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Soundscape experience of public spaces in different world regions: A comparison between the European and Chinese contexts via a large-scale on-site survey[a)]

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JASA ARTICLE

Soundscape experience of public spaces in different world regions: A comparison between the European and Chinese contexts via a large-scale on-site survey[a)]

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ABSTRACT:
The influence of cultural background on the soundscape experience in public spaces has been widely acknowledged. However, most studies have not used standardized protocols for soundscape perception data collection, nor have they gathered large datasets across different regions of the world to investigate possible cultural differences. This study explored the relationships between soundscape descriptors, perceived dominance of sound sources, and overall soundscape qualities and whether these relationships differ across world regions. A database of over 2000 soundscape surveys was collected *in situ* in outdoor public spaces in Europe and China. Results highlighted differences in how European and Chinese participants perceived the pleasantness and dominance of different sound sources. Specifically, the positive correlation between perceived pleasantness and natural sounds was stronger for European participants. For Chinese participants, vibrant soundscapes were positively correlated with perceived dominance of natural sounds, whereas in Europe, they were associated more with human-generated sounds. Perceived loudness had a greater effect on the appropriateness dimension for the Chinese sample than that for the European sample. This study provides a deeper understanding of how the geographical/cultural context can influence soundscape perception in public spaces and suggests that such country-specific factors should be considered when designing urban soundscapes.
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I. INTRODUCTION

In soundscape studies, the concept of "context" is of utmost importance.[1,2] Although it is generally understood to refer to the space where the soundscape experience is taking place (see the soundscape definition of "acoustic environment as perceived […] by people, in context."[3]), the ISO 12913-1:2014 standard and the soundscape research community at large tend to interpret it as a much broader concept that goes beyond the mere physical space to include social and relational constructs. Indeed, in Sec. 3.2 of the ISO document, context is defined as a notion that "includes the interrelationships between person and activity and place, in space and time" and can influence the soundscape interpretation through several factors such as "attitude to the sound source and to the producer of the sound, experience and expectations (including cultural background, intentions or reason for being at a place), as well as other sensory factors, like visual impression and odour."[3] Nevertheless, Tarlao and colleagues note that "the influence of context on soundscape is a broad and diverse question"[4] and research on contextual factors is scarce and relatively unstructured at the moment with new frameworks and models still emerging.[5,6]

The cultural background and geographical context of individuals and communities indeed appear to be key aspects in a soundscape investigation, those that we intuitively understand to have a potentially strong influence on how sound environments and events are interpreted by people. Yet, the ISO standard and subsequent technical specifications relating to data collection and analysis do not explicitly detail how to account for such differences.[7,8] Also, despite being generally acknowledged as an important topic by soundscape scholars around the world, the literature specifically addressing cross-cultural differences in soundscape assessments is, in fact, very limited.[9–11]

Yang and Kang[12] focused on the European context. In their soundscape study, 9200 interviews were conducted in 14 urban open public spaces in different European cities. The authors observed that while the subjective evaluation of the sound level generally related well with the mean, L_{eq}, such strong associations could not be determined instead between subjective evaluation of the sound level and the acoustic comfort assessment, suggesting that there may be other factors or dimensions that are not well captured by a generic "acoustic comfort" scale. Yu and Kang[13] looked at the possible effects of cultural factors on the individual

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assessment of the acoustic quality in residential areas, comparing case studies in Sheffield [United Kingdom (UK)] and Taipei (Taiwan). One clear example of the effect of cultural difference on sound perception from this study concerns sound source preference: insect sounds were more preferred in Taiwan compared to the UK, whereas church bells were more preferred in the UK compared to Taiwan. The semiotics and semantics of sound sources are certainly likely to play an important role in soundscape appreciation.[14,15] This is the point that has found some confirmation in the literature, for instance, Hermida and colleagues[16] stated that for the soundscape meaning formation of a place, the users' previous experiences, their activities, and the cultural and spatial aspects that influence the practices developed in the places should be considered. In a cross-national comparison (i.e., France, Korea, and Sweden) on the soundscape assessment of urban parks, Jeon and colleagues[17] showed that across countries, similarities in the assessment of pleasantness of soundscapes can be observed. However, sociocultural effects are found in the soundscape eventfulness scores as are difference in individual assessments of specific sound sources. Deng *et al.*[18] performed a cross-national comparison of soundscape assessment of public spaces between China and Croatia; their study found that the Chinese sample tended to give more importance to the eventfulness dimension as opposed to the Croatian sample, which gave more importance to the pleasantness dimension, and in terms of sound sources, natural sounds and children had mainly positive correlations to sonic and environmental satisfaction in China, whereas sounds of human activities had mainly negative correlations to sonic and environmental satisfaction in Croatia.

Overall, there is consensus that much of the soundscape experience outcome results from the semantic implications and cultural meanings that the listeners associate with being exposed to a specific sound source.[3] Axelsson and colleagues[19] have previously shown that with their participants' sample in Sweden, soundscape pleasantness was negatively correlated with technological sounds, such as traffic and industrial noise, but it was positively correlated with natural sounds such as birdsong or rustling leaves. Similarly, they observed a positive correlation between soundscape eventfulness and the presence of human sounds (e.g., voices, footsteps, etc.). This led them to theorize that introducing natural and human sounds while reducing technology sounds in any given acoustic environment may potentially enhance the quality of urban soundscapes. Such associations between sound sources and specific soundscape attributes/dimensions/descriptors[20] (e.g., calmness, vibrancy, etc.) have been confirmed by subsequent studies as well over the years,[6,21–23] although they have never been actually tested systematically across cultures and countries. Indeed, most studies thus far could not rely on both standardized (i.e., comparable) protocols for soundscape data collection and large datasets gathered on site in different regions of the world, which would allow for a deeper and more meaningful investigation of possible cultural differences across countries. There is an obvious and intrinsic complexity with "defining" let alone "measuring" the concept of "culture." It is certainly challenging (if not impossible) to capture the entirety of a culture, particularly in studies relying on "quantitative" protocols. Although a country where data are collected may not fully capture the cultural nuances of its respondents, it is often used as a practical proxy for studying cultural differences due to its association with shared language, history, and societal norms. In this study, the focus on global macro-areas (Europe and China) acknowledges that the data collected represent the soundscape perceptions and experiences of individuals within specific geographical regions, which may not perfectly align with any single cultural group.

The International Soundscape Database (ISD),[24] generated within the context of the Soundscape Indices (SSID) project,[25] represents an opportunity for the soundscape research community to compare soundscape assessments that were effectively collected with the same (translated) survey instrument and general protocol in different countries as it comprises soundscape responses sourced in different European and Chinese cities. Therefore, this study aims to address the following research questions:

- Do soundscape descriptors and perceived dominance of sound sources categories relate similarly across world regions?
- Does "pleasantness" as a single dimension capture the "overall soundscape quality" of a place, and is there any difference in this relationship across world regions?
- What are the relationships between the perceived loudness of a soundscape and its perceived overall quality and appropriateness across world regions?

II. METHODS

A. Data collection protocol

This study will look at individual responses to acoustic environments (i.e., soundscape assessments) gathered *in situ* at different locations around the world from general members of the public (adults), i.e., users of the public space. Data collection was performed in the context of the SSID project,[25] which generated the ISD.[24] Further details of the data collection protocol can be found in Mitchell *et al.*[26] Overall, the soundscape assessment section mainly refers to Method A of the ISO 12913 technical specifications, part 2,[7] which was, in turn, adapted as a protocol based on the eight soundscape descriptors proposed by Axelsson and colleagues:[19] pleasant, vibrant, eventful, chaotic, annoying, monotonous, uneventful, and calm. Furthermore, in this study, there are further questionnaire sections about perceived loudness of the acoustic environment, overall quality and appropriateness of the soundscape, and perceived dominance of some sound sources categories, namely, traffic noise (e.g., road traffic, railways noise, etc.), other sounds (e.g., sirens, loading of goods, etc.), sounds from human beings (e.g., chat, children playing, etc.), natural sound

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(e.g., birdsong, water feature, etc.). While no detailed instructions were given to participants about the interpretation of the idea of "dominance" of sound sources, it seems fair to assume that it may not necessarily be related to their "loudness" but rather to the duration of their (temporal) presence in the sound environment under consideration.[27] The items of the protocol with the corresponding scales are reported in Table I.

Part 3 of the ISO 12913 series on data analysis[8] then specifies how the separate eight scores of the perceptual attributes category (i.e., the soundscape descriptors[20]) should be converted into a set of *x*-*y* coordinates to pin any given soundscape assessment onto a pleasant-eventful circumplex space.[19] This is because while the eight perceptual attributes scales are presented separately to the interviewees for them to score, they are not unrelated and together describe a circumplex space with two orthogonal dimensions, pleasant-annoying and eventful-uneventful. Thus, a soundscape that is both pleasant and eventful is vibrant; both annoying and eventful is chaotic; both annoying and uneventful is monotonous; and both pleasant and uneventful is calm.[19] Mitchell and colleagues recently proposed a method[28] to next visualize the overall soundscape assessment of a location (rather than individual assessments or central tendencies for those) on the circumplex model, and an example is reported in Fig. 1, where all the assessments of a soundscape data collection session can be plotted and

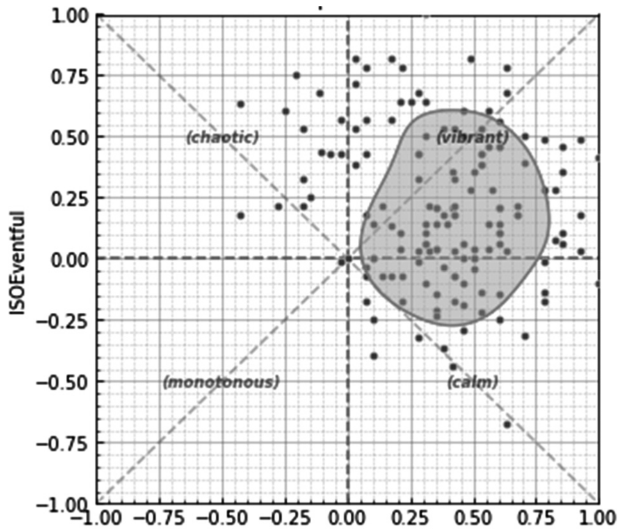

FIG. 1. Soundscape assessments gathered within the SSID project during a data collection session outside the Tate Modern Gallery in London (UK) in 2019; each dot represents the pleasant-eventful assessment of a single participant, and the contour line represents the 50th percentile of all the soundscape scores for the sample. The two dimensions of pleasantness and eventfulness define four quadrants of possible soundscape assessment: vibrant, chaotic, monotonous, and calm.

then statistical calculations can be applied. Such an approach is particularly helpful when looking at comparisons between different sets of soundscape assessments.[29]

TABLE I. Items of the SSID protocol for soundscape data collection on site considered for the current study; some scales are flipped/recoded to keep direction of attribute consistent.

Category	Question	Scale
Perceptual attributes	For each of the eight scales below, to what extent do you agree or disagree that the surrounding sound environment you just experienced was… • Pleasant; • vibrant; • eventful; • chaotic; • annoying; • monotonous; • uneventful; and • calm	Totally disagree (1)–totally agree (5)
Sound sources dominance	To what extent do you presently hear the following four types of sounds? • Traffic sounds; • other sounds; • sounds from human beings; and • natural sounds	Not at all (1)–dominates completely (5)
Overall soundscape quality	Overall, how would you describe the present surrounding sound environment?	Very bad (1)–very good (5)
Soundscape appropriateness	Overall, to what extent is the present surrounding sound environment appropriate to the present place?	Not at all (1)–perfectly (5)
Perceived loudness	How loud would you say the sound environment is?	Not at all (1)–extremely (5)

B. Selection of the soundscape sites

Specifically, data considered in this study were collected for Europe: in the UK (London, population, 9.0×10^6), in Italy (Venice, population, 261 900), in Spain (Granada, population, 232 200), in the Netherlands (Groningen, population, 200 300), and in China (Shenyang, population, 8.3×10^6; Shenzen, population, 12.6×10^6). From the perspective of the database and the Europe/China stratification, it was considered that in terms of territorial extension, it was reasonable to regard a specific country like China as a macro-area on a global scale, which is similar to how Europe is considered as another global region. When examining and presenting data, it is accepted to use "meaningful regional groupings" as a standard approach, which is also recommended in the United Nations (UN) guidelines.[30] These regional groupings should aim to "*capture real-world characteristics that are of particular interest for analysis.*"[31]

Table II reports a brief description of the locations selected for this study from the SSID database. The rationale for site selection was covering a rather broad range of public urban spaces where different sound sources (which would elicit a correspondingly broad range of soundscape assessments on the eight soundscape scales) could reasonably be expected. It is important to reiterate that the focus of the study lies on urban settings: extending the scope to consider comparisons between, for instance, "rural" China and rural Europe would likely pose significant challenges. The

TABLE II. The 26 locations included in the measurements campaign in Europe and China. The dominance of sound sources was assessed by the authors on site and via the recordings: the information is qualitative in nature and should be interpreted as merely descriptive of the site.

