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Acoustics — Soundscape —

Part 3:
Data analysis

Acoustique — Paysage sonore —

Partie 3: Analyse de données

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Foreword

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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise.*

A list of all parts in the ISO 12913 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 12913 series on soundscape was developed in order to enable a broad international consensus and to provide a foundation for communication across disciplines and professions with an interest in soundscape. ISO 12913-1 provides the definition of and a conceptual framework for the term 'soundscape'. ISO/TS 12913-2 provides requirements and supporting information on data collection and reporting for soundscape studies, investigations and applications. This document provides guidance on how to analyse data collected in agreement with ISO/TS 12913-2.

Acoustics — Soundscape —

Part 3: **Data analysis**

1 Scope

This document provides requirements and supporting information on analysis of data collected in-situ through methods as specified in ISO/TS 12913-2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12913-1, *Acoustics — Soundscape — Part 1: Definition and conceptual framework*

ISO/TS 12913-2:2018, *Acoustics — Soundscape — Part 2: Data collection and reporting requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12913-1 and ISO/TS 12913-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
confounder
factor influencing the collected responses that is not controlled or systematically considered

EXAMPLE Sequential effect, certain scaling effects like the range effect, or demand characteristics.

4 General

As mentioned in the Introduction of ISO/TS 12913-2:2018, "*The concept of soundscape was adopted to provide a holistic approach to the acoustic environment, beyond noise, and its effect on the quality of life. Soundscape investigations intend to assess all sounds perceived in an environment in all its complexity. To do this, soundscape studies use a variety of data collection methods related to human perception, the acoustic environment and the context. Importantly, the study of soundscape relies primarily upon human perception, and only then turns to physical measurement.*" Data collection is based on this focus and requires a respective analysis (see References [1],[2]).

For the analysis of qualitative and quantitative data through methods specified in ISO/TS 12913-2, methods and tools shall be applied as provided in this document. Given the diversity of the data collected (qualitative and quantitative), corresponding analysis methods could take precedence depending on the needs of the project or the research question, and should be integrated for a holistic understanding of the soundscape. In general, descriptive statistics are used to describe and summarize the collected perceptual data, such as measures of central tendency, measures of dispersion (see Reference [3]).

For quantitative measures of dependence, inferential statistics using parametric and non-parametric tests shall be applied depending on the respective data. Fulfilment of model assumptions (e.g. normality distribution) shall be carefully assessed, especially in the case of small numbers of participants. If needed, appropriate remedial measures shall be applied. However, as soundscape investigations are intended to be "holistic in covering all auditory sensations as well as all other context variables such as visual stimuli and personal expectations" [ISO/TS 12913-2], the use of statistical analysis methods (e.g. statistical hypothesis testing) is recommended, but may be less important in case of qualitative or explorative methods. For qualitative data, a variety of approaches are available to systematically analyse qualitative data using some kind of step by step coding principles to generalize the observations. In addition, soundwalks are a method for bringing diverse parties together and provide a common basis for communication.

Because of factors that could influence results, a thorough discussion of potential confounders (i.e. bias effects) shall complete the general data analysis. Confounders are, for example, the sequential effect (a previous site influences the assessments of the following site) (see Reference [4]) certain scaling effects, like the range effect (tendency to use full range of a scale independent from stimuli set) (see Reference [5]), or demand characteristics (cues, like the instruction text or the behaviour of the person leading the soundwalk, that signal the research goal and influence assessments) (see Reference [6]).

NOTE Based on the collected data, it is possible to study classification of sites. For the study of classification of sites, different statistical clustering methods are available, which allows for identifying relevant variables for clustering and determining the similarity or dissimilarity of sites.

5 Analysis of quantitative data

The quantitative data obtained by means of questionnaires in soundscape investigations shall be analysed depending on the respective level of measurement (i.e. nominal, ordinal, interval, and ratio). Any correlation analysis shall be chosen in accordance with the level of measurement of the questionnaire data. Inferential statistical tests regarding the level of significance of differences in evaluation between sites and/or correlations shall be carried out and probability values reported. Any chosen method (e.g. measure of central tendency, measure of dispersion, correlation analysis, and statistical hypothesis testing method) shall be reported. For more information, see Annex A (Method A) and Annex B (Method B).

6 Analysis of qualitative data

Data from qualitative interviews shall be transcribed for reporting and further analysis. The style of transcription, whether clean read, verbatim or strict verbatim transcription, depends on the object of the investigation. For the analysis via the Grounded Theory, the clean read transcription style is sufficient. Violations of common rules for conducting interviews (ethical rules, being suggestive, being prejudiced) shall be reported, and the related data excluded from further analysis.

Qualitative data shall be analysed by scientifically proven systematic text analysis methods, such as the Grounded Theory (see Reference [7]), Qualitative Content Analysis (see Reference [8]) or Social Network Analysis as part of mixed-methods design (see Reference [9]). The process of analysis shall follow these methods and be described. For more information, see Annex C.

