Soundscape evaluation in urban green spaces:
The case study of Bragança, Portugal

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1. Introduction

Soundscape is a concept first used by Schafer at the end of the 1960's in analogy to landscape (Kang, 2007). From then on, many other authors have used this concept to account for the subjective experience and, therefore, to account for noise in cities in a more positive manner (Raimbault and Dubois, 2005). Soundscape is a sound or a combination of different sounds, causing different human sensations as a result of its physical characteristics, meaning and relevance to the listener. In the last decades, an ever increasing number of unique soundscapes have completely disappeared or they have simply been transformed into uncharacterised contemporary city soundscapes, in which traffic noise has become the dominant keynote (Kang, 2007).

Regulations based on sound pressure levels are important measures to mitigate consequences arising from exposure to urban noise, but further actions are required because creating «silent» cities is far from being a viable solution. The best strategy is to create urban soundscapes that can be pleasant to the citizens. Brown (2003) argued that pleasant soundscapes must be achieved through the definition of acoustic objectives at the level of urban planning, based on the information content of the sound and not on the level of the sound, as is done in conventional noise abatement and control assessments.

Urban green spaces have increasingly been considered as part of an effective and sustainable solution based on a constructive city planning process. The positive impacts of the vegetation in urbanized areas rely mostly on its ability to attenuate noise levels and to preserve/promote natural urban soundscapes (Bolund P. and Hunhammar S. 1999; Lam *et al.*, 2005).

Within the framework of an ongoing research project, soundscapes of four urban green areas located in the city of Bragança, Portugal, were evaluated with the purpose of identifying factors that may influence soundscapes pleasantness.

2. Methodology

Green Spaces - Brief Description

Soundscapes were evaluated in four urban green spaces during the daytime period (Figure 1): *Fervença* greenway – *Polis* (PO), *Quinta da Braguinha* park (BR), *Cavaleiro Ferreira* Square (CF) and *António José de Almeida* garden (AA). The selection of these spaces was based on various factors, being the most relevant their principal functions and the level of use.

Green areas (grey color)		Main Characteristics	Main Functions
Quinta da Braguinha Park Bragança, Portugal	Quinta da Braguinha Park Bragança, Portugal	This is a very recent green area concluded in 2002 within the framework of the *Quinta da Braguinha* urbanization project, aiming to offer some aesthetic, social and environmental services. This park of approximately 2 ha consists mainly of lawn areas, planted with several young trees. There is also a playground structure for children and some physical maintenance elements for adults. This area is flanked by traffic roads, which are the main artificial noise source.	Recreation, Leisure, Walking, Relaxation
Cavaleiro Ferreira Square Bragança, Portugal	Cavaleiro Ferreira Square Bragança, Portugal	This space, located in the heart of the city, was constructed in 1957 and is one of the most popular urban place in Bragança. The traditional geometric forms exist in the design of this area. Remarkable characteristics are the tree belt displayed along its perimeter and the fountain with several water jets. This space of about 0.25 ha has many short duration users and is surrounded by relatively high traffic roads.	Tourism, Leisure, Political, Economical and Educational Activities
José António de Almeida Garden Bragança, Portugal	José António de Almeida Garden Bragança, Portugal	This garden is located in the centre of the city, near the left bank of the Fervença river. It has approximately 0.5 ha and is constituted of two levels. Interviews were conducted in the lower level, which is the most appealing area of the garden. About 40% of this lower level consists of beds of flowers, grass, shrubs and trees of large sizes. The remaining part is composed of stones and there are also some equipment. The traffic road crossing the southern side of this space constitutes the main artificial noise source.	Relaxation, Leisure, Cultural Events
Fervença Greenway - Polis Bragança, Portugal	Fervença Greenway - Polis Bragança, Portugal	This urban green corridor of about 4 ha comprises the both sides of the Fervença river in its passage through the city centre. This area is an important cultural and ecological heritage of the city. In this park, natural and artificial elements are harmoniously intertwined, creating an acoustical environment with natural and artificial sounds. Most of the area is covered with grass or spontaneous herbaceous. Another singular characteristic is the abundant riparian vegetation together with some isolated trees. The topography of the area with sloping banks, especially on the right edge, substantially reduces the exposure to road noise.	Tourism, Education, Recreation, Leisure, Walking, Relaxation

Figure 1: *Basic information on the green spaces in the city of Bragança, including site plan, main characteristics and main functions.*

Field Surveys

Field surveys were conducted by direct questionnaire, between May and September of 2007. A total of 201 interviews were done throughout the four locations: 56 at the António José de Almeida garden, 53 at the Fervença Greenway-Polis, 53 at Cavaleiro Ferreira square and 39 at the Quinta da Braguinha park (Figure 2).