Location	Group	Description	Dominant sound source(s) in typical condition
Camden Town, London (UK)	Europe	Exit/entrance to the underground train station	Traffic noise and music
Euston Tap, London (UK)	Europe	Public transport interchange	Traffic noise
Marchmont Garden, London (UK)	Europe	Pocket park	No dominant sounds
St. Pancras Lock, London (UK)	Europe	Canal walk by a canal lock, mostly green	People talking, children at play, and a waterfall
Regent's Park Broadwalk, London (UK)	Europe	Walk in a large park	Birdsong and people talking
Regent's Park Japanese Garden, London (UK)	Europe	A garden within a large park	Waterfall
Russell Square, London (UK)	Europe	Square, mostly green	Fountain, people talking, traffic noise
St. Paul's Churchyard, London (UK)	Europe	Cathedral's churchyard	Traffic noise and people talking
St. Paul's Paternoster Row, London (UK)	Europe	Small, enclosed square, paved	Traffic noise and people talking
Tate Modern, London (UK)	Europe	Waterfront, mostly paved	People talking and music
Torrington Square, London (UK)	Europe	Square, paved	Traffic noise and people talking
Piazza San Marco, Venice (Italy)	Europe	Square, paved, waterfront	Live music, people talking, seagulls
Viale Giuseppe Garibaldi, Venice (Italy)	Europe	Park	People walking, birdsong
Plaza Mirador de San Nicolas, Granada (Spain)	Europe	Paved square on a hill, trees, view	Live music, people talking, birdsong
Plaza de Bib-Rambla, Granada (Spain)	Europe	Paved square, some trees	People talking, people walking, birdsong
Plaza Palacio de Carlos V, Granada (Spain)	Europe	Paved square, some trees	People talking, people walking, birdsong
Plaza Campo del Principe, Granada (Spain)	Europe	Two atriums	People talking, water fountain
Noorderplantsoen, Groningen (Netherlands)	Europe	Park	People walking, birdsong
Dadong Square, Shenyang (China)	China	Large paved square	Distant traffic
Zhongshan Park, Shenyang (China)	China	Paved square within a park	Distant music, distant talking
Olympic Square, Shenyang (China)	China	Waterfront, paved	Distant conversation
Zhongshan Square, Shenyang (China)	China	Large paved square	Traffic noise, people talking
Lianhuashan Park's Entrance, Shenzen (China)	China	Forest park	Amplified music, people talking
Lianhuashan Park, Shenzen (China)	China	Forest park	Amplified music, people talking, birdsong
Pingshan Street, Shenzen (China)	China	Street	People talking, domestic and workshop sounds
Pingshan Park, Shenzen (China)	China	Paved square, some trees	Traffic, people talking, amplified music

objective was not necessarily to find spaces in European and Chinese cities that share similar morphology, layout, or audio-visual features of the built environment. Instead, the emphasis was on identifying spaces that express similar functions and uses by people (e.g., a park that serves as a place of restoration, a bustling street or plaza for social activities, a commuting/transit area, etc.). By focusing on the "function" of the space, a wider range of sound sources profiles and compositions can be explored, resulting in a broader spectrum of scores obtained on the provided semantic scales from participants.[32,33] Yet, other physical elements of an urban public space, such as its morphology and geometrical configuration, also modulate its acoustic environment and, consequently, may potentially lead to different soundscape experiences,[34–36] such that these aspects should also be carefully considered.

While the protocol mentioned in Sec. II A is now relatively well established in the soundscape scientific community, collecting data in different countries and languages poses its own challenges when it comes to accurately translating the soundscape descriptors for use in non-English speaking contexts. This is an issue that deserves careful consideration from scholars and practitioners and is indeed attracting attention in recent research projects.[37–41] For this study, in each country, the local language was used to present the questionnaire to participants, using translations of the protocol as reported in Aletta *et al.*[37]

C. Participants

Basic demographic data were sought from all participants, although providing the information was not mandatory to take part in the study. In the European sample (i.e., UK, Spain, Italy, and Netherlands combined), there were 2325 respondents, 53.9% female, 46.1% male, $M_{age} = 34.3$ years old, $SD_{age} = 15.5$ years old; in the Chinese sample, there were 1955 respondents, 48.5% female, 51.5% male, $M_{age} = 40.3$ years old, $SD_{age} = 17.1$ years old. The breakdown of the total database by language is English (ISO 639:eng), 45.7%; Dutch (ISO 639:nld), 2.1%; Spanish (ISO 639:spa), 5.7%; Italian (ISO 639:ita), 1.6%; and Mandarin Chinese (ISO 639:cmn), 44.9%. Occasionally, the survey may have been offered to a participant in one of the selected languages that did not match the "local" national language of the site (e.g., a native Spanish-speaking resident in the UK preferring to fill the questionnaire in Spanish rather than English), but these deviations were typically below the 2% of the sample across sites.

III. RESULTS

When comparing the European and Chinese datasets, visual inspection of the distributions of the individual scores assigned by participants to the scales revealed substantially similar trends across all the items of the questionnaire (these are available in the Appendix), such that it was reasonable to exclude significant effects of sampling bias between the two world regions. Although the technical specifications in part 3 of the ISO 12913 recommend a trigonometric transformation of the median of the eight scores of the soundscape attributes into two coordinates (i.e., ISO pleasant and ISO eventful),[8] in the context of this study, it was decided to work with untransformed data. The main reason for this is that the local language versions of the protocol are yet to be fully validated, therefore, applying the ISO part 3 transformations may result in essentially different soundscape circumplex spaces and comparing those directly may be misleading. To illustrate this issue, a principal component analysis (PCA) was conducted on the European and Chinese datasets, and the results can be found in the Appendix. The European PCA yielded two primary components, which closely align with the existing literature, namely, pleasant-annoying and eventful-uneventful, with the secondary axes located approximately as expected for the soundscape circumplex. However, in contrast, the Chinese results do not clearly exhibit eventful-uneventful on the second axis, and the angular relationships between the attributes deviate significantly from the ideal circumplex. These findings suggest that the strict projection from the ISO cannot be currently applied to data from the Chinese translation. Thus, for all subsequent levels of analysis, it was decided to work directly on the five-point Likert scale values.

When looking at associations between items of the protocol, a Bonferroni correction has been applied to account for possible family-wise type I errors which may occur in case of multiple comparisons. The most conservative scenario of $m = 8$ hypothesis with a target $\alpha = 0.05$ is taken as a baseline and it requires the Bonferroni correction to test each hypothesis at $\alpha = 0.05/8 = 0.00625$ significance level.

A. Relationships between soundscape descriptors and sound sources across world regions

The first question to address was whether different soundscape dimensions and the perceived dominance of sound sources categories would relate similarly in the European and Chinese samples. For this purpose, a set of Mantel-Haenszel tests of trend was run to determine if linear associations existed between the scores of the single soundscape descriptors (i.e., pleasant, calm, uneventful, monotonous, annoying, chaotic, eventful, and vibrant) and the scores of perceived dominance of the sound sources categories (i.e., traffic sounds, other sounds, human sounds, natural sounds): both sets of variables were scored from one to five with the verbal modifiers of the Likert scales ranging from "totally disagree" to "totally agree" for the former and from "not at all" to "dominates completely" for the latter. These tests were run separately for the European and Chinese datasets.

Table III reports all the abovementioned sound source/soundscape descriptor combinations and shows if the Mantel-Haenszel tests of trend revealed a statistically significant linear association between the items of the questionnaire, comparing China and Europe. A few general patterns can be identified, both within and between the Chinese and European samples, and to support the visualization of such trends, Figs. 2–5 also depict some of the investigated associations as examples.

Soundscape pleasantness was positively associated with the perceived dominance of natural sounds, but the correlation was much stronger for the European sample than the Chinese sample. Traffic sounds and other sounds, on the other hand, are negatively associated with pleasantness, but also in this case, the effect is much stronger for the European rather than the Chinese sample. Interestingly, human sounds did not appear to be correlated with soundscape pleasantness. Indeed, the interpolation lines in Fig. 2 show that for European participants, the soundscape pleasantness quickly decreases with increasing perceived traffic sounds while the trend stays much more uniform for the Chinese participants; likewise for increasing perceived dominance of Natural sounds, there is a quick increase in pleasantness for European participants but a relatively stable trend for Chinese participants. Annoying being the opposite soundscape descriptor to pleasant, as per the soundscape circumplex model,[19] it was reasonable to expect an essentially symmetric pattern for the associations just described, as it can be observed in Table III and Fig. 3; also in this case, it is interesting to notice that human sounds do not correlate with annoyance in either region.

The associations of sound sources dominance with perceived soundscape calmness follow a somewhat similar pattern as per the pleasantness dimension (see Fig. 4); however, for the Chinese sample, no statistically significant association ($p > 0.05$) was observed between calmness and perceived dominance of traffic sounds. On a different note, human sounds dominance is negatively correlated with calmness for the European and Chinese samples.

On the soundscape attribute "vibrant," the European and Chinese samples revealed slightly divergent trends (see Table III and Fig. 5). For European participants, increasingly vibrant soundscapes were positively correlated with perceived dominance of human sounds and no statistically significant correlations with traffic sounds, natural sounds, and other sounds; while for Chinese participants, increasingly vibrant soundscapes where positively correlated with perceived dominance of natural sounds and negatively correlated with perceived dominance of traffic and other sounds (and no correlation with human sounds). Hence, it seems possible for the Chinese sample to experience vibrancy in a more natural sound environment rather than one characterized by human presence as per the European sample.

For the attribute chaotic, both samples show an expected pattern with positive correlations with traffic, human, and other sounds, and negative correlations with natural sounds. Essentially, the same applies to the attribute monotonous but with negative correlations with perceived dominance of human sounds for the European sample and no associations of these two sound source types for the Chinese sample (see Table III). Thus, for the Chinese sample, conventionally "positive" sound sources do not seem to help in "reducing" monotonous scores for a soundscape.

TABLE III. Statistical significance of associations between soundscape descriptors and perceived sound sources dominance items; *. Correlation is significant at the 0.00625 level (two-tailed).

Mantel-Haenszel linear-by-linear association Chi-squared test				
Association	Region	$\chi^{2(1)}$	p	r
Traffic sounds * pleasant	Europe	342.124	<0.001	−0.450*
	China	39.470	<0.001	−0.143*
Other sounds * pleasant	Europe	268.298	<0.001	−0.398*
	China	51.013	<0.001	−0.163*
Human sounds * pleasant	Europe	3.650	0.056	−0.046
	China	2.461	0.117	−0.036
Natural sounds * pleasant	Europe	344.514	<0.001	0.451*
	China	12.583	<0.001	0.081*
Traffic sounds * annoying	Europe	261.914	<0.001	0.395*
	China	7.796	0.005	0.064*
Other sounds * annoying	Europe	237.841	<0.001	0.376*
	China	30.335	<0.001	0.126*
Human sounds * annoying	Europe	0.483	0.487	0.017
	China	7.075	0.008	0.061
Natural sounds * annoying	Europe	189.973	<0.001	−0.336*
	China	1.076	0.300	0.024
Traffic sounds * calm	Europe	248.025	<0.001	−0.384*
	China	0.047	0.829	−0.005
Other sounds * calm	Europe	189.614	<0.001	−0.335*
	China	13.137	<0.001	−0.083*
Human sounds * calm	Europe	44.992	<0.001	−0.163*
	China	31.675	<0.001	−0.128*
Natural sounds * calm	Europe	298.049	<0.001	0.420*
	China	17.715	<0.001	0.096*
Traffic sounds * vibrant	Europe	5.473	0.019	0.057
	China	20.035	<0.001	−0.102*
Other sounds * vibrant	Europe	0.002	0.962	−0.001
	China	18.601	<0.001	−0.098*
Human sounds * vibrant	Europe	27.855	<0.001	0.129*
	China	3.446	0.063	0.042
Natural sounds * vibrant	Europe	1.696	0.193	0.032
	China	11.355	<0.001	0.077*
Traffic sounds * chaotic	Europe	257.398	<0.001	0.391*
	China	8.412	0.004	0.066*
Other sounds * chaotic	Europe	217.656	<0.001	0.359*
	China	23.410	<0.001	0.110*
Human sounds * chaotic	Europe	39.277	<0.001	0.153*
	China	12.824	<0.001	0.082*
Natural sounds * chaotic	Europe	180.784	<0.001	−0.327*
	China	2.622	0.105	−0.037
Traffic sounds * monotonous	Europe	31.099	<0.001	0.136*
	China	50.780	<0.001	0.163*
Other sounds * monotonous	Europe	44.553	<0.001	0.163*
	China	27.957	<0.001	0.121*
Human sounds * monotonous	Europe	11.538	<0.001	−0.083*
	China	2.716	0.099	−0.038
Natural sounds * monotonous	Europe	21.913	<0.001	−0.114*
	China	5.531	0.019	−0.054
Traffic sounds * eventful	Europe	0.702	0.402	0.020
	China	1.441	0.230	−0.027
Other sounds * eventful	Europe	0.815	0.367	0.022
	China	0.074	0.786	−0.006
Human sounds * eventful	Europe	43.786	<0.001	0.161*
	China	4.739	0.029	0.050
Natural sounds * eventful	Europe	2.619	0.106	−0.039
	China	3.790	0.052	0.044

