Reliability of In-Situ Measurements of Acoustic Environments

André Fiebig[1]

[1] *HEAD acoustics GmbH, 52134, Herzogenrath, E-Mail:Andre.Fiebig@head-acoustics.de*

Introduction

Recently, the international standard ISO 12913 part 2 (Acoustics-Soundscape-Part 2: Data Collection) is recently under development [1]. Although soundscape research has a long and rich tradition, a common agreement about measurement specifications is still missing. Since it is expected that in the upcoming standard ISO 12913-2 recommendations regarding methods and measurements in the context of soundscape studies will be given, a further discussion about where, when or how long must be measured is reasonable.

In the following the data gained by repeated soundwalks (in-situ acoustical and perceptual measurements) is analyzed with respect to test quality criteria reliability. The reliability criterion is related to the accuracy of data and measurement procedure. It considers the aspect whether the same results would be produced if the research procedure were to be repeated [2].

Data Base

The soundwalk method was repeatedly applied to investigate Aachen city center soundscapes. Eight locations were repeatedly visited, where binaural measurements with a mobile recording system with binaural headset were carried out. In addition, 57 participants took part and among others provided ratings on 5 pt. category scales with respect to perceived loudness and unpleasantness. The data base available for the investigation of reliability issues is displayed in table 1.

Table 1: Details of Repeated soundwalk measurements

	Date	Acoustical measurements	Perceptual measurements
Soundwalk	twice per year in 2010, 2011, 2012, 2105	3 minutes per location	among others, category scaling
Soundwalk	one per month (Oct. 2015 to February 2016	5 minutes per location	no measurements

The same acoustical measurements were performed apart from the fact that in later soundwalk measurements the duration of the acoustical measurements was increased from 3 to 5 minutes. The soundwalk participants were requested to listen to the respective location and experience it with all senses for a duration of 3 minutes. After listening the participants were asked to fill out a questionnaire and provide some assessments.

For the later soundwalks, the acoustical measurements were performed without participants attending. Most of the soundwalks with participants were performed within the framework of the COST network on soundscape of European cities and landscapes [3].

Table 2: Description of soundwalk locations

Location	Short Description
Location 1	Intersection of busy roads close to historical city gate
Location 2	Intersection between a pedestrian area with many restaurants and a street with road traffic
Location 3	Pedestrian area with shops and restaurants
Location 4	Intersection point with traffic lights between a pedestrian area and a busy street
Location 5	Square near city hall with a fountain and cafeterias
Location 6	Rectangular square surrounded by historic buildings with no commercial activity
Location 7	Green area full of people and surrounded by shops
Location 8	Square close to a road used only by public transportation

The different sites were selected with respect to diversity. Table 2 exhibits short descriptions of the eight urban locations, which were repeatedly visited and evaluated. For more information see [4].

Introduction to Reliability

In order to determine generality of observations in experiments, test quality criteria like objectivity, reliability and validity were introduced. The concepts of validity, reliability and generalizability have in modern social science obtained the status of some scientific holy trinity [5]. Reliability covers the aspect of accuracy of a measurement procedure. It considers the aspect whether the same results are obtained if the same measurement is repeated. A high reliability is a prerequisite condition for validity. In detail, temporal reliability (same results achieved when a measurement is repeated at a later time) and comparative reliability (same result is obtained when the same test is applied to different samples taken from the same population) can be investigated. Although a high reliability does not automatically mean a high validity, it is at least a prerequisite to validity. However, if a measurement procedure is systematically biased, a high reliability can occur, although the obtained results are not valid at all. A highly unreliable measure cannot be produce valid results at all.

Reliability of In-situ Acoustical Measurements

The soundwalk method was applied to repeatedly measure (table 2) eight locations with a calibrated and equalized binaural headset. All binaural measurements were done with defined orientation of the headset and a fixed position. The soundwalks were always carried out on weekdays and in the afternoon. However, most conditions were varying, like season, weekday, time of the day (between 2 p.m. and 7 p.m.) and group of participants (between-subjects design of experiment). This means that the acoustical data was collected under unstable, completely uncontrolled conditions.

