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Soundscape descriptors in eighteen languages: Translation and validation through listening experiments

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A R T I C L E I N F O

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A B S T R A C T

This paper presents the outcomes of the "Soundscape Attributes Translation Project" (SATP), an international initiative addressing the critical research gap in soundscape descriptors translations for cross-cultural studies. Focusing on eighteen languages – namely: Arabic, Chinese, Croatian, Dutch, English, French, German, Greek, Indonesian, Italian, Japanese, Korean, Malay, Portuguese, Spanish, Swedish, Turkish, and Vietnamese – the study employs a four-step procedure to evaluate the reliability and cross-cultural validity of translated soundscape descriptors. The study introduces a three-tier confidence level system (Low, Medium, High) based on "adjusted angles", which are a measure proposed to correct the soundscape circumplex model (i.e., the pleasant-eventful space proposed in the ISO 12913 series) of a given language. Results reveal that most languages successfully maintain the quasi-circumplex structure of the original soundscape model, ensuring robust cross-cultural validity. English, Arabic, Chinese (Mandarin), Croatian, Dutch, German, Greek, Indonesian, Italian, Spanish, Swedish, and Turkish achieve a "High" confidence level. French, Japanese, Korean, Malay, Portuguese, and Vietnamese demonstrate varying confidence levels, highlighting the importance of the preliminary translation. This research significantly contributes to standardized cross-cultural methodologies in soundscape perception research, emphasizing the pivotal role of adjusted angles within the soundscape circumplex model in ensuring the accuracy of dimensions (i.e., attributes) locations. The SATP initiative offers insights into the complex interplay of language and meaning in the perception of environmental sounds, opening avenues for further cross-cultural soundscape research.

1. Introduction

Standardizing the measurement of people's responses to the experience of an acoustic environment – i.e., the soundscape assessment– is a challenging undertaking, in which researchers and other stakeholders have put growing efforts over the past 15–20 years [15,40,20,24,9]. As far as urban soundscape studies are concerned, this is still an ongoing process, started in 2008, when the International Organization for Standardization (ISO) formed the Working Group 54 "Perceptual assessment of soundscape quality" (ISO/TC 43/SC 1/WG 54) to support harmonization in soundscape theory and methodological approaches [7]. The working group was tasked with developing the ISO 12913 series on soundscape; its activities so far have led to the publication of three parts (a full standard and two technical specifications), namely: ISO 12913-1:2014, covering the general soundscape framework and definitions [36], ISO/TS 12913-2:2018 covering soundscape data collection methods and reporting requirements [37]; and ISO/TS 12913-3:2019 covering soundscape data analysis [38].

The ISO/TS 12913-2:2018 is of special interest, as it deals with the more methodological aspects of a soundscape study. These technical specifications (TS) provide actual protocols (as informative annexes) for data collection of individual responses to acoustic environments experienced either on site as for Methods A and B (through soundwalks), or off-site as for Method C (through narrative interviews). The attributes and semantic scales proposed in Methods A and B mainly come from soundscape literature [68,11]. In particular, the protocol of Method A includes eight soundscape descriptors that were originally developed by researchers at Stockholm University as part of the "Swedish Soundscape Quality Protocol (SSQP)" [10]. Soundscape descriptors are "*measures of how people perceive the acoustic environment*" [3] and their use is now well-established in soundscape studies as they are implemented in associations with scales (e.g., Visual Analogue Scales, Likert scales, etc.), as part of questionnaires to assess a soundscape [8].

Characterizing how soundscapes are experienced by people is indeed one of the main goals of the soundscape approach, and for this process to be successful, it is necessary to use descriptors and scales that can consistently define perceived qualities of physical acoustic environments, across samples and locations. However, the current protocols are only available in English. The concept of "measuring perception" brings in some psychometric issues on its own [26,25,47], and one of the main aspects being currently debated within the soundscape community is whether using a set of soundscape English descriptors in non-English speaking regions is feasible at all [4]. There is no consensus on whether the meaning of the soundscape descriptors reported in Method A of the technical specifications can be easily translated into other languages [58]. Addressing this challenge is becoming urgent also in light of the fact that this method is now prevalent in soundscape studies [1,5]. Scientific literature on the translation of soundscape descriptors is limited, and previous research has already identified some concerns in adapting the English version of such perceptual attributes for other regions [21,73,39,2], so the applicability of the questionnaire proposed in the Method A of the ISO/TS 12913-2:2018 in non-English speaking countries remains problematic. For soundscape studies in particular, Jeon and colleagues [39] concluded that while standardizing data collection instruments for perceived soundscape qualities, "*it is necessary to validate the linguistic versions before they are published. This must be done by cross-national comparison with a standardized data collection procedure, using the same set of stimuli, conditions and equipment. Without this rigorous procedure, there is a risk that the results obtained by the different linguistic versions are not comparable, which is the aim of a standard.*"

For similar socio-acoustic survey tools focused on noise annoyance, the question of translation was indeed considered [13,79]. For instance, in the ISO/TS 15666:2003 (revised in 2021) dealing with the assessment of noise annoyance, the exact wording of the questions of the protocol (as well as its scales and modifiers) is proposed officially in nine languages: English, Dutch, French, German, Hungarian, Japanese, Norwegian, Spanish, and Turkish [34]; and with the 2021 revision the following eight languages were added: Danish, Chinese, Korean, Romanian, Polish, Portuguese – Brazilian, Thai, Vietnamese.

Overall, in cross-cultural studies, the translation process is frequently a major methodological challenge, where researchers have to transfer scales and instruments from one language to another, often with limited resources [18]. Researchers may need to use questionnaires in different languages that should "have the same meaning" to test hypotheses about human behaviour and responses to certain situations and stimuli, so the question arises of "how good does a translation have to be, before it is usable?" [14]. Back-translation is a common approach for quality assessment in international and cross-cultural social research; it requires a translated text to be re-translated back into the source language by an independent translator who does not have knowledge of the original material. If any mismatches emerge between the back-translation and the source material, one can infer that translation errors occurred in the target language version [14]. While this is a convenient approach, many scholars agree that back-translation should not be used as a stand-alone tool and a combination of different translation techniques is desirable as part of a broader process that will vary depending on the research field and the purposes of the translation project [18,76]. This is particularly true when emotions assessment and perceptual outcomes are involved, as in the case of soundscape studies.

Majid and Levinson observe that l*anguage* – as a human capacity, rather than a particular tongue – mediates between the individual nature of sensation and the cultural world that constructs the perceptual domain, where the cultural world provides the sensory space, of which soundscapes are a component, that humans perceive [48]. To summarize this concept with a quote by the same authors, we could say that "*Language gives us intersubjective sensory experience, without which there could not be a social science of the senses*" [48], p.10. Majid and colleagues have also previously questioned whether languages would differ in how they code the senses, and the auditory and olfactory domains, in particular [49]. The authors show that different languages express different degrees of codability for the sound domain. For instance, Turkish shows a higher codability for stimuli in the auditory domain compared to English, which has in turn higher codability for sounds compared to Malay. These hierarchies vary across sensory domains and different languages exhibit different hierarchical patterns.

In soundscape research, the lack of adequate translations for soundscape descriptors to be included in questionnaires constitutes a major research gap. For this reason, an international network with soundscape researchers from different regions of the world was established under the name of "Soundscape Attributes Translation Project" (SATP). The overall objectives of the SATP initiative are: 1) providing a set of validated translations for the soundscape descriptors proposed in Method A of the ISO/TS 12913-2:2018 for an initial set of languages; and 2) providing suitable materials and applying a robust method for validating languages that may be considered for addition in the future. This paper aims to describe the general context of the SATP initiative and its stages, as well as proposing an assessment of the results of the project for the first eighteen languages: Arabic, Chinese, Croatian, Dutch, English, French, German, Greek, Indonesian, Italian, Japanese, Korean, Malay, Portuguese, Spanish, Swedish, Turkish, and Vietnamese.

2. Methodology

2.1. The Soundscape Attributes Translation Project (SATP)

The activities of the SATP network started in May 2019 with a first group of collaborators with relevant expertise and special interest in soundscape studies, based in different countries around the world. The original network covered 15 languages, with 24 research groups and international institutions involved, with the project being coordinated in the UK by the Acoustics Group of the Institute for Environmental Design and Engineering, at University College London. As of April 2022, the network had expanded to cover 18 languages, with more research groups, and corresponding local languages, expected to join soon. Over the past five years, the SATP network has been quite dynamic, losing and gaining partners/languages, as one could reasonably expect considering the voluntary nature of the initiative, which has relied on limited financial resources. The first group of collaborators came together informally, in general reflecting languages from regions of the world where soundscape research is well-established and research groups that were already active in this discipline. Calls for expressions of interest to join the SATP network were also posted on several academic and professional social media platforms (e.g., ResearchGate, LinkedIn), which led to new research collaborations. To date, the network remains open to members of the scientific community wanting to establish working groups for additional languages. Fig. 1 shows a map with the locations of the currently active collaborators of the SATP initiative.

Whenever a SATP working group was established, the UCL coordinators would assign a label/ID to it that could identify the language of interest, as per the classification proposed in the ISO 639-3:2007[35] (see also Table 1). This standard aims to cover all known natural languages, it is often used in linguistic literature to univocally identify language names that may otherwise be ambiguous. It provides a useful categorization via three-letter codes to distinguish macrolanguages and collective languages from individual languages. In this context, the SATP initiative makes no claims whatsoever on possibly contested language identifiers/labels, and it relied entirely on the ISO 639-3 framework. In addition, an ID was assigned for each institution which contributed to translations or data collection in particular to enable differentiation between different groups, approaches, or dialects within the same ISO 639-3 language.