The questionnaire consisted of four sections: 1. related to the socio-demographic profile of the interviewees; 2. two questions about their perception on acoustics comfort in their residential area and in the place of the interview; 3. evaluation of preferences over sounds identified in the location; 4. noise control measures (not included in this poster). For all questions, except those from section 1, each interviewee answered in accordance with a five level Likert scale.

Sound measurements

Sound measurements were also performed to assess the acoustics environment in each area, by using a Bruel & Kjaer sound meter, model 2260 (Figure 2). The measuring system was kept away from the interviewees in order to avoid interferences arising from the conversation between the interviewer and the interviewee.

Figure 2: *Pictures showing details about field work (interviews and measurements).*

3. Main Results and Discussion

In the following sections, the soundscapes of the four green spaces are briefly described and discussed. A brief comparison between the objective and subjective evaluation is addressed as well.

Objective Evaluation: Acoustic and Psychoacoustics Indicators

Acoustic and psychoacoustic indicators were calculated from sound measurements (Table1): Equivalent continuous sound level (LAeq), percentile levels (LAn), peak sound pressure level (LApk), equivalent continuous sound level corrected for tonal and impulsive components (LAr) (IPQ, 1996), spectrum gravity centre (G) (Raimbault *et al.*, 2003) and the Zwicker loudness index, N (Zwicker *et al.*, 1991).

Table 1: *Average values of acoustic and psychoacoustic indicators obtained in the four urban green spaces.*

Acoustic/Psychoacoustic parameter	AA	BR	CF	PO
LAeq (dBA)	57	56	65	60
LA1 (dBA)	65	65	70	68
LA10 (dBA)	60	58	66	63
LA50 (dBA)	56	52	64	57
LA90 (dBA)	52	48	63	55
LA99 (dBA)	50	45	52	54
LApk (dBA)	91	92	97	95
LAr (dBA)	58	57	65	62
G (Hz)	411	350	431	615
N (sones)	10	8	17	10
Nº of measurements	56	39	53	53

Green: lowest values; **Red:** Highest values

The four places exhibited different acoustic conditions. Taking into account the results from the kruskal-Wallis test, these differences are significant for a 5% level (α=0,05). CF is the space where environmental sound reaches the highest levels and loudness. LAeq for the daytime period reaches values near 65 dBA, LA90, which is mostly used as a background noise indicator, exceeds 60 dBA and N is equal to 17 sones. On the other hand, BR is the quietest location, with LAeq = 54 dBA, LA90=47 dBA and N=8 sones. AA and PO are characterised by similar acoustic conditions, with higher acoustic energy when compared to BR. The slightly higher values of G, registered in PO, suggest the influence of other sound sources comparatively to the other studied locations.

Subjective Evaluation - Acoustic comfort

The interviewees were asked to characterise acoustic comfort in both their residential area and the green space using a five level Likert scale. This scale ranges from 1 (very uncomfortable) to 5 (very comfortable). The results are depicted in figures 3 and 4, respectively.

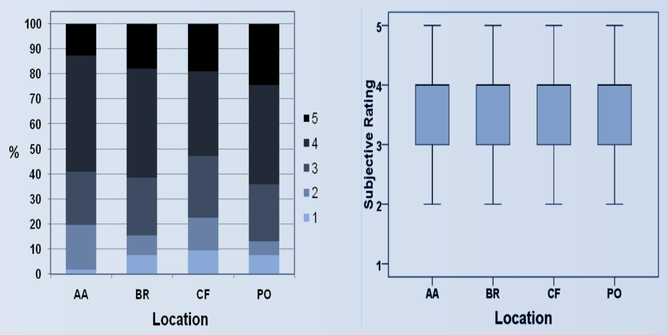

Figure 3: *Subjective rating of the acoustic comfort in the residential area of interviewees.*

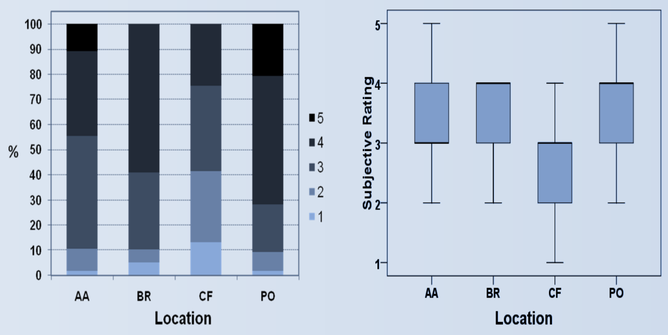

Figure 4: *Subjective rating of the acoustic comfort in the different green spaces.*

Figure 3 displays a very similar pattern in the responses given by the interviewees, indicating that all of them have experienced similar acoustic environments in the places where they live in. This trend is very plausible, because Bragança is a small city where noise is nearly restricted to the main road traffic axis that crosses the city. These results constitute a good sign for the confidence of the subjective evaluation.

