Influence of urban climate on perception responses in soundwalks: case study Aachen

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1. Introduction

This study presents results collected during the field work of the Urban Future Outline project - UFO (2015), a research project funded by the Excellence Initiative of the German federal and state governments in order to establish a platform for research on urban spaces. It is part of HumTec Project House (2015) and is divided into four distinct areas, namely: Urban Turn (U-Turn), Future Mobility (FuMob), Future Energy (FuEne), Future Ecosystem (FuEco). The last one focuses on studies of combined stresses like heat, noise and particulate matter. The results presented in this paper are included in the context studied by FuEco sub-project. On the acoustical area various strategies for obtaining data related to environmental stress factors were adopted, such as sound monitoring, noise mapping, sound perception interviews, soundwalks and the consultation with governmental agencies to compare results.

In recent years, based on socio-environmental and environmental health studies, as well as on urban planning, the scientific community has rethought the assessment of noise and its effects on quality of life. It is suggested to take into account all of the sound in an environment in its complexity, ambivalence, meaning and context considering the conditions and purposes of its production and perception (NWIP ISO 12913-2:2014). Consequently, it has been found that studies on soundscape and landscape, as both are based on perception by people follow a comparable experimental setup. The perceptual construct (soundscape) is related to physical phenomena (acoustic environment) (ISO/DIS 12913-1: 2014).

The definition of soundscape, according to ISO/DIS 12913-1 (2014) reads as follows: „Acoustic environment as perceived or experienced and/or understood by a person or people, in context“. The context may influence soundscape through the auditory sensation, the interpretation of auditory sensation, and the responses to the acoustic environment. One of the factors that influence the acoustic environment is weather.

The perception of the context includes a set of perceptions, such as the auditory, visual, sensory, and weather conditions. For this reason the present study aims to investigate the influence of urban climate on the perception of the environment in the visual, auditory, climatic and cultural aspects.

2. Methodology

For the study of soundscapes NWIP ISO 12913-2 (2014) recommend a triangulation, that is, a combination of several methods. In this study the combination of methods for environmental evaluation is shown in Fig. 1.

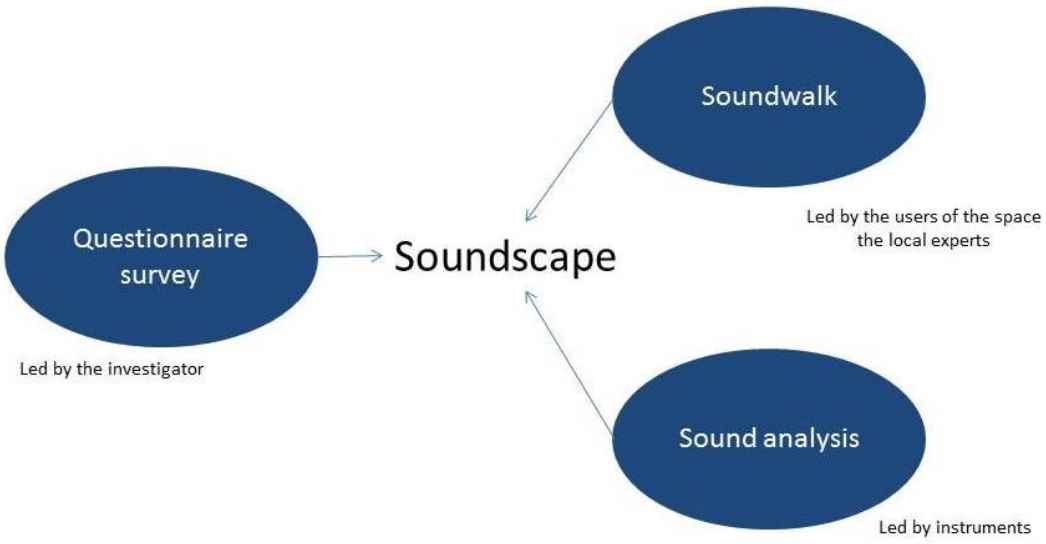

Fig. 1 Triangulation: combination of evaluation methods for the soundscape approach (adapted from NWIP ISO 12913-2:2014)

According to Schafer (1969), soundwalking is an empirical method to evaluate a soundscape and its components in several locations. Semidor (2006) suggested the use of binaural microphone system plugged into a DAT recorder. This equipment allows the collection of sound data that will be evaluated in conjunction with the subjective data collected through questionnaires or sound perception interviews.