The soundscape descriptors considered in the context of the SATP initiative, and used as a reference for the subsequent translations, are the eight English attributes associated with five-point Likert scales, proposed in the Method A of Part 2 of the ISO technical specifications [37]; namely: *pleasant, vibrant, eventful, chaotic, annoying, monotonous, uneventful, calm,* as shown in Fig. 2, describing the soundscape circumplex model (SCM). The soundscape circumplex model (SCM) was originally developed by Axelsson and colleagues [11], following a listening experiment that led to a bi-dimensional space where any soundscape may be located in relation to two principal orthogonal components of "pleasantness" and "eventfulness". According to the SCM theory, the pleasant-eventful space further identifies four more dimensions (and, consequently, quadrants) rotated by 45° with respect to the pleasant-eventful space; thus, a soundscape that is both pleasant and eventful is vibrant; a soundscape that is both pleasant and uneventful is calm; a soundscape that is both annoying and eventful is chaotic; and a soundscape that is both annoying and uneventful is monotonous. The SCM, and the eight soundscape attributes (dimensions) composing it, were later effectively adopted as the foundation for the instrument of Method

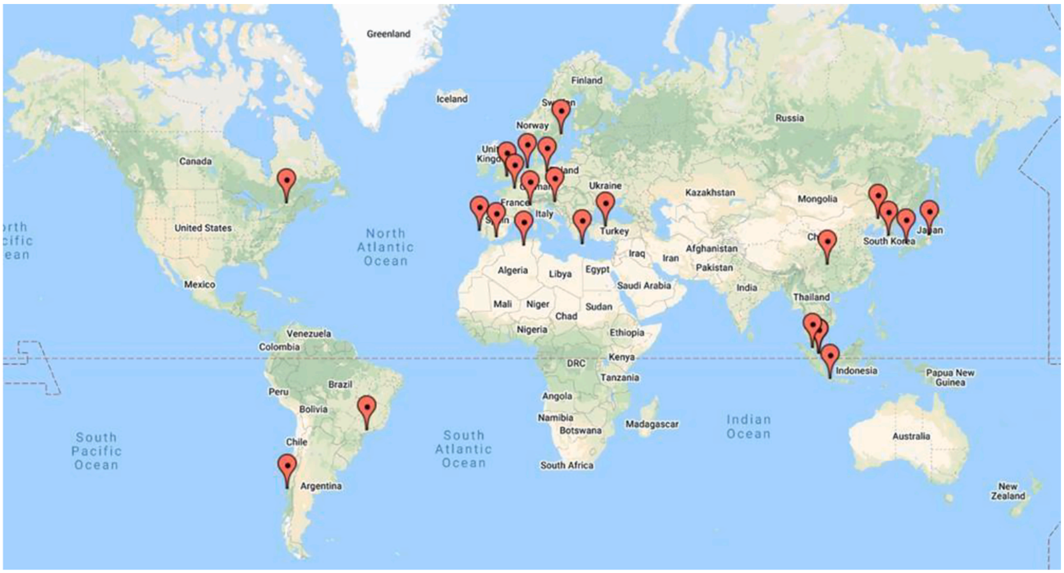

Fig. 1. Locations of the research groups currently active in the SATP network.

Table 1
Summary of the different methods the single SATP working groups used to determine the soundscape descriptors translations in different languages.

Methods used to determine soundscape attributes (descriptors) translations							
ISO 639-3:2007 Language code	**Language name**	**Soundscape experts panel**	**Focus Group**	**Linguistic approach**	**Pilot listening experiment or data collection**	**Soundwalk**	**Reference(s) from previous soundscape literature**
ISO 639:eng	*English*	–	–	–	–	–	–
ISO 639:arb	Standard Arabic	●					
ISO 639:cmn	Chinese (Mandarin)	●	●				
ISO 639:hrv	Croatian	●					●
ISO 639:nld	Dutch	●					●
ISO 639:fra	French	●					●
ISO 639:deu	German	●			●		●
ISO 639:ell	Greek	●		●			
ISO 639:ind	Indonesian		●			●	
ISO 639:ita	Italian	●					●
ISO 639:jpn	Japanese	●		●	●	●	●
ISO 639:kor	Korean	●	●		●		●
ISO 639:zsm	Malay	●	●		●		
ISO 639:por	Portuguese	●			●		
ISO 639:spa	Spanish	●					●
ISO 639:swe	Swedish	●					●
ISO 639:tur	Turkish	●	●			●	●
ISO 639:vie	Vietnamese		●				

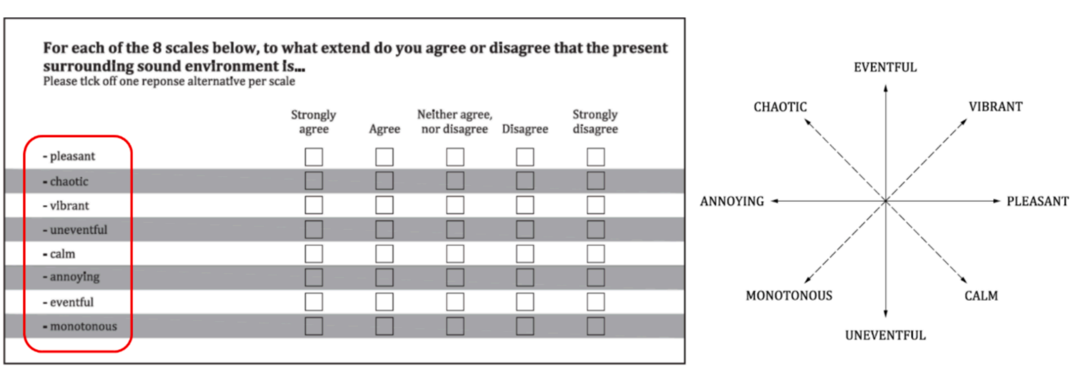

Fig. 2. The eight soundscape attributes of ISO 12913-2 Method A considered in the SATP initiative highlighted in red (left), and the soundscape circumplex model (SCM) with the same eight dimensions (right) – adapted from Fig. C.4 of ISO/TS 12913-2 and Fig. A.1 of ISO/TS 12913-3. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A in Part 2 of the ISO technical specifications, with each attribute associated to an independent five-point Likert scale ranging from "strongly agree" (1) to "strongly disagree" (5), reflecting the individual's assessment of that particular dimension. The technical specifications of Part 3 of the ISO 12913 series then provide a trigonometric transformation (reported in its Eqs. A.1 and A.2), which reduce the eight-dimensional scores into a pair of coordinates to be plotted on the pleasant-eventful space [38].

The long-term goal of the SATP initiative is therefore to provide a soundscape protocol that is "equivalent" to the one presented in Fig. 2 in languages other than English, as well as a reliable process and set of materials that are usable for the task, for future applications by other working groups and researchers. For organizational reasons the SATP was divided into two main work packages, Stage 1 "preliminary translations" and Stage 2 "listening experiments and validation". For Stage 1, the working groups were tasked with providing the best possible translations of the eight soundscape descriptors in their local language, based on the English reference. For Stage 2 a listening experiment had to be carried out independently by all working groups in the local language (version translated from Stage 1) with native speakers, using a common set of auditory stimuli and standardized equipment and procedure for calibration, to assess the quality of the translations.

2.2. Preliminary translations (Stage 1)

For the purpose of providing the best possible set of translated descriptors, a broad range of methodological approaches was applied across the SATP network. Each working group defined its own data collection strategy for Stage 1, independently. The common guiding principles were: 1) considering the reference data collection instrument (i.e., the scales: Pleasant, Annoying, Eventful, Uneventful, Monotonous, Exciting, Calm, Chaotic), the goal should be about retaining the "meaning" of the dimensions and their mutual relationships as per the original soundscape circumplex model (i.e., see Fig. 2 and [11], rather than pursuing a literal translation of the single English attributes; 2) consequently, the working groups also agreed that if a single attribute would not adequately render the meaning of the original soundscape dimension, a set of 2–3 attributes used in combination on a single scale would be acceptable to match as closely as possible the original perceptual construct [4].

Table 1 shows the different methods used by the working groups to identify the best translation for the eight original descriptors. It can be observed that researchers often used a combination of approaches and techniques, as it would be expected in translation studies. Most working groups relied on expert panels, which consisted of open unstructured discussions among the local soundscape experts and members of the research team, frequently starting with a back-translation of the ISO 12913 instrument, and an iterative process to refine the set of attributes, until consensus was reached.

Occasionally, formal focus groups were organized where laypeople attended and specialist advice from linguistic experts was also sought, either via the focus group itself, or on a one-to-one basis. Some working groups organized listening experiments where they either asked participants to consider the suitability of some candidate translations or directly piloted the preliminary translations in laboratory listening experiments or soundwalks (see, e.g., [6,70,43,44,81,56,22,55,80,71,78,59,60,42,46,41,69,85]. Finally, whenever available, working groups also relied on previous studies and scientific literature dealing with translation aspects in soundscape studies [64,63,23,57].

2.3. Listening experiments and validation (Stage 2)

This section describes the second stage of the SATP initiative, namely the listening experiments that made use of the individual translations, as well as the preparatory stages that led to them for the working groups. It will cover how the auditory stimuli were selected, some general data about the overall sample (across languages), and the shared protocol for the experimental sessions. Considering the extended network of SATP participants, when some descriptive statistics are reported (e.g., demographics of the sample), these will refer to the aggregated sample, rather than individual languages/groups.

2.3.1. Stimuli selection

In preparation for the validation stage of the project, it was necessary to select a meaningful set of auditory stimuli that all research groups in the SATP network could use in their local experiments. For practical reasons, it was decided that University College London would provide the common set of recordings to use internationally. These were sourced from the database of the Soundscape Indices (SSID) project [53,54] and complemented with some additional recordings made *ad hoc*. Binaural recordings were performed following the recommendations of ISO/TS 12913-2:2018. At each relevant location an operator with a calibrated portable recorder (SQobold, HEADacoustics GmbH) and head-mounted microphones (BHS II, HEADacoustics GmbH) would capture a few minutes of the local sound environment, with the goal to extract some meaningful 30-second excerpts to use in the listening experiment. The rationale for sourcing all the audio stimuli from London was that it would provide acoustic environments that are "globalized" enough and less likely to lean towards "unique" scenarios where cultural meaning of sounds is more influential [61]; in other words, a sound environment recorded in London may quite possibly be similar to another one recorded in some other global city, while the opposite is not necessarily true.

