The measurement of soundscapes – Is it standardizable?

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ABSTRACT

Beyond doubt, soundscaping is on the rise. Soundscape investigations are increasingly performed and soundscape research takes place extensively in recent years. Unfortunately, there is little agreement about adequate measurement procedures, reporting requirements and soundscape indicators. Although the general openness, interdisciplinary roots and multi-dimensionality of the soundscape approach are very important to preserve, a certain consensus about measurement procedures, reporting requirements and analyses tools is needed. In particular, a common denominator with respect to measurement procedures is required, since due to the diversity of measurement procedures the comparability and compatibility of soundscape investigations is very limited.

The paper will refer to recent soundscape studies and their outcomes and will discuss the applied methods and procedures. Since the standardization of soundscape aspects is already under way (ISO/DIS 12913), e.g. regarding terms, minimum reporting requirements and measurement protocols, a thorough discussion of soundscape methods and procedures is imperative.

Keywords: Soundscape, measurement   I-INCE Classification of Subjects Number(s): 56.3

1. INTRODUCTION

It is well known, that the soundscape approach gains in significance and that numerous soundscape investigations were carried out based on different procedures, measurements and approaches. This diversity of applied methods and procedures is caused and stimulated by the general openness and multidisciplinarity of the soundscape idea. In contrast to the noise control approach, the general idea of soundscape is to ask not only for *how much noise* in terms of level but also to ask simply about the *quality of noise*. Soundscape is understood as *"an environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society*." [1] The Soundscape concept intends to provide a more holistic evaluation of "noise" and its effects focusing on human perception.

It is evident that standards can help to harmonize efforts and endeavors. Conformity to international standards reassures to gain knowledge on an efficient, comparable and reasonable way. Moreover, according to ISO "*International Standards on air, water and soil quality, on emissions of gases and radiation and environmental aspects* [and on noise] *contribute to efforts to preserve the environment and the health of citizens*."[2] In this regard, any standard in the scope of soundscape is intended to protect public health, to support human well-being and to ensure a certain level of quality of life. Such standards could be adopted by national governments as regulatory requirements in order to be more successful against harmful noise than in the past. Since at least one million healthy life years are lost every year from traffic related noise in the western part of Europe and approximately 1.8 % of all myocardial infarctions are attributable to road traffic noise [3], conventional ways of analyzing and interpreting environmental noise must be challenged. Soundscape standardization is meant to deal with environmental noise more properly and to provide new tools to derive efficient measures for improving acoustic environments and their perception.

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2. ACTIVITIES OF THE WORKING GROUP 54 OF ISO/TC 43/SC 1

The working group 54 of ISO/TC 43/SC 1 has recently started to work on a future standard on methods and measurements in soundscape studies. Topics, like minimum reporting requirements, measurement protocols, relevant indicators, or acquisition methods are put up to thorough discussion.

It is evident that any standardization of measurement procedures and techniques will trigger the applied procedures in soundscape research. This statement makes clear the particular importance of a soundscape standard and the responsibility of the working group.

First of all, a variety of investigation techniques, taxonomy and measurement methods are conceivable and in practice. In general, there is no need for limiting the means of investigating soundscapes. The soundscape idea aims for a holistic view integrating interdisciplinary all aspects into one approach. Thus, to constrict soundscape research to a kind of “corset of detailed regulations” would decrease the general power of the soundscape concept. It is evident that a certain openness is needed to match the soundscape procedures to the specifics and particularities of the investigated place.[4] The choice of the measurement positions depends on the purpose of the measurements and must consider the respective type of soundscape to be investigated. However, a common denominator must exist to make studies comparable and to make and accelerate progress in the field of soundscape research. This includes measurement aspects like location, duration, height, time of day, equipment, etc.

3. SOME THOUGHTS TO SOUNDSCAPE MEASUREMENTS

Although there are not any established guidelines for measuring soundscapes, some general recommendations can be given and existing regulations can be scrutinized with respect to their relevance for soundscape studies.