TABLE III. (*Continued*)

Mantel-Haenszel linear-by-linear association Chi-squared test				
Association	Region	$\chi^{2(1)}$	p	r
Traffic sounds * uneventful	Europe	2.775	0.096	−0.041
	China	0.045	0.833	0.005
Other sounds * uneventful	Europe	1.627	0.202	0.031
	China	8.137	0.004	0.065*
Human sounds * uneventful	Europe	40.795	<0.001	−00.156*
	China	1.126	0.289	−0.024
Natural sounds * uneventful	Europe	0.347	0.556	0.014
	China	1.411	0.235	0.027

The rest of the associations between sound sources dominance and the attributes eventful and uneventful are mainly non-statistically significant, but an interesting exception is a positive correlation for the European sample of the attribute eventful with the perceived dominance of human sounds (and the "symmetrical" negative correlation with the attribute uneventful), which is not observed for the Chinese sample. Therefore, having in mid the pleasant-eventful space, for the European sample, the perceived dominance of human sounds seems to discriminate soundscapes along the vertical eventfulness dimension but not its orthogonal pleasantness dimension, whereas the Chinese sample is mostly indifferent to human sounds.

B. Relationships between overall soundscape quality and soundscape pleasantness across world regions

To address the second research question, a further set of Mantel-Haenszel tests of trend was run to determine if linear associations existed between scores of the overall soundscape quality item (see Table I) and the soundscape descriptors pleasant and annoying, with the rationale for testing the latter being that pleasant and annoying are opposite attributes on the soundscape circumplex model, thus, the associations may be stronger or weaker depending on the "direction" from which the relationship is viewed. Again, tests were run separately for the European and Chinese datasets. Overall soundscape quality was positively correlated with soundscape pleasantness for the European and Chinese samples with small variations in terms of strength of the association, as shown in Table IV. An essentially symmetrical trend applies for the correlation between overall soundscape quality and soundscape annoyance, as visible also in Fig. 6, with the strengths of the associations for these pairs of items (Europe and China) being slightly weaker than the former ones (see Table IV).

C. Relationships between perceived loudness, overall soundscape quality, and soundscape appropriateness across world regions

For the third research question, a final set of Mantel-Haenszel tests was performed to explore linear associations

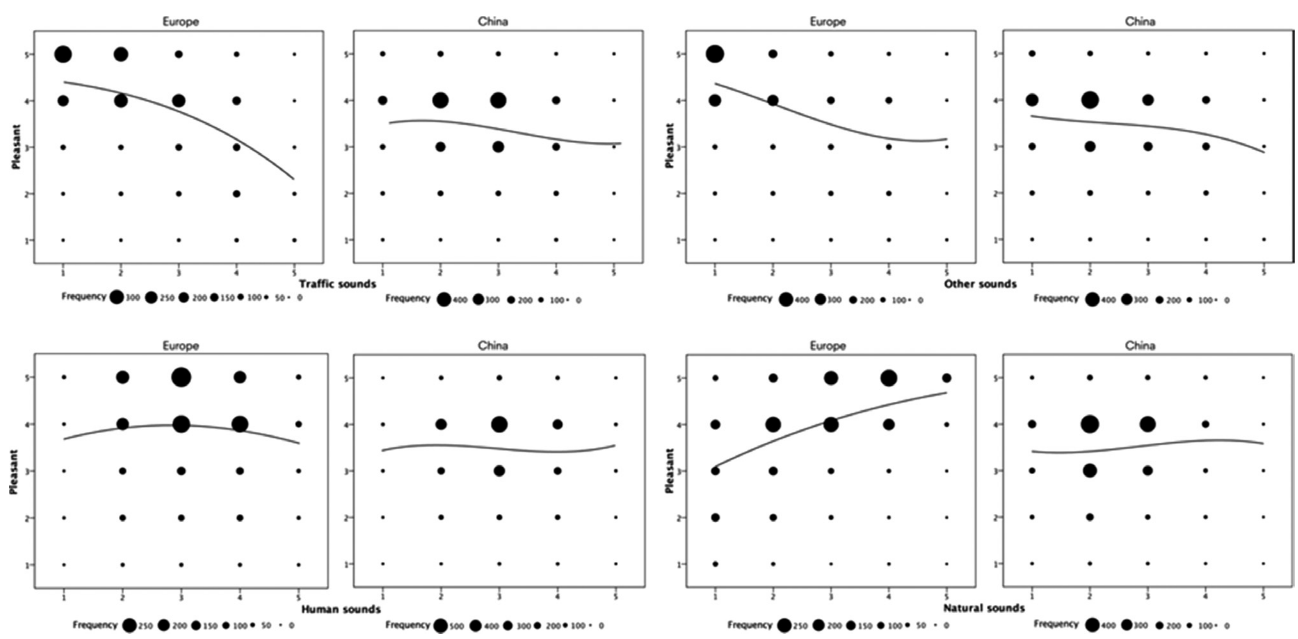

FIG. 2. Scatterplots of pleasantness scores as a function of perceived sound sources dominance (with regression line) for the European and Chinese samples (traffic sounds, top left; other sounds, top right; human sounds, bottom left; and natural sounds, bottom right).

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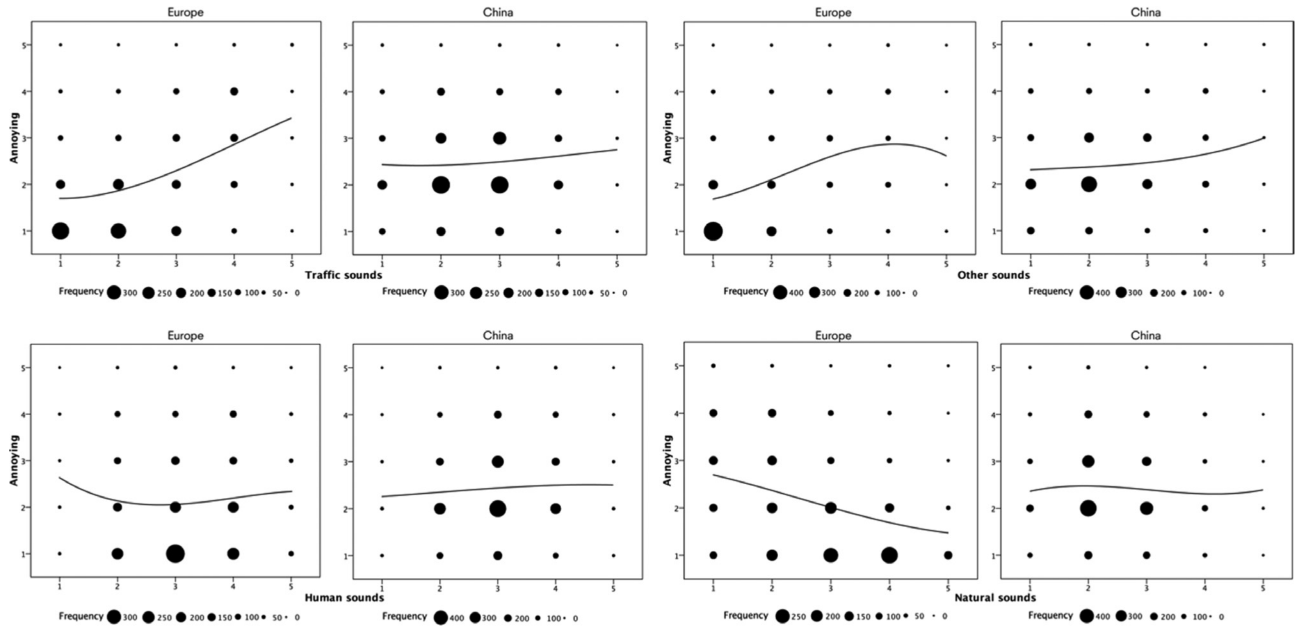

FIG. 3. Scatterplots of annoyance scores as a function of perceived sound sources dominance (with regression line) for the European and Chinese samples (traffic sounds, top left; other sounds, top right; human sounds, bottom left; and natural sounds, bottom right).

between the scores of perceived loudness (see Table I) and the items related to a general assessment/appreciation of a soundscape—i.e., overall soundscape quality and soundscape appropriateness. For the European and Chinese samples, there were statistically significant negative correlations between perceived loudness and overall soundscape quality and soundscape appropriateness (see Table V); however, for soundscape appropriateness, the correlation was much weaker for the European sample than for the Chinese sample, which can also be observed in Fig. 7, where soundscape appropriateness is decreasing with increasing perceived loudness, much more quickly for China than for Europe.

IV. DISCUSSION

Following the approach adopted for data analysis in this study, it is worth highlighting a few points about its theoretical assumptions. Considering the overall pleasantness-eventfulness soundscape model as proposed by Axelsson and colleagues[19] and adapted from Russell's circumplex

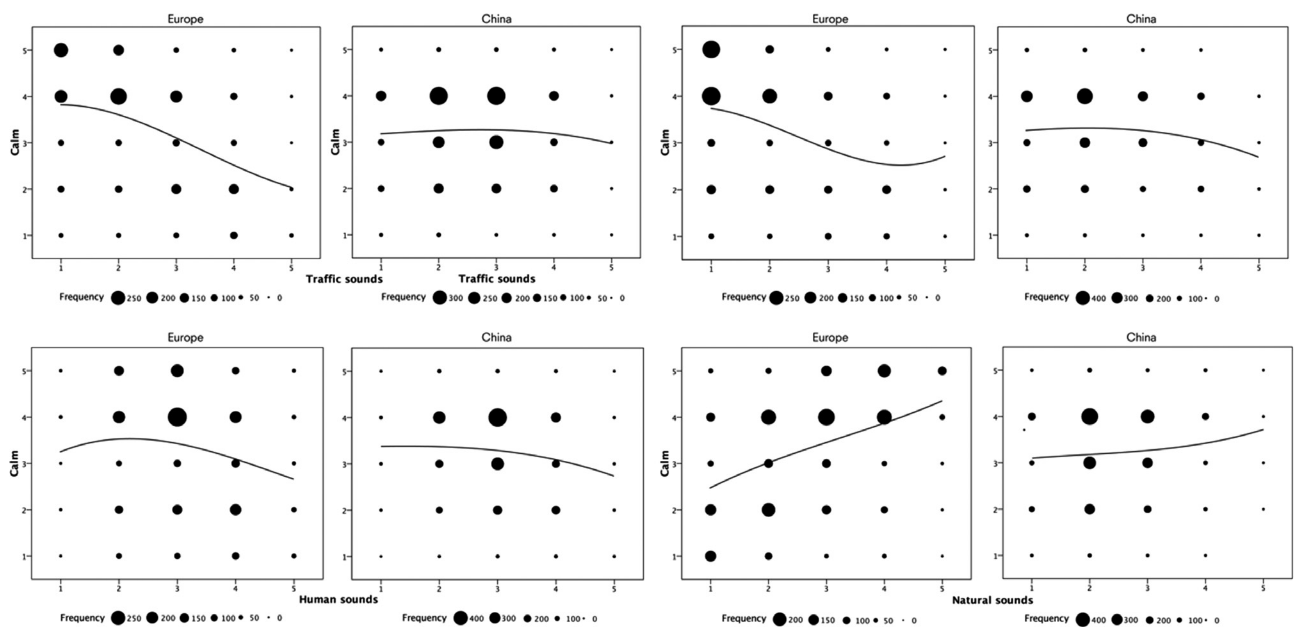

FIG. 4. Scatterplots of calmness scores as a function of perceived sound sources dominance (with regression line) for the European and Chinese samples (traffic sounds, top left; other sounds, top right; human sounds, bottom left; and natural sounds, bottom right).

