PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Exploring associations between soundscape assessment, perceived safety and well-being: a pilot field study in Granary Square, London

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ABSTRACT

The number of soundscape studies is growing steadily over time and the discipline as a whole is going through a process of methodological standardization. Yet, more empirical evidence is needed about the benefits of experiencing positive soundscapes for health, well-being and quality of life. In this study, a pilot questionnaire was distributed to 50 users of a public open space in London (Granary Square), which consisted of a standardized protocol for collecting soundscape data (ISO 12913-2:2018, Method A), the World Health Organisation-Five Well-Being questionnaire (WHO-5) and a short protocol to assess perceived safety. Results show that associations between negative soundscape dimensions and lower well-being scores exist at a statistically significant level ($p < .05$) and other further insights into the relationships between sound perception and perceived safety. By making a stronger case for policy makers and planners, these findings contribute to the discourse of approaching the management of the urban acoustic environments in a proactive rather than reactive way, to promote healthy and supportive urban spaces.

Keywords: Soundscape, Well-being, Perceived safety; Quality of Life, Public space

1. INTRODUCTION

Soundscape studies are gaining momentum in the broader field of environmental acoustics and their impact is starting to be reflected in practice and policy documents and initiatives (1, 2). The international research community is thus putting a lot of effort into standardizing frameworks, definitions and methodologies, to foster best practices in soundscape characterization, management and design (3–6). Nonetheless, in order to increase its impact and outreach, soundscape research is still required to provide empirical evidence of the additional benefits given by this approach (7), particularly in the context of urban design, public health and quality of life, which are dominating the public discourse and the socio-political agenda (8–10).

In a recent literature review on associations between soundscape dimension and health effects, Aletta et al. (11) pointed out that in future soundscape studies where individual responses on the acoustic environments are gathered, additional items should be included in the data collection protocols, referring to health, quality of life and other factors affecting the holistic experience of a place,so that associations can be established between these domains. Exploring such relationships would ultimately allow supporting a public health argument at policy-making level, and boost the development of operational tools, such as soundscape indicators and prediction models (12, 13).

For this purpose, a pilot study was performed within the broader “Soundscape Indices – SSID” project (14) and a questionnaire was submitted to users of an open public space, which included items related to the perception of the acoustic environment (i.e., the soundscape), self-reported well-being and perceived safety. The aim of this pilot was evaluating whether associations between the three aforementioned components could be identified. In parallel, binaural recordings were performed, and the main corresponding sound levels and psychoacoustic parameters were computed, so that objectively measured values could potentially inform the interpretation of the perceptual data.

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2. METHODS

Data collection was performed in accordance with the recently released Part 2 of the ISO soundscape standard (15). The following subsections report on the general procedure implemented for the survey, the protocol used to gather individual responses about the perception of the environment and the acoustic measurements performed via binaural recordings. This study received ethical approval in accordance with UCL Research Ethics policy through the procedure implemented at the Institute for Environmental Design and Engineering (Departmental approver's letter on 17th July 2018).

The case study is Granary Square (Figure 1), located in central London (UK). The rationale for selecting this site is that it offers a reasonably broad range of possible acoustic environments (variety of sound sources) and is used by different types of people (e.g., workers vs. tourist, different age groups, etc.) for several activities (e.g., leisure, work, commuting, etc.).

Figure 1 – 360-degree views from different spots in Granary Square, the case study in central London.

2.1 Survey procedure

The survey took place between the 18th and the 25th of July, 2018. Acoustic measurements were performed and questionnaires submitted to members of the public during week days, between 10:00 am and 05:00pm, for a total of five data collection sessions. A researcher would approach potential volunteers individually to fill in the questionnaire (described in Section 2.2) and perform a one-minute binaural recording (described in Section 2.3) while they were completing the form. The questionnaire was presented using a Google form document showed to participants via a tablet, or using printed forms. Informed consent to take part in the study was sought from participants in advance. Completing the questionnaire usually took 10 minutes for each participant.

2.2 Questionnaire

The questionnaire used in this pilot study consisted of three main themes, each one being divided in question categories (not available to participants) that were made in turn of several items: (a) soundscape; (b) well-being; and (c) perceived safety. The questionnaire used on site is reported in Table 1.

