened its land borders just a few days before (July 1, 2021).
- Tourists tended to travel in smaller groups, to concentrate their visit in the city of Porto and to change their travel habits. In fact, a consequence of these changes is related to the time of outdoor exposure in a given place and the time spent in the shade or in the sun during their recreational activities. In addition to this, there was a reduction in the number of tour buses during the summer of 2020 the need to wait in the same area/place for some time, but also the use of a face mask. These findings may still raise some doubts, but the significant conclusions obtained regarding the above mentioned time of exposure, either in the shade or in the sun, and the subsequent thermal sensations established during the year of 2020 for statistical purposes, may reveal themselves as extra evaluation elements on tourism practice.

These conditions should be compared with those of 2019, where tourists presented more thermal discomfort. On the other hand, we should make clear that the interpretation of results should highlight factors of significance other than higher temperatures.

In situations with hot thermal conditions, satisfaction with the thermal environment prevailed. Kántor et al. (2012) and Kovács et al. (2016) stated that humans are less vulnerable in situations in which they are enjoying the outdoor climate on their own accord [32,95]. Same results were found in this study on Szeged (Hungary). Nevertheless, the COVID-19 outbreak and the effects of climate change on thermal comfort during tourist practice reveal that studies are needed to clarify both current situation, and which strategies to use in the medium and long term.

5.1. Theoretical and managerial implications

The results of this study have local validity and can be applied to different climates and cultural areas without adaptation. They can contribute to the elucidation of issues that influence thermal comfort in urban spaces in Porto and similar climatic contexts. In-depth understanding of these issues will allow the development and adoption of urban design practices, improving the environment and encouraging its use at different times of the year.

Urban design initiatives are needed, such as increasing the amount of shaded area, planting trees, and providing greater environmental diversity in the geographic space, to mitigate the impact of adverse microclimatic conditions. Greater adaptive opportunities and improvements in thermal comfort for tourists and general satisfaction in the city should be provided. Setting up new spaces post-COVID-19 is a pretext to allow the creation of points of contact between tourists and residents. The city must have small spaces, yet well distributed, that allow tourists to enjoy themselves. The allocation of blue spaces is also essential. Alternatives to increase comfort zones can be tested with the improvement of these conditions, as proposed by several authors [62,96,97] in big cities (e.g. Lisbon, Portugal).

Some short-term initiatives have been taken based on urban acupuncture interventions (e.g., mobile gardens, temporary pedestrian zones), which can increase tourists and residents' enjoyment.

5.2. Limitations and future research directions

Several studies have highlighted the need for further research on an international scale. Therefore, we must emphasize the importance of developing human-biometeorological thermal comfort guidelines regarding the outdoors, and, within the scope of this investigation, three elements should probably be standardized in future investigations:

(1) In the design of the questionnaire, standardizing the subjective judgment scales suitable for thermal comfort studies would be beneficial. This should include appropriate scales (e.g., thermal perception, thermal preference, acceptability), both regarding the number of response alternatives, as well as the text. The standard should also provide guidance on statistical analysis of survey data. It should be noted that many of the investigations use methodologies that do not meet basic requirements when it comes to international patterns, scales used to measure opinion and even certain statistical tests.
(2) Thermal comfort indices should be recommended in guidelines and standards, revealing their usefulness and suitability - as well as guidance on how the calibration of these indices can be performed based on objective measurements and/or calculations and subjective responses of thermal perception. An additional indicator may be the mentioning of the perceived air temperature on a wide scale. Few studies have used this (e.g., Rutty & Scott, 2010 [23]) namely when analyzing thermal conditions in loco. In terms of tourism practice, it can prove to be a good indicator.
(3) The description of the investigation - location of measurements, description of the methods (position, type of data and precision of the instruments).

Additionally, it is necessary to introduce new parameters for measuring Clothing insulation (Clo). Little is known about the effects on thermal comfort of having to wear a face mask during the journey and exposure to extreme heat conditions in pandemic situations. As we are facing its widespread use for long periods of time, almost as if it were just another permanent piece of clothing, it seems clear that it would be useful to introduce it into ASHRAE's reference manual and bring it to the questionnaires that assess individual thermal comfort. In this regard, Mora & Meteyer (2018) [98]reported that although clothing insulation factors (Clo) referenced by ASHRAE [99] are used in health literature, this does not yet include specific measured Clo values for protective clothing (such as face masks). This is also why we state there is a pressing need for data on thermal properties, thermal insulation, and vapor permeability of the various types of face masks (surgical or social). Likewise, research data on the effect of body movement on increasing air velocity and isolation is needed [100].

