Soundscape standardization dares the impossible - Case studies valuing current soundscape standards

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ABSTRACT

Recently, the ISO/TS 12913-2, the second part of the ISO soundscape series, was published supporting detailed information on data collection and reporting for studies using the soundscape approach. This part includes guidelines for soundwalks, interviews, acoustical measurements and defines minimum reporting requirements. The conceptual framework and soundscape related definitions are provided by the ISO 12913-1. Finally, part 3 of ISO 12913 is underway addressing aspects and needs of the data analysis. This ISO soundscape series provides a foundation for communication across disciplines and offers guidance on how to perform soundscape investigations, but at the same time the question could be raised whether a concept asking for a holistic, context-sensitive view can be subject to standardization at all. The ISO working group had to address this issue in detail. The paper will reflect on the apparent contrast between identifying a common methodological basis of soundscape studies for standardization and the general holistic requirement of the concept soundscape. Based on case studies, views on the apparent conflict are discussed and the value of soundscape standards harmonizing the data collection process is assessed by considering the outcome of soundscape case studies.

Keywords: Soundscape, environmental noise assessment

1. INTRODUCTION

Investigations using the soundscape approach have a history over decades. Based on literature reviews it is evident that soundscape investigations and research gain considerably in popularity. For example, To et al. showed by a systematic review that soundscape studies were getting popular since 2005, while soundscape studies in Asian countries have become more popular since 2011 [1]. According to To et al. the number of publications per year has increased rapidly and this trend still continues till this day. Unfortunately, a major drawback of this development impeding a stronger impact on community noise and environmental noise assessment applications was apparently that a broad diversity of opinions about the definition of soundscape and the general aims of soundscape studies existed and thus the use of the term 'soundscape' has become idiosyncratic and ambiguous as it is stated in the introduction of the first international soundscape standard [2]. The definition of the term 'soundscape' in an ISO document and providing a conceptual framework, which describes the process of perceiving our acoustic environment, might help to overcome such drawbacks. Researchers can now rely on the provided definitions, which were based on a common agreement by the working group members and experts. Or researchers can apply a deviating definition relating their differing soundscape understanding to the definitions provided in ISO 12913-1 [2]. A standard can provide orientation for followers as well as opponents.

The same applies for the data collection in soundscape investigations. It is broadly acknowledged that soundscape as a perceptual construct of an acoustic environment in context is a multifaceted phenomenon and therefore cannot be measured with a single number [3]. In order to 'measure' perception in context a multitude of methods for data collection were applied focusing on qualitative or quantitative methodologies at almost equal measure. According to Botteldooren et al. interviews or questionnaires are most commonly used in soundscape investigations [3]. In most cases, these tools are applied in a soundwalk, which describes a method that implies a walk in an area with a focus on listening to the acoustic environment [4]. Thus, the ISO/TS 12913-2 aims for harmonizing the collection of data by which relevant information on the key components people, acoustic environment

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and context is obtained, measured and reported and provides detailed information about the most common data collection methods: How to do soundwalks, how to apply questionnaires, how to conduct interviews, how to perform acoustic measurements [4].

2. Aspects of standardization

2.1 Acoustic measurements

Recordings of acoustic environments build the foundation in soundscape research through analyzing and understanding the soundscape in a real or virtual environment [5]. The ISO/TS 12913-2 defines that the acoustic environment must be binaurally recorded. It is noted that binaural acoustic measurements record sound as if a human listener is present in the original sound field maintaining all spatial information. According to the ISO/TS 12913-2 binaural recordings should be the basis for aurally adequate analysis, for the reproduction of acoustic environments (e.g. in laboratory-based listening experiments) or for the purpose of preservation and archiving. Hong et al. reviewed applied spatial audio recording techniques for soundscape design, which were commonly used and concluded that binaural measurement systems as recording technique for soundscape studies is most commonly used due to its simplicity providing a good spatial quality for static listening positions [5]. For interactive spatial audio reproduction in soundscape studies Ambisonics is currently the leading recording technique but lacks international standards so far to rely on.

2.1.1 Experimental study to investigate the need for binaural measurements

Several studies investigating soundscapes still work with monaural recordings for acoustical analysis and playback. According to the current technical specification ISO/TS 12913-2 the use of binaural measurements methods is mandatory maintaining all spatial information. In order to investigate the need for binaural data in soundscape studies an experiment was carried out analyzing perceptual and judgmental differences respectively due to the used recording technique. The studied research question was whether binaural data in comparison to monaural data of the same acoustic environment yield different soundscape related assessments in a laboratory context?