The soundscape theme consisted of three question categories, namely: sound sources, perceived affective quality and overall quality. This part of the questionnaire was derived from the standardized protocol proposed in Method A of the soundscape ISO technical specifications (15). The well-being theme referred to the Five Well-Being Index (WHO-5), which is a short self-reported measure of mental well-being (16).

Table 1 – Questionnaire used on site; the first three categories refer to the soundscape theme, whilst the remaining categories refer to the well-being and perceived safety themes.

Category	Question	Item(s)	Scale/Response Type
Sound sources	To what extent do you presently hear the four following types of sounds?	Environmental noise (e.g., traffic, construction, industry); Sounds from human beings (e.g., conversation, laughter, children at play, footsteps); Natural sounds (e.g., singing birds, flowing water, wind in vegetation)	Not at all (1); A little (2); Moderately (3); A lot (4); Dominates completely (5)
Perceived affective quality	For each of the 8 scales below, to what extent do you agree or disagree that the present surrounding sound environment is…	Pleasant; Chaotic; Vibrant; Uneventful; Calm; Annoying; Eventful; Monotonous	Strongly agree (1); Agree (2); Neither agree, nor disagree (3); Disagree (4); Strongly disagree (5)
Overall quality	Overall, how would you describe the present surrounding sound environment?	–	Very good (1); Good (2); Neither good, nor bad (3); Bad (4); Very bad (5)
	Overall, to what extent is the present surrounding sound environment appropriate to the present place?	–	Not at all (1); Slightly (2); Moderately (3); Very (4); Perfectly (5)
WHO-5	Please indicate for each of the five statements which is closest to how you have been feeling over the last two weeks	I have felt cheerful and in good spirits; I have felt calm and relaxed; I have felt active and vigorous; I woke up feeling fresh and rested; My daily life has been filled with things that interest me	All of the time (5); Most of the time (4); More than half of the time (3); Less than half of the time (2); Some of the time (1); At no time (0)
Perceived safety	To what extent do you agree or disagree with the following statements about the surrounding environment?	I feel worried; I feel safe	Strongly agree (1); Agree (2); Neither agree, nor disagree (3); Disagree (4); Strongly disagree (5)

The protocol has been found to have adequate clinical validity in screening for depression and general well-being (17). The perceived safety theme referred to assessing safety (or lack thereof), perceived by users of a public space (e.g., fear of aggression vs. relaxation etc.). There are no clearly established or standardized protocols to assess such dimension, but a few tools have been proposed over the years, so the items proposed in this study refer to other studies retrieved in the literature (18, 19).

2.3 Binaural recordings

The ISO/TS 12913-2:2018 document requires the acoustic environment of the investigated site to be characterised through binaural (or other spatial audio) recordings. The rationale is also being able to support the analysis of the subjective data with measured physical parameters. Measurements were performed using a binaural recording system, composed of portable audio recorder EDIROL (ROLAND, R-44, 24 bit 192 Hz DIGITAL), connected to an head-mounted pair of 1/8" omnidirectional microphones DPA MICROPHONE (NEUTRIK, mc-mmx, DAD6001 P48 - 12V-48V) equipped with small windshields. The recording time was a one-minute interval, which was recorded simultaneously while the participants were filling the questionnaire. During the measurement, the operator (height: 1.70 m) was staying as close as possible to the participants/listeners' position, keeping the head steady to conduct the binaural recordings in a stationary condition. In order to minimize the influence of unwanted reflections, a minimum distance of one meter from reflecting surfaces was kept.

3. RESULTS

3.1 Definition and analysis of the variables involved

For the soundscape-related questions (i.e., the Sound sources, Perceived affective quality, and Overall quality categories in Table 1) each item was considered individually as an ordinal variable (ranging from 1 to 5). The scales for some items of these categories were "flipped" (regardless of how the questions were originally presented to participants) so that a higher score would always reflect a higher level of "agreement" with the attribute/statement considered.

