A joint evaluation of interviews of sound perception and noise mapping: a case study in Aachen.

Margret Sibylle Engel[1], Teresa Schmidt[2] and Janina Fels[1]

[1] *Institute of Technical Acoustics, Medical Acoustics Group, RWTH Aachen University, E-Mail:margret.engel@akustik.rwth-aachen.de*

[2] *Communication Science & Human-Computer Interaction Center, RWTH Aachen University*

Introduction

This study presents results from data collected during the project design of the Urban Future Outline project (UFO), funded by the Excellence Initiative of the German federal and state governments, aiming to establish a platform for research on urban spaces. UFO is divided into four sub-projects, and the content featured in this paper concerns the sub-project "Future Ecosystem" (FuEco), which focuses on studies of combined stresses like heat, noise and particulate matter.

The study was conducted in the city of Aachen, Germany, whose main characteristic is to be a border town of medium size, between Germany, the Netherlands and Belgium, with a population of about 240,000 inhabitants. Because Aachen is located in a border region the number of tourists there is high. For the present study a region located in the urban area was chosen, which should encompass a green area and be characterized by a large movement of people and vehicles. Therefore the area chosen was the Elisengarten region (a recreational park in the center of Aachen), including the Friedrich-Wilhelm-Platz, which is characterized by multiple locations to bus stop. Therefore, the noise characterization encompassed urban spaces with different uses.

The aim of this study was to conduct a survey, based on spatial criteria, about the sound perception at four locations in the central region of Aachen. To this end, we first made a sound survey of the area, followed by data collection on sound perception through interviews at selected points. In order to interpret the answers on perception in a broader context, the respondents were also asked about their weather perception, air quality, as well as their views on the site, which was the object of study. The presentation of results by spatial area was possible thanks to the use of the Geographic Information System tools, through the commercial software ESRI ArcGIS ®.

The Geographic Information System (GIS) is a set of tools to deal with geographic information through the collection, storage, retrieval, processing and visualization of data about the real world for a specific purpose [1]. A major reason for the use of GIS is the understanding of a phenomenon that has both spatial, geographical and temporal dimensions [2].

Methodology

Study Area

As can be seen in Figure 2, monitoring points were distributed in the study area, characterized by different colors, as follow: blue dots represent places where we used a measurement set Sennheiser KE-4 capsule omnidirectional microphone and a Zoom-H6 multitrack recording device, that monitored a sampling rate of 44.1 kHz during the entire time span over four to five hours during the daytime, helping to characterize point sources, such as background noise (people talking, children playing and nature sounds). Each day a point was monitored, and simultaneously perception interviews were conducted at these sites; red dots are the points that helped characterize line sources in the generation of noise mapping. At these points sound monitoring was carried out with sound level meter, Norsonic SPM 116 over a period of 10 minutes together with the vehicle counting.

The results of monitoring at all points were used for comparison of measured and simulated sound levels through the noise mapping, thus enabling its validation.

It is important to describe the characteristics of the places where occurred the perception interviews to help the understanding of the responses obtained through the same. The location of point A has a few cafes and a playground for children. Next to the monitoring point there is a large library and a parking house. Point B also has several cafes nearby and bus stops. This is a large movement of people point because in the vicinity there is a unique pedestrian street. Point E is in the middle of the garden called Elisengarten. There are a few places to sit and an archeological center. Point F has in its surroundings a fountain, called Münzbrunnen and street furniture.

Noise Mapping

To noise mapping was used the software SoundPLAN®. The method used for calculation of sound sources in line was NMPB-Routes-96 [3] and the one used for point sound sources was ISO 9613-2 [4].

The following parameters for noise modeling were used: calculation area of 1.73 km^2; contour has spacing of 5 meters, totaling to the calculation area 48 contours lines with altitude ranging from 155 m to 200 m, enabling the generation of the digital terrain model; 171 buildings were included, of which four with one floor, 17 with two floors, 36 with three floors, 85 with four floors, 21 with five floors and 8 over 20 meters high. It is estimated that each floor has three meters high. In addition, sound absorption instruments were inserted on the ground at representative locations. In the garden area were deployed 6 lawn areas and four with harder surface area, as sidewalks, in order the representatives areas. There were simulated 10 line sources and a point source, corresponding to the point E in the middle of the garden. The point source was used due to the fact that the pavilion of Elisenbrunnen is a great sound barrier for the sound levels from Friedrich-Wilhelm-Platz, preventing sound propagation.

Control receivers were inserted in the simulations, which are equivalent to the points of fixed and movable sound monitoring. The results were compared in the receiver with those of monitoring. In this way it was possible to calibrate the model and see which the best results according to the inclusion of sound sources.
After the calculation of the noise maps, they were exported in shape file format (.shp) and worked with ArcGIS software.