In order to investigate the reliability of the in-situ measurements, 35 different acoustical parameters were computed for each measurement (like sound pressure level indicators, loudness, sharpness, roughness, impulsiveness, Relative Approach). To make the variation of acoustical results of repeated measurements independent of the unit, the coefficient of variation (see equation 1) was determined.

$$c_v = \frac{\sigma}{\overline{x}} \qquad (1)$$

The coefficient of variation is the standard deviation divided by the sample mean of a certain data set and indicates the variation of measurement results independently of the unit. The acoustical results of the different measurements were repeatedly determined varying the considered duration of measurement.

Figure 1 illustrates for the soundwalks, where the measurement duration was 5 minutes that the mean coefficient of variation, indicating the relative spread of acoustical results of the repeated measurements over the different locations, decreases gradually with increasing the measurement duration. This means that the acoustical results obtained by repeated measurements were around 10% more similar, if the measurement duration is increased from 1 to 5 minutes.

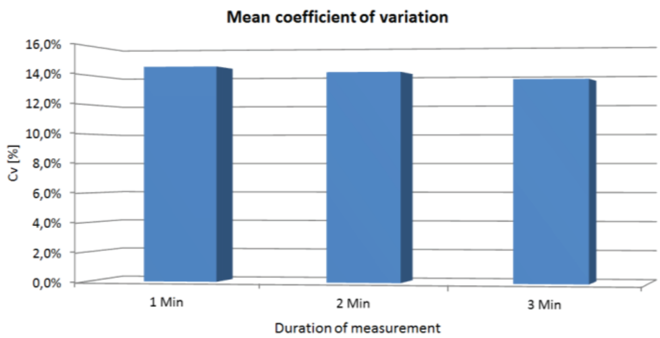

Figure 1: Mean coefficient of variation of 35 acoustical parameters of 13 repeated measurements in dependence of measurement duration

As an example, figure 2 and 3 display the change of variation of loudness measurement results per location. In general, the similarity of loudness results according to the DIN 45631/A1 is higher 20 % if the measurement time is increased from 1 to 3 minutes. Figure 3 shows that the interquartile range of the loudness results per location is smaller in case of three minutes instead of considering only 1 minute measurements in most cases. This means that an increase of measurement duration of in-situ acoustic measurements increases the reliability to a certain extent. Moreover, figure 4 illustrates that the level of similarity of acoustical measurement results obtained by repeated measurements depends on the respective locations. Some locations show greater coefficients of variation than others, which means that the obtained results are more varying from measurement to measurement.

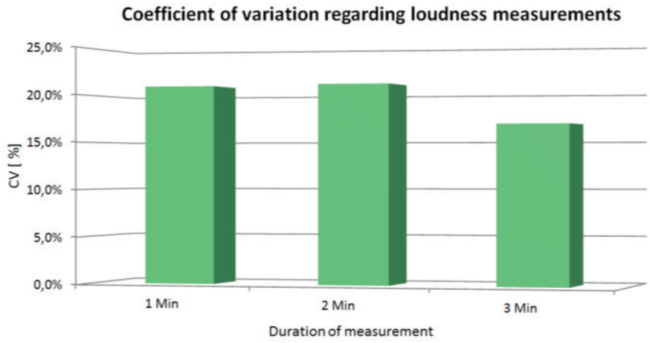

Figure 2: Coefficient of variations of loudness measurement results of 13 repeated measurements in dependence of measurement duration

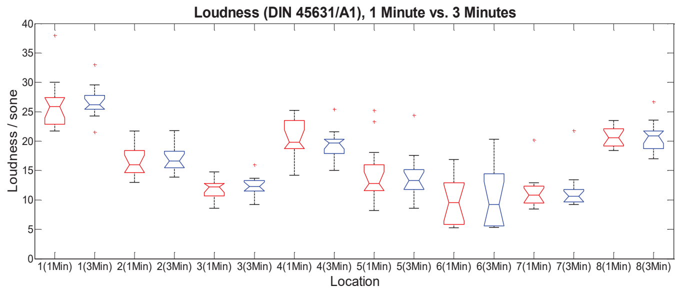

Figure 3: Box-whisker plot: Loudness measurement results of 13 repeated measurements per location. Red: Loudness results of measurements with a duration of 1 minute; blue: Loudness results of measurements with a duration of 3 minutes