Regarding the items of the WHO-5 category, the WHO guidelines recommend a formula to combine the five items into a single normalized well-being score ranging from 0 (worst outcome) to 100 (best outcome) (16). However, considering the small sample size of this pilot study and the limited statistical power that this would have implied using the score in association with other variables, in this context a different clustering approach was used to define a new well-being variable (20). In order to define a "Self-reported Well-being" variable, a *k*-means cluster analysis was performed on the scores of the WHO-5 items; the algorithm was forced into a two-cluster solution, since a convergence was achieved due to no or small change in cluster centres after only two iterations of the clustering algorithm (SPSS IBM v.22). The mean scores of five items were then analysed as a function of cluster membership. Considering the positive direction of the WHO-5 items, a high level of agreement reflects a better well-being condition. The five items were always higher for cluster 2 than for cluster 1, therefore the two clusters were interpreted as follows: "Low" (cluster 1) and "High" (cluster 2) well-being. These were then considered as categorical levels of the "Self-reported Well-being" variable.

A similar approach was used for the Perceived Safety category of the questionnaire based on two items. In order to define a new "Perceived safety" variable, a *k*-means cluster analysis was similarly performed on the scores of the "*I feel worried*" and "*I feel safe*" items, forcing the algorithm into a two-cluster solution, since a convergence was achieved due to no or small change in cluster centres again after only two iterations of the clustering algorithm. The mean scores of two items were then analysed as a function of cluster membership. Considering the direction of the two scales, cluster 1 would represent "Low" perceived safety, whilst cluster 2 would represent "High" perceived safety. These were then considered as categorical levels of the "Perceived safety" variable.

3.2 Association between soundscape, well-being and safety data

In order to explore possible associations between the items of the three main themes of the questionnaire, a set of independent-samples t-tests was then run to determine if the scores of the soundscape-related items were different between the Low (n = 24) and High (n = 26) Self-reported Well-being groups, and between the Low (n = 21) and High (n = 29) Perceived Safety groups. This included all the 13 variables (questions/items), corresponding to the soundscape-related items, as reported in Table 1 (i.e., Sound sources, Perceived affective quality, Overall quality).

Looking at the Self-reported Well-being analysis, for the Chaotic soundscape item, the High well-being group (M = 2.96, SD = 0.96) had statistically significantly lower scores than the Low well-being group (M = 3.54, SD = 0.98), $t(48) = 2.119$, $p = .039$ (Figure 3, on the left). A similar trend emerged for the Monotonous soundscape item, where the High well-being group (M = 2.27, SD = 0.78) had statistically significantly lower scores than the Low well-being group (M = 2.71, SD = 0.75), t(48)

= 2.028, p = .048 (Figure 3, on the left).

When considering the Perceived safety analysis (Figure 3, on the right), the situation is similar, but a slightly different set of variables is affected. For the Chaotic item, the High perceived safety group (M = 2.97, SD = 1.05) had statistically significantly lower scores than the Low perceived safety (M = 3.62, SD = 0.81), $t(48)$ = 2.384, p = .021. A similar trend can be observed for the Uneventful soundscape item, where the High perceived safety group (M = 2.10, SD = 0.77) had statistically significantly lower scores than the Low perceived safety group (M = 2.86, SD = 0.85), $t(48)$ = 3.259, p = .002. The same applies to the Annoying soundscape item: the High perceived safety group (M = 2.14, SD = 0.79) had statistically significantly lower scores than the Low perceived safety group (M = 2.67, SD = 0.80), $t(48)$ = 2.330, p = .024. Finally, a difference for the Perceived safety variable also emerged for one of the items of the sound sources dominance. Indeed, for the Human sounds items, the High perceived safety group (M = 3.55, SD = 0.57) had statistically significantly lower scores than the Low perceived safety group (M = 4.00, SD = 0.84), $t(48)$ = 2.252, p = .029.