The guiding principle when selecting the binaural recordings was having acoustic scenes that would be well-balanced in terms of composition of different sound source types, and also have the potential to elicit a broad range of responses across the soundscape circumplex model (i.e., covering in a rather even way the pleasant-eventful space). To achieve that, a pilot listening experiment was performed at University College London to extract the 27 desired audio stimuli from a starting pool of 80 recordings, subsequently narrowed for the pilot to 43 recordings (with some stimuli from the SSID database left as reserve materials). Eight expert listeners from the Acoustics Group at UCL Institute for Environmental Design and Engineering were asked to listen to the 43 recordings and sort them into nine clusters matching the soundscape circumplex space (calibration and playback settings were the same as per the description in the following section), as shown in Fig. 3. This resulted in eight matrices, and after comparing them, the 27 stimuli for which most consensus was found across the eight participants were selected, following the general approach that three stimuli should be chosen for each of the nine quadrants of the simplified soundscape circumplex model in Fig. 3. A further listening exercise was subsequently conducted by two UCL Acoustics Group experts to finalize the dataset of 27 stimuli to be used in the Stage 2 listening experiments of the SATP initiative by the international partners (final deletions/additions are reported again in Fig. 3).

The recording locations eventually selected in London cover diverse urban and natural settings, each offering unique acoustic environments. For instance, Covent Garden and Leicester Square represent bustling urban areas, characterized by pedestrian activity, street performers, and occasional vehicle sounds. Camden Town Station features transportation noise and the hustle of commuters. Regent's Park and Victoria Park offer tranquil surroundings with sounds of birds, rustling leaves, and distant traffic. Regents Canal at various points exhibits a mix of urban and natural sounds, including passing boats, pedestrian chatter, and wildlife along the towpath. More information about the exact locations of the recordings can be retrieved from [61], and some description of the noticeable sound sources in each recording can be found in [55].

After the pilot experiment was completed, a de-briefing session was carried out with its eight participants to reflect collectively on common perceptual features that ideal *pleasant, vibrant, eventful, chaotic,*

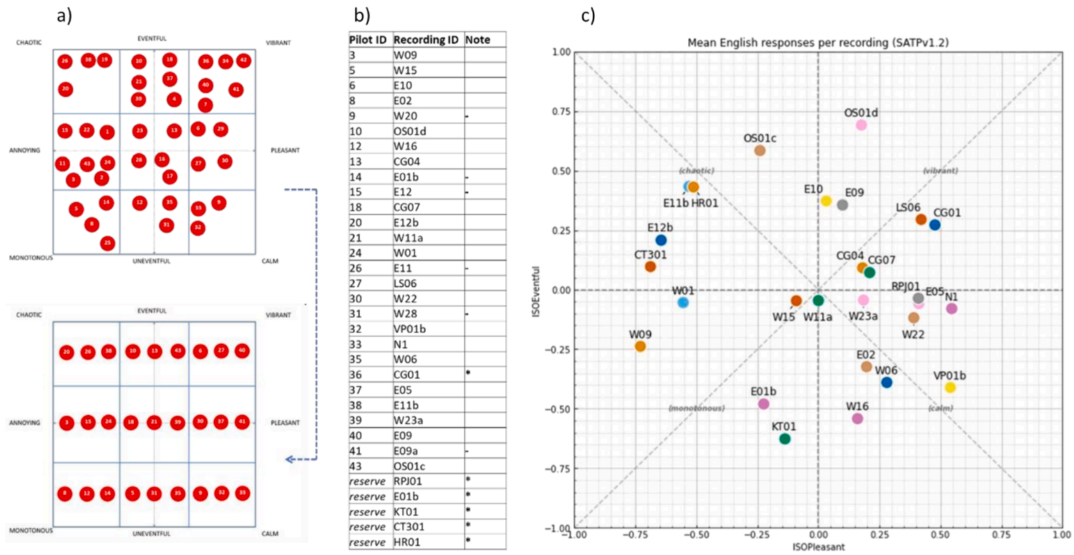

Fig. 3. a) Example of data collection from participant #1 of the pilot experiment for stimuli selection (top left); stimuli selected via the pilot for the listening experiment arranged by the 9 quadrants of a simplified soundscape circumplex model; b) pilot id – recording ID correspondence with further deletions/additions of stimuli (– indicates stimuli eventually disregarded, * indicates stimuli eventually added); c) plot of the final full 27-stimuli dataset of the experiment carried out in English and mean scores on the ISO Circumplex model (i.e., plotted on the pleasant-eventful space according to the trigonometric transformations of ISO/TS 12913-3:2019).

annoying, monotonous, uneventful, calm, soundscapes would exhibit. Some recurring themes emerged and are summarized in the Results section.

2.3.2. Participants and protocol

In total, 706 participants (M = 51 %, F = 49 %; $M_{age} = 28.8$; $SD_{age} = 10.6$) were involved in the set of experiments carried out by the SATP partners internationally, with 18 experiments in as many countries. An umbrella ethical approval for the SATP project was granted via the Bartlett School of Environment Energy and Resources Local Research Ethics Committee (approval letter on August 12th, 2019, by the UCL Institute for Environmental Design and Engineering Ethics Lead), and one of the conditions for data and protocol sharing among partners was making sure that local ethical approvals would also be in place wherever experiments were planned, before any data transfer could happen between parties.

Since there was a common set of stimuli, agreeing on a shared calibration procedure for playback was particularly important to ensure that participants would be exposed to the same sound environment conditions in the different countries. The calibration procedure is described in detail in [43–45], and details on the equipment that each working group was required to use are reported in [61]. In summary, the headphone calibration for the SATP partners involved determining the sensitivity of the headphones (e.g., Sennheiser HD650, or equivalent) and calculating the required voltage for a 1 kHz calibration signal at 94 dB SPL. Using a sound card with optional amplification, the headphones were connected, and a multimeter measured the voltage output. The gain knob was adjusted to achieve the calculated voltage, and this setting was fixed for subsequent tests. The procedure ensured uniform loudness for binaurally recorded soundscapes during SATP experiments, enhancing the reliability of spatial audio evaluations [61].

In each country, participants were invited to a facility arranged by the local research groups, either a laboratory or listening room where the background noise level would be low enough not to compete with the quietest stimulus of the experiment. After reading the participant information sheet and providing consent, participants would be quickly briefed on the task and trained, then the experimental session would start. The pre-experiment training consisted of an explanation by the researcher about the rationale of the translation project, and a listening trial for the participant with an audio recording that was not included in the set of experimental stimuli and a mock-up soundscape assessment to allow participants to familiarize with the interface. The 27 audio stimuli were then presented in one of five randomized orders to each participant via a laptop connected to an external sound card and open circum-aural headphones. Each stimulus would last 30 s and after listening to it, participants were requested to score each of the eight soundscape descriptors by responding to the question "*To what extent do you think the sound environment you just experienced was…*" using a slider ranging from "not at all" (0) to "extremely" (100). Fig. 4 shows the interface used to collect data by most working groups (for practical reasons some working groups used a slightly different digital interface or also marksheets and pens). The reason for choosing a 0–100 scale instead of the five-point Likert scale recommended in Part 2 is some convenience when it comes to analysing data statistically (e.g., parametric tests, PCA, etc.). Participants were requested to score the scales after they had listened to the full recording and were allowed to play back the recordings as many times as they wished. Each experimental session lasted approximately 30–45 min, and in some countries a small electronic voucher (e.g., 5 GBP, or similar in different currency) was offered to participants completing the experiment as a token of appreciation for their time.

2.3.3. Data preparation

Upon collection of the data by each working group, this data was then shared centrally with the coordinating group at University College London to check and collate. Data was first de-randomized according to the randomization schemes used by the local working groups and labels were assigned identifying each recording. Language and Institution IDs were assigned to identify the source of the data. Each participant was assigned a unique ID by appending their identifying number from the source working group with the Institution ID (e.g. 'UCL_1'). Where demographic information was provided, this was matched with the appropriate participant, then the data from all 18 working groups were compiled into a single spreadsheet. In order to allow data from the eight attributes to be combined across the variations translations, these columns were renamed as PAQ1 through PAQ8 (with PAQ1 = pleasant, PAQ2 = vibrant, and so on counterclockwise around the circumplex; PAQ standing for perceived affective quality). In cases where the local working group trialled different variations on translations for the

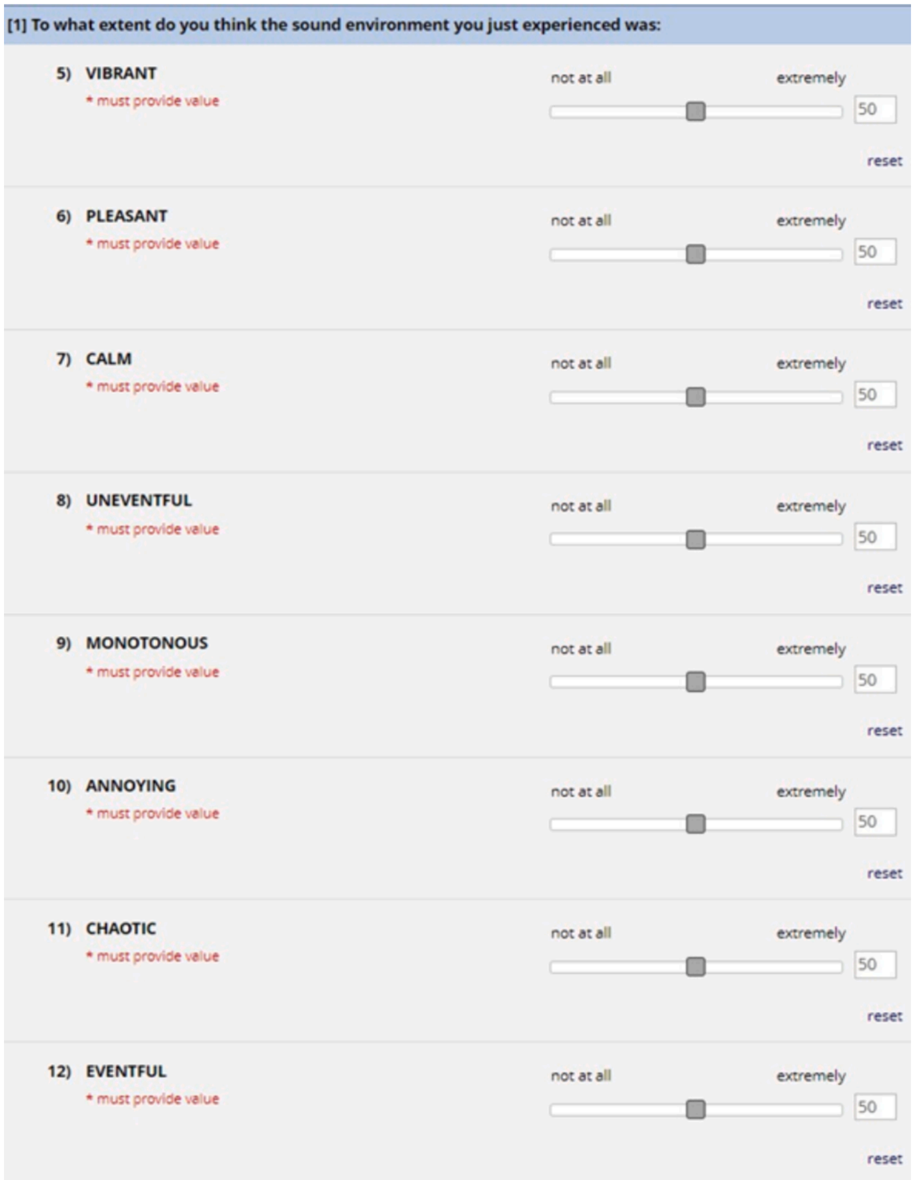

Fig. 4. Example of data collection interface (English version) – Individual responses in most cases were collected and managed using REDCap electronic data capture tools hosted at University College London (UK) [30].