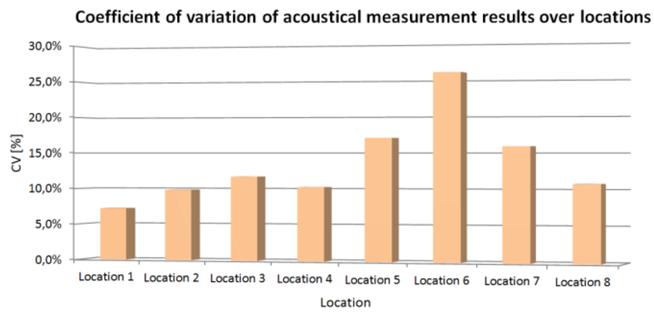

Figure 4: Coefficient of variation of 35 acoustical parameters of 13 repeated measurements over locations

Figure 5 emphasizes the location-dependent similarities of the acoustical measurement results obtained by repeated measurements (5 soundwalks conducted over 5 successive months) over the locations. It can be seen that greater dissimilarities occur at the locations 5, 6 and 7. Obvious particular events influence the acoustical measurement results. In case of location 5 and 6 a Christmas market led to different acoustical results in November and December. In October at location 7, a helicopter was overflying during the binaural measurement and a PA system was operating, heavily influencing the measurement. In contrast to it, other locations show comparably small differences between the results of the repeated measurements like location 1 to 4.

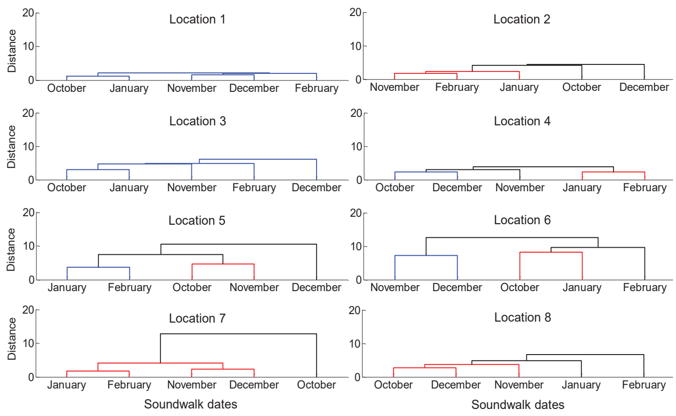

Figure 5: Cluster analysis of acoustical data per soundwalk (35 acoustical values per measurement) over locations. Cluster analysis based on average linkage method using Euclidean distances.

Finally, by means of a 2-way ANOVA the effect of the factor "location" was compared to the effect of "repeating measurements". Both factors were statistically significant. However, as expected the location related acoustical differences (η^2=0.4) are much greater than the differences between the different soundwalks (η^2=0.06). The small effect size of the factor "repeating measurements" indicates that the repeated measurements cause in fact (statistically significant) different acoustical results. However, any differences due to the repetition of measurements are clearly less meaningful than the acoustical differences related to the investigated locations.

Reliability of In-situ Perceptual Measurements

During the soundwalks and after listening three minutes to the environmental noise of the respective locations, the soundwalk participants were requested, among others, to assess the loudness (How loud is it here?) and the unpleasantness (How unpleasant is it here?) on five point unipolar continuous category scales with additional verbal labeling ranging from "not at all" to "extremely" [6]. The experimental leader clearly indicated the time period relevant for the respective assessments. The participants were requested to listen in silence the entire three minutes and to use all senses to perceive the respective soundscape. To reduce the relevance of sequential effects, the order of the visited locations was varied over the soundwalks. The soundwalk group sizes ranged from 4 to 9 participants. All participants were unfamiliar with the visited locations and had no previous knowledge about the locations and their noises.

In total, 57 participants (36 male, 21 female) took part in the eight soundwalks performed from 2010 to 2015. The participants were mostly young researchers with comprehensive background knowledge about soundscape.