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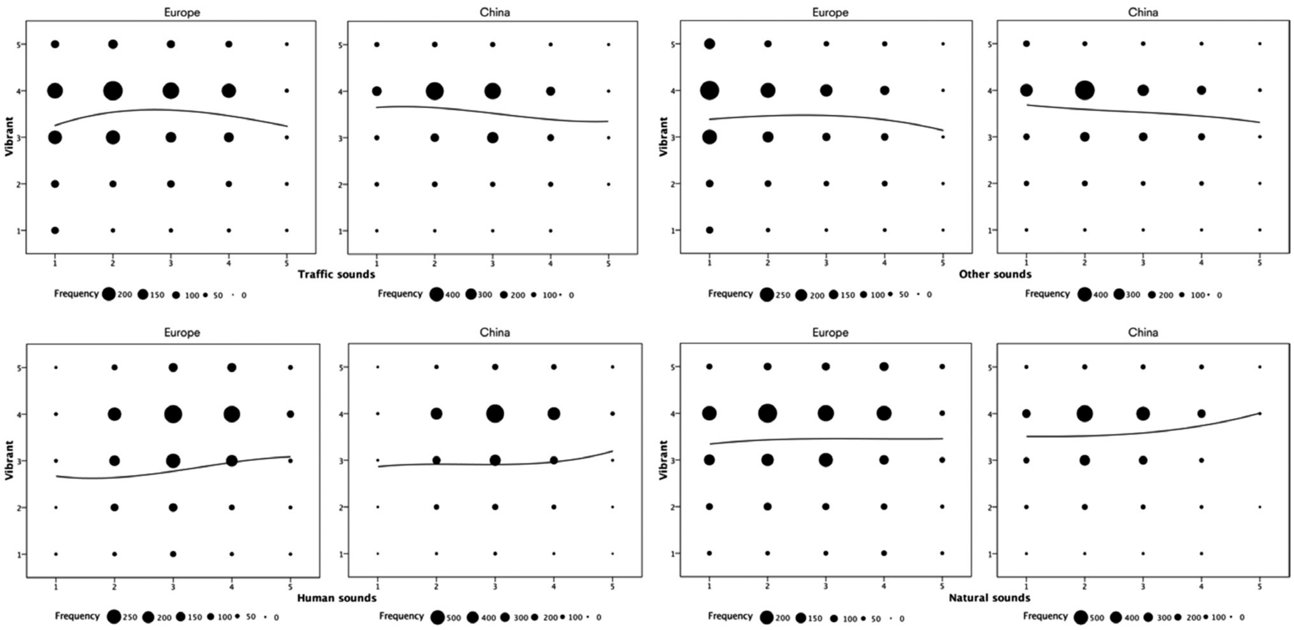

FIG. 5. Scatterplots of vibrancy scores as a function of perceived sound sources dominance (with regression line) for the European and Chinese samples (traffic sounds, top left; other sounds, top right; human sounds, bottom left; and natural sounds, bottom right).

model of affect,[42] it is fair to assume that there is a difference between its "conceptual" space and "mathematical" space. The conceptual space is underpinned by the "circularity" assumption, i.e., a spatial model in which the eight soundscape dimensions are arranged in a circular fashion, in the following order: pleasant, vibrant, eventful, chaotic, annoying, monotonous, uneventful, and calm (see Browne[43] for the mathematical distinctions between circumplex, quasi-circumplex, and circular factors). Following from Russell, this theory holds that valence and arousal as the principal components of affective emotion explain the highest degrees of variance in people's perception. It is this *general* relationship in the theory that defines conceptual space. Although Russell (and subsequently Axelsson) did claim strict correspondences between affective dimensions and angles on the circumplex, such structure has never been properly confirmed in statistical terms for the soundscape circumplex specifically.[43,44] On the other hand, the trigonometric transformations imposed by the ISO/TS 12913-3:2019 formulas to reduce the eight individual scores to a pair of Pleasant-Eventful coordinates define a very "rigid" mathematical space, where it is essential that the soundscape dimensions strictly retain their mutual positions and relative angles for the model to be valid.

The statistical approach adopted in this study does not deny the circumplex theoretical basis, but the use of projection specified in the ISO/TS 12913-3:2019 would require that the attribute translations closely match the relative angles between the (English) soundscape attributes. Nothing suggests that the translations of the *individual* soundscape attributes in languages other than English are wrong (i.e., pleasant and the Mandarin translation of pleasant are equivalent), and indeed this study builds on the work currently being performed within the Soundscape Attributes Translation Project (SATP) to address this issue by using the "best possible" translations.[37] However, there is not enough evidence that different languages express the mathematical relationships among the attributes (i.e., the angles) in the same way, therefore, the mathematical space cannot really be confirmed for now. Hence, the strategy of analysing associations/correlations on an attribute-by-attribute basis is possibly a sensible compromise to work on the available dataset as it does not invalidate the conceptual space and investigates the perceptions on equivalent attributes individually and, to some extent, it avoids "potentially invalidating" the mathematical space.

TABLE IV. Statistical significance of associations between overall soundscape quality and the soundscape descriptors pleasant and annoying; *. Correlation is significant at the 0.00625 level (two-tailed).

Mantel-Haenszel linear-by-linear association Chi-squared test				
Association	Region	$\chi^{2(1)}$	p	r
Overall soundscape quality * pleasant	Europe	600.101	<0.001	0.595*
	China	551.246	<0.001	0.472*
Overall soundscape quality * annoying	Europe	396.520	<0.001	−0.486*
	China	201.494	<0.001	−0.324*

A. Sound sources affecting the soundscapes assessments between world regions

The results show that there is a difference in the way that European and Chinese participants assess soundscape pleasantness. The correlation between pleasantness (and calmness) and the perceived dominance of natural sounds is stronger for European participants than for Chinese participants. Additionally, the negative association between

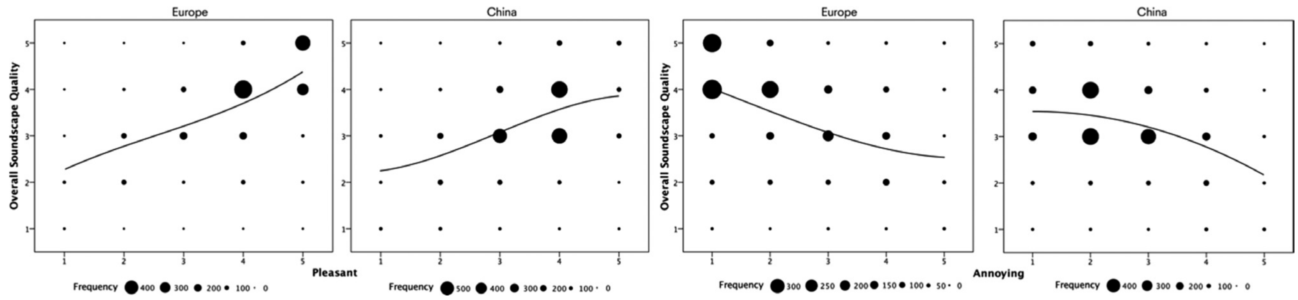

FIG. 6. Scatterplots of overall soundscape quality as a function of (left) perceived pleasantness and (right) annoyance (with regression line) for the European and Chinese samples.

pleasantness and traffic sounds is also stronger for European participants. European and Chinese cultures may have different values and beliefs about what constitutes a pleasant soundscape, and these cultural differences may influence how people perceive sounds in their environments.[12,13] Being exposed to different types of environmental sounds during daily life possibly affects how different populations experience soundscapes (e.g., Chinese participants may be more accustomed to and, therefore, less sensitive to traffic sounds than European participants). This is also connected to situational factors, such as sampling in populations living in different levels of urbanization and different access and exposure to natural acoustic environments (e.g., in urban parks).[45] It is worth noting that all such hypotheses are not mutually exclusive and there might be interactions at play and/or other factors that could influence the results.[46]

The concept of vibrancy is receiving increasing attention in urban soundscape studies.[47–50] It has been previously reported that vibrant soundscapes tend to be associated with the presence of human sounds (e.g., footsteps, laughter, music, and activity);[6,21] however, results from this study suggest that this may have been merely a European understanding of the concept, whereas for the Chinese context, vibrant soundscapes seem to relate more generally to acoustic environments with an overall perceived richness and diversity of sounds and, as such, potentially applicable to urban and natural spaces. These kinds of discrepancies and ambiguities about the meaning of vibrancy were somehow also reflected in the translation process of the term, where several iterations were needed between the UK-based and China-based working groups originally developing the protocol to find consensus.[37]

TABLE V. Statistical significance of associations between perceived loudness, overall soundscape quality, and soundscape appropriateness; *. Correlation is significant at the 0.00625 level (two-tailed).

Mantel-Haenszel linear-by-linear association Chi-squared test				
Association	Region	$\chi2(1)$	p	r
Perceived Loudness * overall soundscape quality	Europe	202.717	<0.001	−0.346*
	China	199.597	<0.001	−0.322*
Perceived Loudness * soundscape appropriateness	Europe	20.265	<0.001	−0.109*
	China	485.798	<0.001	−0.342*

A general consideration is that for the Chinese sample, the correlations between perceived dominance of sound sources and soundscape attributes were always less extreme—i.e., the Chinese sample seems to be more indifferent to semantic content of sound sources when it comes to assessing soundscapes dimensions. In more speculative terms, it may also indicate that Chinese participants are less likely to be influenced by the specific sounds that compose a sound environment and more likely to focus on the overall experience of the soundscape—i.e., they listen more "holistically."[51,52]

In this sense, Fig. 8 provides a summary schematic representation of all the associations discussed above and previously presented in Table III, plotted on an adapted version of the soundscape circumplex model, to map the relationships between soundscape descriptors and sound sources for the European and Chinese samples.

B. Pleasantness driving the overall soundscape experience of a place

Results showed that in the Chinese and European contexts, the valence-related dimension of the soundscape circumplex model (i.e., the annoying-pleasant horizontal axis) was the underlying construct that the participants had been using to form their own assessment of the overall soundscape experience of a given public space. This is somewhat in contrast with earlier findings in the literature,[17,18] where it had been suggested that significant differences existed in soundscapes pleasantness appreciation between Western and Eastern cultures within the soundscape framework. However, previous studies were more limited in terms of samples sizes and distributions, hence, it could be argued that with increased coverage of possible soundscapes in the bidimensional pleasant-eventful space, such differences in soundscape valence tend to decrease and assessments converge. Furthermore, there is still an ongoing debate about what the overall soundscape quality item, as currently phrased in the ISO protocol, is actually capturing when presented to layperson participants ("Overall, how would you describe the present surrounding sound environment?"); it has been previously argued that by focusing on the "overall" element of the question, participants may be more inclined to bring in more non-acoustic aspects (e.g., preconception, expectations, visual context, etc.) into the soundscape assessment task, making the item, again, strongly dependent

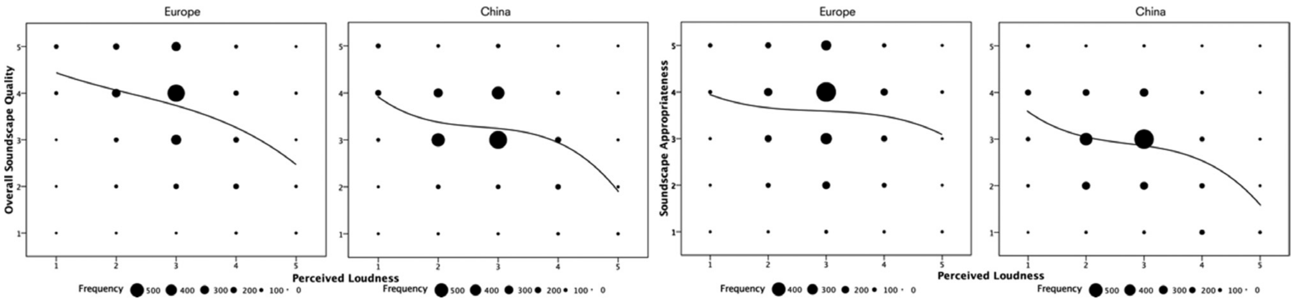

FIG. 7. Scatterplots of overall soundscape quality (left) and soundscape appropriateness (right) as a function of perceived loudness (with regression line) for the European and Chinese samples.

on the context where the survey is conducted.[20] Further disentangling this relationship in future studies would also be relevant from a practical perspective as this poses the question about whether shortened/simplified soundscape data collection protocols may be implemented when there are limited resources and/or other constraints on surveying members of the public using the full list of attributes of the ISO/TS 12913-2:2018. However, evaluating any part of the environment, including its soundscape, in isolation is not feasible. Humans inherently integrate various factors, including preconceptions, expectations, and visual context, into their judgments whether consciously or unconsciously. Previous studies on urban spaces show that isolating a specific sensory aspect, such as visual elements or density/densification, may lead to assessment issues in other domains.[53,54]

C. Associations between loudness and overall soundscape quality descriptors

Generally, the perceived loudness of the acoustic environments was still an important factor of the overall soundscape quality and appropriateness assessment. Interestingly,