In conclusion, more studies are needed not only to foresee research gaps, but also to bring some clarity on thermal comfort, namely in the tourism sector in urban areas, where leisure is greatly affected by outdoor conditions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research was funded by FCT Portugal, grant number SFRH/BD/129153/2017 and Lab2PT – Landscapes, Heritage and Territory Laboratory – AUR/04509 and FCT through national funds and when applicable of the FEDER cofinancing, in the aim/under the scope of the new-partnership agreement PT2020 and COMPETE2020– POCI 01 0145 FEDER 007528.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.buildenv.2021.108246.

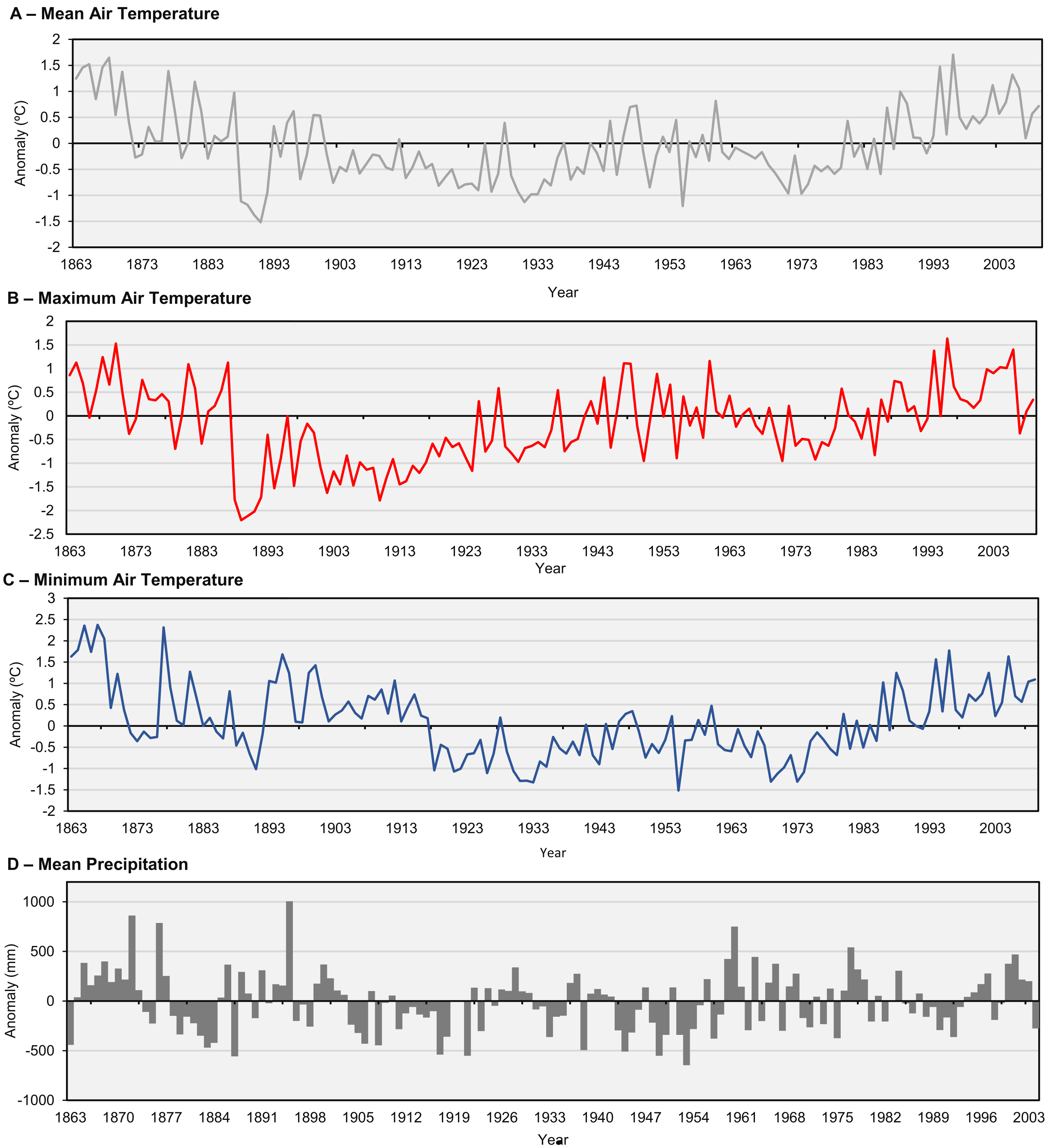

Fig. A.1.