Perception interviews

In the interviews of sound perception we used a structured questionnaire with open and closed questions. It was composed of 49 questions, 10 of which referred to sound perception in the monitored sites. The subjects covered in the same were as follows: the auditory classification, existence of hearing problems, the use of hearing aids, acoustic comfort, its restoration according to the sonic environment, and speech intelligibility. Each interview lasted about 12 minutes. The number of interviews at each point can be seen in Table 1.

Table 1: Quantity of interviews in each point

Point	Name	Quantity of respondents
A	Mayersche (book store)	42
B	Glaskubus (square)	40
E	Elisengarten (garden)	58
F	Münzbrunnen (fountain)	48
	Total	188

A cross-tabulation between the results of sound perception and the points where the interviews were conducted was made. Then the geographical coordinates of these points were added. This cross-tabulation was imported and converted into a layer in ArcGIS, which made possible its presentation along with the noise map.

Results and Discussion

The European Commission Working Group through the assessment of exposure to noise - WG-AEN [5] recommends that the difference between measurement and simulation in a noise mapping should range between ±5 dB.

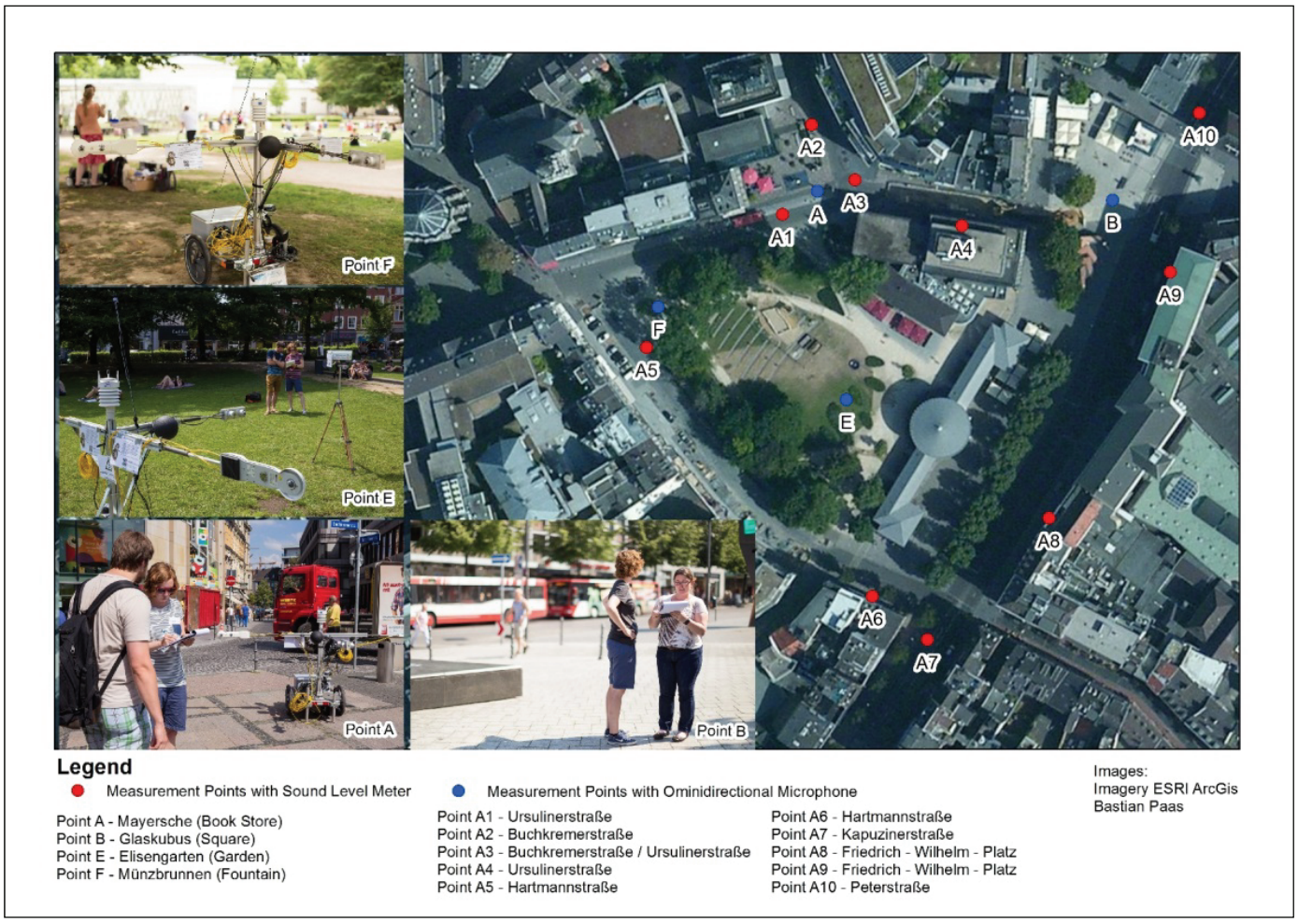

Figure 1: Map, measurement devices, and distribution of the measurement points

Looking at Table 2, it is found that the noise map was validated.