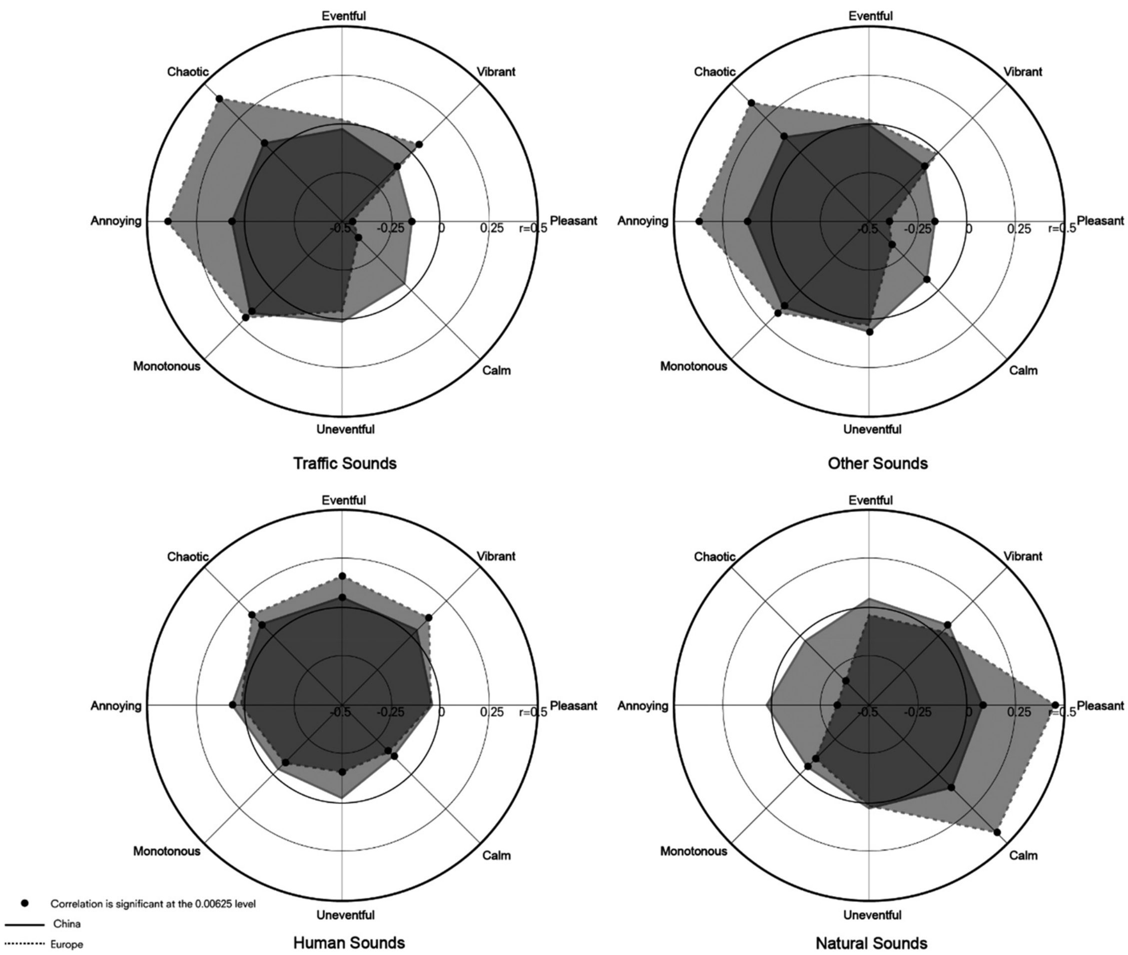

FIG. 8. Radar plots of statistical significance of associations between soundscape descriptors and perceived sound sources dominance item for the four ISO 12913 sound sources categories for Europe and China. The radial axis represents the Pearson correlation coefficients as presented in Table III ($-0.5 < r < 0.5$).

it was less so for the Chinese sample and its correlations between loudness and appropriateness, which were weaker than those for the European sample. That is, the Chinese sample was less tolerant toward louder acoustic environments and considered them to be less appropriate. Whereas cultural difference may certainly play a role in this context, other person-related factors may be affecting this outcome, such as demographic factors[55] (as in Erfanian *et al.*[55]) or noise sensitivity aspects.[56,57]

D. Limitations

A general limitation is, of course, related to a potential sampling bias. One could argue that the deviations observed in soundscape ratings are simply due to objective physical differences in the acoustic environments at the different locations where soundscape perceptions data were surveyed. A similar potential sampling bias certainly goes beyond the simple site/location scale and applies equally to a higher scale of city/region/country. On this note, it is worth highlighting that this study does not claim to establish causal relationships between specific acoustic parameters and soundscape assessments and test them between countries—it rather suggests that when large enough samples or participants are surveyed and diverse enough urban locations that are representative of a community/society are included, there are still some residual differences that are likely to be ascribable to cultural meanings associated with sound sources and how these form different soundscape dimensions.

In terms of further limitations, the translations aspects (especially for the eight soundscape descriptors of the circumplex model) are still an issue and potential source of uncertainty. Some differences may be accounted for by translation-related issues rather than actual cultural differences. However, based on concurring work going on within the SATP, every effort was made in this study to use the best possible translation of the soundscape descriptors in the local languages (English, Spanish, Italian, Dutch, and Chinese) and contain this potentially confounding factor.[37]

Despite efforts made in translation, there is a possibility that some perceptual aspects that contribute to the formation of one's soundscape experience may have been overlooked or inadequately represented in the questionnaire, as the closed-questions configuration of ISO's Method A itself limits the opportunities for respondents to fully express their thoughts and feelings. Indeed, one of the core principles of soundscape research is the "triangulation" of different methodologies (e.g., structured questionnaires and narrative interviews) to better capture the nuances of people's perception of sound environments.[58] Yet, in the context of this study, structured questionnaires and protocols such as those proposed in the ISO 12913 series are more likely to offer practical data comparability across different regions, facilitating quantitative analysis, and allow for meaningful cross-cultural comparisons. Furthermore, it may be argued that the evolutionary significance of soundscapes could be more fundamental than culture in addressing this environmental assessment as previously proposed in the literature.[59]

At participant's level, it is important to acknowledge that individual differences and person-related factors may influence how individuals experience and evaluate urban soundscapes.[48] Previous research has indeed highlighted that, among other factors, demographic variables and socioeconomic status can exert a statistically significant impact on soundscape perception; however, it is worth noting that the magnitude of these effects is often relatively small, potentially rendering them negligible in large-scale surveys or broader contexts.[55]

Regarding the statistical analysis of the associations, it should be noted that the Mantel-Haenszel test of trend cannot discriminate between independent and dependent variables;[60] furthermore, it is worth noticing that the Mantel-Haenszel test of trend assesses whether the linear component of the association between two ordinal variables is statistically significant and not that the association is linear *per se*,[60] therefore, it cannot be excluded that for some cases, a potentially stronger and statistically significant curvilinear association could exist.[61] However, in the context of this study, determining if soundscape descriptor assessments determine sound sources perceived dominance or vice versa is outside the scope as the main focus was on whether the associations would hold between the European and Chinese datasets. Furthermore, this specific test would require that the variables involved be intervally scaled; this is something that has already been discussed in soundscape literature[44] and remains an open question. Yet, with the focus on the Europe-China differences, it seems fair to assume that the verbal modifiers of the Likert scales can be straightforwardly translated without introducing further errors as it has been achieved for other socio-acoustic surveys in the past.[62]

V. CONCLUSIONS

Cross-cultural differences in soundscape assessment have historically been considered to be an important topic by the scientific community; however, attempts at investigating those have been limited and rely on relatively small samples of participants or range of locations. By looking at data sourced from diverse world regions, the present study aimed to offer some insights into potential culturally driven differences in how people react to individual dimensions of the soundscape circumplex model of affect by using standardized protocols for data collection across different countries and involving relatively large samples of participants in Europe and China. The main conclusions of this study are

- A positive correlation between soundscape pleasantness and perceived dominance of natural sounds was observed: this association was stronger for European participants ($r = 0.451$) than for Chinese participants ($r = 0.081$). On the other hand, the negative correlation between pleasantness and traffic sounds was also stronger for European participants ($r = -0.450$) compared with the Chinese sample ($r = -0.143$); the calmness construct followed a very similar pattern for both samples;

- soundscape vibrancy was positively correlated with perceived dominance human sounds ($r = 0.129$) for European participants; however, for Chinese participants, vibrant soundscapes were positively correlated with perceived dominance of natural sounds ($r = 0.077$) and negatively correlated with perceived dominance of traffic sounds ($r = -0.102$) and other sounds ($r = -0.098$);
- soundscape pleasantness is an important dimension in the formation of an overall soundscape experience assessment for the European ($r = 0.595$) and Chinese ($r = 0.472$) samples; and
- the perceived loudness of a sound environment does not considerably affect the perceived soundscape appropriateness for the European sample ($r = -0.109$), but it does for the Chinese sample ($r = -0.342$; i.e., the louder, the less appropriate in this case).

These findings reinforce the idea that different communities (and potentially cultures) across world regions have indeed different perceptions of what constitutes an acceptable or desirable soundscape and acoustic environment. Understanding these differences is crucial for developing effective soundscape management strategies and design interventions that consider the diverse needs and values of different communities and individuals, including aurally diverse people.[63] Additionally, it will also help to deepen our understanding of how different communities interact with and relate to their environment, which can have important implications for environmental conservation and sustainability.[64] Soundscapes are shaped by cultural norms, beliefs, and values—these, of course, are not "eternal" either and will changeover time and evolve as societies do. Acknowledging these differences is the first step toward creating more inclusive and supporting living environments.

ACKNOWLEDGMENTS

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AUTHOR DECLARATIONS

Conflict of Interest

The authors declare that they have no conflicts to disclose.

Ethics Approval

Ethical approval for the study was obtained via the low-risk research departmental route at UCL Bartlett School of Environment, Energy and Resources – Research Ethics Committee (UCL BSEER REC) (approval letter, 14 October 2019), and all participants approached on site at the different public spaces provided informed consent before taking part in the survey.

DATA AVAILABILITY

The data that support the findings of this study are openly available in Ref. 24. The ISD: An integrated multi-media database of urban soundscape surveys—questionnaires with acoustical and contextual information (0.2.2) [dataset], available at Zenodo (Ref. 65).

APPENDIX

Distributions of the scores for the questionnaire items across regions

Distributions for the European and Chinese sample groups are reported in Figs. 9–23 for the scores on the eight soundscape attributes, the overall soundscape quality, the overall soundscape appropriateness, the perceived dominance of sound source types, and the perceived loudness.

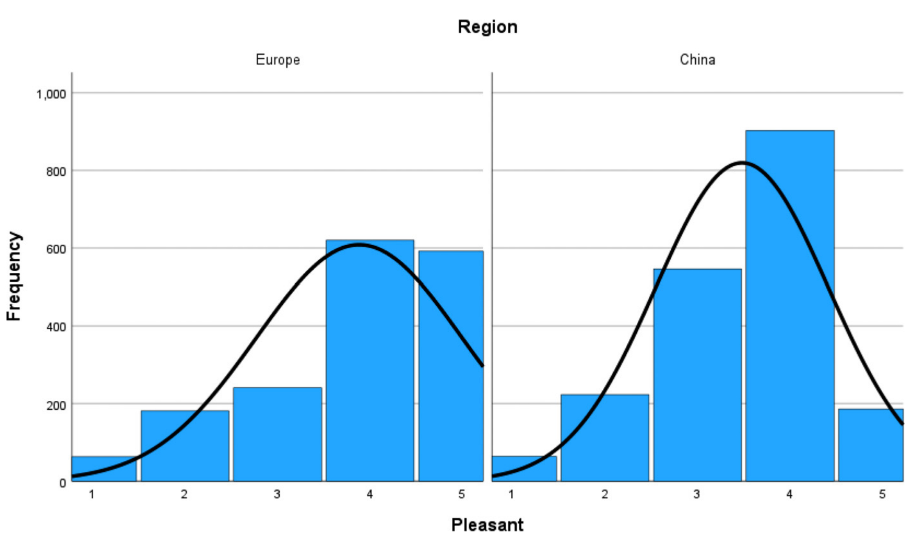

FIG. 9. (Color online) Distributions of the scores for the attribute pleasant, showing comparison between the European (left) and Chinese (right) samples.

