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COST short term scientific mission: training course on soundscape analysis: soundwalk, recordings, analysis and listening tests

P. N. Dökmeci^a, F. Aletta^b, M. Frost^c, I. Garcia^d, M. Galuszka^e, J. Kocinski^e, H. Lin^f, A. Mundt^c, M. Tomás^g, K. Genuit^h and B. Schulte-Fortkamp^c

^aUniversity of Sheffield, School of Architecture, S10 2TN Sheffield, UK

^bRi.A.S. Built Environment Control Laboratory, Second University of Naples, 81031 Aversa, Italy

^cTechnical University of Berlin, Einsteinufer st., 10587 Berlin, Germany

^dTecnalia, Parque Tecnológico de Bizkaia, 48160 Derio, Spain

^eInstitute of Acoustics, Adam Mickiewicz University, 85 Umultowska Str., 61 614 Poznan, Poland

^fForeign Economic Cooperation Office, Ministry of Env Protection of the People's Republic of China, 115 Xizhimennei Nanxiaojie, Xicheng District, 100035 Beijing, China

^gAAC Acústica + Lumínica, Parque Tecnológico de Álava, Miñano, E-01510 Vitoria-Gasteiz, Spain

^hHEAD Acoustics GmbH, Ebertstr. 30a, 52134 Herzogenrath, Germany
p.dokmeci@sheffield.ac.uk

The collaborative and comprehensive work of group-1, who have attended the short term scientific mission (STSM) initiated through COST: Action TD0804, for the training on soundscape recording and analysis techniques is presented. Group-1 was composed of 9 young researchers who were trained by experienced researchers. The theoretical part of the training school included firstly, introduction to measurement technology, its theory and practical use and secondly, the basic analysis of sound by the conventional indicators and psychoacoustic parameters. Practice on field study was accomplished through semi-structured interview techniques, and evaluation of the recorded dialogue by grounded theory. All these theoretical and practical exercises were followed by a case study. The case study was designed as a sound walk on a pre-defined route, which was accompanied with binaural recordings and soundscape evaluation survey. The STSM for training on the soundscape recording and analysis was accomplished through the presentations and discussions of the results for the case studies of the groups. The results of the recordings and surveys as well as the results of the comparative lab-listening tests of the recorded sound samples of group-1 are presented and discussed as the major parts of this study.

1 Introduction

1.1 The Term ‘Soundscape’

Perception and signal analysis and processing in the auditory system have been researched for many decades. Schafer introduced the concept of soundscape in 1977, as a research field that concentrates on the real perceptual process [1]. The current research on soundscape is still at the stage of describing and identifying the problems. Brown summarized about 33 years of soundscape approach to the acoustical environment [2]. They are focused on a few special cases, like for example the evaluation of soundscapes for residential areas. It is important to emphasize that most of the authors started to use the term ‘soundscape’ to emphasize the way the acoustic environment is perceived [3] and understood by an individual, or a society.

There is currently a lack of standardization and measurement procedures. Nevertheless, it is worth stressing that the EU Environmental Noise Directive recognized the importance of ‘quiet areas’ but there is no definition and method by which such ‘good’ sound environments can be measured [4]. Researchers in environmental and community noise are also beginning to investigate the contribution that soundscape approaches can make to an understanding of human response to noise in both urban and non-urban contexts. This includes the effect of source and context on human experience of noise [5] and the potential restorative capacities of soundscapes on human health and well-being, including the value of high quality acoustic environments to people otherwise living in noisy urban areas [6]. There has also been a broadening focus within studies of human perception of environmental sound; from a long-standing emphasis on annoyance and disturbance only,

towards more understanding of human interpretation and preference for different sound environments [7].

1.2 How to Study Soundscapes?

As it was noticed by Brown [2], despite the growing evidence that measurements based on level or loudness are unable to account for much of human preference for outdoor soundscapes [8], the search for physical acoustical correlates continues. Genuit and Fiebig [9], amongst others, propose that hearing-related physical parameters, other than the averaged intensity of the acoustic stimulus, will be necessary to characterize environmental sounds. Measures such as sharpness, roughness and fluctuation strength of sound have been suggested [10, 11], as have acoustic properties of sound events [10], and music-likeness [12], with emphasis on the spectral and temporal properties of sound—though there is little evidence to date that these explain human preference in outdoor sound environments. It was shown that whilst a low level of sound may be a characteristic of some areas that are of high acoustic quality, quiet is not the antithesis of noisy [13]. Thus, many areas that people might judge to be of high acoustic quality are not quiet.