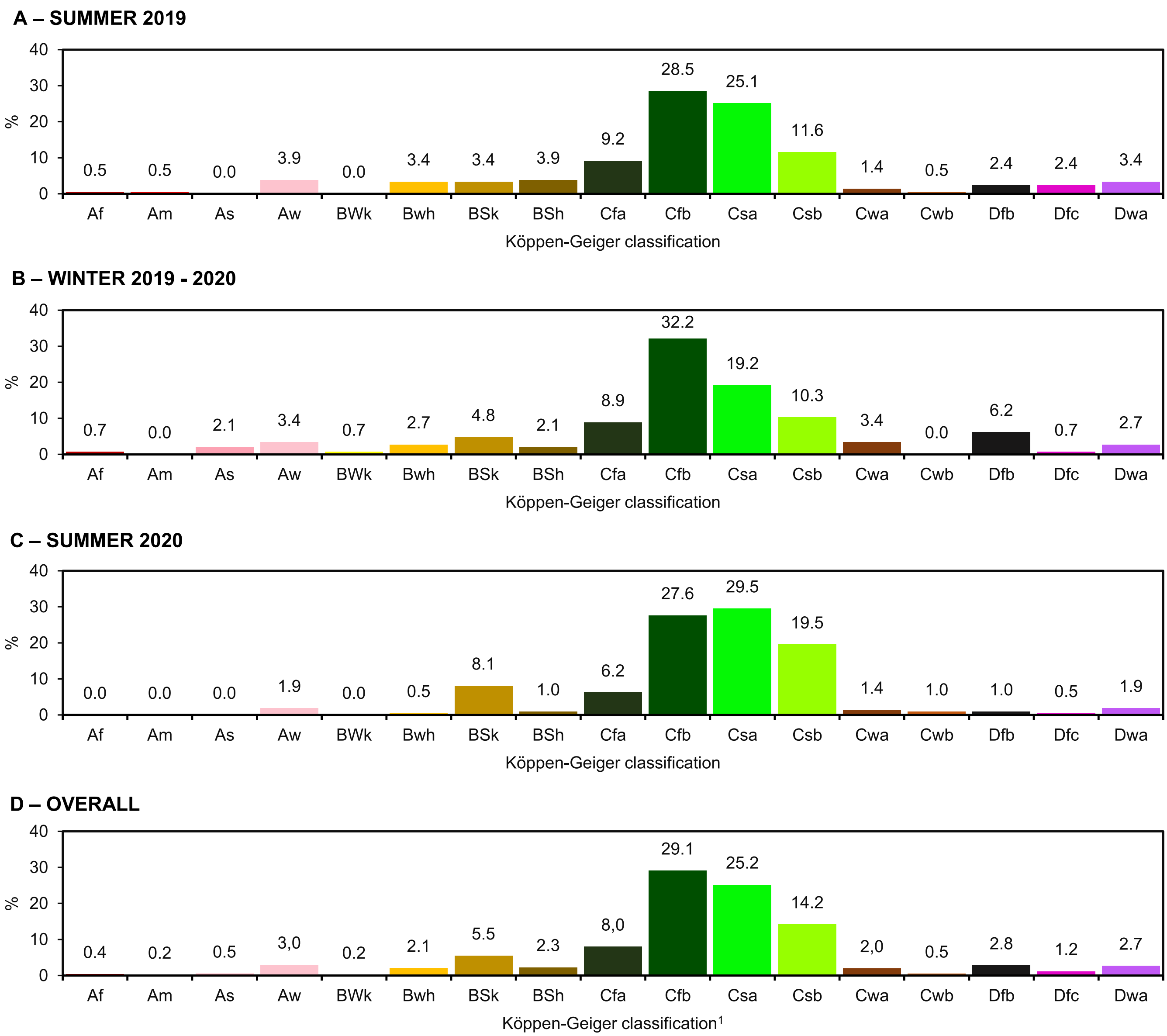
A – SUMMER 2019
%
0.5 0.5 0.0 3.9 0.0 3.4 3.4 3.9 9.2 28.5 25.1 11.6 1.4 0.5 2.4 2.4 3.4
Af Am As Aw BWk Bwh BSk BSh Cfa Cfb Csa Csb Cwa Cwb Dfb Dfc Dwa
Köppen-Geiger classification
B – WINTER 2019 - 2020
%
0.7 0.0 2.1 3.4 0.7 2.7 4.8 2.1 8.9 32.2 19.2 10.3 3.4 0.0 6.2 0.7 2.7
Af Am As Aw BWk Bwh BSk BSh Cfa Cfb Csa Csb Cwa Cwb Dfb Dfc Dwa
Köppen-Geiger classification
C – SUMMER 2020
%
0.0 0.0 0.0 1.9 0.0 0.5 8.1 1.0 6.2 27.6 29.5 19.5 1.4 1.0 1.0 0.5 1.9
Af Am As Aw BWk Bwh BSk BSh Cfa Cfb Csa Csb Cwa Cwb Dfb Dfc Dwa
Köppen-Geiger classification
D – OVERALL
%
0.4 0.2 0.5 3,0 0.2 2.1 5.5 2.3 8,0 29.1 25.2 14.2 2,0 0.5 2.8 1.2 2.7
Af Am As Aw BWk Bwh BSk BSh Cfa Cfb Csa Csb Cwa Cwb Dfb Dfc Dwa
Köppen-Geiger classification[1]

Fig. A.2.