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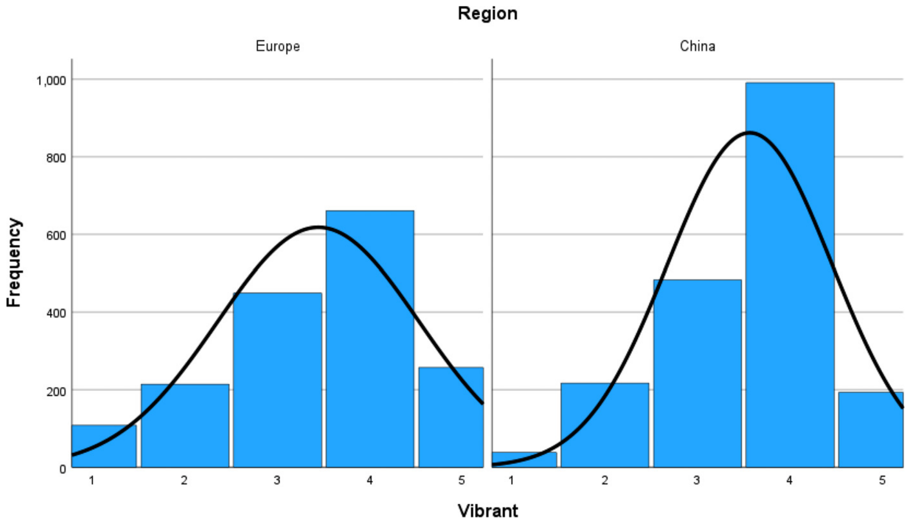

FIG. 10. (Color online) (Color online) Distributions of the scores for the attribute vibrant, showing comparison between the European (left) and Chinese (right) samples.

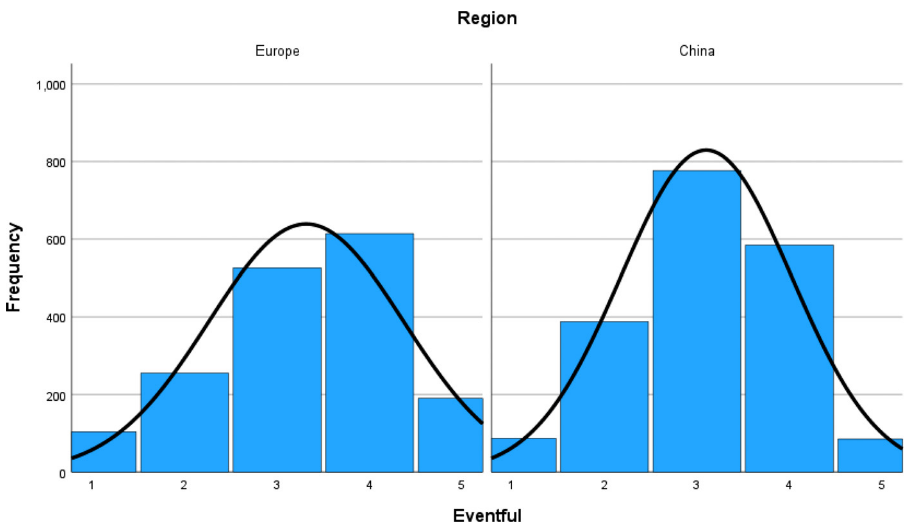

FIG. 11. (Color online) Distributions of the scores for the attribute eventful, showing comparison between the European (left) and Chinese (right) samples.

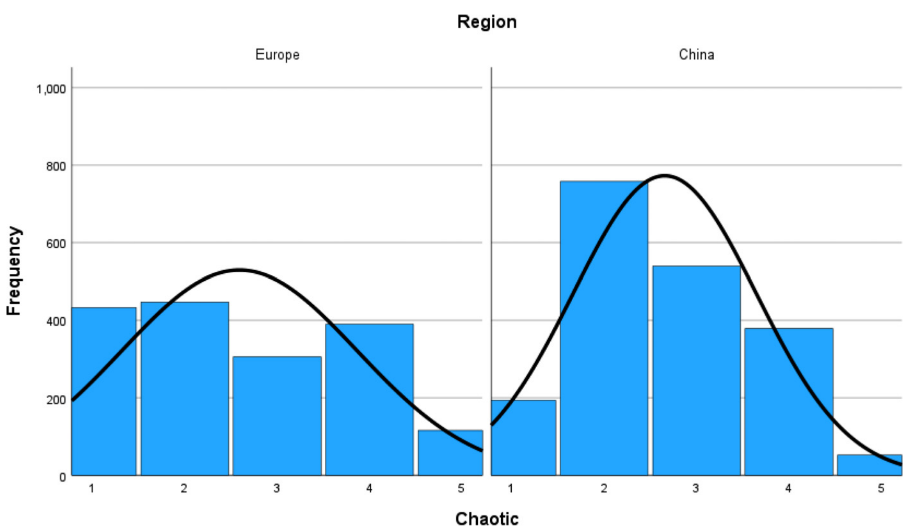

FIG. 12. (Color online) Distributions of the scores for the attribute chaotic, showing comparison between the European (left) and Chinese (right) samples.

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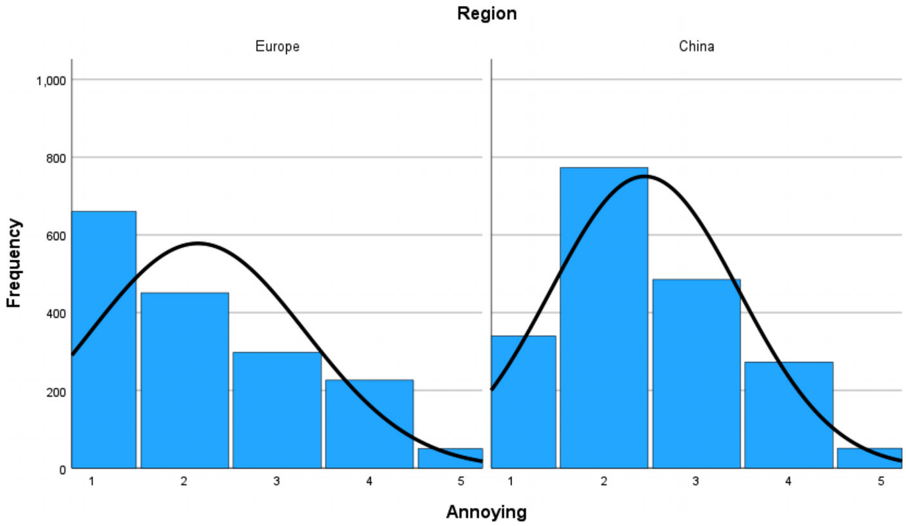

FIG. 13. (Color online) Distributions of the scores for the attribute annoying, showing comparison between the European (left) and Chinese (right) samples.

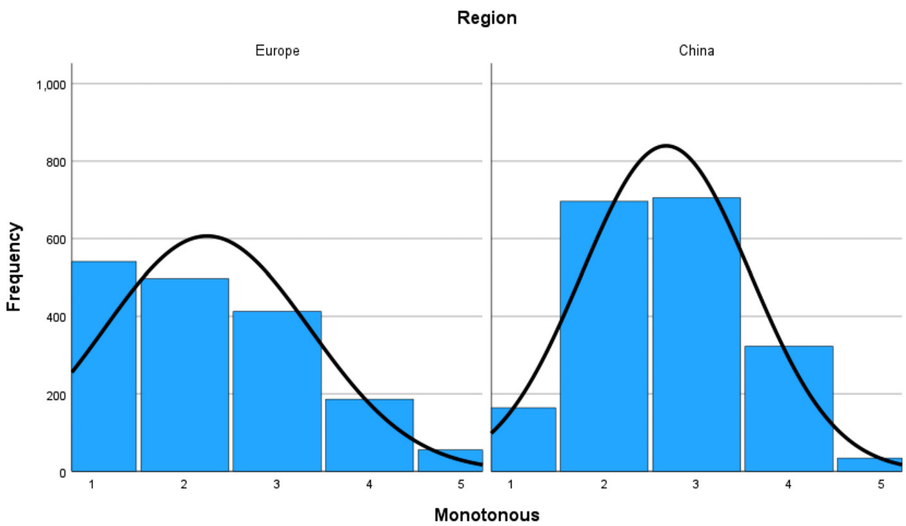

FIG. 14. (Color online) Distributions of the scores for the attribute monotonous, showing comparison between the European (left) and Chinese (right) samples.

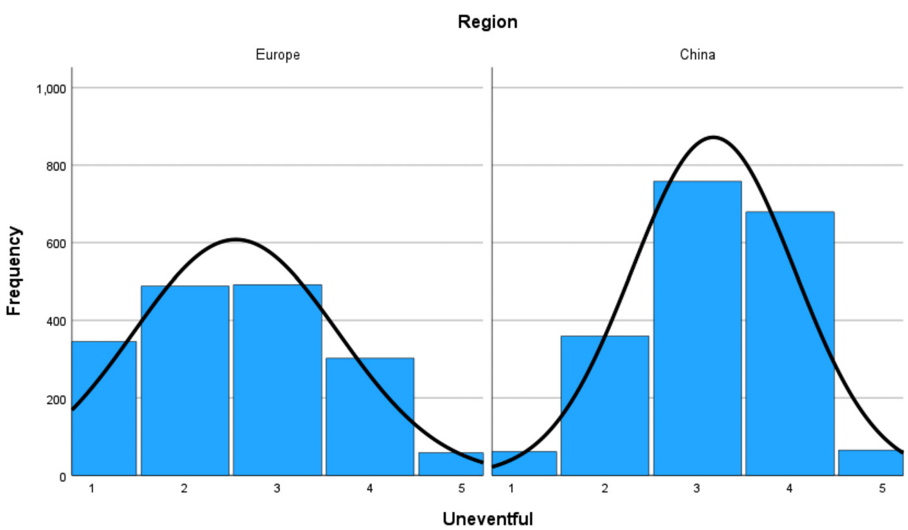

FIG. 15. (Color online) Distributions of the scores for the attribute uneventful, showing comparison between the European (left) and Chinese (right) samples.

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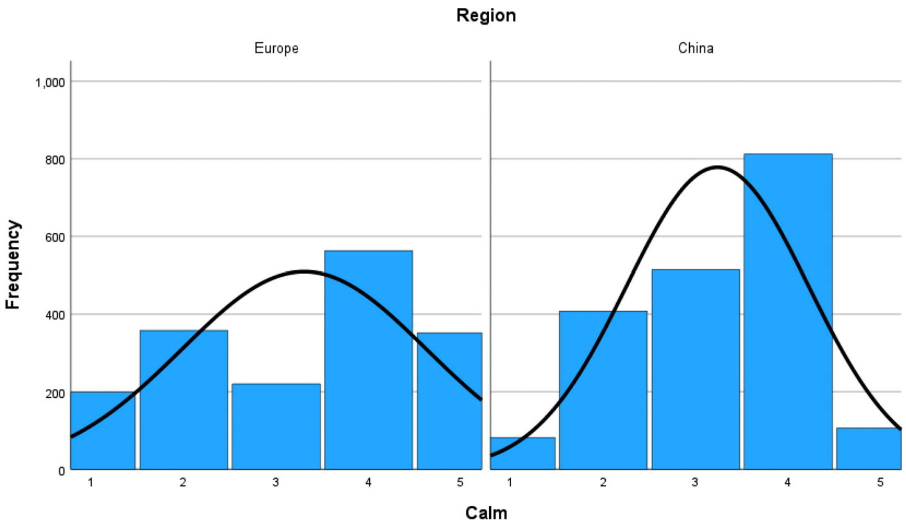

FIG. 16. (Color online) Distributions of the scores for the attribute calm, showing comparison between the European (left) and Chinese (right) samples.

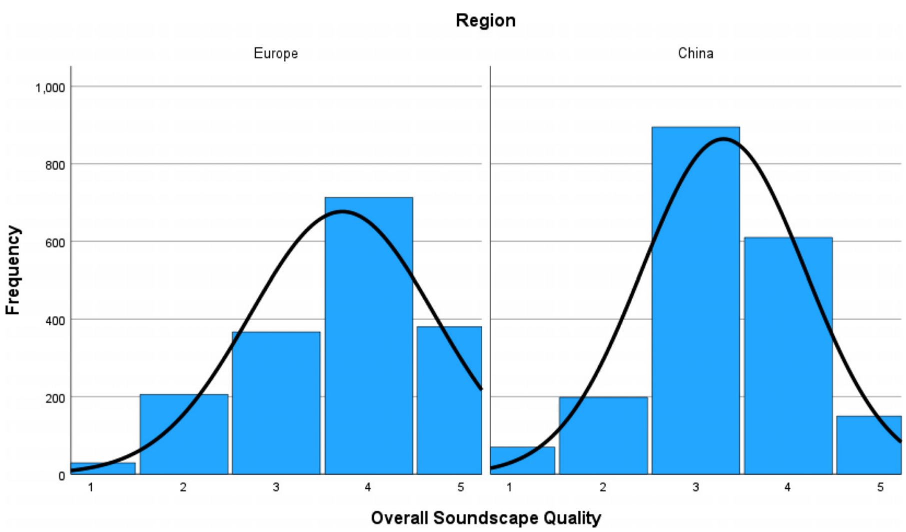

FIG. 17. (Color online) Distributions of the scores for the item overall soundscape quality, showing comparison between the European (left) and Chinese (right) samples.