attributes, we referred to the studies published by those teams and included only the translation recommended by the authors. In the case of the German translation [56] which recommended two viable translations, we use Strategy 1 (Maximized circumplexity), as this was identified in their similar analysis to perform best, showing an excellent fit in regard to quasi-circumplexity.

As each institution's dataset was collected and prepared to be added to the overall dataset, several data quality checks were applied. Missing data and responses which still contained entirely neutral responses (i.e., a score of 50 for all questions, which is the starting default value) were excluded. We then calculated the standard deviation of responses for each attribute in the institution data, both across the entire dataset and separately for each recording. This was compared with the standard deviation values observed across the other institutions' datasets. While we did not apply any *a priori* expectations that the mean perceptual responses would be consistent across all languages (i.e., that every recording would be perceived as approximately equally pleasant), we did expect that the deviation of responses would be fairly consistent. This check of the standard deviation was therefore applied to check for transcription errors, repeated participants, etc.

Once a dataset was consolidated and confirmed for a given language, it was added to the overall SATP database, which is available in [61], where data about the sample size and other demographics of each language dataset can also be retrieved. Fig. 5 represents the density plots of all PAQ scores for all 27 stimuli, aggregated for each language [52].

3. Data analysis

The concept of the psychometric circumplex model, first introduced by Guttman [29], revolves around the idea of a circular relationship among variables. It describes specific patterns in correlation matrices in which "as one moves diagonally away from the main diagonal, intercorrelations at first decrease, then increase" [27]. When represented graphically, as the correlation strength increases, the radial distance between the variables around the circumference of a circle decreases; as the correlation strength decreases, the radial distance increases. This relationship means that the circumplex structure represented in Fig. 2, with each of the variables located exactly 45° apart around the

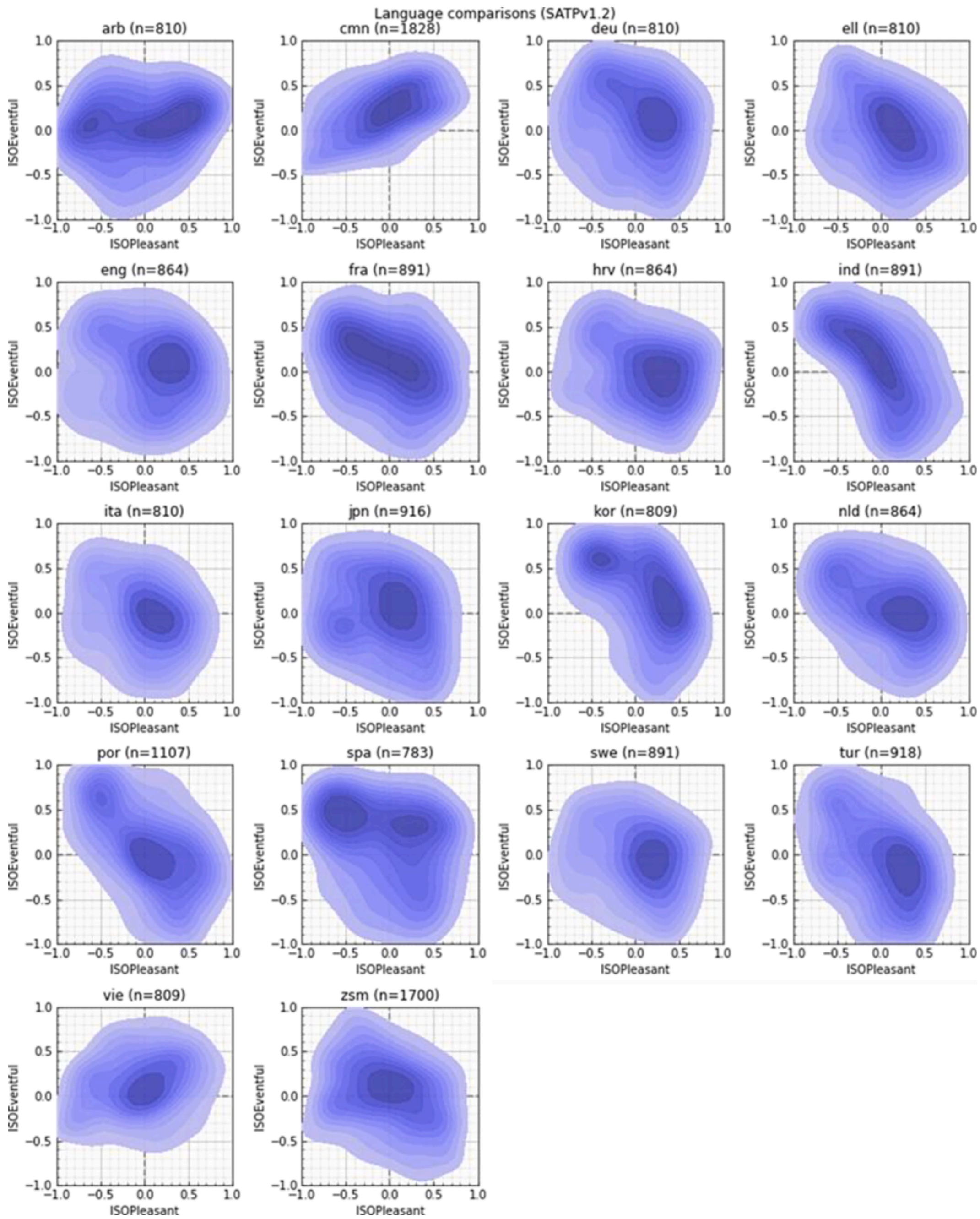

Fig. 5. Density plots representing the all-sample all-stimuli datasets for each language, generated with the `soundscapy` tool [52]; n represents the number of data points for each language dataset.

circumference of the circle, implies a very specific pattern in the correlation matrix of the soundscape attributes.

Browne further expanded on the circumplex model [16] by differentiating between equal spacing and equal communality (or radii) constraints. However, the rigidity of the circumplex can also be relaxed, leading to the concept of a quasi-circumplex. The term "quasi" implies a departure from strict adherence to equal spacing and equal communality (where the variables are all located at an equal radius from the origin), allowing for some flexibility in the arrangement of variables. This flexibility is often necessary in order to accommodate the complexity of psychological constructs, which may not always fit neatly into a rigid circumplex structure. This results in four variations on the circumplex model: the circular model (or unconstrained quasi-circumplex) where the variables are loosely arranged in a circular order but do not have a consistent spacing or radius; the equal-spacing quasi- circumplex where the factors are equally spaced around a circle but may have varying radii; the equal-communality quasi-circumplex where the variables maintain a consistent radius but may be locating at varying angles; and the strict circumplex described above. These models and their implications are further discussed in [66] and in the Supplementary Material [51].

Several studies (within the SATP network, or prior to it) have used a Principal Component Analysis (PCA) on datasets in different languages as a "validation" of the English version of the SCM (e.g., [62]). However, Confirmatory Factor Analysis may be a better first approach to confirm the theoretical structure. Tarlao et al. [74] were the first to use a structural equation model (SEM) to investigate the factor loadings and circumplex structure of soundscape factors. It is worth noting that the models in both [11,17] were found from principal components analysis (PCA), which is itself a type of Exploratory Factor Analysis (EFA). An EFA, crucially, seeks to identify possible underlying variables when an *a priori* hypothesis of the underlying constructs has not yet been established. An EFA, however, is not capable of testing whether the hypothesized factors are consistent with the measurements, and a Confirmatory Factor Analysis (CFA) would be typically required in this case [12,82]. To the best of the authors' knowledge [72,74,43–45], are possibly the only authors to have investigated any of the SCM variants using a CFA.

We therefore apply a CFA methodology developed specifically for the analysis of circumplex models. Browne's circular stochastic process model [16] enables researchers to test whether the underlying structure of a sample correlation matrix conforms to a circumplex pattern and allows testing against the quasi-circumplex model variations. In addition, Browne's model returns estimates for the angle and communality for each variable, giving their locations on a circle.

We propose a four-step procedure for testing translations of quasi-circumplex models based on the work by Rogoza et al. [66]. This extended procedure is tailored to the testing of multiple translations of the same circumplex instrument. A detailed discussion of the development of this procedure is given in the Supplementary Material, and the associated analysis code is hosted at: https://osf.io/jvna2/. As noted in [56], two approaches can be taken when attempting to translate the circumplex attributes. The first approach would attempt to achieve direct concurrence with the original instrument, where each attribute is directly correlated with the corresponding scale from English. If the circumplex structure were identical between the two languages then this approach would allow for the most direct comparison between the two languages. However, if the circumplex structure is not identical, then this approach would lead to a loss of information. In addition, this approach essentially locks in the English circumplex structure as the reference, precluding any updates or changes to the English attributes and carrying over potential weaknesses in the English structure to the other languages.