1.3 Hearing vs. the Mind

It must be emphasized that listening is a complex process, which involves multi-levelled attention and higher cognitive functions, including memory, template matching, foregrounding (attentive listening) and backgrounding (holistic listening) [14, 15]. One should however keep in mind that as the listening experience in a sonic environment evolves, the listener switches between different listening styles: from the more holistic listening in readiness waiting for familiar or

important sounds to emerge (expected or not), to listening in search expecting particular sounds in a context, or even to story listening focusing attention on one particular sonic story within the multitude of sounds.

With this definition, listening is part of a multi sensory experience. Visual information – and to a lesser extent other sensory information – may trigger the expectation for a sound to occur and therefore facilitate attention being drawn to it. Furthermore, meaning can be regarded as the collections of associations that are triggered or evoked in the person's mind by hearing the sounds. These associations influence (and determine) how we interpret the world around us and also depend on other sensory inputs, knowledge about the environment, and expectations grounded in current intentions and previous experience [16].

One must keep in mind that in most situations where the soundscape approach is usable, the whole environment can be observed, measured and steered or even controlled. There seems to be a clear lack of knowledge on what environmental sounds people actually hear when they are not listening in search or listening for the story. An afterwards surveys can only reveal remembered sounds. Attention plays an important role in that process. Fundamental research is complicated because of the importance of context and activities. Trying to measure with people often includes the risk that the experimenter to focus on the participant's attention to the sonic environment in general or to a particular feature of it – thereby ignoring other senses such as visual information.

1.4 Hearing vs. Vision

There is general agreement between researchers that all senses interact with each other at each time. The term soundscape is strongly connected to landscape, which suggests that their definitions should be analyzed together. Cognitive appraisal of the sounds heard within the (audio-visual) environment, together with the meaning they convey could lead to reinforcement of positive or negative emotions triggered by the audio-visual environment. This may in turn focus listening in search of the positive or negative sounds within the sonic environment. Moreover, different senses can give different information and thus different meaning for the same event.

An interaction between hearing and sight, however can occur in many different ways, namely one can become more dominant and

can attract an attention [17, 18]. McGurk and MacDonald in 1976 confirmed that, when stimuli from both modalities (audio and vision) are presented together, a resulting impression can be inconsistent with both modalities, and called this the 'McGurk effect' [19].

Gidlof-Gunnarsson and Ohrstrom in 2007 suggest that green areas that are placed near the subject influence the overall subjective annoyance [20]. This research suggests that not only the level of acoustic comfort is important, with the corresponding landscape and the accessibility to attractive places nearby. Moreover, the long-term annoyance caused by noise can be influenced by sensations from other modalities as well as the possibilities related to urban area visual modifications.

2 The Soundscape Analysis at the STSM in Aachen

The above-described concepts were researched within COST (European Cooperation in Science and Technology) Action TD0804 (Transport and Urban Development). The main objective of the Action TD0804 was to provide the underpinning science for soundscape research and make the field go significantly beyond the current state-of-the-art, through coordinated international and interdisciplinary efforts. Within this Cooperation a STSM (Short-Term Scientific Mission) entitled 'soundscape-measurement, analysis, and evaluation' was organized in Aachen, Germany in July 2011. The STSM mainly focused on performing soundscape experiments in field and laboratory including the collection, analysis and interpretation of the audio, visual and descriptive data. In order to accomplish this aim, soundwalks, acoustical measurements, listening tests in-situ and in laboratory (without and with visual stimuli) as well as subjective assessment of the soundscape (and landscape) were performed.

2.1 Soundwalk and Recording Points

A soundwalk was carried out in the city center of Aachen by two groups of participants during the afternoon on Tuesday, 12th July.. The data gathered by group 1 is presented in this paper. Eight measurement points with different characteristics (different urban soundscapes and landscapes) were investigated starting with at P1 and ending with P8.

At each location the 3 min. signals were recorded using HEAD Acoustics SQuadriga

binaural set used by one of the participants [21]. The measurements were carried out with fixed orientation of headset and a fixed position. During the recordings any subjective impressions (feelings and thoughts they had during their presence in that location) could be written down in the evaluation form. Moreover, some soundscape features (loudness and unpleasantness) were also assessed using 5 point unified continuous scale. It should be stressed that in such conditions all participants have used all senses for their subjective evaluations. Simultaneously, some pictures were taken in each place and used in laboratory part in which the previously recorded signals were again assessed in a special enclosure using headphones in two conditions, namely without any visual stimuli and with a picture of the place, projected on a screen.