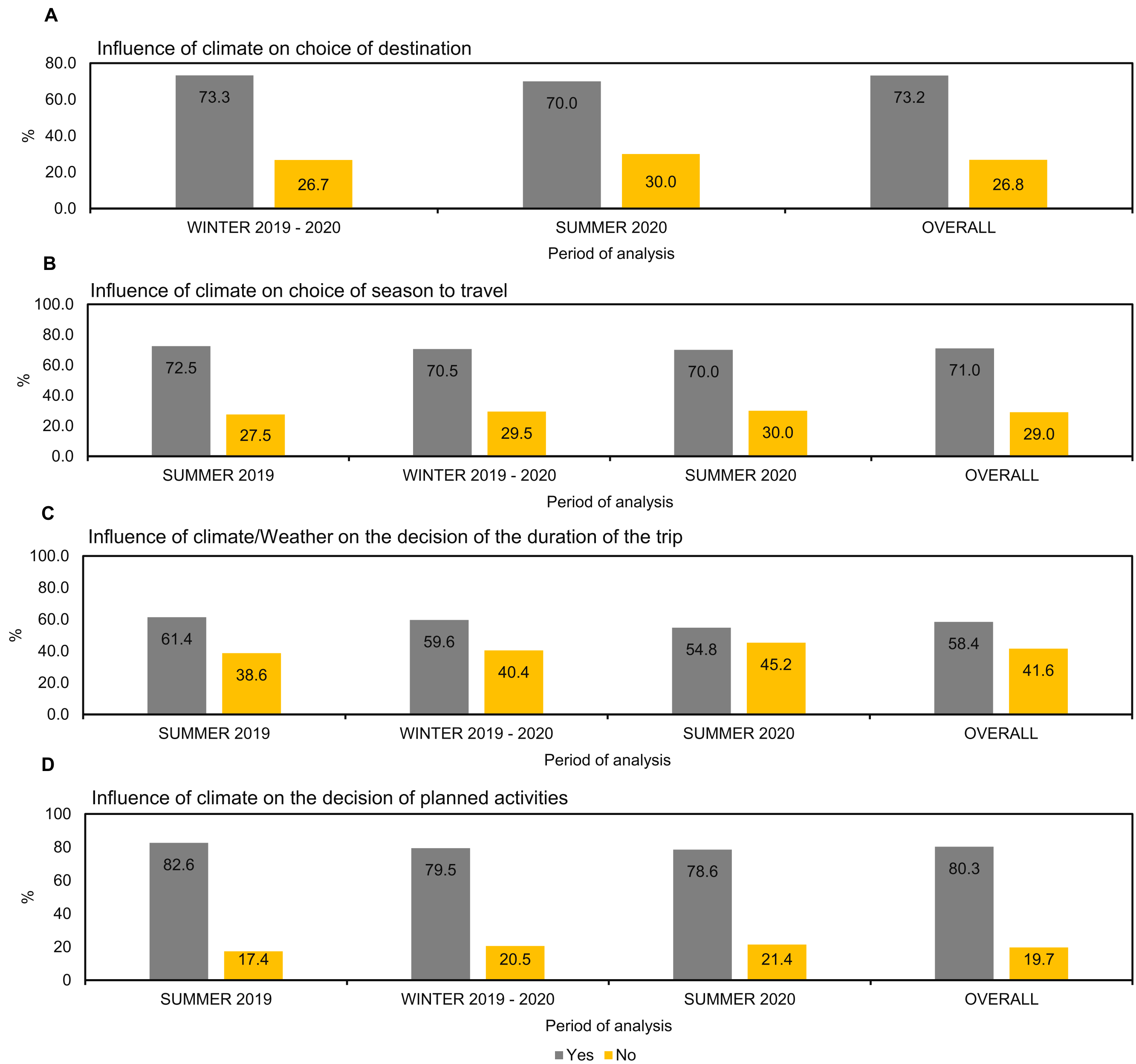

Fig. A.3.

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