The second approach would instead attempt to achieve the same circumplex structure in the new language as in the original language or, as we will do here, to adjust for the differences in the circumplex structure between the languages. Given that at minimum a quasi-circumplex structure can be confirmed, then the deviations in either the angles or communalities from the ideal circumplex structure can be measured and accounted for. In theory, once these deviations are accounted for, then all of the languages will sit within the same global circumplex space and can be directly compared. Our procedure is therefore designed to test for the quasi-circumplex structure, derive any necessary adjustments to the structure for a given language, and test the application of this adjustment.

Step 1: Confirm Circular Ordering: In line with the procedure taken in [28] and previously employed for the SCM by Lam et al. [43–45] the first step involves confirming the circular ordering of circumplex scales [75]. The randomized test of hypothesized order relations (RTHOR) compares obtained order relations for scales against their hypothesized order in a circular model. This step is intended to initially confirm that the unconstrained ordering of the variables is retained during the translation process. The correspondence index (CI) ($p < 0.05$, $CI > 0.7$) [33] is employed as a descriptive measure, with thresholds indicating a good fit [28].

Step 2: Confirm Quasi-Circumplex Structure: We confirm the structure of the circumplex instrument by applying Browne's [16] circular stochastic process model with a Fourier series correlation function. This model represents a non-standard Structural Equation Model (SEM) specifically tailored to testing circumplex structures, which allows a researcher to examine the extent to which the underlying structure of a sample correlation matrix conforms to a circumplex pattern. The four model variations (unconstrained circular, equal spacing quasi-circumplex, equal-communality circumplex, and strict circumplex with equal spacing and equal communality) can each be investigated using this model. For the unconstrained and quasi-circumplex models, Browne's model allows for the estimation of the angles and communalities of the circumplex scales. From these results for the equal-communality model, we can derive the adjusted angles for each translation (representing how the particular arrangements of attributes around the circumplex for that translation), which can be used in the next steps of the analysis.

This analysis is implemented in the CircE package [27] in R (R Stats, 2018). The analysis is applied to each translation separately, testing each of the four model variations, and CircE provides a suite of SEM fit indices. We then assess the model fit against the following set of fit indices: Comparative Fit Index ($CFI > 0.92$) [32], Goodness of Fit Index ($GFI > 0.90$) [66], and Standardized Root Mean Square Residual ($SRMR < 0.08$) [32]. Once each of the model variations are assessed against the above fit indices, we can determine whether that model variation is a good fit for the data. If the strict circumplex model meets the fit thresholds across the translations tested, then the procedure can be continued and no adjustment will be needed. If, however, the structure of some or all of the translations are found to have a quasi-circumplex structure, then adjustments will need to be derived and applied to ensure cross-comparability between the translated instruments. If the model variation for the equal-communality model (where the angles are allowed to vary) is a good fit for the data, then we can use the derived angles from CircE as adjustments to the circumplex structure.

Step 3: Locate External Variables Within Circumplex: Once the general circumplex structure is tested, it is possible to investigate the likelihood to locate an external variable (this could be an objective feature such as sound level dB or it could be another perceptual or psychometric variable such as tranquillity) within the empirical circumplex. This involves using the Structural Summary Method (SSM) [84] to examine the likelihood of locating external variables within the empirical circumplex. SSM fits a sinusoidal curve to data points, providing crucial estimations like model fit (R^2), elevation, amplitude, and angular displacement. In the case of the soundscape circumplex and our SATP data, we don't have an external variable with a defined theoretical location within the circumplex – for instance loudness does not have a defined location within the circumplex where it is expected to be located. The SSM analysis for Steps 3 and 4 was performed using the circumplex package v0.1.4 [50].

Step 4: Accurately Locate Circumplex Items: Inspired by [83], the final step proposes using the circumplex structure of the survey itself as theoretical expectation. Yik et al. propose that one circumplex can be located within another by calculating the SSM correlation between each of the scales of the reference circumplex and the test circumplex. In this way, each scale of the reference circumplex can be located within the test circumplex, and we can test (1) whether the SSM fit is sufficient for each scale (i.e. step 3) and (2) whether these empirical locations meet our expectations. The process to do this is as follows: (1) For both the reference and test circumplex, calculate the mean value of each scale for each recording; (2) Calculate the SSM correlation between each scale of the reference circumplex and the test circumplex, in our case using the corrected angles; and (3) Test the congruence between the empirical locations and theoretical expectations using the Procrustes congruence test [66]. Further discussion on the process of assessing the Procustes congruence, which differs slightly from [66], can be found in Supplementary Material (A), and its Sections 2.4.1 and 2.4.2.

This four-step procedure aims to validate circumplex instruments across multiple translations, offering a robust framework for comparing data from different languages. The adaptations made to Rogoza and colleagues' original procedure [66] enhance its applicability to diverse linguistic contexts. Once the four-step procedure is completed for each translation, a set of adjusted angles and the fit indices scores are determined. Based on the fit indices and which steps of the procedure a translation can pass, a level of confidence in the consistency of the structure of the translated quasi-circumplex instrument is assigned. We therefore have a high confidence that those translated instruments which are confirmed to have a quasi-circumplex structure and thus pass all four steps using the adjusted angles will be able to accurately and consistently locate a soundscape description within their respective circumplex. By applying the adjusted angles when calculating the circumplex location, it is expected that these derived ISOPleasant, ISOEventful coordinates can be compared across the translations without requiring further correction.

4. Results

This section presents some qualitative results of the pilot that was carried out for the stimuli selection in Section 2.3.1, as well as the outcomes of the statistical analysis, reported in Section 3, performed on the actual datasets generated via the listening experiment, described in Section 2.3.2.

4.1. Recurring themes characterizing the soundscape descriptors

The pilot experiment and subsequent de-briefing session with its participants provided some useful insights into the general understanding of the eight descriptors/dimensions of the soundscape circumplex model, which future studies can take into account when expanding the set of stimuli for similar investigations.

Pleasant soundscapes: people tend to understand pleasant soundscapes as relatively backgrounded acoustic environments, with a mix of natural and human sources and water features, with a relatively high predictability, no sudden changes, leaning towards calmness, but not necessarily that "slow" and "quiet". **Calm** soundscapes: these should have distant low-level natural source(s), and some light breeze, a relatively small number of them, balanced frequency range, slow temporal variations, slow and mild onsets and offsets so that new sources or disappearing ones are not making a big difference; city hum is still acceptable, provided that it is very low level and distant. **Vibrant** soundscapes: these are composed of human sounds, people talking loudly (but happily, not screaming), potentially children sounds, some music, a market- or bazar-like context; such acoustic environments may be found in public semi-enclosed spaces, so vibrant soundscapes may well refer to a perceived feeling of reverberation (i.e., actually physically reverberant space). **Annoying** soundscapes: these are often characterized by a single or multiple clearly distinguishable annoying noise sources, asynchronous with each other, high temporal variation (of frequency and level), or single sources breaking the silence (sudden and sharp onsets and offsets); rougher sound sources are more annoying (examples: motorbikes more than car, machinery noise, etc.). **Monotonous** soundscapes: typically, low-medium level of fan-like kind of sound (s); this could either be stationary/constant or repetitive with short intervals of silence (e.g., low-level distant frequent cars passing-by, or machine-humming, regardless of level but very constant); no single sound events against a background (low signal-to-noise ratio). **Chaotic** soundscapes: usually found on roads (honking, pass-by, sirens) and air traffic, other sounds of construction sites, many sources of various types, asynchronous with each other, also coming from different directions, quite loud, no pattern; highly disorganized in terms of their occurrence, type, frequency contents, etc.; one of their main features is being unpredictable. **Eventful** soundscapes: the best way people seem to be able to describe eventful is something like a mix of both chaotic and vibrant; chaotic in a way that unpleasant sound sources might be present, but they have higher level of predictability and are not so loud, and vibrant in a way that human sounds are present too, but "less joyful" (and no music at all). **Uneventful** soundscapes: these are the ones that people tended to identify with "silence" or more accurately, as a "lack of clearly identifiable sources", an acoustic environment conveying a feeling of emptiness and vacuum; if sources are present, they should be non-recognizable and very low level (i.e., "*I hear something, but I cannot really tell what that is…*").

4.2. Performance of the different translations

In this section, the performance of the translated soundscape descriptors across various languages is assessed, focusing on the steps involved in the validation process. Initially, the circular ordering of scales is examined, followed by the evaluation of fit indices to ensure the quasi-circumplex structure. Subsequently, the Structural Summary Method (SSM) is employed to confirm the scales' positions within each language's circumplex space. Finally, the impact of adjusted angles on the accuracy of circumplex scale locations is explored.

Step 1: Confirm Circular Ordering: The circular ordering of scales, a crucial element in maintaining the quasi-circumplex structure, was not confirmed in the translations for Malay (zsm) and Vietnamese (vie); i.e., the order of some scale was not in the normally expected arrangement of the attributes around the circumplex space. Consequently, these languages are excluded from further analysis in the subsequent steps.

Step 2: Confirm Quasi-Circumplex Structure: The second step dealt with the fit indices evaluation. Among the remaining 16 languages, all but four – French (fra), Korean (kor) Portuguese (por) and Japanese (jpn) – satisfactorily pass the fit indices thresholds. The comprehensive fit indices scores, including Comparative Fit Index (CFI), Goodness of Fit Index (GFI), and Standardized Root Mean Residual (SRMR), demonstrate the performance of the translations in maintaining the quasi-circumplex structure. This is reported in Table 2.

Step 3: Locate External Variables Within Circumplex: Moving forward with the 12 translations that meet the fit indices criteria, all of them demonstrate high SSM model fits. Each attribute within every translation consistently exceeds an R^2 value of 0.89, emphasizing the robustness of the translated quasi-circumplex instruments. Therefore, all of the 12 translations are carried on to the fourth and final step.

Step 4: Accurately Locate Circumplex Items: When applying adjusted angles to the circumplex scale locations, congruence with theoretical positions is notably enhanced, as shown in Table 3. Particularly, the application of adjusted angles addresses potential discrepancies; for instance, the unadjusted angles for the Chinese (cmn) translation fall below the fit threshold, yet with adjusted angles, a substantial improvement is observed (see Fig. 6). This underscores the significance of adjusted angles in ensuring accurate and consistent circumplex scale locations across translations.