Method

A with-subject design of experiment was carried out, where the participants received an instruction with incomplete information about the main goal of the study.

Subjects

16 subjects (12 male, 4 female) with the average age of 25.9 (standard deviation ±2.9) took part in the experiment. All participants reported normal hearing. In agreement with ethical procedures, written consent was obtained from all of the participants.

Apparatus

All sounds were presented via a programmable equalizer (labP2) applying automatically the corresponding equalization for playback of binaural signals and headphones (HD 650). The playback system was calibrated and equalized. Instruction texts and interview questions were presented on computer screens. All assessments were collected via touchscreen.

Stimuli

Recordings of environmental noises recorded in different cities (Berlin, Düsseldorf, Osaka, London, Sheffield) were presented. The sounds were simultaneously recorded with a calibrated monaural microphone (M 360 ICP microphone ¼“, Microtech Gefell) and a calibrated binaural headset (SQobold in combination with BHS II, HEAD acoustics) at the same location. All sound samples were edited to duration of 30 s. Figure 1 shows the spectra of the two recordings of one location (Osaka Kansai, Japan). Although the spectra show similarities, as expected they are far from being identical. Due to the equalization of a binaural recording to have signals for the acoustical analysis available which are fairly compatible to single microphone measurements, the determined sound pressure level or loudness values are comparable (monaural recording: L_{Aeq}: 68.7 dB(A), loudness: 27 sone; binaural recording: L_{Aeq_left}: 69.8 dB(A), L_{Aeq_right}: 69.2 dB(A), $loudness_{left}$: 26.9 sone, $loudness_{right}$: 26.0 sone according to ISO 532-1 [6]).

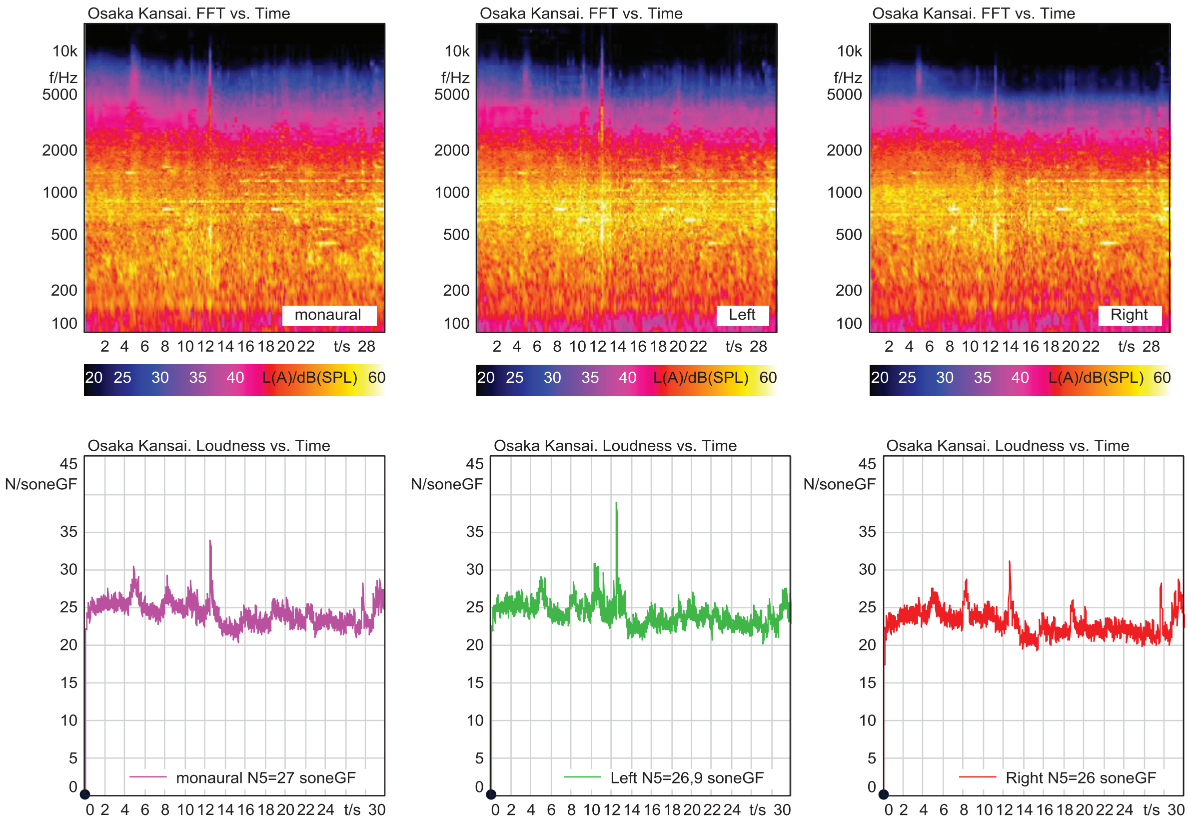


Figure 1 – Environmental noise recordings of Osaka Kansai (left: monaural recording; right: binaural recording (left and right channel)). Top: FFT (A-weighted) vs. time; bottom: Loudness according to ISO 532-1 vs. time