3 Measured results of Soundscapes

The aim of the measured-based analysis was to record and to analyse 8 predefined measurement locations. For acoustic analysis and description of the soundscapes, a total of 180 seconds measurements were done in each point location. Upon recording, participants had the opportunity to evaluate both, the perceived pleasantness and the perceived loudness by using a 5-point scale. In addition, participants took notes on their impressions and thoughts of the overall environment.

These recordings were evaluated over time by focusing on the following parameter; sound pressure level (L_p (dB(A)), FFT, loudness (DIN 45631), sharpness (DIN 45692), roughness (Hearing-Model), fluctuation strength, and relative approach [10, 22]. In addition, the single value of the measurement was identified, to enable a comparison with the averaged results. As an example, the analysis of the first measuring point (Point 1-Ponttor: nearby a noisy crossroad) is explained.

First, the analysis of the A-weighted sound-pressure-level is considered. It should be noted that the temporal average level ascertained (in course of the 180 seconds mentioned) was 73.8 dB (A) to the left ear, and 75.6 dB (A) to the right ear. Since each microphone of the 'SQuadriga-System' must be considered a measuring microphone in terms of mono-aural measuring microphones, the question should be raised at the beginning of the analysis whether one microphone is more precise than the other, or which value should be used. The left channel at 73.8 dB (A) was chosen for analysis and representation.

By using the averaged level, significant information on; 'which emission source is relevant for the perception?' was lost. For this reason other parameters for further investigation of the perception were used.

3D Fourier analysis was used to analyse frequency ranges. Low frequencies were in the orange area throughout almost the entire 180 seconds, which resulted into a higher sound pressure level, also showing that these low frequencies were more present than medium (pink), or high frequencies (blue to black). One event was noticeable at approximately on 155th second; the level of high frequencies was considerably higher than in the rest of the sample. However, this analysis does not give any close insight into the perception of the point.

The next parameter used was loudness. Analysis of this parameter was developed by Zwicker, to create a substitute for understanding perception of sound pressure level [23]. Over the course of time during the measurements in this study, varying values of loudness was noted, but it must be pointed out that the peak at 155th second is significantly higher than the amplitude of the level measurement: it is roughly 85 SoneGF. Since the unit 'sone' represents a linear perception, this has to be read as the peak being perceived thrice as loud as the average loudness (27.5 SoneGF to the left ear). According to Zwicker this must be interpreted as symbolising an event which attracts substantial attention [27].

Sharpness was also considered for the analysis. This parameter takes into account the fact that signals with a significant portion of highs are perceived as highly annoying. The part that stood out within the measurement of loudness, stands out again similarly for sharpness values. Other parameters for psychoacoustic analysis are, roughness, and fluctuation strength. Once again these illustrations emphasise a certain time frame, confirming its significance at the 155th second.

The final method used was the 'relative approach. This method 'unmasks' a cluster of signals, and it was developed by *Head-Acoustics*. These clusters can also influence human perception. The signal in the example showed no clusters, except within the time frame mentioned before (155thsec).

It is evident that within this time frame a highly noticeable event must take place, according to the relevant psychoacoustic method of the measurements. This example was especially chosen, because it offered palpable results and illustrations.

Similar to this explanatory representation of the analysis, all of the eight points at the soundwalk has been analysed. Due to the volume of this paper, all detailed results cannot be given.

The findings do not allow for a terminal evaluation concerning the various soundscapes at all the 8 location points. Without the on-site experts (subjective evaluation by the frequent users of the space), their perceptions, and their context, the concluding interpretation of the data is impossible. Only a combination of the analysis of the semantic differential, with the measurement-based investigation and its comments can provide for proximate and complete representation of the human perception on-site. This analysis will be displayed in the following section.

4 Perception of Soundscapes

The soundwalk method was used for analyzing the sonic environment in different point locations in a pedestrian route [24, 25]. Two different approaches are combined in each location: measurements of psychoacoustic indicators and perception evaluations of the participants. One of the objectives of the analysis is to correlate the results of psychoacoustic parameters, to identify which of the objective parameters were strongly associated with the perception of the soundscape in each location. The participants were asked to assess their perceived loudness and perceived unpleasantness of the sound environments that they hear in each location separately.

In many evaluation points, similar tendencies in the perceived loudness, perceived unpleasantness and psychoacoustic loudness were noted. This result leads the interest of deepening in the possibility of using the psychoacoustic loudness as an index to estimate the unpleasantness in the different locations of the soundwalk.