In summary, the performance evaluation indicates that most

Table 2
Performance of the SATP languages translations in the first two steps of the validation process. Scores for the equal-spacing quasi-circumplex models are reported. The model fit for the equal-communalities model is considered satisfactory (and therefore carried on to Step 3) for: CI > 0.7; and CFI > 0.92; and GFI > 0.90; and SRMR < 0.08.

Language	Participants (n)	Step 1	Step 2			Carried on to Step 3
		CI	CFI	GFI	SRMR	
arb	30	0.889	0.971	0.969	0.044	Yes
cmn	68	0.819	0.960	0.954	0.044	Yes
deu	30	0.972	0.943	0.915	0.059	Yes
ell	30	0.917	0.928	0.934	0.079	Yes
eng	32	0.986	0.934	0.907	0.052	Yes
fra	33	0.931	0.919	0.913	0.098	No
hrv	32	0.861	0.949	0.926	0.065	Yes
ind	33	0.771	0.933	0.923	0.078	Yes
ita	30	0.910	0.944	0.932	0.069	Yes
jpn	34	0.833	0.892	0.896	0.087	No
kor	30	0.819	0.952	0.941	0.084	No
nld	32	0.812	0.967	0.943	0.056	Yes
por	70	0.764	0.925	0.917	0.092	No
spa	61	0.965	0.920	0.910	0.063	Yes
swe	35	0.972	0.944	0.924	0.053	Yes
tur	34	0.812	0.927	0.915	0.079	Yes
vie	30	0.694	–	–	–	–
zsm	63	0.674	–	–	–	–

Table 3
Correspondence between the general circumplex and the language-specific circumplex.

Language (ISO 639-3:2007)	Equal Angles Procrustes	Adjusted Angles Procrustes
arb	0.980	0.984
cmn	0.879	0.990
deu	0.976	0.984
ell	0.973	0.980
eng	0.984	0.984
hrv	0.983	0.986
ind	0.938	0.983
ita	0.976	0.975
nld	0.942	0.979
spa	0.969	0.980
swe	0.974	0.978
tur	0.925	0.981

translations successfully maintain the quasi-circumplex structure, ensuring the reliability and cross-cultural validity of the soundscape descriptors. Based on which steps the different languages could make it through, we proposed a three- tier level of confidence in the translation, after the adjusted angles are applied; namely: "Low" (i.e., languages not passing Step 1), "Medium" (i.e., languages not passing Step 2), and "High" (i.e., languages carried on to and passing Steps 3 and 4). Therefore, adjusted angles, as reported in Table 4, emerge as a critical factor in refining the accuracy of circumplex scale locations, emphasizing their importance in the context of cross-cultural soundscape research.

5. Discussion

While exploratory in nature, to the best of the authors' knowledge, the SATP initiative is the first systematic attempt to harmonize the translations of soundscape assessment attributes proposed in the ISO/TS 12913-2:2018 in several languages at once. One of the main theoretical challenges the SATP partners encountered, was the possibility of translating each of the eight attributes/descriptors of the ISO technical specifications via a single word in each language. This proved particularly difficult when considering the transition from alphabetic to logographic linguistic systems; thus, more terms were often necessary to retain the meaning, and are accordingly recommended for use as per the ISO framework. Almost every group opted to avoid a one-word translation of the English attributes and often aimed for 2–3 terms that would together convey more clearly the meaning of the perceptual construct of interest. This approach has been previously discussed in soundscape studies and is generally accepted as good practice [77,2].

It is worth highlighting that the soundscape circumplex model from which the eight attributes are derived was originally developed in Swedish and only then translated into English [10]. In particular, in the study by Axelsson and colleagues [11] that eventually led to the soundscape circumplex model, which is mostly in use nowadays, 116 attributes were subjected to a principal component analysis (PCA), which would then result in the pleasantness-eventfulness space. In that study, all 116 attributes were originally used in Swedish, with fluency in Swedish as a requirement for the participants to join the listening experiment. Axelsson and colleagues translated them into English only for illustrative purposes for publication in the Journal of the Acoustical Society of America [11]. Their translations were guided by dictionaries, and thesauruses for English synonyms, accompanied by discussions within the Swedish research group. The main challenge was that, in many cases, multiple Swedish terms in the original list may correspond to the same (and single) attribute when translated to English. For example, there are several Swedish terms that might have been translated into "pleasant". The Swedish researchers' choices were often guided by the terms that Russell used in his studies on perceived affective quality of places in general [67]. That is, terms that Russell used in his research were considered as established in environmental psychology, and consequently given priority for the soundscape-related translations, and additional English terms would be introduced when running out of options among terms that Russell used. Subsequently, the main discussions in the Swedish research group were about how to name the underlying components discovered. On the "positive" extreme of the principal (horizontal) component "pleasant" emerged clearly as the appropriate attribute, but the "negative" extreme of the same component was less obvious; the Swedish group decided to label it as "annoying" because this term was established in community noise research, as opposed to "unpleasant", as Russell did. The Swedish group also had discussion about the lower-left quadrant of the soundscape circumplex model (i.e., uneventful and annoying). Russell labelled that quadrant as "boring" but this did not fit the Swedish group's empirical results, so it was labelled as "monotonous" (this was despite attempting not to use modal-specific terms). With respect to the English attributes that eventually made it into ISO/TS 12913-2 Method A, their selection by the Working Group 54 was also informed by the results of the Positive Soundscapes Project [17]. Those translations were validated by Axelsson with a study in Sheffield, UK [8], even though they were never actually published in peer-reviewed literature.

For this purpose, it was indeed also desirable to standardize the translation methodology, providing suitable protocols and materials. Since the research community is now using the English translation rather than the original Swedish version to translate the model into other languages, some uncertainty and error are already "cascaded" to any subsequent translation. However, based on the SATP results, the

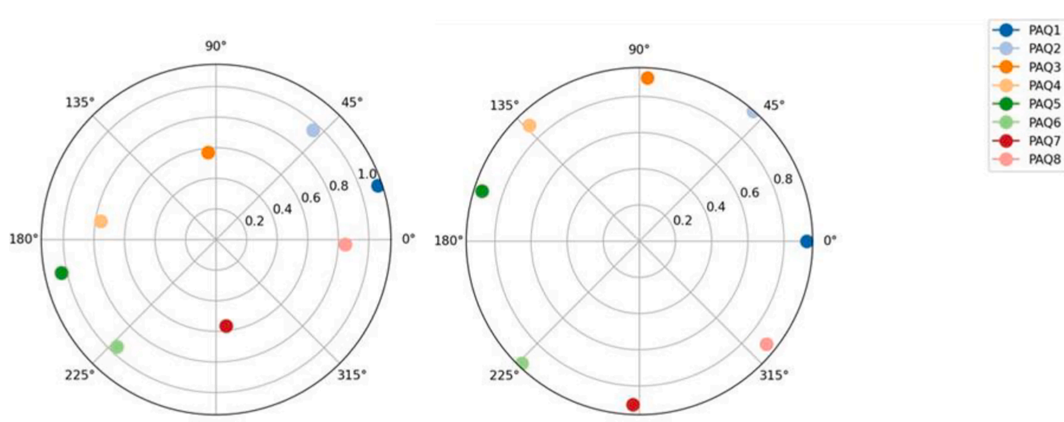

Fig. 6. Unadjusted (left) and adjusted (right) angles for the 8 PAQs on the Chinese (cmn) circumplex, as an example.

Table 4
Summary of the SATP translations of the eight PAQs in languages other than English (transliteration in Latin characters reported in parentheses, when applicable), with adjusted angles to be implemented for adjustment, and assigned confidence in the consistency of the structure of the translated quasi-circumplex instrument after adjustment; adjusted angles are reported only for the languages with high confidence after adjustment. The levels of confidence are assigned as follows: "Low" (languages not passing Step 1), "Medium" (languages not passing Step 2), and "High" (languages carried on to and passing Steps 3 and 4)