For example, the height of the microphones should be chosen according to the actual or expected position and height of the receiver. [5] Since in soundscape investigations the receiver is usually a human being, the measurement height is narrowed down to typical heights of humans. This clearly contrasts the “indoor” noise measurement position according to the ISO 1996-2 [5], where the microphone position should be in 0.5 m in front of an open window or the noise maps principle, where the sound pressure level calculations are related to a height of 4 m. This is not a typical receiver position and therefore it is not suitable in a soundscape study.

Regarding measurement time intervals, soundscape measurements must cover all variations caused by prominent noise sources. Prominent noise sources represent sources, which could be classified with soundscape related terms such as signals, soundmarks or keynote sounds. These prominent sound sources or events must not be energetically prominent; they must be considered if they attract attention, beyond their contribution in sound pressure level. A soundscape measurement must be long enough to sufficiently encompass all emission situations which are needed to obtain a representative, complete “picture“ of the whole soundscape with its expected important, typical sound events and sound sources.

The acquisition of acoustic data of soundscapes requires the application of binaural measurement techniques. Because of complex environmental sound situations caused by several spatially distributed sound sources it is important to use binaural technology to consider masking effects, sound impression, spatial distribution and complex phase relations adequately. Measurements with binaural technology are necessary if subsequent (aurally-accurate) reproductions of noise are required, e.g. in the case of further examination of the sounds in laboratory listening tests [6]. “Copies” of the acoustic environment as close as possible to humans’ perception are needed especially regarding archiving and re-experiencing the acoustic scenery for comparability and analyses reasons. Consequently, the use of binaural technologies seems to be imperative to be able to record and reproduce environmental noise in an aurally-accurate way. It is highly proposed to perform stationary measurements, since any movement of the system and equipment carrying person can cause unwanted noise, which does not represent the measured soundscape. For artificial head measurement systems the use of a tripod is recommended. For outside recordings the use of windshields is mandatory. The equalization of the binaural measurement systems must be chosen with respect to the sound field situation of the investigated soundscape.

It is clear that the time signals of the binaural recordings must be digitally stored. The sampling rate should not go below 44.1 kHz.

Moreover, in contrast to conventional environmental noise measurement regulations, in soundscape investigation the main focus does not lie in separating different source contributions, but to record and analyze environmental sound as a combination of all relevant sound sources as perceived by individuals within the soundscape. The separation of the contributions of the different sound sources is considered for analytical and legal reasons in noise policy, but the examination and assessment of the whole remains inevitable. The concept of the soundscape requires to analyze the acoustic environment as a whole as well as in its different facets.

It is important to point out that measurement guidelines must cover both dimensions to be inherent in soundscape studies: “measurement by persons” and “measurement by instruments”. Both types of measurements must be addressed in a soundscape standard about methods and measurements in soundscape studies. These measurement types are mandatory in complete soundscape investigations. In this regard, soundwalks, questionnaires and explorative interviews have to complement the acoustical measurements and psychoacoustic analysis of soundscapes.

Another aspect concerns the use of indicators. In accordance to the ISO 1996-3 the preferred noise descriptor for the specification of noise limits is the equivalent continuous A-weighted SPL. [5] It is very obvious that the description of the acoustic environment in the scope of soundscapes is not based on a simple time-averaged A-weighted SPL value. It is central to fit potential indicators to the perception and the appraisal of the concerned people. Indicators must cover aspects like acoustic and psychoacoustic appraisal as well as context appraisal. Those indicators must be beyond simple acoustic indicators. Indicators can also be related to non-acoustic aspects relevant for soundscape perception, which can cover perceptual, psychological, physiological and physical variables.