In addition to established text analysis methods, other methods to gather and analyse qualitative data (such as behavioral mapping, observational analyses, analysis of social interaction, walking patterns; see examples in References [61], [62], [63], [64]) are available and, if determined appropriate in certain cases, shall be applied.

7 Analysis of binaural data

The binaural recordings are the basis for characterizing the acoustic environment at the receiver as the sound from all sound sources modified by the environment [ISO 12913-1]. The measurements and their psychoacoustic analyses enable the determination of the (basic) auditory sensations evoked by the sound. Any binaural recording shall be equalized for the analysis as specified in ISO/TS 12913-2, approximating a monaural microphone measurement.

After applying the recording equalization, the remaining signals of the left and right channels are separately processed to determine (psycho-)acoustic metrics.

The different metrics used (e.g. $L_{\mathrm{Aeq},T}$, $L_{\mathrm{Ceq},T}$, $L_{\mathrm{AF5},T}$, $L_{\mathrm{AF95},T}$, N_5, N_{95}, N_{rmc}, S_{50}, IACC) shall be linked to the perception and the assessment of the concerned people [ISO/TS 12913-2]. In general, the consideration of acoustic analysis results shall provide a basis for the evaluation and classification of soundscapes by complementing the perceptual data. Moreover, based on the results of the binaural data analysis, given sufficient position data, maps based on psychoacoustic and other data can be determined. For more information, see Annex D.

8 Triangulation

The general idea of triangulation is to achieve a higher level of validity if different methods applied lead to the same result and hierarchical agglomerative clustering complement each other. Triangulation for soundscape measurement is a technique that facilitates validation of data through cross verification of three components: people, context and acoustic environment. In particular, it refers to the application and combination of several research methods in the study of the same phenomenon. For more information, see Annex E.

Annex A
(informative)

Analysis of data related to Method A

A.1 General

Method A, described in C.3.1 of ISO/TS 12913-2:2018, consists of category scales containing five response categories.

A.2 Determination of central tendencies of responses

For the analysis of the collected responses by means of Method A as described in C.3.1 of ISO/TS 12913-2:2018, numbers shall be assigned to the response categories of the category scales as follows.

The five response categories of questionnaire part 1 (see Figures C.2 and C.3 of Annex C of ISO/TS 12913-2:2018) from left ('not at all') to right ('dominates completely') are assigned scale values from 1 to 5.

The five response categories of questionnaire part 2 (see Figure C.4 of Annex C of ISO/TS 12913-2:2018) from left ('strongly agree') to right ('strongly disagree') are assigned scale values from 5 to 1.

The five response categories of questionnaire part 3 (see Figure C.5 of Annex C of ISO/TS 12913-2:2018) from left ('very good') to right ('very bad') are assigned scale values from 5 to 1.

The five response categories of questionnaire part 4 (see Figure C.6 of Annex C of ISO/TS 12913-2:2018) from left ('not at all') to right ('perfectly') are assigned scale values from 1 to 5.

For all category scales, the level of measurement is ordinal, which means that the median values should be reported as the measure of central tendency, and the range as the measure of dispersion. See Table A.1.

Table A.1 — Assigned scale values to rating scales of Method A and statistical measures

Part (see ISO/TS 12913-2)	Scale values to be assigned	Measure of central tendency	Measure of dispersion
1 (sound source identification)	1 ,2 ,3, 4, 5	median	range
2 (perceived affective quality)	5, 4, 3, 2, 1	median	range
3 (assessment of surrounding sound environment)	5, 4, 3, 2, 1	median	range
4 (assessment of the appropriateness)	1, 2, 3, 4, 5	median	range

A.3 Determination of two soundscape dimensions based on perceived affective quality responses

Environmental psychologists have repeatedly demonstrated that when people are asked to freely describe how they perceive environments they respond affectively (see Reference [10]).

These affective responses can be represented in a two-dimensional model where the main dimension is related to how pleasant or unpleasant the environment was judged, and therefore noted as pleasantness. The second dimension is related to the amount of human and other activity (see

Reference [11]). For soundscape, this second dimension is represented by how eventful or uneventful the acoustic environment is perceived to be, and therefore noted as eventfulness (see Reference [12]). An eventful environment is busy with human activity, for example a city centre or other sound events produced by non-human agents, whereas an uneventful environment is completely devoid of human activity, for example a wilderness area or during late evening hours in a residential area without social, commercial and industrial activity. If the previously mentioned pleasantness and eventfulness axes are taken as perpendicular, further labelling corresponding to human judgments can be prescribed to two additional axes rotated 45°on the same plane. At a rotation of 45° from the two main dimensions, are two alternative dimensions representing environments that are chaotic and stressful versus calm, and environments that are monotonous and dull versus vibrant and exciting (see References [12] and [13]). According to the two-dimensional model, vibrant soundscapes are both pleasant and eventful, chaotic soundscapes are both eventful and unpleasant, monotonous soundscape are both unpleasant and uneventful, and finally calm soundscapes are both uneventful and pleasant.