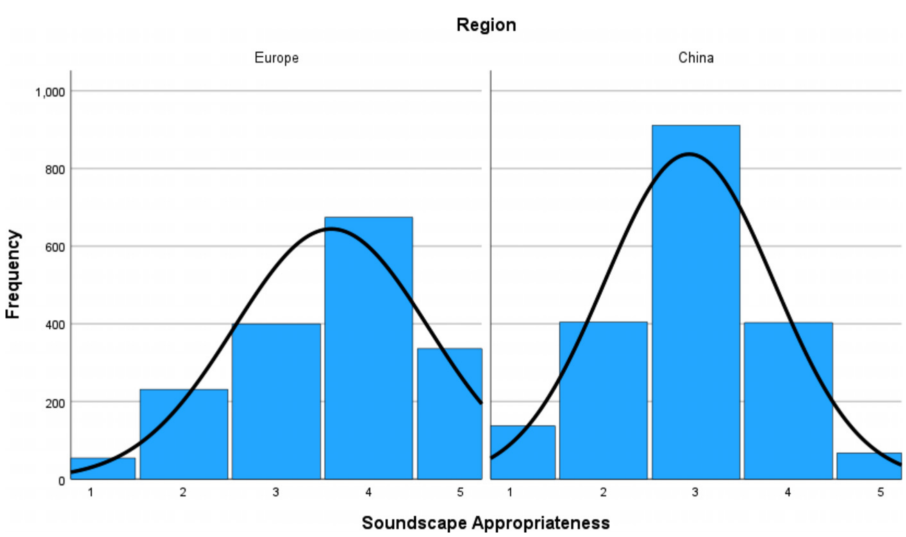

FIG. 18. (Color online) Distributions of the scores for the item soundscape appropriateness, showing comparison between the European (left) and Chinese (right) samples.

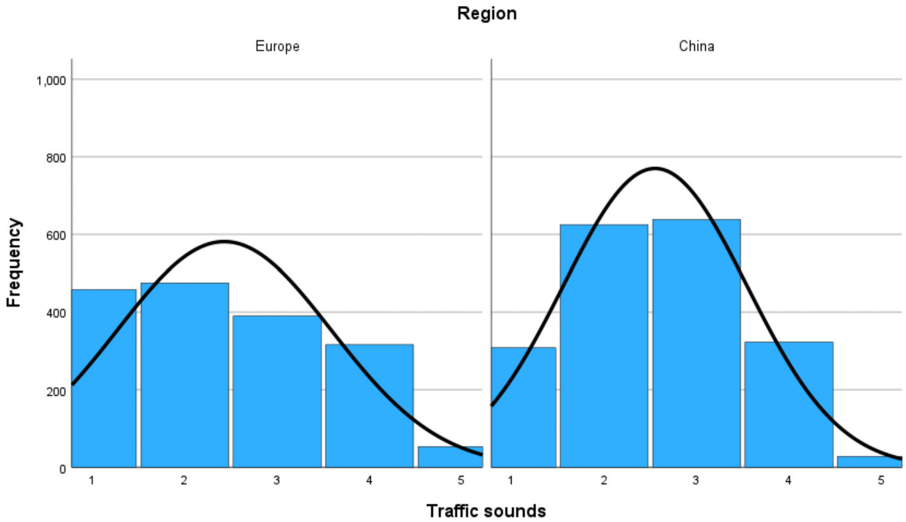

FIG. 19. (Color online) Distributions of the scores for the perceived dominance of the sound source category traffic sounds, showing comparison between the European (left) and Chinese (right) samples.

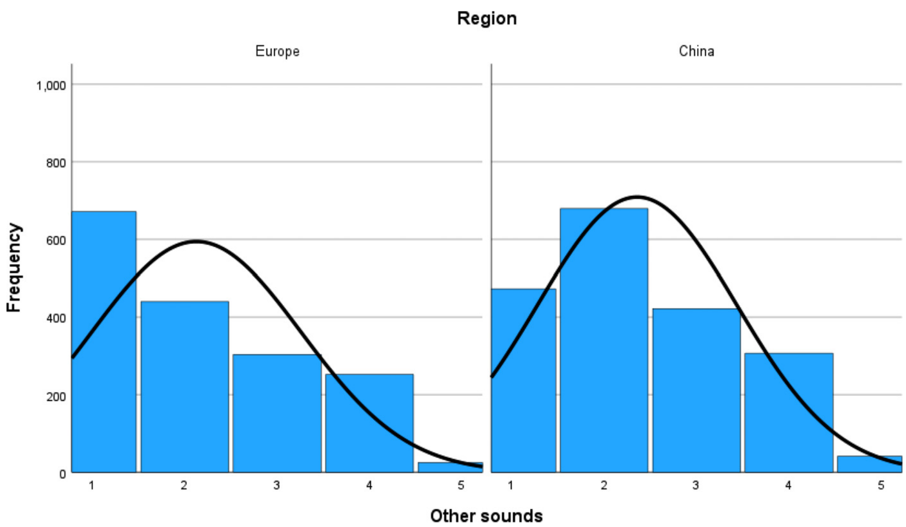

FIG. 20. (Color online) Distributions of the scores for the perceived dominance of the sound source category other sounds, showing comparison between the European (left) and Chinese (right) samples.

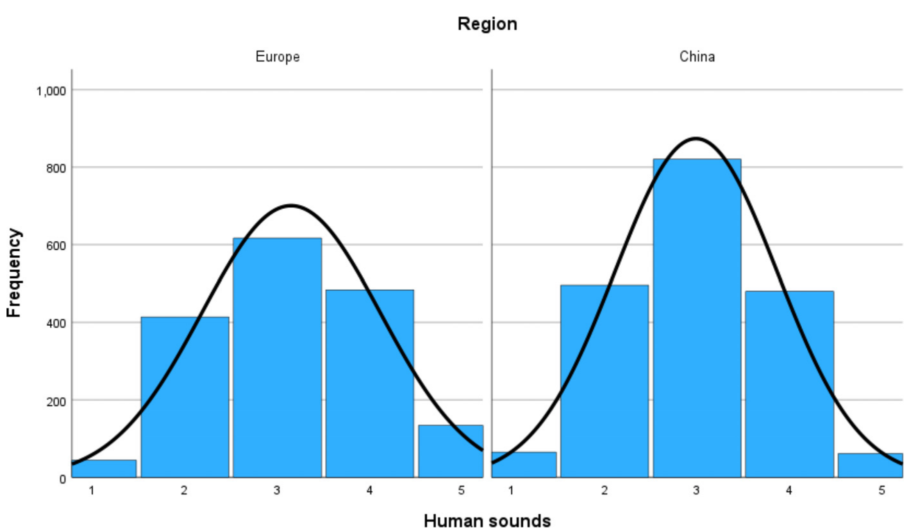

FIG. 21. (Color online) Distributions of the scores for the perceived dominance of the sound source category human sounds, showing comparison between the European (left) and Chinese (right) samples.

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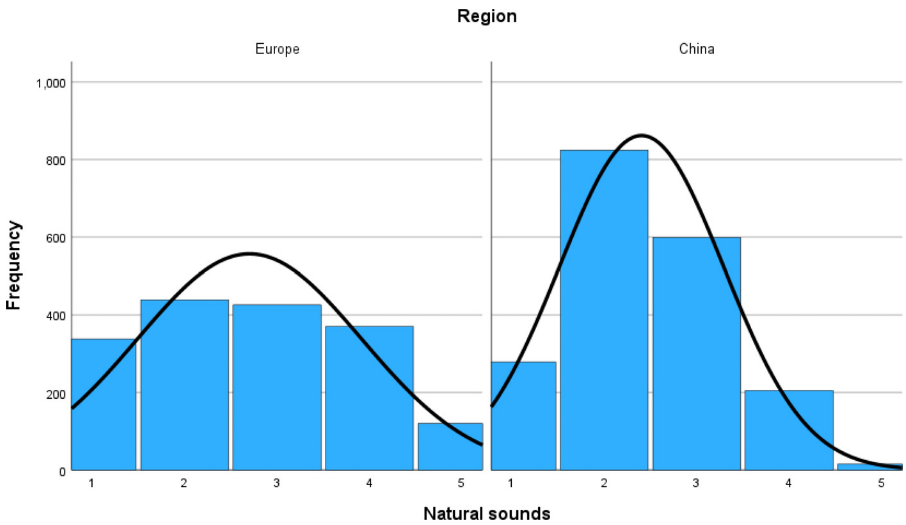

FIG. 22. (Color online) Distributions of the scores for the perceived dominance of the sound source category natural sounds, showing comparison between the European (left) and Chinese (right) samples.

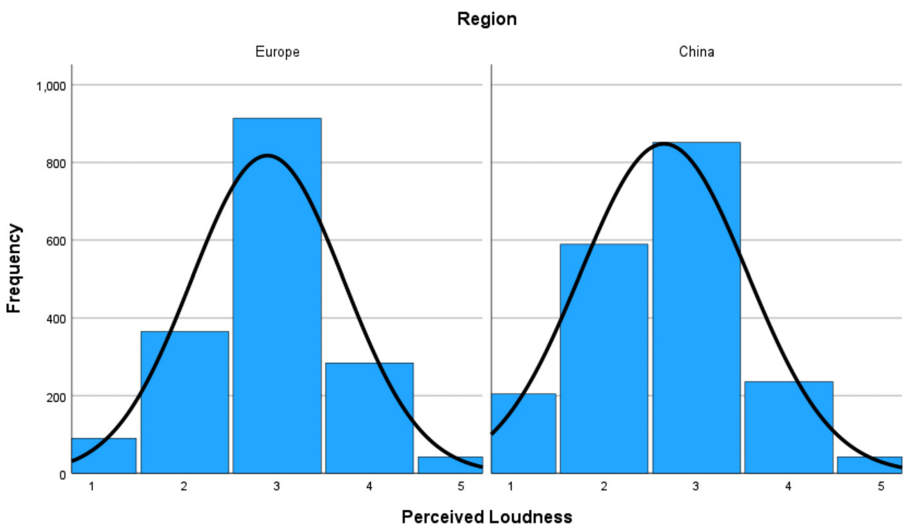

FIG. 23. (Color online) Distributions of the scores for the perceived dominance of the item perceived loudness, showing comparison between the European (left) and Chinese (right) samples.

TABLE VI. KMO and Bartlett's test for European dataset.

KMO measure of sampling adequacy		0.865
Bartlett's test of sphericity	Approximate Chi-square	7519.471
	degrees of freedom	105
	Significance level	<0.001

TABLE VII. Communalities. Extraction method, PCA for European dataset.

	Initial	Extraction
Traffic sounds	1.000	0.433
Other sounds	1.000	0.349
Human sounds	1.000	0.219
Natural sounds	1.000	0.341
Pleasant	1.000	0.680
Chaotic	1.000	0.584
Vibrant	1.000	0.344

TABLE VII. (*Continued*)

	Initial	Extraction
Uneventful	1.000	0.461
Calm	1.000	0.659
Annoying	1.000	0.596
Eventful	1.000	0.484
Monotonous	1.000	0.342
Overall soundscape quality	1.000	0.557
Soundscape appropriateness	1.000	0.268
Perceived loudness	1.000	0.339

TABLE VIII. Total variance explained for European dataset.

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	Percent of variance	Cumulative percent	Total	Percent of variance	Cumulative percent
1	4.663	31.085	31.085	4.663	31.085	31.085
2	1.994	13.292	44.378	1.994	13.292	44.378
3	1.096	7.306	51.684			
4	0.981	6.538	58.222			
5	0.885	5.897	64.120			
6	0.813	5.423	69.542			
7	0.733	4.884	74.426			
8	0.729	4.861	79.287			
9	0.623	4.156	83.443			
10	0.570	3.798	87.241			
11	0.472	3.147	90.389			
12	0.426	2.842	93.231			
13	0.392	2.615	95.846			
14	0.342	2.283	98.129			
15	0.281	1.871	100.000			

TABLE IX. Total variance explained. Extraction method, PCA for European dataset.

	Rotation sums of squared loadings		
Component	Total	Percent of variance	Cumulative percent
1	4.659	31.057	31.057
2	1.998	13.321	44.378

TABLE X. Component matrix. Extraction method, PCA for European dataset.[a]

	Component	
	1	2
Traffic sounds	0.657	−0.044
Other sounds	0.581	−0.107
Human sounds	0.052	0.465
Natural sounds	−0.577	0.085
Pleasant	−0.820	0.090
Chaotic	0.742	0.182
Vibrant	−0.014	0.586
Uneventful	−0.048	−0.677
Calm	−0.779	−0.230

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TABLE X. (*Continued*)

	Component	
	1	2
Annoying	0.762	−0.123
Eventful	0.142	0.681
Monotonous	0.262	−0.523
Overall soundscape quality	−0.743	0.073
Soundscape appropriateness	−0.480	0.194
Perceived loudness	0.524	0.255

[a]Two components extracted.