In the present study, the triangulation method for evaluating the soundscape consisted of conducting soundwalks, in which participants evaluated the environmental perception of a particular area in Aachen, Germany by filling in a questionnaire. At the same time, the weather conditions (i.e., temperature, wind speed and relative humidity) were monitored, as well as the acoustic conditions.

2.1 Study Area

The study was conducted in the region of Aachen at the central area called Elisenbrunnen. The area count with four monitoring points, comprising a small park (Elisengarten, points E and F), a playground area (Point A), as well as an area of cafés with bus stops nearby (point B).

Fig. 2 Study area

In the present study the coordinators of the soundwalk scheduled that the participants had to evaluate three consecutive points. In the Elisenbrunnen area it was possible to run 24 routes, with three evaluation points, as follows: route 1 (points A-B-E), route 2 (points A-B-F), and so forth.

In this study, 44 participants attended the soundwalks. 43.2% persons were female and 53.8% male; and 50% of participants have aged between 17 and 21 years, 36.4% between 22-30 years and 13.6% fall within the age group 31-40 years.

Fifteen of 24 possible routes were used. A total of 132 responses on the perceptual ratings were collected and evaluated.

2.2 Instrumentation

For the soundwalks the research team had at its disposal equipment for sound monitoring and weather conditions. For sound monitoring we used a set Sennheiser KE-4 capsule omnidirectional microphone, KE-3 binaural microphones and a Zoom-H6 multitrack recording device that monitored a sampling rate of 44.1 kHz during the entire time span. The microphone calibration was performed with a B&K 4231 calibrator.

To monitor the weather conditions we used a Humidy and Temperature Sensor Testo 625 and an Anemometer Windmaster 2 Pro.

The acoustical and weather monitoring had the same duration as the time required for evaluation of the monitoring locations with the aid of environmental awareness questionnaires. The time for each individual rating ranged between 3 and 13 minutes.

2.3 Questionnaire Design

In the soundwalks we used a semi-structured questionnaire with open and closed questions. The questionnaire was divided into three parts: 1) demographic information and weather perception; 2) landscape perception, acoustical perception and economic factors; 3) expectations regarding environmental noise in an urban area. Results from parts 1) and 2) are reported in this paper.

The content addressed followed the recommendations of Jennings & Cain (2013) for conducting a survey of the information items that comprise a landscape, as well as of the factors that influence it in a positive or negative way, like the interventions through architectural projects. Other issues addressed were as follows: how the participant felt about the place, if he possessed analytic hearing thanks to the identification of the sound sources, and what was his opinion of such sources.

For this study, nationality was used as demographic information. This type of data was in nominal scale.

The weather conditions were surveyed in closed format on six items, each rated on an ordinal scale of six levels (i.e., for the question “How would you generally describe the weather today?” the answers options were: very bad, bad, rather bad, rather good, good and very good).They aimed to examine how the informant felt about each weather parameter raised: temperature, sun heat, humidity, wind speed, wind speed comfort, and weather in general.

Each participant provided one response on each variable in the first part of the questionnaire for the demographic and weather condition perception questions. This study only used one acoustical and one landscape perception question item. These two items were again rated on a six-level ordinal scale (i.e., for the question “What do you think of the current location?” the answers options were: very uncomfortable, uncomfortable, rather uncomfortable, rather comfortable, comfortable and very comfortable). The acoustical question was about background noise in the place. And, the landscape question was about what the participant thought of the current location. As those questions were in the second part of the questionnaire, the sample consisted of 132 responses from 44 participants providing responses at three evaluation points.

Statistical analysis was performed using IBM SPSS Statistics 22. The following statistical analyses were performed: Spearman Correlation Coefficient (ρ) and Pearson Chi-squared (χ^2) for scale and ordinal data as well as Cramer’s V association measure between ordinal and nominal variables. The a *priori value* of α for null hypothesis significance testing was chosen at 0.05.