The relation of the perceived unpleasantness and loudness were found to be very similar except some locations, which do not fit perfectly with the graph. The reason for this result may be the presence of other acoustical parameters and their contribution for the subjective evaluation of the locations. Apart from loudness, that influences the perceived unpleasantness, roughness can also be seen as another important psychoacoustic indicator. Furthermore, there are also other non-acoustical factors that can affect the environmental experience regarding the sonic environment. The context, and cultural/personal dimensions of the

participants could also be effective on the evaluation of perceived unpleasantness.

4.1 Lab Analyses on Soundscapes

The perception of the environmental sound of a specific place (soundscape) is defined, not only considering the acoustical aspects, but also the aesthetics, climatic factors etc. and the interactions among them [26]. Nevertheless, the community characteristics regarding cultural, social and personal aspects have influence in this acoustical perception and in the related environmental experience [27, 28].

However, laboratory analysis regarding the perception of sound environment is an approach for the soundscape study that can be useful to obtain a larger sample of data than the field studies, since it provides an exposure to a sound environment in a regular and under control situations [27, 29]. Taking into account this context, the aim of this section is to compare the perception results obtained in the field and in the laboratory, regarding the sound experience of the 8 soundwalk points. It is important to mention that the laboratory analysis was developed after the field study and the participants in both approaches are the same.

The laboratory test was accomplished the day after the soundwalk to the same group of students. In the first session, the binaural audio recordings of the 8 sites (P1 to P8) were reproduced by headphones and the group was asked to answer the same questions that were in the soundwalk about perceived loudness and unpleasantness through specially designed touch screens.

Afterwards a more immersive session of the test was arranged: five of the eight points of the soundwalk were selected and their audio recordings were reproduced while the corresponding photos were projected onto a white screen, in order to get a visual association with the audio signals. Also in this case the group was asked to answer the two questions on perceived loudness and unpleasantness.

4.2 Relation between Lab and Field Results

The results of both the laboratory tests (with pictures and without pictures) were compared with the field results of the soundwalk. The comparison between the visual lab test and the non-visual lab test showed a strong relation of the results; this doesn't necessarily mean that the visual component has no influence on the subject's assessment, but rather that there could be a

recall from the previous experience due to the short time interval between the two test sessions and the subjects tend to assess the scenarios in the same way (memory effect).

Some differences were noticed in the lab trend and the field results, which were possibly generated by the lack of the complex environmental stimuli provided by the *real* world. “The individual experiences, the environment around the participant in a complex and holistic way, and the *sum* of all these inputs produce on the participant a psychological and physiological effect” [30]. This multisensory interaction is almost impossible to reproduce in a non-immersive test, and for this reason some parts of the environmental information of the individual is lost. For example, a higher value for the field test was achieved for the unpleasantness assessment in Point 8 (Elisenbrunn), which was probably influenced by a very bad smell coming from a manhole cover that could not be reproduced in the test sessions. On the other hand, it was realized that there were some aspects that could change the lab evaluation of a soundscape. It is important that, both sound levels are the same (in the lab and in field). For instance in point 6, according to the results, the reproduced level in the lab (with and without photos) appeared higher than in the field.

Finally, the measured psychoacoustic loudness (N) was normalized to the five-point scale of the perceived loudness (N-lab and N-field) to make it comparable with the subjects’ assessment. A strong correlation was found for the three results. The lower rating for the perceived N-field of Point 6 (Aachener Dom) was possibly influenced by the particular spatial configuration of the site (huge empty square between City Hall and Aachener Dom with no pedestrians or commercial activities).

5 Conclusions

The soundscape research is carried out as a part of the STSM that was initiated by COST Action TD0804. In this part of the study 9 young researchers took part. Soundwalk technique with synchronized acoustic recordings and post-signal analyses and subjective evaluations were done at 8 different locations in Aachen city centre. One other method in the study was lab-listening tests that included with or without visual input situations. For the post-signal analysis of the recorded data, 4 methods were used; 3D Fourier analysis (FFT), acoustic parameters (SPL), psychoacoustic parameters (N, R, S, FS), and relative approach. The results highlight that, 1- Only one analysis method would not be sufficient for obtaining detailed

results for a soundscape study, 2- By using averaged SPL values, important data on the sound environment may be lost, 3- loudness as well as roughness are good psychoacoustic indicators that relates well with perceived unpleasantness, 4- the subjective ratings of perceived loudness and unpleasantness in the field, in the lab with visual input and in the lab without visual input are found to be strongly related with each other, 5- the relatively scaled result of psychoacoustic loudness (measured in the field) found to be strongly related with perceived loudness in the field and in the lab. It has also been noted that, visual recall might affect the lab tests. In addition, it is observed that soundscape evaluation of a physical environment may be influenced not only by acoustical properties but also by the inputs through other senses like vision or olfactory.

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