Experimental procedure

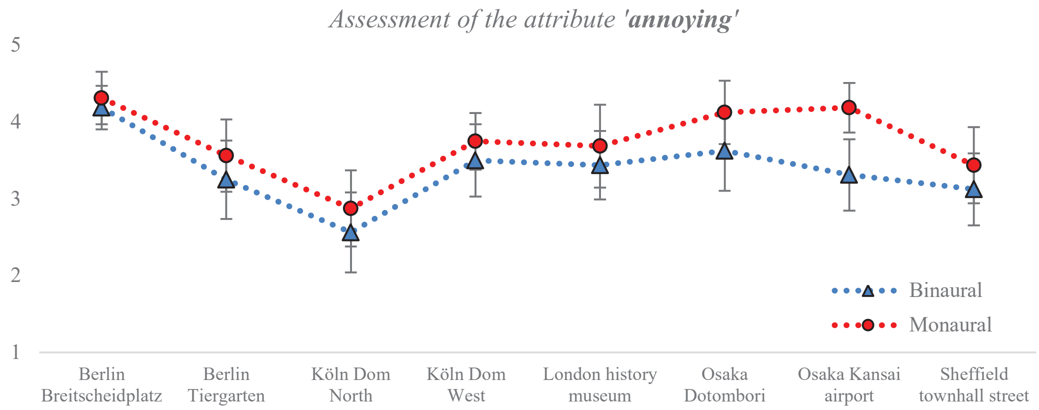
The participants were requested to assess environmental noise stimuli on a semantic differential consisting of eight 5-point category scales. The participants had to assess to what extent they agree or disagree that the presented sound is perceived as pleasant, chaotic, vibrant, uneventful, calm, annoying, eventful, and monotonous. The instruction and attributes were given in English in accordance to the ISO/TS 12913-2. After a sound was terminated, the participants assessed their overall impressions regarding the different attributes. To introduce the range of sounds, several sounds were presented first from the set of stimuli without requesting any assessments. After the demonstration of several sounds, a training sequence took place, where the participants familiarized with the evaluation tasks. They were informed that the assessments of sound examples gained in this part of experiment will not be analyzed.

Then, the first part of the experiment took place, where 16 sounds in total were sequentially presented and assessed by the participants. After a three minute break, 10 sound samples were presented in the second part of the experiment, which had to be assessed on an 11-point category scale with respect to the perceived level of 'pleasantness'. The category scale was similar to the category scale defined in the ISO/TS 15666 [7]. To reduce the importance of sequence effects, the order of sounds was randomized. It was controlled that sounds recorded at the same place were separated by at least three different stimuli.

Results

Figure 2 illustrates the assessments of the different environments recorded via a single microphone or a binaural headset for two attributes 'annoying' and 'pleasant'. In both cases, statistically significant differences between assessments of the monaural and binaural playback were observed (*annoying*: $F_{(1,240)}=7.85$, $p<0.01$, *pleasant*: $F_{(1,240)}=5.9$, $p<0.05$) without any interaction effects.

The assessments of the remaining attributes showed differences as well, but these differences were not statistically significant, but partially close to statistical significance (e.g. *eventful*: $F_{(1,240)}= 3.6, p=0.06$).