NOTE Based on the tradition in environmental noise research, the term 'annoying' is used instead of 'unpleasant' in the model used in this document. However, some sociological models ascribe a stronger sense of intentionality to sounds that are annoying compared to those that are unpleasant.

The results from part 3 (see A.1) are further processed to derive the values on two dimensions (pleasantness and eventfulness) for each site. Results can be reported in a two-dimensional scatter plot with coordinates for the two dimensions 'pleasantness' and 'eventfulness' (see Figure A.1). The coordinates for 'pleasantness' are plotted on the X-axis, and the coordinates for 'eventfulness' on the Y-axis. Every data point in the scatter plot represents one investigated site.

The coordinate for pleasantness P is calculated by means of Formula (A.1):

$$P=(p-a)+\cos 45°\cdot(ca-ch)+\cos 45°\cdot(v-m) \quad \text{(A.1)}$$

The coordinate for eventfulness E is calculated by means of Formula (A.2):

$$E=(e-u)+\cos 45°\cdot(ch-ca)+\cos 45°\cdot(v-m) \quad \text{(A.2)}$$

where

a is annoying;

ca is calm;

ch is chaotic;

e is eventful;

m is monotonous;

p is pleasant;

u is uneventful;

v is vibrant.

In Formulas (A.1) and (A.2), cos45° is used as a weighting function to adjust for the 45° rotation in the two-dimensional model (Figure A.1). The range of the coordinates that results from the formulas is $\pm\left(4+\sqrt{32}\right)=\pm 9{,}66$. To change the range to ±1, divide the coordinates by $\left(4+\sqrt{32}\right)$.

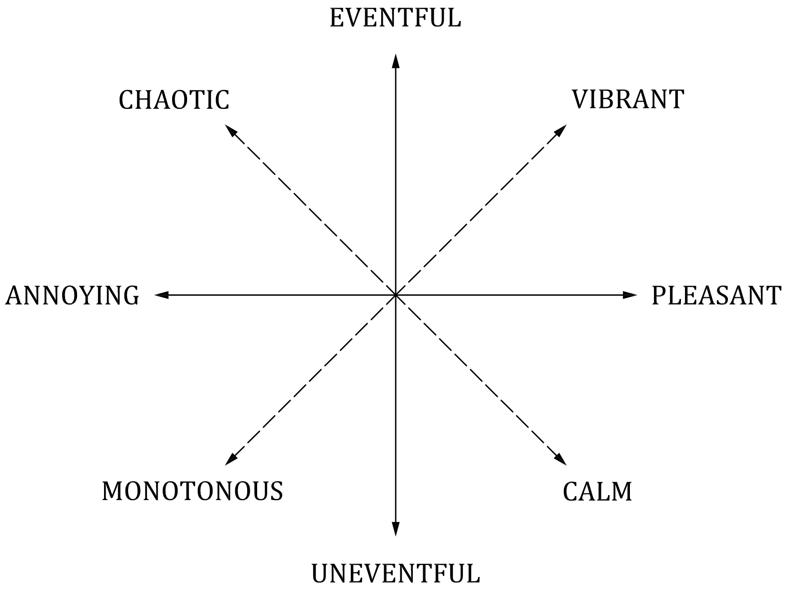

Figure A.1 — Graphical representation of Formulas (A.1) and (A.2)

NOTE The generality of the two-dimensional model is still under examination (see for example Reference [65]) and it is noted that the two-dimensional model requires further validation across languages and sites.

A.4 Link of Method A results to acoustic data

Rating data collected via questionnaires should be linked to the results of the acoustic data analyses in order to identify potential relationships (see References [14] and [15]). These relationships may be investigated by means of statistical analyses, such as correlation analyses, linear regression or ANOVA (see References [47]). The adequate correlation analysis depends on the level of the measurement scale (e.g. ordinal vs. interval). For ordinal data, the Spearman's rank correlation coefficient, r_{spearman}, should be calculated (see Reference [16], [46], and [60]) using Formulas (A.3) and (A.4).

$$r_{\text{spearman}} = 1 - \frac{6 \cdot \sum_{i=1}^{n} d_i^2}{n \cdot \left(n^2 - 1\right)} \quad \text{for untied ranks} \tag{A.3}$$

$$r_{\text{spearman}} = \frac{2 \cdot \left(\frac{n^3 - n}{12}\right) - T - U - \sum_{i=1}^{n} d_i^2}{2 \cdot \sqrt{\left(\frac{n^3 - n}{12} - T\right) \cdot \left(\frac{n^3 - n}{12} - U\right)}} \quad \text{for tied ranks} \tag{A.4}$$

where

d_i is the difference in paired ranks;

n is the number of cases;

$$T = \frac{\sum_{j=1}^{k(x)} \left(t_j^3 - t_j\right)}{12};$$

$$U = \frac{\sum_{j=1}^{k(y)} \left(u_j^3 - u_j\right)}{12};$$