Figure 6 and 7 show the assessments regarding perceived loudness and unpleasantness of the eight locations collected over the years. It can be seen that there is a certain similarity between the mean judgments of the locations collected in different soundwalks. Only rarely statistically significant differences occur between the years (see for example location 6, where in 2012 an unexpected construction site and its noise caused deviating ratings). The relative large confidence intervals are due to the small samples.

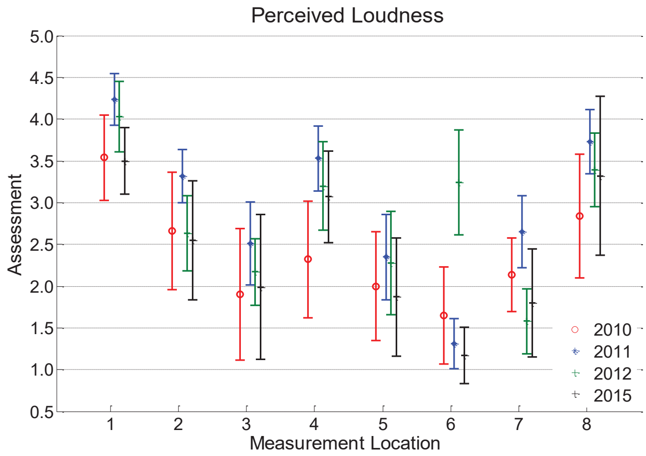

Figure 6: Assessments of perceived loudness of eight measurement locations averaged over groups per year. Arithmetic mean values and 95 % confidence intervals are shown.

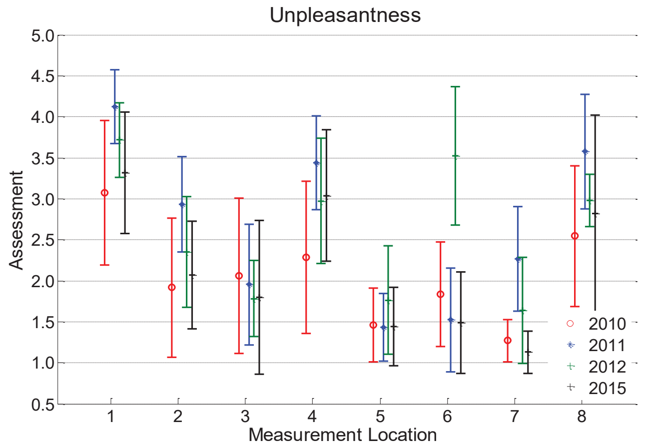

Figure 7: Assessments of unpleasantness of eight measurement locations averaged over groups per year. Arithmetic mean values and 95 % confidence intervals are shown.

The relative comparable assessments collected over the years illustrate that field data collected by the soundwalk method, where several confounding variables cannot be controlled, can provide reliable data to a certain extent. Obviously, the different locations evoke consistently comparable loudness and unpleasantness ratings over the years. Since the data was achieved by means of a between-subjects design of experiment, memory effects can be excluded. Of course, it must be mentioned that the soundwalk participants judged the respective locations from the visitor perspective. These judgments might be different compared to resident assessments.

If the data collected over the different soundwalks is merged, clear trends regarding the locations perceived as quiet and pleasant can be recognized (see figure 8) and the different locations can be clearly distinguished with respect to their sound quality in terms of judged loudness and pleasantness. Moreover, it can be seen that both evaluation criteria are not congruent and statistically significant differences are obtained between loudness and unpleasantness assessments for all locations (except location 4).