4. CASE STUDIES AND LESSON LEARNED

Within the framework of COST network on soundscape of European cities and landscapes [7] different workshops were organized in Aachen, where young researcher performed soundscape related measurements. In total, experiences with respect to soundscape measurements were gained over three years. The data collected over three years provide the opportunity to study the invariance of Aachen soundscapes. Figure 1 illustrates the data collection process. Participants walked through the city of Aachen and listened to certain places (for more details about the considered locations see [8]), which were thoroughly selected with respect to diversity and representativeness. Frequently, the relevant places for soundwalk are chosen by local residents, since they are the experts of the soundscape under scrutiny. Soundwalks are participatory group sound and listening walks through the environment.

The participants were requested to stand close to a defined spot with a specified viewing direction. They should listen carefully to the place with all senses without thinking about the evaluations tasks. An experimenter attends the soundwalk to guide the participants and to control that the participants comply with specified measurement conditions. The evaluation tasks comprises continuous ratings on category scales regarding loudness and (un-)pleasantness, comments (“going through my mind”) and information about heard sound sources.

It has to be remarked that in the planning of a soundscape investigation, the selection of the test sample must comprehensively be dealt with. Who are the experts? Who for example has to participate in a soundwalk? The investigations described in this paper worked with visitors of the soundscape, which were not familiar with the visited and assessed places. It is obvious that the perception and assessment of the experienced soundscapes might differ from those of local residents. Since the perception of soundscapes is based on acoustical as well as non-acoustical aspects, the perception of visitors and residents is very likely to be different. This has to be taken into account with respect to the interpretation of the results of soundscape studies and their generality level.

Figure 1 – Soundwalk impressions. Soundwalk participants listened consciously to the soundscape at a length of three minutes and gave assessments subsequent to the listening

Although over a period of three years, the different soundscapes (8 locations) were subject to assessment by soundwalk participants and to psycho-acoustical analysis based on three minutes recordings only. All diverse measurements were performed at the same time of day and on weekdays. It turned out that acoustical and perceptual differences between soundscapes were greater than between the variations within a soundscape. Figure 2 displays the similarity in spectra of the recordings of the same soundscape measured over three years. The road is only open for public transportation, which causes only intermittent road traffic events of heavy vehicles leading to obtrusive, broadband single noise events. Buses emit low frequency engine noise below 200 Hz. Moreover, high frequency noise caused by small fountains at ground level is observable in all spectra. Consequently, although environmental noise “fragments” of the investigated locations with a length of only three minutes were available for comparison, similar psychoacoustic properties and patterns were found. Three minutes recordings turned out to be more representative for the different locations than expected. More information about psychoacoustic similarity of the different locations can be in [9]. This indicates that a short measurement period can already encompass all relevant acoustical patterns and particularities. The measurements have shown that over a period of three years the soundscapes were stable in an acoustical sense and their acoustic characteristics were preserved. This observation provides information about adequate measurement intervals for soundscape studies.