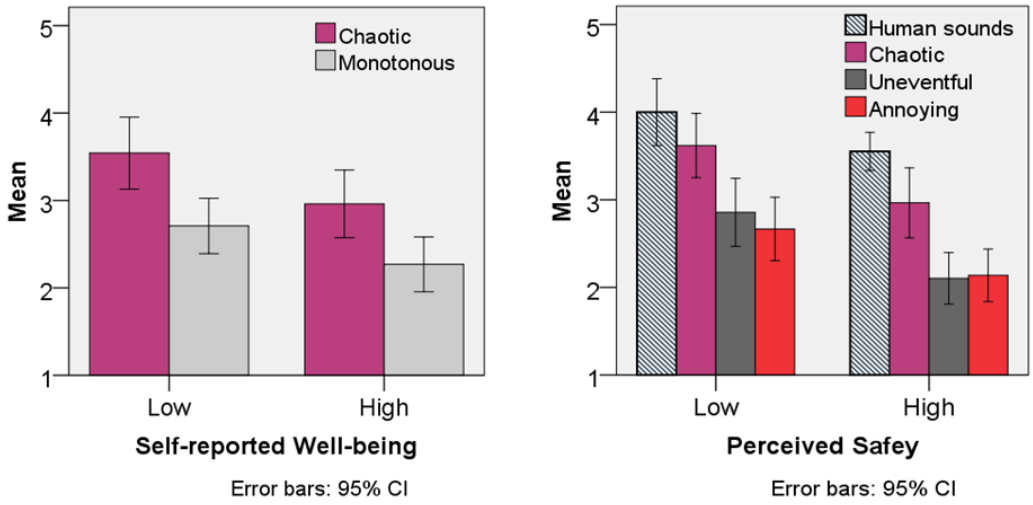

Figure 3 – Left: mean scores and 95% Confidence Interval of the Chaotic and Monotonous attributes, as a function of the Self-reported Well-Being variable; Right: mean scores and 95% Confidence Intervl of the Human sounds variable and the Chaotic, Uneventful and Annoying attributes, as a function of the Perceived Safety variable.

3.3 Psychoacoustic data

Psychoacoustic parameters (Loudness and Sharpness) and the A-weighted equivalent sound level (SPL) were computed from the binaural recordings, using the Simcenter LMS Testlab (Siemens PLM Software, v.17). Figure 4 shows the distributions of the average values (arithmetic mean of the left and right channel) for the sample of 50 participants related to the three parameters. It can be observed that sound levels were moderately high, with most of the sample between 65 and 75 dBA. Likewise, Loudness levels for most of the sample ranged between 20 and 30 sone. The sample was also exposed to moderately sharp acoustic environments with most of the values ranging between 1.3 and 1.6 acum. Overall, this set of objective measures is compatible with the sound sources noted on site by the researchers, typically consisting of human sounds, water sounds (fountains), and some traffic noise and construction noise. In order to get further insights into possible associations between objectively measured parameters and subjectively gathered data, a set of Spearman's rank-order correlation test was run to assess the relationships between the physical parameters (SPL, Loudness and Sharpness) and all the items of the soundscape and perceived safety themes of the questionnaire. The WHO-5 items were excluded from this analysis: they refer to the previous two-week period for the interviewees, thus associations with the levels measured on the spot would be meaningless. If discarding internal correlations between the acoustic parameters (which are expected), only two statistically significant associations were identified between objective and subjective measures. There was a small positive correlation between SPL and Human sounds, $r_s(48)$ = .296, p = .037, and a small negative correlation between Sharpness and Calm, $r_s(48)$ = -.316, p = .025.

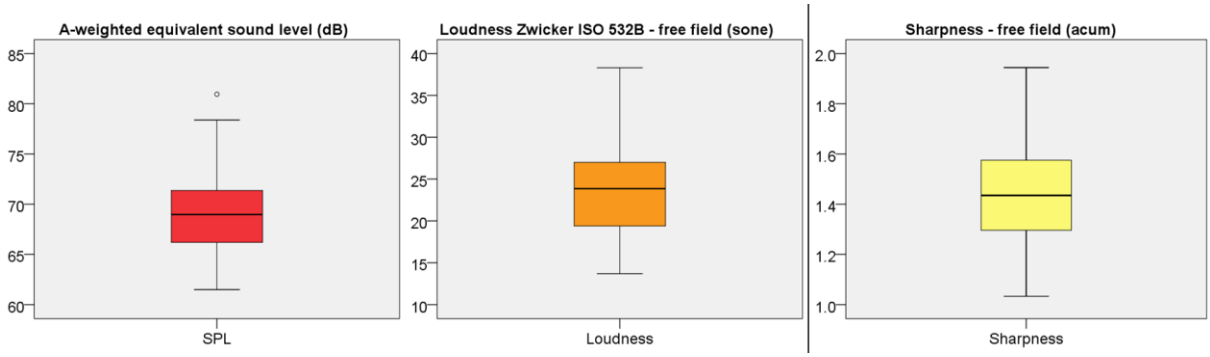

Figure 4 – Distributions of the mean values of the objective parameters calculated from the binaural recordings for the 50 participants.