Table 2: Validation of the noise mapping

Point	Measurement (LAeq) dB(A)	Simulation (Lday) dB(A)	Difference dB(A)
A	65.8	68.4	+1.5
B	69.7	68.4	-1.3
E	62.6	65.1	+2.5
F	63.6	59.3	-4.3
A1	62.4	62.0	-0.4
A2	64.0	64.8	-0.8
A3	75.1	74.4	-0.7
A4	70.2	73.3	+3.1
A5	58.5	62.6	+4.1
A6	64.6	68.3	+3.7
A7	70.6	72.7	+2.1
A8	66.7	70.6	+3.9
A9	75.3	77.5	+2.2
A10	70.8	75.5	+4.7

The noise mapping indicates that the highest noise levels are on Friedrich-Wilhelm-Platz, between 70 and 80 dB (A), where there is high bus circulation due a concentration of bus stops in the area. There are also great traffic in the Ursulinerstraße until to point A because nearby there is a parking house, allowing sound levels up to 75 dB (A). In Elisengarten region the sound levels vary from 50 to 60 dB (A).

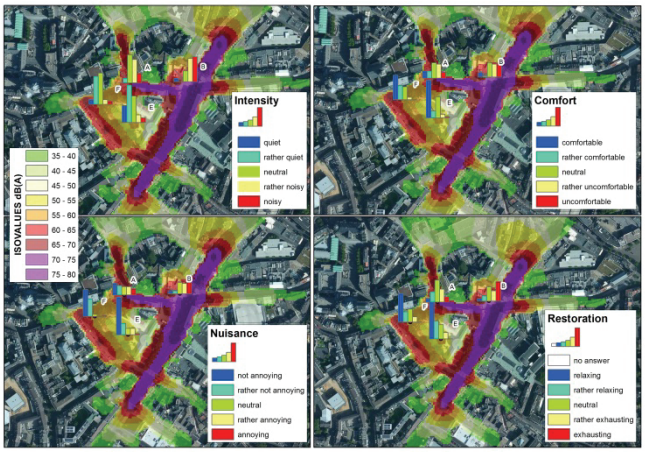

Figure 2: Sound perception response

Comparing the results of the noise mapping with the sound perception, registered in Figure 3, it appears that the point B was identified as noisy and the other points as neutral or rather quiet with regard to intensity perception. As for the acoustic comfort of these sites informants were of the opinion that points E and F are comfortable and the points A and B are neutral, there are some respondents that also felt uncomfortable at point B. Referring to nuisance point B was indicated as a place where respondents are annoyed by the noise of the region. In addition, points A, E and F presented more frequently answers that such sites are not annoying regarded to noises. Finally, with regard on the restoration of well-being through the sonic environment, respondents reported that at point B they felt exhausted, at points E and F relaxed and at point A neutral.

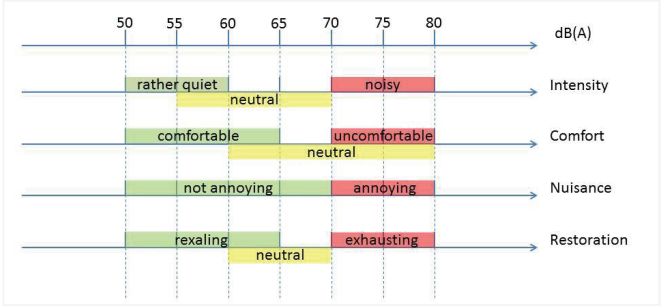

Figure 3: Comparison between noise levels and frequent responses

Figure 3 shows that the most frequent answers of discomfort, exhaustion, annoyance and that the environment is noisy occur in places with sound levels over 70 dB(A).

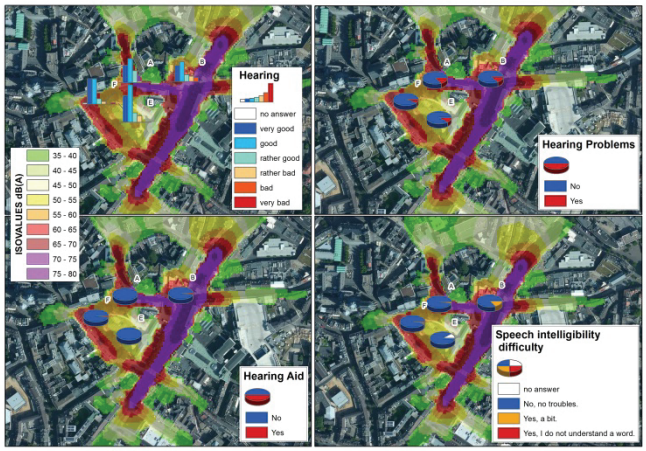

Figure 4: Hearing response

Respondents evaluated themselves with regard to their listening skills (Figure 4). With regard to possible difficulties in speech intelligibility, they informed they had no such difficulty; however, it was noted that, with regard to point B, a small number of them showed some difficulty in understanding of the acoustic signal of the interviewer.