ISO 639-3:2007 code	Language	PAQ1	PAQ2	PAQ3	PAQ4	PAQ5	PAQ6	PAQ7	PAQ8	Confidence (with adjustment)
ISO 639:eng	English	Pleasant	Vibrant	Eventful	Chaotic	Annoying	Monotonous	Uneventful	Calm	**High**
Adjusted angles		**0°**	**46°**	**94°**	**138°**	**177°**	**231°**	**275°**	**340°**	
ISO 639:arb	Standard Arabic	ممتع / سار (mumtae/ sar)	ديناميكي / محمس/ حيوي (dinamiki / mohamis / hayawi)	نابض بالحياة / حافل بالأحداث (nabid bialhayaa / hafil bial'ahdath)	فوضوي/ صاخب (fudwi/ sakhib)	غير ممتع / غير سار / مزعج (ghir mumtae/ ghir sar/ muzej)	رتيب / ممل (ratib/ momil)	هامد / خالي من الأحداث (hamid/ khali min al'ahdath)	هادئ (hadi)	**High**
Adjusted angles		**0°**	**36°**	**45°**	**135°**	**167°**	**201°**	**242°**	**308°**	
ISO 639:cmn	Chinese (Mandarin)	愉快的 (yúkuài de)	热闹的/ 有活力的 (rènào de/ yǒu huólì de)	引人注意的 / 有故事性的 / 引人遐想的 / 身临其境的 (yǐn rén zhùyì de/ yǒu gùshì xìng de/ yǐn rén xiáxiǎng de/ shēn lín qí jìng de)	喧闹的 / 混乱的 (xuānnào de/ hǔnluàn de)	恼人的 / 烦人的 / 烦躁的 (nǎorén de/ fánrén de/ fánzào de)	枯燥的 / 无趣的 / 单调乏味的 (kūzào de/ wúqù de/ dāndiào fáwèi de)	平淡无奇的 / 难以共鸣的 / 无体验感的 (píngdàn wú qí de/ nányǐ gòngmíng de/ wú tǐyàn gǎn de)	平静的 (píngjìng de)	**High**
Adjusted angles		**0°**	**18°**	**38°**	**154°**	**171°**	**196°**	**217°**	**318°**	
ISO 639:hrv	Croatian	ugodan	uzbudljiv / živahan	sadržajan / pun događaja	kaotičan / uznemirujuć	neugodan	dosadan	besadržajan / prazan	smirujuć	**High**
Adjusted angles		**0°**	**84°**	**93°**	**160°**	**173°**	**243°**	**273°**	**354°**	
ISO 639:nld	Dutch	aangenaam / prettig	levendig / vrolijk	druk / dynamisch	chaotisch / hectisch	onaangenaam / onprettig	saai / eentonig	rustig / statisch	kalm / rustgevend	**High**
Adjusted angles		**0°**	**43°**	**111°**	**125°**	**174°**	**257°**	**307°**	**341°**	
ISO 639:fra	French	agréable / plaisant	stimulant / dynamique	animé / mouvementé	agité / chaotique	gênant / dérangeant	ennuyeux / monotone	inerte / amorphe	calme / tranquille	**Medium**
Adjusted angles		-	-	-	-	-	-	-	-	
ISO 639:deu	German	angenehm	lebendig / abwechslungsreich	ereignisreich / dynamisch	chaotisch / hektisch	störend / lästig	monoton / eintönig	ereignisarm / statisch	ruhig / erholsam	**High**
Adjusted angles		**0°**	**64°**	**97°**	**132°**	**182°**	**254°**	**282°**	**336°**	
ISO 639:ell	Greek	ευχάριστο (efcháristo)	ζωντανό (zontanó)	με πολλά ή / και σημαντικά γεγονότα (me pollá í / kai simantiká gegonóta)	χαοτικό (chaotikó)	ενοχλητικό (enochlitikó)	μονότονο / βαρετό (monótono / varetó)	χωρίς πολλά ή / και σημαντικά γεγονότα (chorís pollá í / kai simantiká gegonóta)	ήρεμο (íremo)	**High**
Adjusted angles		**0°**	**72°**	**86°**	**133°**	**161°**	**233°**	**267°**	**328°**	
ISO 639:ind	Indonesian	menyenangkan	bersemangat	ramai	ribut	mengganggu	menjemukan	sepi	tenang	**High**
Adjusted angles		**0°**	**53°**	**104°**	**123°**	**139°**	**202°**	**284°**	**308°**	
ISO 639:ita	Italian	piacevole / confortevole	vivace / stimolante	dinamico / vario	caotico / confuso	spiacevole / irritante	monotono / noioso	stabile / stazionario	calmo / tranquillo	**High**
Adjusted angles		**0°**	**57°**	**104°**	**142°**	**170°**	**274°**	**285°**	**336°**	
ISO 639:jpn	Japanese	快い (kokoroyoi)	楽しい (tanoshī)	色々なことが起こる (iroirona koto ga okoru)	雑然とした (zatsuzento shita)	うるさい (urusai)	単調な (tanchōna)	何も起こらない (nani mo okoranai)	穏やかな (odayakana)	**Low**
Adjusted angles		-	-	-	-	-	-	-	-	
ISO 639:kor	Korean	유쾌한 / 기분 좋은 (yukwaehan / gibun joh-eun)	활기찬 / 생동한 (hwalgichan / saengdonghan)	활동적인 / 역동적인 (hwaldongjeog-in / yeogdongjeog-in)	혼란스러운 / 혼잡한 (honlanseuleoun / honjabhan)	불쾌한 / 성가신 (bulkwaehan / seong-gasin)	단조로운 / 지루한 (danjoloun / jiluhan)	비활동적인 / 정적인 (bihwaldongjeog- in / jeongjeog-in)	조용한 / 차분한 (joyonghan / chabunhan)	**High**
Adjusted angles		**0°**	**56°**	**90°**	**124°**	**151°**	**251°**	**275°**	**288°**	
ISO 639:zsm	Malay	menyenangkan	rancak	meriah	huru-hara	membingitkan	membosankan	tidak meriah	tenang	**Low**
Adjusted angles		-	-	-	-	-	-	-	-	
ISO 639:por	Portuguese	agradável / prazeroso	animado / vibrante	agitado / movimentado	caótico	irritante / desagradável	monótono / entediante	sem acontecimentos / estático	tranquilo / calmo	**Medium**
Adjusted angles		-	-	-	-	-	-	-	-	
ISO 639:spa	Spanish	agradable / placentero	estimulante / vibrante	con actividad / dinámico	caótico / confuso	desagradable / molesto	monótono / aburrido	sin actividad / estático	calmado / tranquilo	**High**
Adjusted angles		**0°**	**41°**	**103°**	**147°**	**174°**	**238°**	**279°**	**332°**	
ISO 639:swe	Swedish	behagligt / trivsamt / tilltalande	levande / spännande / uttrycksfullt	händelserikt / livligt / aktivt	kaotiskt / rörigt / bullrigt	störande / obehagligt / otrivsamt	enformigt / andefattigt / livlöst	händelselöst / inaktivt / passivt	lugnt / stilla / rogivande	**High**
Adjusted angles		**0°**	**66°**	**87°**	**146°**	**175°**	**249°**	**275°**	**335°**	
ISO 639:tur	Turkish	keyifli	coşkulu	hareketli	karmaşık	rahatsız edici	tekdüze	durağan	sakin	**High**
Adjusted angles		**0°**	**55°**	**97°**	**106°**	**157°**	**254°**	**289°**	**313°**	
ISO 639:vie	Vietnamese	dễ chịu / thoải mái	sống động / náo nhiệt	sôi động / sinh động	hỗn loạn / hỗn độn	khó chịu / phiền toái	đơn điệu / buồn tẻ	tẻ nhạt / nhàm chán	yên bình / tĩnh mịch	**Low**
Adjusted angles		-	-	-	-	-	-	-	-	

English translation essentially confirms the original Swedish attributes.

The circumplex model of affect has been very popular in environmental psychology and indeed in soundscape applications. Even though there is significant evidence backing it up, the techniques commonly employed to assess the model come with notable constraints [65]. Therefore, the proposed four-step validation process aimed to overcome some of these shortcomings.

5.1. Overall performance of the translations

The assessment of the translated soundscape descriptrs across various languages, via the four-step procedure described before, reveals nuanced differences in their performance, emphasizing the significance of adjusted angles in ensuring the reliability of the quasi-circumplex structure. Notably, the English descriptors, serving as a reference, demonstrate precise allocations with specific adjusted angles for each PAQ. Among the languages assessed, those achieving “High” confidence after the application of adjusted angles include Arabic, Chinese (Mandarin), Croatian, Dutch, English, German, Greek, Indonesian, Italian, Spanish, Swedish, and Turkish. These languages consistently maintain the quasi-circumplex structure, suggesting a robust cross-cultural validity. Conversely, French, Japanese, Korean, Malay, Portuguese, and Vietnamese exhibit either “Medium” or “Low” confidence levels, as they fail to meet the criteria for the first two steps of the validation methodology, and therefore applying adjusted angles is either not feasible at all, or not recommended. Both the French and Japanese SATP working groups had considered different sets of attributes for some of the items, so it is possible that different versions of the translated protocols may yield higher level of confidence after angles adjustment [59,71].

The cross-cultural nature of the SATP initiative introduced unique challenges and opportunities in the translation process, addressing interactions between language and perceptual constructs. Recognizing the diversity in linguistic structures, the project faced the complex task of capturing the nuanced meanings of soundscape attributes across a spectrum of languages. The transition from alphabetic to logographic languages, as observed for instance in the translation of Mandarin Chinese and Japanese, exemplifies the need for flexibility and adaptability in characterizing complex soundscape attributes. The decision by many language working groups to employ 2–3 terms instead of a single-word translation aligns with the nuanced nature of soundscape descriptors, emphasizing the richness and depth of cross-cultural interpretations.

Exploring the reasons behind the success of some translations compared to others can unveil key factors contributing to the accurate representation of soundscape attributes within specific linguistic and cultural contexts. For instance, we didn’t observe any obvious pattern based on the methodological approaches adopted by the working groups for the preliminary translations of Stage 1 – i.e., no particular translation method led to more successful translations, compared to others. Yet, we did observe that failing the four-step validation process was more prevalent in languages not belonging to the Indo-European languages family. There is no reason to believe that the translation of the soundscape attributes in languages that didn’t pass one or more of the four steps of the validation process was “inaccurate” *per se*; it merely signals that such languages may not easily conform to the pre-imposed circumplex structure of the pleasant-eventful space derived from the ISO framework, and therefore the original experimental design (and consequent principal component analysis), as per the study by Axelsson and colleagues, might need to be replicated for those particular languages. It is also possible that this effect is due to cultural differences in perceptions of soundscapes [5,1], where regardless of the language or attributes used, cultural differences would result in different principal components or different structures being revealed. Further replications of Axelsson and Stage 2 listening experiments with bilingual participants would help elucidate these differences. Additionally, even validated languages may be considered for replicating the original Axelsson’s experiment.

Overall, one important aspect that is emerging from the SATP results is that English shouldn’t necessarily be taken as the reference language to initiate new preliminary translations according to Stage 1 (nor for comparative analysis of the listening experiments of Stage 2). A possible alternative on how to approach this task for “new” languages could be starting from a “proximity” language to identify candidate soundscape attributes, which would be in line with linguistic theories looking at languages/dialects as a regional continuum of spoken tongues – see for instance [19] or [31]. To some extent, even though it was not explicitly reported as a formalized method in Table 1, this is what happened in some cases within the soundscape expert panels of Stage 1 for some languages (e.g., Italian-Spanish, or Spanish-Portuguese).