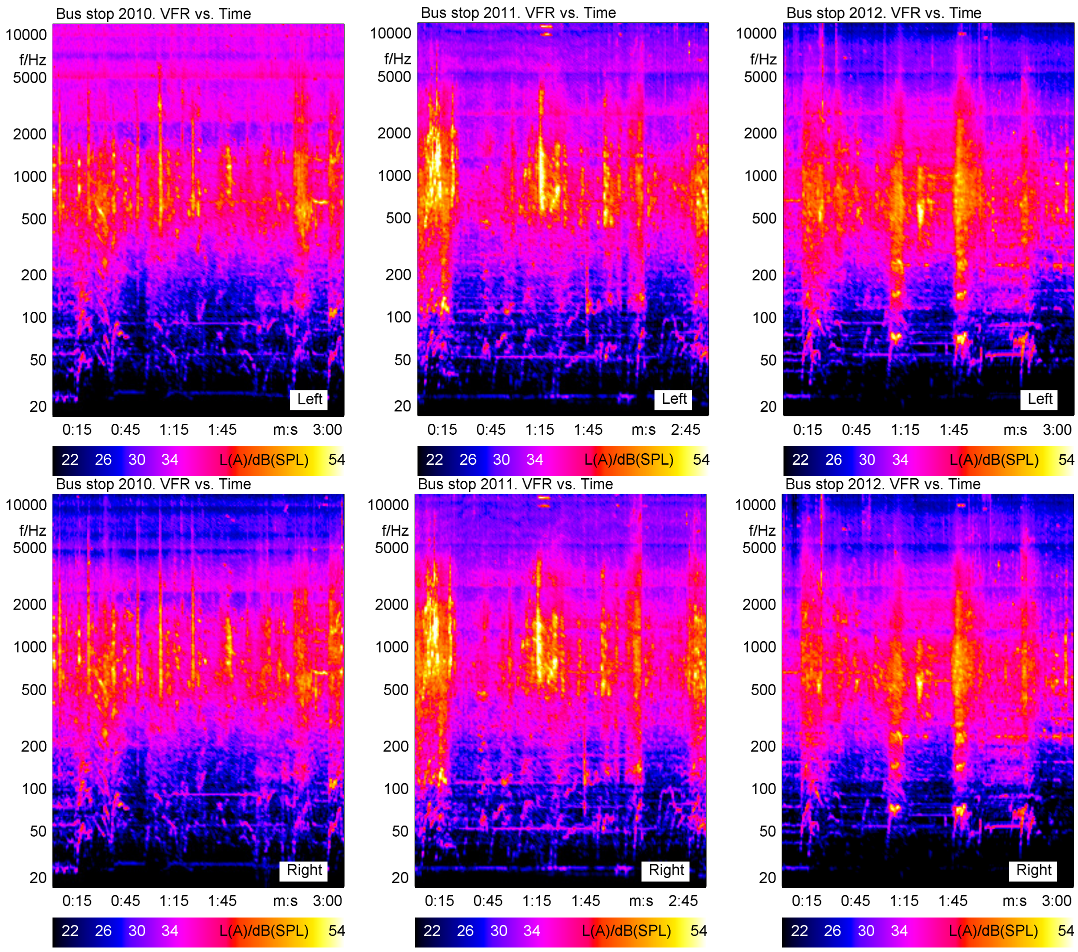

Figure 2 – Comparison of the noise at Busstop location measured over three years (left: 2010, middle 2011, right: 2012; top: left channel, bottom: right channel). VFR (variable frequency resolution spectrum) vs. time

The measurements were carried out with a calibrated mobile recording system with binaural headset. It turned out to be useful due to its easiness of use. The aurally-accurate recordings were perceived by the participants afterwards in laboratory context as authentic and realistic. Figure 3 illustrates the measurement and/or “documenting” of the experienced acoustical environments by means of a binaural mobile recording system. The recording person has to consider several measurement aspects in order to carry out properly the binaural measurement. The recording person has to be silent, is not allowed to move the head, has to protocol the measurement conditions (exact location, viewing direction, weather conditions, particular incidents, etc.). For more accurate measurements the use of artificial head measurement systems is recommendable.

Figure 3 – Binaural measurement during soundwalk. Left: Binaural recording via binaural headset; right: Binaural recording via artificial head measurement system and binaural headset

As already mentioned, the soundwalk participants performed ratings with respect to perceived loudness and unpleasantness on category scales and gave additionally comments. In detail, in-situ ratings were requested regarding the questions "*How loud is it here?*" and "*How unpleasant is it here?*" on a five point continuous category scale with additional verbal labeling (not at all, slightly, moderately, very, extremely). In general, the participants reported that the category scales were easy to handle and they could express their perception with respect to loudness or unpleasantness. Moreover, due to the multi-dimensionality of the soundscape perception, they needed and used extensively the „free words option“ (going through my mind).

It turned out that the judgments of the different locations were comparable over the years. This observation is very astounding. Although the sounds as well as the soundwalk participants varied over the years comparable perceptions and assessments were provoked.