TABLE XI. Rotated component matrix. Extraction method, PCA; rotation method, Varimax with Kaiser normalization for European dataset.[a]

	Component	
	1	2
Traffic sounds	0.658	−0.018
Other sounds	0.585	−0.084
Human sounds	0.033	0.467
Natural sounds	−0.580	0.062
Pleasant	−0.823	0.058
Chaotic	0.734	0.212
Vibrant	−0.037	0.585
Uneventful	−0.021	−0.678
Calm	−0.769	−0.261
Annoying	0.767	−0.092
Eventful	0.114	0.686
Monotonous	0.283	−0.512
Overall soundscape quality	−0.745	0.044
Soundscape appropriateness	−0.488	0.175
Perceived loudness	0.513	0.276

[a]Rotation converged in three iterations.

TABLE XII. Component transformation matrix. Extraction method, PCA; rotation method, Varimax with Kaiser normalization for European dataset.

Component	1	2
1	0.999	0.040
2	−0.040	0.999

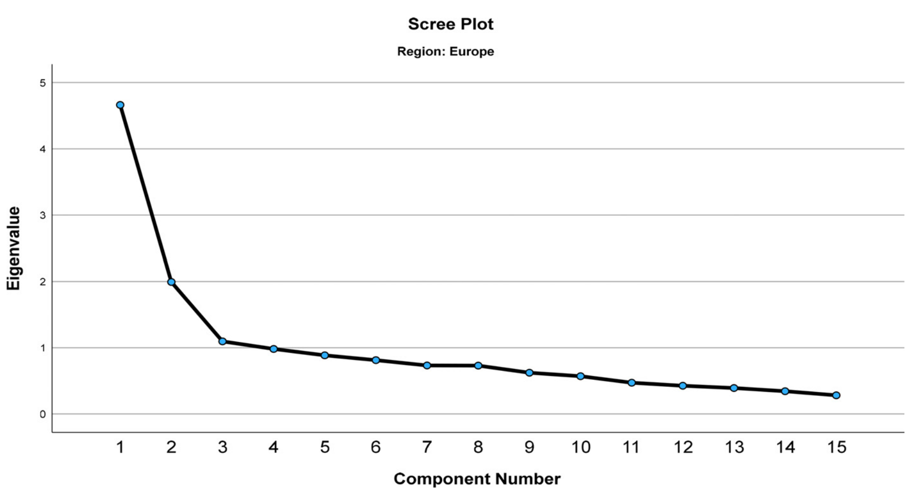

FIG. 24. (Color online) Eigenvalue as a function of number of extracted components from the PCA on the European sample.

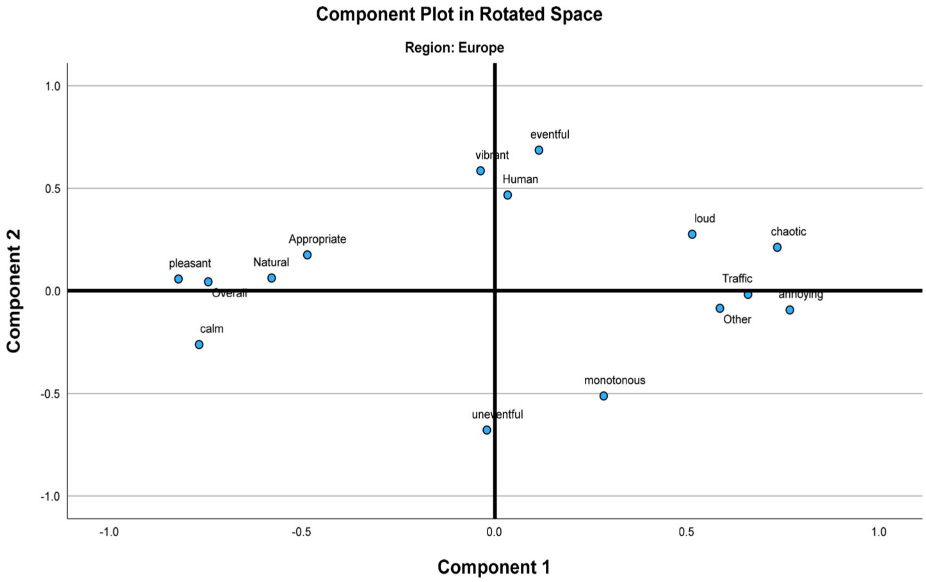

FIG. 25. (Color online) Items of the questionnaire plotted in the rotated space defined by the two main components extracted from the PCA on the European sample.

TABLE XIII. KMO and Bartlett's test for Chinese dataset.

KMO measure of sampling adequacy		0.789
Bartlett's test of sphericity	Approximate Chi-square	5024.187
	degrees of freedom	105
	Significance level	<0.001

TABLE XIV. Communalities. Extraction method, PCA for Chinese dataset.

	Initial	Extraction
Traffic sounds	1.000	0.431
Other sounds	1.000	0.490
Human sounds	1.000	0.016
Natural sounds	1.000	0.027
Pleasant	1.000	0.507
Chaotic	1.000	0.463
Vibrant	1.000	0.439
Uneventful	1.000	0.129
Calm	1.000	0.440
Annoying	1.000	0.517
Eventful	1.000	0.005
Monotonous	1.000	0.209
Overall soundscape quality	1.000	0.528
Soundscape appropriateness	1.000	0.412
Perceived loudness	1.000	0.326

TABLE XV. Total variance explained for Chinese dataset.

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	Percent of variance	Cumulative percent	Total	Percent of variance	Cumulative percent
1	3.478	23.184	23.184	3.478	23.184	23.184
2	1.460	9.734	32.918	1.460	9.734	32.918
3	1.327	8.848	41.765			
4	1.267	8.450	50.215			

TABLE XV. (*Continued*)

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	Percent of variance	Cumulative percent	Total	Percent of variance	Cumulative percent
5	1.028	6.855	57.070			
6	0.993	6.618	63.687			
7	0.839	5.596	69.284			
8	0.794	5.292	74.576			
9	0.717	4.781	79.358			
10	0.626	4.175	83.533			
11	0.604	4.029	87.561			
12	0.552	3.683	91.244			
13	0.474	3.163	94.407			
14	0.439	2.927	97.334			
15	0.400	2.666	100.000			

TABLE XVI. Total variance explained. Extraction method, PCA for Chinese dataset.

	Rotation sums of squared loadings		
Component	Total	Percent of variance	Cumulative percent
1	2.861	19.073	19.073
2	2.077	13.844	32.918

TABLE XVII. Component matrix. Extraction method, PCA for Chinese dataset.[a]

	Component	
	1	2
Traffic sounds	−0.299	0.584
Other sounds	−0.385	0.585
Human sounds	−0.121	−0.032
Natural sounds	0.139	0.085
Pleasant	0.693	0.163
Chaotic	−0.611	−0.300
Vibrant	0.615	0.247
Uneventful	0.062	0.354
Calm	0.540	0.384
Annoying	−0.667	−0.269
Eventful	0.052	−0.049
Monotonous	−0.418	0.185
Overall soundscape quality	0.721	−0.090
Soundscape appropriateness	0.542	−0.345
Perceived loudness	−0.494	0.286

[a]Two components extracted.

TABLE XVIII. Rotated component matrix. Extraction method, PCA; rotation method, Varimax with Kaiser normalization for Chinese dataset.[a]

	Component	
	1	2
Traffic sounds	0.074	0.652
Other sounds	0.003	0.700
Human sounds	−0.118	0.040
Natural sounds	0.163	−0.006
Pleasant	0.667	−0.247

https://doi.org/10.1121/10.0020842

TABLE XVIII. (*Continued*)

	Component	
	1	2
Chaotic	−0.675	0.088
Vibrant	0.649	−0.134
Uneventful	0.248	0.261
Calm	0.663	0.022
Annoying	−0.704	0.144
Eventful	0.016	−0.070
Monotonous	−0.246	0.385
Overall soundscape quality	0.551	−0.473
Soundscape appropriateness	0.261	−0.587
Perceived loudness	−0.253	0.512

[a]Rotation converged in three iterations.

TABLE XIX. Component transformation matrix. Extraction method, PCA; rotation method, Varimax with Kaiser normalization for Chinese dataset.

Component	1	2
1	0.833	−0.553
2	0.553	0.833

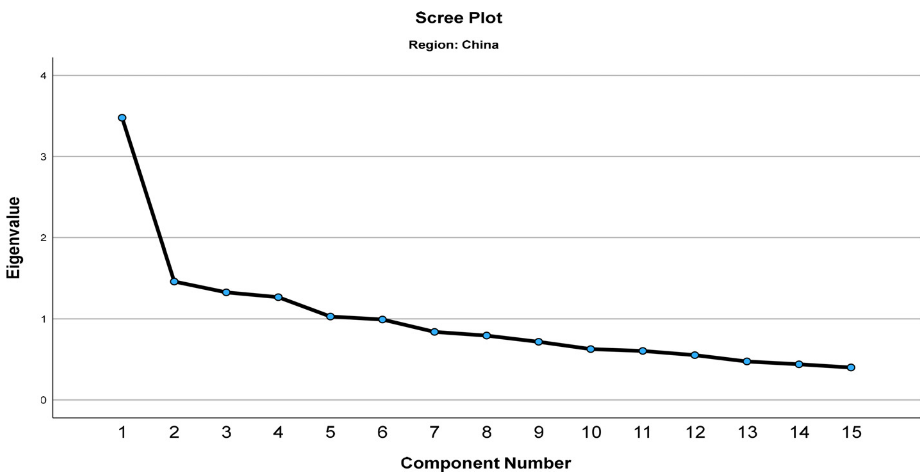

FIG. 26. (Color online) Eigenvalue as a function of number of extracted components from the PCA on the Chinese sample.

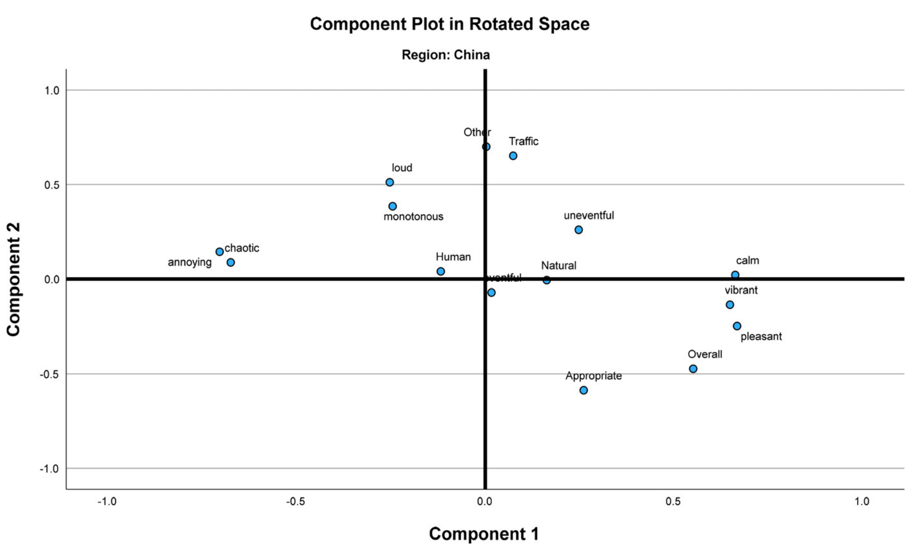

FIG. 27. (Color online) Items of the questionnaire plotted in the rotated space defined by the two main components extracted from the PCA on the Chinese sample.

Factor analysis

A PCA was run separately for the European and Chinese datasets on the soundscape questionnaire items in Table I. The suitability of PCA was assessed prior to analysis. Inspection of the correlation matrix showed that all variables had at least one correlation coefficient greater than 0.3. The overall Kaiser-Meyer-Olkin (KMO) measures were 0.865 for Europe and 0.789 for China. Bartlett's test of sphericity was statistically significant for Europe and China ($p < 0.001$), indicating that the data were likely factorizable.

Visual inspection of the scree plot and eigenvalues greater than one indicated that two components should be retained for Europe and China.[66] A varimax orthogonal rotation was employed to aid interpretability. The rotated solution exhibited "simple structure."[67] The interpretation of the data was consistent with soundscape literature about the circumplex model for the European dataset with more deviations for the Chinese dataset along the eventful-uneventful dimension.

Region: Europe

See Tables VI–XII and Figs. 24 and 25 for information related to the Principal Component Analysis (PCA) performed on the European dataset.

Region: China

See Tables XIII–XIX and Figs. 26 and 27 for information related to the Principal Component Analysis (PCA) performed on the Chinese dataset.

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