3. Results and Discussion

The association of the monitored weather conditions and perceived weather conditions were analyzed using the Spearman correlation coefficient. The analysis was first performed on the complete sample, and then again on two sub-samples split based on individual responses of negative perception (i.e., from “rather uncomfortable” to “very uncomfortable”) and positive perception (i.e., from “rather comfortable” to “very comfortable”). In the total 132 responses, 62 responses were rated negative and 70 responses rated positive. Only the significant results are reported in Tab.1.

Tab. 1 Spearman Correlations (ρ) results from weather measurement vs weather perception

	Sample Perception Item	Avg Temperature	Max Temperature	Min Temperature	Avg Wind Speed	Avg Humidity
Complete Sample	How would you generally describe the weather today?	.535***	.492***	.502***	-.451**	-.370***
	How do you feel about the temperature today?	.342*	.388**	.358*	-	-.315***
	What do you think of the current location?	-	.277***	.182*	-.223**	-
	How do you feel about the background noise in this place?	-	.268**	-	-.197***	-
Subsample with Negative Perceptions	How do you feel about the background noise in this place?	.253*	-	.329**	-	-
Subsample with Positive Perceptions	How do you feel about the background noise in this place?	-	.317**	.257*	-	-

Legend: (-) not significant; (red) negative correlation, (<0.4) weak correlation; (>0.4 to <0.5) moderate correlation; (> 0.5) strong correlation, (*) p<.05, (**) p<.01, (***) p<.001.

For the analysis on the complete sample, there exist a trend of positive correlation between temperature and perceived comfort in general weather condition, temperature, location preference, and background noise. There are strong correlations between “How would you generally describe the weather today?” and the average and minimum temperatures. All other correlations are moderate or weak.

Almost all correlations are positive only few negative correlations occurred, such as:

“How would you generally describe the weather today?” vs wind speed,

“What do you think of the current location?” vs wind speed,

“How do you feel about the background noise in this place?” vs wind speed,

“How would you generally describe the weather today?” vs average humidity and

“How do you feel about the temperature today? vs average humidity.

The results suggest that when wind speed and average humidity are increasing, the perceptual response tends to increase discomfort.

For the analyses on the split subsamples, the following results were observed:

1. On the negative perception subsample there are positive weak correlations between “How do you feel about the background noise in this place?” and average as well as minimum temperatures. It means that when the minimum and average temperatures increased, the comfort related to the background noise increased also.
2. On the positive perception subsample there are positive weak correlation between “How do you feel about the background noise in this place?” and maximum as well as minimum temperatures. It means that when the minimum and maximum temperatures increased, the discomfort related to the background noise increased also.

As the results have shown an ambiguous response, further analysis will be realized to understand better this issue.

The same coefficient was calculated to analyze the main weather perception parameter vs individual weather perception parameters.

There is only one negative correlation between the subjective feeling regarding wind speed (comfort) and the wind speed perception with ρ = -.301 (p = .047). Strong correlations are noted between “How do you feel about the heat of the sun today?” and “How would you generally describe the weather today?” with ρ = .533 (p=.002), or “How do you feel about the temperature today?” with ρ = .503 (p = 0.000). So the perception of “warming sun” is positively associated with general weather perception and temperature perception. Other strong correlations occurred between “How do you feel about the background noise in this place?” and “What do you think of the current location?” with ρ = .576 (p = 0.000). It means that the place perception depends on the background noise of this place. There is a moderate correlation between “How do you feel about the temperature today?” and “How would you generally describe the weather today?” with ρ = .460 (p = .002). And there is a weak correlation

between “How do you feel about the humidity in the air today?” and “How would you generally describe the weather today?” with ρ = .300 (p = .048).

Tab.2 compares the dominance of each individual measured weather metrics in the prediction of each perceived weather condition. For the description of the weather there are a greater association between the perceived parameter and the following sequence of measured parameters: maximum and minimum temperatures, average humidity, average temperature and wind speed. For perceived temperature the importance of the measured parameters are the following: humidity average, temperature average, wind speed, minimum and maximum temperatures. Measured wind speed is not significant for the wind speed description, but humidity average and temperature (average, maximum and minimum) are significant. Wind speed (comfort) has greater association with humidity average, temperature (maximum, minimum and average) and wind speed.