First of all, figure 4 shows that the different locations were differently judged with respect to perceived loudness and unpleasantness. As expected, a one-way Analysis of Variance (ANOVA) confirmed that the different arithmetic mean values differ highly statistically over the different locations (perceived loudness: $F=39.7$, $p=0.0^{**}$; unpleasantness: $F=30.4$, $p=0.0^{**}$). It can be clearly seen that in case of measurement location 6, a much larger interquartile occurs. Figure 5 illustrates that the participants judged location 6 significantly different in 2012 compared to the other years. The judgments in 2012 were worse; the sound was perceived as louder and more unpleasant. Figure 6 explains the systematically deviating judgments in 2012. The historic urban square known for its quietness was acoustically interfered by construction noise. This additional, atypical noise found its way into the judgments. This example makes clear that the occurrence of certain noises and noise sources can influence the perception of a soundscape significantly. As long as such noises are not representative for the investigated soundscape, the collected data is of limited explanatory power. This has to be kept in mind with respect to the investigation of soundscapes.

A two-way Analysis of Variance (ANOVA) confirmed that the measurement locations were highly significantly judged differently ($F=66.2$, $p=0.0^{**}$) and that the evaluation items "perceived loudness" and "unpleasantness" were highly significantly judged differently ($F=19.1$, $p=0.0^{**}$). Loudness and unpleasantness are not congruent dimensions. Moreover, a significant interaction effect was observed. ($F=2.1$, $p=0.036^{*}$).

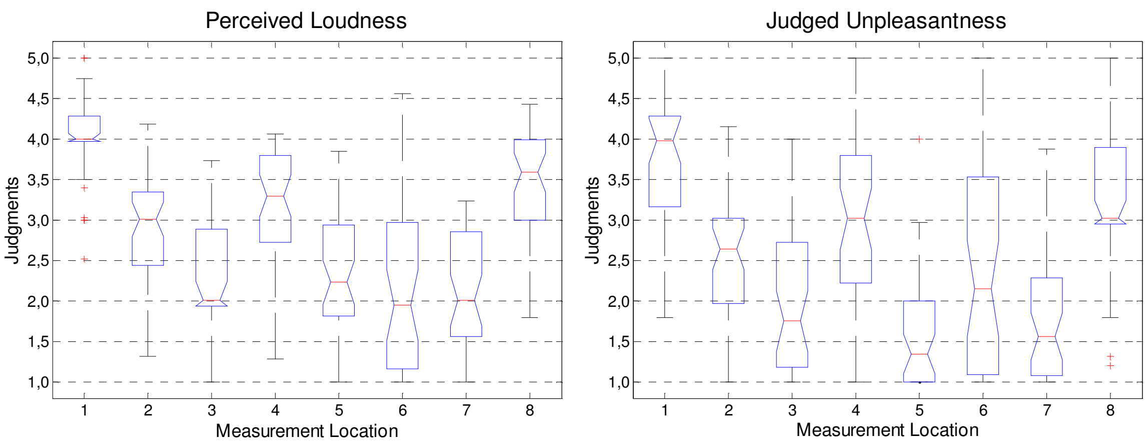

Figure 4 – Box-whisker plots. Comparison of perceived loudness (left) and unpleasantness ratings (right) over the eight measurement locations.