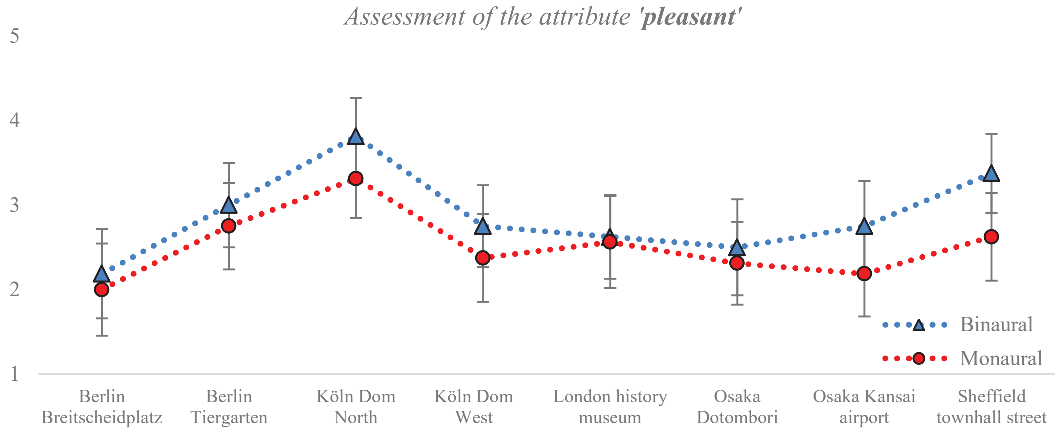


Figure 2 – Assessments (means and 95% confidence interval) of monaural and binaural noise stimuli regarding the attributes “annoying” (top) and “pleasant” (bottom)

In subsequent interviews, the suitability of the used attributes was discussed. It turned out that attributes like pleasant, annoying and eventful were judged to be highly appropriate, whereas attributes like “vibrant” and “chaotic” were assessed as less appropriate. However, no attribute was classified as inappropriate.

Discussion

The presented experiment has shown, as expected, that the spatial hearing impression is important with respect to soundscape related assessments like ‘pleasant’ or ‘annoying’. I.e., the assessments of acoustic environments differ between monaural and binaural reproductions. This observation supports the specifications defined in the ISO/TS 12913-2. Because the majority of the participants did not indicate in a post-experimental interview that they noticed that they listened to the different locations twice, in a monaural and binaural way, it is likely that the influence of potential demand characteristics is not vitally important. Interestingly, in the ISO/TS 12913-2 attributes explicitly related to the spatial auditory impression are not provided [8]. Potentially, such attributes might be relevant for comprehensive investigations of soundscapes perception in particular in case of studying indoor soundscapes.

2.2 Measurements of human sensations, responses and outcomes

In the past a vast amount of methods and tools from multiple disciplines were applied to measure perception of acoustic environments in context in order to meet the general holistic requirement of the soundscape approach to understand sound perception in all its complexity. The diverse methods range from bio-monitoring, questionnaires, interviews, mind mapping to observational studies or even big data applications. The ISO/TS 12913-2 emphasizes the concept of soundscape as a holistic approach and requests to investigate each soundscape situation from several viewpoints. According to the ISO/TS 12913-2 this requires performing a soundwalk and/or a questionnaire and/or a guided interview. Those methods are explicitly described and explained in the ISO/TS 12913-2.

Because the ISO/TS 12913-2 proposes different methods for data collection in the context of human sensation and responses, a study using different proposed methods including rating scales from the ISO/TS 12913-2 compared the gained results. Based on repeated soundwalk measurements performed in Aachen, it was observed that the results of the different rating scales aiming to explore similar semantic dimensions (e.g. analogue scale with the attribute *unpleasant* compared to the discrete ordinal scale with the attribute *pleasant*) correlate statistically significant in all cases of similar attributes [9]. The correlation coefficients are shown in table 1. Moreover, it was observed that both scale types exhibit similar standard deviations [9]. However, in case of the analogue rating scales the considered locations were judged as slightly more pleasant and less loud in average indicating the inevitable impact of the scale design and format on the respective results.

Table 1 – Correlation of assessments collected with selected rating scales from Method A and Method B proposed in ISO/TS 12913-2

Rating scales (Method A – Method B)	Pearson correlation coefficient
pleasant (bipolar (agreement) discrete) vs. unpleasant (unipolar, analogue)	-0.77**
annoying (bipolar (agreement), discrete) vs. unpleasant (unipolar, analogue)	0.65**
calm (bipolar (agreement), discrete) vs. loudness (unipolar, analogue)	-0.76**

Interestingly, the results of the acoustical measurements performed during the repeated soundwalks show similar results. By means of a 2-way ANOVA the effect of the factor “location” was compared to the effect of the factor “repeated measurements”. Although both factors were statistically significant, the location factor related to acoustical differences between the eight considered locations ($\eta^2=0.4$) was much greater than the differences between the different soundwalks performed in 2010, 2011, 2012 and 2015 ($\eta^2=0.06$) [10].