4. Discussion

The studies investigating directly the associations between the perception of the acoustic environments (i.e., the soundscape) and well-being and safety-related dimensions are scarce in the current body of literature. For this reason, in the context of this preliminary work, such relationships were explored by stratifying the available sample and checking for differences in soundscape assessments between well-being and perceived safety populations.

In this case study, statistically significant associations emerged for the well-being and perceived safety categories with attributes in the "negative" region of the soundscape circumplex model proposed by Axelsson et al. (21). This seems to suggest that for potentially vulnerable groups (e.g., those who report lower levels of well-being and perceived safety), the acoustic environment is particularly important, since its experience might likely result in more negative soundscapes.

The finding that the Low perceived safety group reports higher perceived dominance of sounds of humans seems to be in contrast with previous studies, where it was suggested that human sounds (either verbal or non-verbal) might help to convey a feeling of social presence and increased safety, regardless of the actual physical presence of people on site (18, 19). A possible explanation for this is that this kind of studies is typically conducted in night-time situations, with no people in sight (empty spaces): in this context, auditory information related to human presence might be beneficial. However, the present survey was conducted in a busy open public space during day-time. Thus, the Low perceived safety group might have overestimated the human sounds as it considers them as an indicator of danger (e.g., pickpockets, anti-social behaviours, etc.). From the soundscape design perspective, this could have some implications as one might want to let sounds other than human-related ones to dominate, in order to enhance perceived safety in these urban contexts.

The positive correlation between SPLs and the perceived dominance of human sounds confirms that this kind of sound sources is the one contributing most to the acoustic environment of the place, which seems to support the interpretation of the implications for perceived safety mentioned above. The negative correlation between Sharpness and the Calm soundscape attribute looks also consistent with the previous finding, as one would expect human sounds to mainly affect the high-frequency region of the spectrum, so when human sounds are decreasing, the soundscape is possibly assessed as being calmer/quieter. Overall, the lack of any other correlations between perceptual dimensions and acoustic metrics highlights once again that soundscape needs to refer to a holistic assessment of a place and other non-acoustic factors and activity-related factors need to be taken into account (22–24). Apart from this, some issues might also be related to the scales of the questionnaire itself, as it is difficult to exclude at this stage that the scaling of the perceptual attributes is free from bias (25).

5. CONCLUSIONS

In this study, a pilot soundscape survey within the Soundscape Indices project was carried out in a public square in central London. The analysis of the preliminary results highlights that for this specific case study:

- The sub-set of participants associated with lower well-being scores assessed soundscapes

more negatively (Chaotic, Monotonous; $p < .05$), compared with the group with higher well-being scores.
- The sub-set of participants associated with lower perceived safety scores assessed soundscapes more negatively (Chaotic, Uneventful, Annoying; $p < .05$) and more dominated by human sounds ($p < .05$), compared with the group with higher perceived safety scores.
- A limited set of statistically significant correlations was found between the perceptual dimensions and the psychoacoustic parameters measured during the questionnaires (SPL/Human sounds, Sharpness/Calm; $p < .05$).

The protocol tested for this study is currently being deployed in several partner sites around the world (14). The results of this pilot study suggest that relationships between soundscape, well-being and perceived safety dimensions should be explored further with larger samples to achieve greater statistical power and unveil other possible relationships that might not have emerged in this specific context. The knowledge coming from such studies should hopefully inform policy-making, planning and urban design, and contribute to the debate about the management of the urban acoustic environments in a proactive rather than reactive way, to promote healthy and supportive urban spaces.

ACKNOWLEDGEMENTS

This research was funded through the European Research Council (ERC) Advanced Grant (no. 740696) on “Soundscape Indices” (SSID).