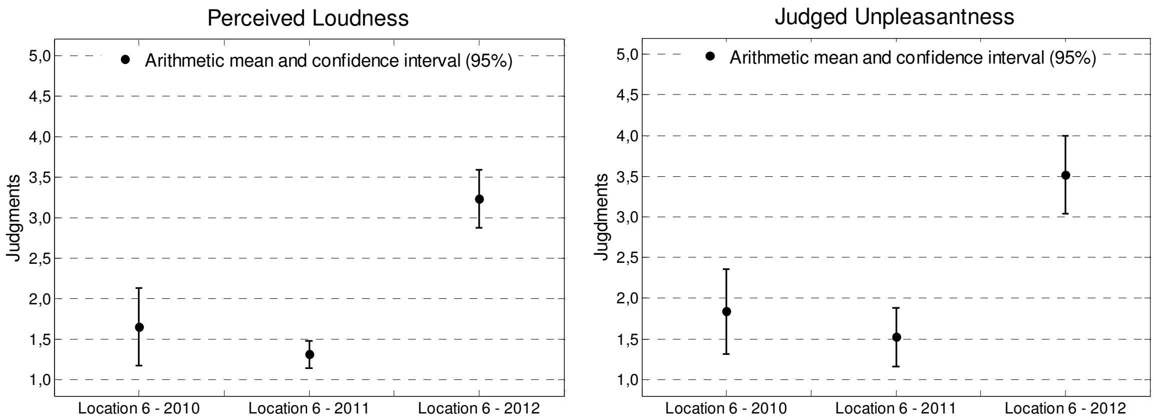

Figure 6 – Comparison of judgments of loudness (left) and unpleasantness (right) of measurement location 6 over three years. Arithmetic mean values and 95 % confidence intervals are shown.

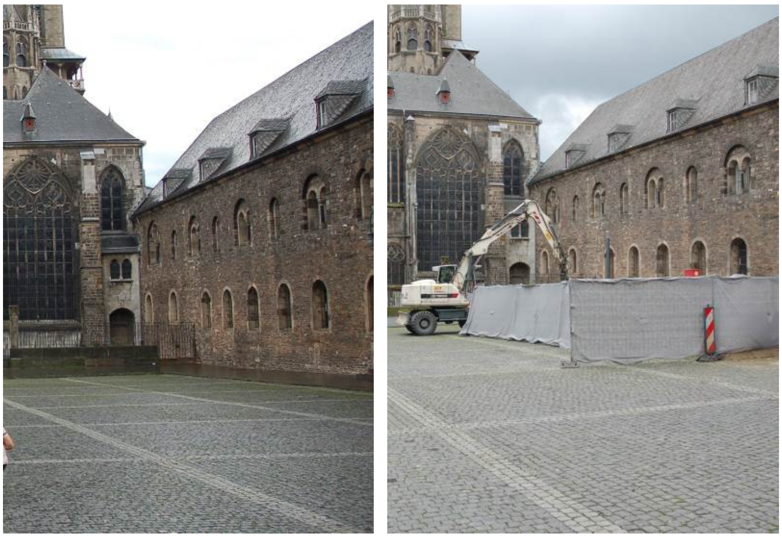

Figure 7 – Measurement location 6 with soundwalk participant in 2011 (left) and the same measurement location in 2012 (right). The construction machinery on the right picture was operating during soundwalk.

However, as shown in figure 7 the judgments of loudness and unpleasantness over the different locations are converging over the years. Although different participants judge different sounds (they do not listen to the exact same sounds), the perception and assessments of the different measurement locations appear to be stable and to be varying only to a small degree indicated by the small confidence interval.

As expected, the inter-individual judgmental differences between groups (2010, 2011, and 2012) are larger than the judgmental differences of the different measurement locations judged over years based on two-sample F-test for equal variances. This confirmed that there are larger deviations between the locations than between the groups; the subjects judged the different locations similarly over a period of three years, which is possibly not surprising. All these results regarding in-situ judgments show on the one hand that a measurement of few minutes can already grasp the acoustical character of a soundscape and on the other hand can evoke similar perceptions and assessments respectively.