It was found that speech intelligibility can be related to the perception of sound intensity and can also be evaluated by comparison with the sound equivalent levels (L_{Aeq}) of the region.

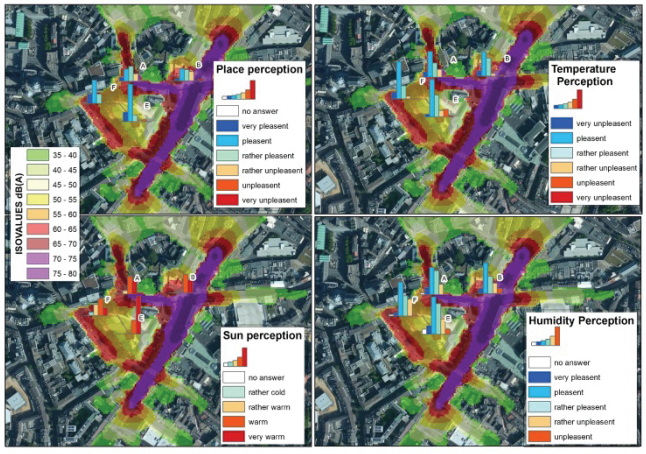

Figure 5: Place and climate perception

As already mentioned in the introduction to this paper, in order to facilitate the understanding of sound perception in the study area we also analyzed the perception data related to place, climate and air quality; these are arranged in Figure 5 and Figure 6.
Respondents reported that they consider the points B, E and F as pleasant places and point A as rather pleasant.
As the perception of temperature and humidity in all places where the survey was conducted, respondents classified these climatic conditions as pleasurable. In general, the weather was considered as "very good" at all points. Regarding the perception of solar radiation, informants rated point E as "very warm" and the other points as "warm". The perception of the wind was classified as "pleasant" at all points; however the point E there were people who felt the wind as unpleasant. As for the perception of wind speed at A and B the wind was considered rather low, while at the other points it was ranked as low. With respect to air quality, people reported that the points A, E and F possessed good air quality, while at B the air quality was considered as rather bad.

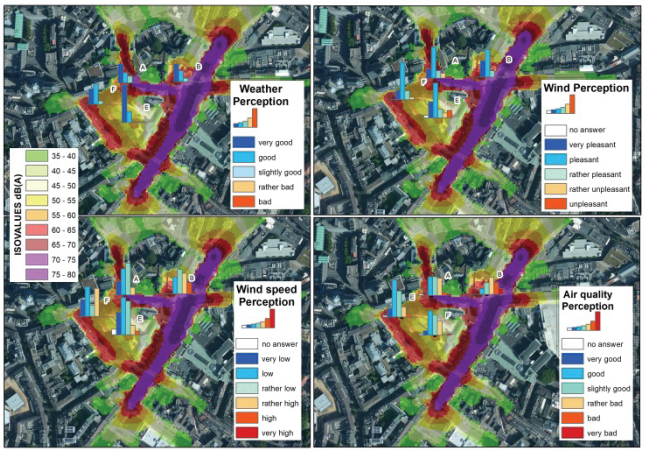

Figure 6: Climate and air quality perception

It appears that there is some relationship between the perception of sound quality and the climate perception, such as solar radiation, wind and wind speed, especially at point E. Data from interviews conducted at this point indicate through that the air circulation was lower as at other points; this fact influenced the general perception of the environment and was also one of the reasons for the negative evaluation of the sound quality at this site. The perception of air quality is influenced by visual perception; so does the perception of sound intensity. Accordingly, by observing several large vehicles circulating at B, for example, respondents associated movement of such vehicles to environmentally polluted environments.

Conclusion

This study aimed to portray, using the spatial dimension, the sound perception at four points of the central region of Aachen. It clearly led to the realization that the sound perception of intensity can be easily compared the equivalent sound pressure level, which is generally used in the generation of noise maps.
Taking into account the most frequent answers on sound perception, there is a clear concession that sound levels above 70 dB (A) are considered noisy, uncomfortable, annoying and exhausting.
The place perception relates to the sound perception clearly regarding nuisance, comfort and restoration. Therefore, the visual perception has great influence on respondents' answers.

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