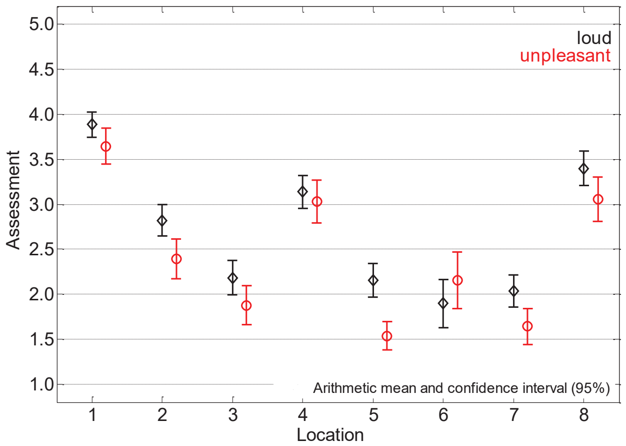

Figure 8: Assessments of perceived loudness and unpleasantness of eight measurement locations averaged over all years. Arithmetic mean values and 95 % confidence intervals are shown.

Conclusions

Beyond doubt, soundscape studies must be carried out in the original context. As a valuable measurement instrument, soundwalks are frequently proposed for exploring urban areas by minds of local experts. To investigate the reliability of acoustical as well as of perceptual data gained by in-situ measurements, consecutive measurements were performed and analyzed.

The presented results suggest that reliable data can be collected by means of in-situ acoustical measurements. Although the soundwalk data (acoustical as well as perceptual data) was repeatedly collected under uncontrolled conditions, the results suggest a reasonable reliability. However, in order to consider reliability aspects in the context of in-situ measurements, it seems inevitable to meet some basic requirements.

It was observed that in most cases a measurement interval of several minutes lead to more reliable acoustical data than only 1 or 2 minutes long measurements. This means that a minimum measurement duration of at least 5 minutes is recommended. However, since certain locations require clearly longer measurements than other locations due to their stronger acoustical variability, preparatory examinations appear reasonable to identify a measurement duration long enough to grasp the acoustics of location reliably. Such preparatory examinations could be repeated measurements preceding a measurement campaign (like a soundwalk with participants) to use a priori knowledge to define a reasonable measurement duration in dependence of the respective character of a location. In general, it is obvious that reliability increases if relevant boundary conditions are recognized and considered (like time of day, day, season, weather, etc.). Interestingly, larger uncertainties in the assessment data were found for locations, which also show larger spread in the acoustical measurement results. This means that certain locations caused more varying loudness and unpleasantness assessments over the different soundwalk measurements, which were also more unstable in an acoustical sense. This observation makes clear that a thorough discussion of the reliability of in-situ measurements is mandatory.

In case that during an acoustical measurement prominent singular events occur (like an overflying helicopter or an ambulance car passing by) which in their (acoustical) meaning are overemphasized in a short-term recording, the measurement duration must be prolonged or the measurement should be repeated. However, a prolongation of the measurement interval is of no use in case the “singular event” is a long-term intrusion into the soundscape, like a Christmas market lasting for weeks. In such cases, the special meaning for a soundscape of such long-term intrusions (like a Christmas market) with respect to the rest of the year must be considered.

Acknowledgment

The author particularly likes to thank Thomas Deutsch for his support in performing and analyzing several soundwalks. Moreover, the author would like to thank all soundwalk participants for their participation.

Literature

[1] ISO/NP 12913-2 (2016). Acoustics. Soundscape, Part 2: Data collection, International Standardization Organization, Geneva, Switzerland (under development)

[2] Marshall, G. (Ed.) (1998). A dictionary of sociology, Oxford University Press, Oxford, New York, UK

[3] COST Action TD 0804, “Soundscape of European Cities and Landscapes”, http://soundscape-cost.org

[4] Filipan, K., Nencini, L., Kaiser, F., Estvez Mauriz, L., Fredianelli, L., Cassina, L., Porupski, D., Chetoni, M., Fiebig, A., Genuit, K., Schulte-Fortkamp, B. (2013). The Study of Soundscape - COST Training School 2012 on "Measurement, Analysis and Evaluation of Soundscapes", AIA/DAGA, Proceedings, Merano, Italy

[5] Kvale, S. (1994). Validation as communication and action. On the social construction of validity, Postmodernist approaches to validity in qualitative research, American Educational Research Association Conference, New Orleans, USA

[6] Fiebig, A. (2015). Acoustic environments and their perception measured by the soundwalk method, Internoise 2015, Proceedings, San Francisco, USA