This observation was supported by a canonical discriminant analysis, which as a classification analysis considered the results of the (psycho-) acoustic measurements. 25 different psychoacoustic metrics of 64 recordings lasting three minutes were computed and used as input for the canonical discriminant analysis. This analysis as a dimension-reduction technique intends to investigate whether groups (locations) can be effectively separated by means of psychoacoustic metrics. In total, 62.5% of cross-validated grouped cases were correctly classified. This means that meaningful data representing the noise characteristics of a certain location can be collected by short-term measurements under uncontrolled conditions. Interestingly, the determined function 1 correlates with the assessments of ‘loudness’ and ‘annoyance’, whereas function 2 was more related to assessments of the attributes ‘vibrant’ and ‘eventful’.

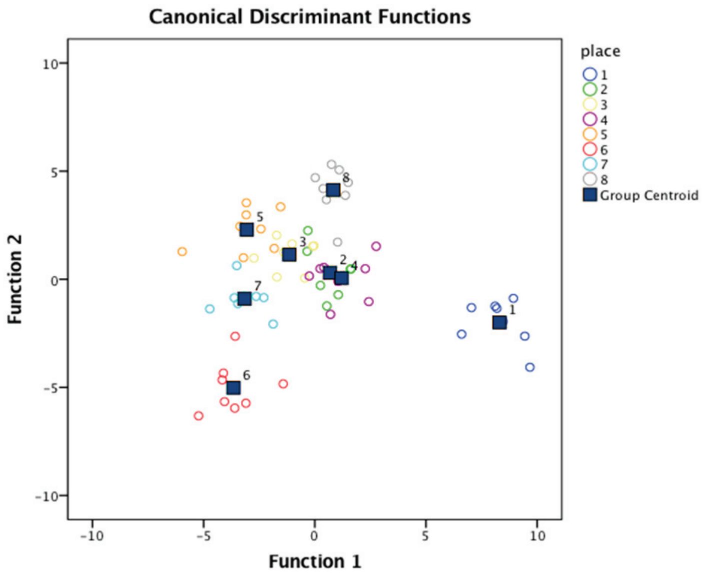


Figure 3 – Result of a canonical discriminant analysis showing function 1 and function 2 using psychoacoustic metrics of repeated measurements at eight different locations. The different colors represent the different locations.

In general, based on the repeated soundwalks it was observed that independent from the used method, whether method A or B, it is possible to collect reliable soundscape related data by means of in-situ physical and perceptual measurements. As expected, if rating scales varying in design and format are applied, different results are achieved. However, as table 1 illustrates, the results gained by different methods described in ISO/TS 12913-2 and potential conclusions drawn are related to each other to a certain extent. It is highly expected that due to the publication of the ISO/TS 12913-2 comparisons of the outcomes of the different defined methods will be subject to further research (for example see [11, 12]). Such studies might help to identify the advantages and drawbacks of the different proposed informative methods.

3. CONCLUSIONS

It is the general intent of the ISO 12913 series on soundscape to enable a broad international consensus and to provide a foundation for communication across disciplines and professions with an interest in soundscape. Due to the fact that the ISO 12913 documents are frequently quoted an impact on soundscape studies and investigations can be assumed without doubt. The availability of the ISO 12913 documents has two major advantages: 1. Due to the extreme diversity of methods in soundscape investigations in the past, a harmonized data collection process will increase the comparability of studies allowing the performance of meta-analyses and thus achieving a higher level of generality.
2. The possibility to reference to soundscape standards might increase the general acceptance of the soundscape approach by authorities and decision-makers. An example might be the current noise action plan in Wales [13]. The Welsh Government adopted a "*Noise and soundscape action plan 2018-2023*" with the intent to implement soundscape interventions in their noise action planning process within the next years.

However, a remaining challenge is to translate the different methods, instructions, verbal labels and attributes proposed in the ISO 12913 into different languages to be used internationally. A broad international application of the harmonized soundscape data collection methods and tools is only possible, when validated translated versions of the ISO 12913 documents are available. First actions determining translations representing the intended semantic dimensions described in ISO 12913 series have shown the complexity of this translation task [14].

In general, it could be argued that the availability of standardized, uniform methods and tools leading to an harmonization of the soundscape data collection process might impede further research and endeavors with respect to development of advanced methods and tools to comprehensively investigate the perception of acoustic environments. It is not unlikely that even more by defining a (tentative) ground truth via an international standard/technical specification, further research is provoked exploring the way humans perceive their (acoustic) environments by alternative, advanced methods. There is always the possibility to compare study outcomes (measurement uncertainties, data spread, effect sizes, etc.) based on alternative, improved methods to standard methods and tools. Without a common agreement on methods such investigations are likely not to be performed on a large scale. In particular, soundscape research needs more scientific evidence of its potential to promote health through cognitive restoration by designing urban environments [15]. It seems that the positive, promotional effect on health needs to be further explored by advanced methods.

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