5.2. Applying the adjusted angles

Making use of these adjusted angles in line with either the analysis recommended in [38] or [52] is quite straightforward. The ISO projection equations (A.1 and A.2 from ISO/TS 12913-3:2019) are adapted to

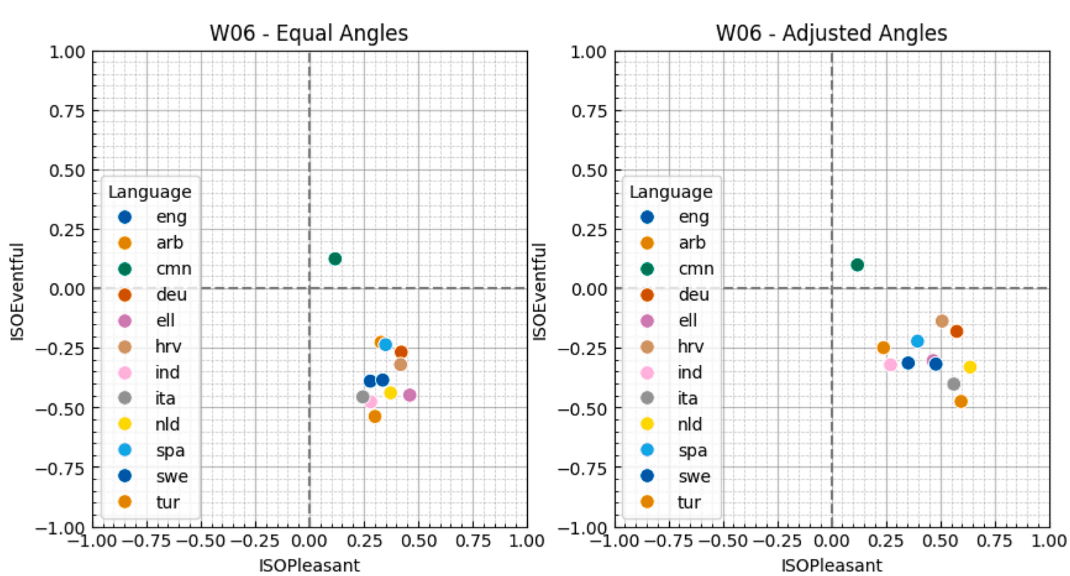

Fig. 7. Mean perception of a given stimulus from the listening experiment (recording W06) plotted on the quasi- circumplex soundscape model for each language with equal (left) and adjusted (right) angles.

these adjusted angles using:

$$P_{ISO} = \frac{1}{\lambda_{Pl}} \sum_{i=1}^{8} \cos\theta_i * \sigma_i \quad (1)$$

$$E_{ISO} = \frac{1}{\lambda_{Ev}} \sum_{i=1}^{8} \sin\theta_i * \sigma_i \quad (2)$$

where i indexes each circumplex scale, θi gives the adjusted angle for the circumplex scale for the appropriate language from Table 3, and σ_i is the value for that scale. The $1/\lambda$ provides a scaling factor (equivalent to the $1/(4 + \sqrt{32})$ from ISO/TS 12913-3:2019) to bring the range of P_{ISO}, E_{ISO} values to $[-1, +1]$:

$$\lambda_{Pl} = \frac{\rho}{2} \sum_{i=1}^{8} |\cos\theta_i| \quad (3)$$

where ρ is the range of the possible response values (i.e., 100 for SATP values or $\rho = 5 - 1 = 4$ for the Likert responses used in ISO/TS 12913-3:2019). λ_{Ev} is calculated the same way but using $\sin\theta_i$ as before.

In more SEM-like terms, we are multiplying each scale by its respective loading expressed in terms of its angle around the circumplex, and then summing the results. Some may argue that we should just directly treat this system as an SEM, however by expressing this projection in terms of the angles, we can directly see how this is related to the circumplex and the projected coordinate point, and more easily compare the results with the results from the SSM analysis. In that vein, we would recommend performing the ISOPleasant & ISOEventful calculations via the Structural Summary Method, rather than the projection method. This would provide a more flexible and informative framework for the analysis and allow for the correlation of the scales with external variables, calculation of model fit, and other useful analyses.

To demonstrate this analysis, Fig. 7 shows the mean perception of recording W06 for each language on the circumplex. By making use of the adjusted angles when calculating the circumplex coordinates, in theory we have adjusted for differences in circumplex structure due to differences in the understanding of the translated attributes, and the coordinates can now be directly compared across languages within a common circumplex space. Ideally, after angle corrections have been applied, any residual differences observed among the locations of the stimulus on the circumplex should not depend on translation issues, and could be ascribed to cultural differences or other contextual factors, as it has also been already discussed in literature [5]. For future developments, to further validate the proposed four-step procedure and reliability of the applied angle corrections, it would be desirable to conduct replications of the SATP listening experiment with bilingual participants (or at least highly proficient in two languages) conducting the assessment twice, and comparing the data.

Following the Step 2 results, assessing the circumplex structure of the translation, since none of the languages (including English) exhibit a strict circumplex structure, the equations provided in ISO/TS 12913-3:2019 are unlikely to render valid circumplex coordinates. These equations assume a strict circumplex with 45-degree angles and would therefore result in distorted representations, even more so when comparing data across languages. It is therefore recommended to make use of the adjusted angles provided in Table 3 for future circumplex analysis.

5.3. Limitations

The SATP framework, while contributing valuable insights into cross-cultural soundscape research, is subject to certain limitations that merit consideration. First, the reliance on the English version of the ISO as a reference point may raise questions about its original adequacy. Examination of fit indices for the English descriptors suggests room for improvement, necessitating a critical re-evaluation of the English ISO protocol to enhance its performance.

Additionally, the selection of stimuli, all sourced in London, prompts a discussion about the generalizability of findings. The assumption that London serves as a representative soundscape for “global” sound environments may warrant further consideration, as different urban soundscapes could influence perceptions. It is important to ensure a comprehensive range of auditory stimuli that encapsulate the full spectrum of relevant soundscape dimensions. Achieving the absolute largest possible range can be challenging due to practical constraints. The selection of stimuli involves a delicate balance between diversity and feasibility, considering factors such as resource constraints, experimental design, and participant engagement. In Fig. 3, the variation within the chosen stimuli set is described, emphasizing the attempt to capture a representative spectrum. However, the pursuit of the broadest range is an ongoing endeavour, and future studies could explore additional stimuli to further enhance the comprehensiveness of the soundscape descriptors.

On the stimuli aspect, an additional consideration pertains to the limitations associated with the choice of recording equipment employed in this study. While some companies offer high-tech audio equipment specifically designed for binaural measurements, questions arise about its appropriateness for binaural recordings. This brings attention to a broader concern within soundscape research, where the prevalent use of binaural technology in recording may not align seamlessly with its intended measurement purposes. Although the nuanced relationship between recording and measurement equipment deserves dedicated exploration, it is essential to acknowledge the potential impact on our study’s outcomes. The choice of recording equipment introduces a layer of complexity, and while every effort was made to use suitable technology, the broader soundscape research community should consider the implications of such methodological choices.

The study’s sample selection, predominantly composed of a convenience sample with a potential skew toward a younger population, raises concerns about the generalizability of the findings to broader demographic groups, but other practical constraints in performing so many listening experiments in different countries had to be weighted in.

Furthermore, while the ISO model provides a standardized framework, its universal applicability might be subject to variation across cultures. The decision not to replicate the circumplex model of affect experiment for each language could be viewed as a limitation. This alternative approach could generate distinct circumplex spaces for each language, potentially offering a deeper understanding of cultural nuances. However, such an approach was deemed impractical within the scope of the SATP project due to resource constraints. The study aimed to provide a cross-comparable framework for soundscape descriptors, ensuring consistency across languages while acknowledging the limitations associated with this methodological choice.

Finally, an important consideration relates to the methodological constraints associated with the proposed “adjusted angle” procedure. The estimation of adjusted angles in this study is based on relatively small samples, typically less than 50 individuals for each language. In Structural Equation Modelling (SEM) terms, these angles represent rough sample estimates with large confidence intervals due to potential sampling errors, which are common in small samples. Given that our study involves within-person repeated measures, the standard error for the estimates should ideally be based on the number of statistically independent clusters (individuals) rather than the total number of observations (measures). To enhance the reliability of the estimated angle values across different countries, we acknowledge the importance of future research incorporating cross-validation with new samples of respondents from each country.

6. Conclusions

The evaluation of translations performed within the SATP initiative demonstrates the successful preservation of the quasi-circumplex structure in most languages, ensuring the reliability and cross-cultural validity of soundscape descriptors. The introduction of a three-tier confidence level based on adjusted angles highlights the critical role these angles play in refining the accuracy of circumplex scale locations, emphasizing their significance in cross-cultural soundscape research. While English served as an (arbitrary) reference, languages like Arabic, Chinese (Mandarin), Croatian, Dutch, German, Greek, Indonesian, Italian, Spanish, Swedish, and Turkish exhibit a "High" confidence level, showcasing consistent maintenance of the quasi-circumplex structure. Conversely, French, Japanese, Korean, Malay, Portuguese, and Vietnamese present varying confidence levels, reflecting challenges in the preliminary translations.

The SATP initiative constitutes the first systematic attempt to harmonize soundscape data collection protocols in several different languages at once. Considering their native speakers, the 18 languages analysed in this first phase of the SATP project would already cover a considerable proportion of the global population; examples of languages that could help increase this quota are: Hindi, Russian, etc.; therefore, the SATP network would welcome collaborators in corresponding regions. The outcomes of the SATP will hopefully support a widespread adoption of validated soundscape descriptors, both in academia and practice. Successfully mapping language (as a human skill) onto senses will depend on culture and society – all senses are different and what happens for sound and hearing may not necessarily apply to other sensory modalities, so more research is needed in this area; as Prof. Asifa Majid clearly put it: "*This is* [...] *why a collaborative endeavour with expert field linguists is necessary* [...]*: it optimizes both standardization for language comparison (*i.e.*, making sure languages are coded in equivalent ways), while doing justice to each language's particulars without carelessly glossing over critical differences*" [49].

The SATP initiative contributes to the broader discourse on the universality of soundscape perception. The varying degrees of confidence across languages achieved via the proposed validation methodology prompt reflections on the influence of cultural backgrounds, linguistic structures and sensory perceptions on the interpretation of acoustic environments. This insight is instrumental not only in refining the translation process but also in advancing our understanding of how individuals from diverse linguistic and cultural backgrounds perceive and evaluate the sound environments around them.

7. Data and code availability

Data supporting this study are openly available as the SATP Dataset (v1.3) on Zenodo at: https://zenodo.org/records/10159673/ [61]. Code for data cleaning and analysis, as well as the Supplementary material, is available from OSF at: https://osf.io/jvna2/ [51].

CRediT authorship contribution statement

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Guest editors of the special issue to which the paper is being submitted: FA; AM; TO; JK; AA. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.apacoust.2024.110109.

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