REFERENCES

1. European Environment Agency. Good practice guide on quiet areas. Luxembourg:; 2014.
2. Welsh Government. Noise and Soundscape Action Plan 2018-2023. Cardiff:; 2018.
3. International Organization for Standardization. ISO 12913-1:2014 Acoustics — Soundscape — Part 1: Definition and conceptual framework. Geneva:; 2014.
4. Kang J, Aletta F, Gjestland TT, Brown LA, Botteldooren D, Schulte-Fortkamp B, et al. Ten questions on the soundscapes of the built environment. Building and Environment. 2016; 108: p. 284-294.
5. Aletta F, Kang J, Axelsson Ö. Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landscape and Urban Planning. 2016; 149: p. 65-74.
6. Kang J. From dBA to soundscape indices: Managing our sound environment. Frontiers of Engineering Management. 2017; 4(2): p. 184-192.
7. Kang J, Aletta F. The Impact and Outreach of Soundscape Research. Environments. 2018; 5(5): p. 58.
8. Bild E, Coler M, Pfeffer K, Bertolini L. Considering sound in planning and designing public spaces: A review of theory and applications and a proposed framework for integrating research and practice. Journal of Planning Literature. 2016; 31(4): p. 419-434.
9. Aletta F, Xiao J. What are the Current Priorities and Challenges for (Urban) Soundscape Research? Challenges. 2018; 9(1): p. 16.
10. World Health Organization. Environmental Noise Guidelines for the European Region. Copenhagen:; 2018.
11. Aletta F, Oberman T, Kang J. Associations between Positive Health-Related Effects and Soundscapes Perceptual Constructs: A Systematic Review. International Journal of Environmental Research and Public Health. 2018; 15(11): p. 2392.
12. Aletta F, Axelsson Ö, Kang J. Towards acoustic indicators for soundscape design. In Proceedings of the Forum Acusticum 2014 Conference; 2014; Krakow.
13. Aletta F, Kang J. Towards an Urban Vibrancy Model: A Soundscape Approach. International Journal of Environmental Research and Public Health. 2018; 15(8): p. 1712.
14. Kang J, Aletta F, Oberman T, Erfanian M, Kachlicka M, Lionello M, et al. Towards soundscape indices. In Proceedings of the International Conference on Acoustics ICA 2019; 2019; Aachen.
15. International Organization for Standardization. ISO/TS 12913-2:2018 Acoustics — Soundscape — Part 2: Data collection and reporting requirements. Geneva:; 2018.
16. World Health Organization. Wellbeing Measures in Primary Health Care/The Depcare Project. Copenhagen:; 1998.
17. Topp CW, Østergaard SD, Søndergaard S, Bech P. The WHO-5 Well-Being Index: A Systematic Review of the Literature. Psychotherapy and Psychosomatics. 2015; 84: p. 167-176.
18. Sayin E, Krishna A, Ardelet C, Briand Decré G, Goudey A. “Sound and safe”: The effect of ambient sound on the perceived safety of public spaces. International Journal of Research in Marketing. 2015;

32(4): p. 343-353.
19. Astolfi A, Orecchia P, Bo E, Shtrepi L, Calleri C, Aletta F. Influence of Soundscapes on Perception of Safety and Social Presence in an Open Public Space. In Aletta F, Xiao J, editors. Handbook of Research on Perception-Driven Approaches to Urban Assessment and Design. Hershey: IGI Global; 2018. p. 126-149.
20. Aletta F, Van Renterghem T, Botteldooren D. Can attitude towards greenery improve road traffic noise perception? A case study of a highly-noise exposed cycling path. In Proceedings of the Euronoise 2018 Conference; 2018; Heraklion.
21. Axelsson Ö, Nilsson M, Berglund B. A principal components model of soundscape perception. Journal of the Acoustical Society of America. 2010; 128(5): p. 2836-2846.
22. Yang W, Kang J. Acoustic comfort evaluation in urban open public spaces. Applied Acoustics. 2005; 66(2): p. 211-229.
23. Jeon JY, Lee PJ, Hong JY, Cabrera D. Non-auditory factors affecting urban soundscape evaluation. Journal of the Acoustical Society of America. 2011; 130(6): p. 3761-3770.
24. Bild E, Pfeffer K, Coler M, Rubin O, Bertolini L. Public Space Users' Soundscape Evaluations in Relation to Their Activities. An Amsterdam-Based Study. Frontiers in Psychology. 2018; 9: p. 1593.
25. Lionello M, Aletta F, Kang J. On the dimension and scaling analysis of soundscape assessment tools: a case study about the "Method A" of ISO/TS 12913-2:2018. In Proceedings of the International Conference on Acoustics ICA 2019; 2019; Aachen.