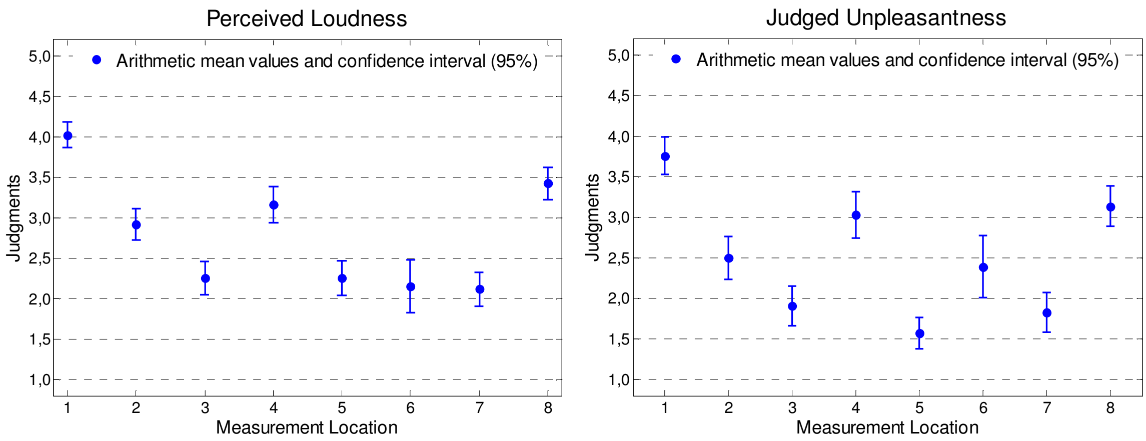

Figure 7 – Comparison of judgments of loudness (left) and unpleasantness (right) of all eight measurement locations averaged over three years. Arithmetic mean values and 95 % confidence intervals are shown.

In the present investigation, the psychoacoustic parameter loudness explains approximately 55 % of the variances in unpleasantness assessments. This variance explanation is higher than observed in other surveys, where usually it is stated that the noise exposure expressed by sound pressure level indicators explains around 30 % of the observed variance in noise annoyance [10]. In general, the psychoacoustic loudness performs significantly better than any sound pressure level indicator. More information about correlation analyses can be in [9]. It can be assumed that due to the visitor perspective of the soundwalk participants non-acoustical factors are less important than in case of residents, who have local background knowledge. This underlines the need to consider always the test sample and its specific relation to the investigated area with respect to the validity and generality of the results.

Finally, based on the collected data an offset between field and laboratory judgments was frequently observed. For example, in [11] it was exemplarily shown that higher loudness and unpleasantness ratings in the laboratory context compared to the soundwalk were observed. They assume that this could be a result of the isolated acoustical information without the context of other senses and the changed focus of participants' attention on sound only.

5. CONCLUSION AND OUTLOOK

All kinds of standards and recommendations in the scope of soundscape investigation have to comply with the general rule: Since soundscape research „relies upon human perception“, all kinds of measurements must always reflect the way soundscape is perceived and understood, by people, in context. This basic rule guides the standardization work and helps to decide for how, when, where and how long must be measured. All measurements must be guided by the way humans typically experience the soundscape under scrutiny.

A common basis of measurement procedures is needed, since due to the diversity of measurement procedures the comparability and compatibility of soundscape investigations is very limited. However, any soundscape standard should not cut down the openness and interdisciplinary roots of the soundscape approach.

The future soundscape standard regarding methods and measurements in soundscape studies have to consider the need for aurally-accurate measurement of the acoustic environments for subsequent psychoacoustic analysis, re-experiencing the acoustic environment and archiving purposes. Moreover, for a psychoacoustic analysis of the soundscape the consideration of psychoacoustic parameters is imperative.[12] In this context, temporal effects, like variation of parameters over time, must be taken into account, since it attracts attention. Moreover, the occurrence of sound sources is important to document and analyze, since it is known that the focus on certain sound sources can change the overall appraisal of soundscapes. [13]

Finally, proposals of limits/ranges from a psychoacoustic perspective e.g. for classification purposes are conceivable, but it is evident that hard, clear cut limits of acoustical parameter cannot be defined, they cannot describe the complex experience of soundscapes. It is very important to emphasize that any soundscape standard regarding methods and measurements in soundscape studies must consider guidelines and recommendations for measurement by persons and measurement by instruments in equal measure.

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