Tab. 2 Chi-squared (χ^2) results of perceived and measured weather conditions

Variable 1 (perceived)	Variable 2 (measured)	General (N=44)		
		Chi^2	df	Sig.
How would you describe the weather today?	Temperature Avg	52.963	36	0.034
	Temperature Max	56.935	36	0.015
	Temperature Min	56.935	36	0.015
	Humidity Avg	56.935	39	0.032
	Wind Speed	34.748	21	0.030
How do you feel about the temperature today?	Temperature Avg	50.004	24	0.001
	Temperature Max	40.004	24	0.021
	Temperature Min	42.711	24	0.011
	Humidity Avg	50.830	26	0.002
	Wind Speed	47.443	14	0.000
What is the wind speed today?	Temperature Avg	77.147	48	0.005
	Temperature Max	73.944	48	0.009
	Temperature Min	72.111	48	0.014
	Humidity Avg	77.611	52	0.012
How do you feel about the wind speed today? (comfort)	Temperature Avg	114.027	48	0.000
	Temperature Max	114.799	48	0.000
	Temperature Min	90.912	48	0.000
	Humidity Avg	115.662	52	0.000
	Wind Speed	44.102	28	0.027

Legend: (-) not significant.

Location and background noise perception at each measurement point were compared with the weather measurements and the results are shown in Tab. 3.

Tab. 3 Chi-squared (χ^2) results from location and background noise perception vs weather data at each measurement point

Variable 1 (perceived)	Variable 2 (measured)	Point A (N=40)			Point B (N=34)			Point E (N=43)		
		Chi^2	df	Sig.	Chi^2	df	Sig.	Chi^2	df	Sig.
What do you think about the current location?	Temperature Avg	60.244	33	0.003	-	-	-	-	-	-
	Temperature Max	60.244	33	0.003	-	-	-	-	-	-
	Temperature Min	59.144	30	0.001	-	-	-	-	-	-
	Humidity Avg	60.244	33	0.003	-	-	-	-	-	-
How do you feel about the background noise in this place?	Temperature Avg	-	-	-	-	-	-	61.986	36	0.005
	Temperature Max	-	-	-	38.518	18	0.003	60.137	33	0.003
	Temperature Min	-	-	-	38.518	18	0.003	61.896	36	0.005
	Humidity Avg	-	-	-	38.518	18	0.003	61.896	36	0.005
	Wind Speed	-	-	-	38.518	18	0.003	-	-	-

Legend: (-) not significant.

Point F has no significant values between measured weather conditions and location perception, as well as background noise perception.

Measured minimum temperature, at point A, is the parameter that has lower χ^2 value on the perception about the current location, with 59.144; and maximum temperature, at point E, has lower χ^2 value on the perception of background noise, with 60.137.

The weather perception has also influence from demographic and cultural background, specifically nationality, as shown in Tab. 4. The sample was composed by 34 Germans, three Chileans, two Brazilians, one Syrian, one

South Korean, one Finnish, one Croatian and one Chinese. Cramer's V analysis shows a distinct association between the nationality of participant and the general description of the weather, as well as perception of wind speed (comfort).

Tab. 4 Cramer's V between demographics and weather perception

Variable 1	Variable 2	General				
		Chi^2	df	Sig.	Cramer's V	Sig.
How do you generally describe the weather today?	Nationality	34.980	21	0.028	0.515	0.028
How do you feel about the wind speed today? (comfort)	Nationality	61.766	28	0.000	0.592	0.000

Legend: For Cramer's V (<0.4) weak correlation; (>0.4 to <0.5) moderate correlation; (> 0.5) strong correlation.

4. Conclusion

This study reported the influence of the urban climate on environmental perception through soundwalks. It can be concluded that:

1. The perception of wind speed is negatively correlated with general perceived weather condition, overall preference of current location, and background noise.
2. It was observed that when humidity average decreased, weather and temperature description were better ranked.
3. When (average and minimum) temperature increases, participants tend to perceive the general weather condition much more positively.
4. When participants related positive responses to sun feeling than perceived weather and temperature had also positive responses. And this type of correlation was strong.
5. When the background noise was perceived positively, the overall location perception also tends to be positive.
6. The wind feeling (comfort) depends on temperature (average, maximum and minimum) and humidity average more than wind speed at all.
7. Weather perception has also influence from demographic and cultural background, like nationality.

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