Concerning the perception on acoustic comfort in the four green spaces (Figure 4), it seems clear that the CF soundscape is significantly different from the others, having received a negative rate on average, with more than 40% of the interviewees finding it «uncomfortable» or "very uncomfortable". The other three locations are very similar. However, while AA and PO were considered «very uncomfortable» by 10% and 20% of respondents, respectively, the best evaluation for BR was «comfortable».

Subjective Evaluation - Preferences of Identified Sounds

The interviewees were asked to identify the most relevant sounds they heard on location and to rate them in relation to their pleasantness/annoyance using the same five level Likert scale (Figure 5).

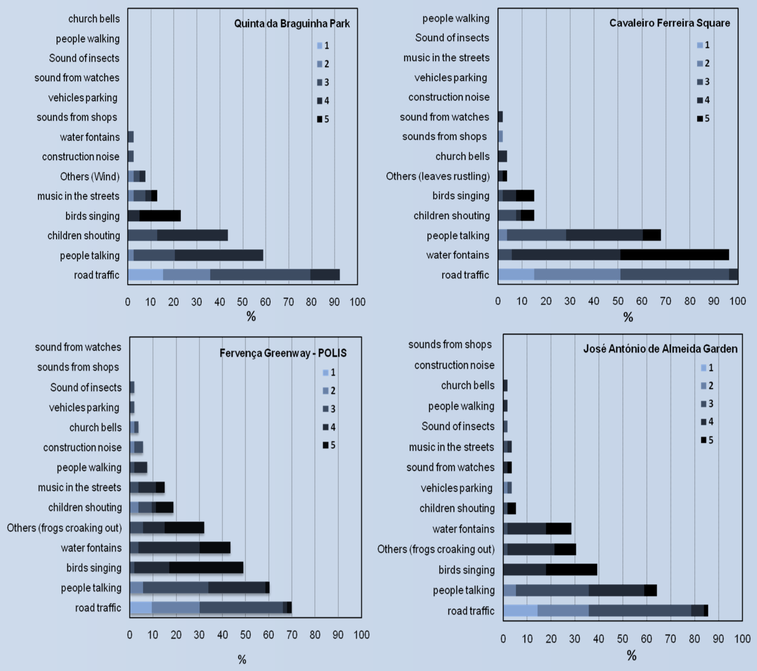

Figure 5: *Users perceptions on local soundscape at the different green areas, identifying isolated sounds and rating them accordingly to five level Likert scale.*

Figure 5 shows that traffic road sound was the most often mentioned as the first plan sound. Besides that, traffic noise was mostly considered as an unpleasant sound, although some interviewees could find it pleasant. On the other hand, more than 75% of the interviewees answered positively to sounds such as water movement, birds singing and frogs croaking. Only a small fraction of the interviewees considered these natural sounds as «unpleasant». As has been reported in the specific literature, natural sounds tend to be more relaxing and less invasive, creating a very positive reaction towards them (Carles *et al.*, 1999). In terms of CF, the soundmark associated to water fountains was mentioned as the most pleasant sound. Curiously, the highest sound levels in this place were registered around this sound source, meaning that magnitude and pleasantness are not always correlated. Results from interviews have also shown relatively higher levels of preference of culturally accepted sounds, such as church bells and street music. The preferences expressed by the interviewees explain why PO soundscape is positively rated. Actually, PO has a singular soundscape, very diversified, where relatively low levels of traffic noise do not interfere with other pleasant sounds such as surrounding speech, birds singing, water movement, frog croaking, footsteps and leaves rustling.

Comparison Analysis - Objective vs. Subjective Evaluation

Different findings were obtained from the objective and subjective evaluations. Considering the results of the acoustic and psychoacoustic indicators, the arrangement from the most to the least pleasant places was: BR, AA, PO, and CF. From the subjective evaluation, PO occupies the first place, being followed by AA, BR and CF. To better understand these relationships, acoustic and psychoacoustic parameters are compared with the subjective rating (Figure 6).

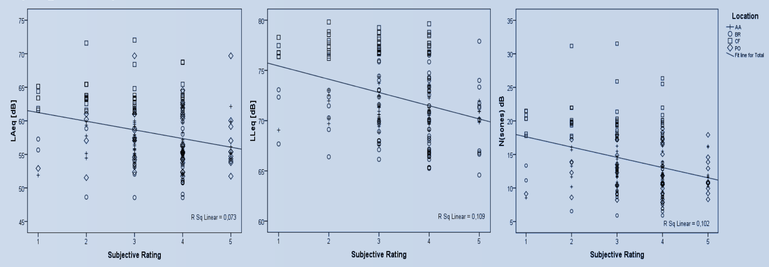

Figure 6: *Acoustics and psychoacoustics parameters versus subjective rating.*

In general, very weak correlations were found, but the trend line shows a negative relationship between the subjective rating and the magnitude of the acoustic and psychoacoustics parameters. As pointed out by other authors (e.g. Miroslava *et al.*, 2004), a unique correlation between physical parameters and corresponding sound perception does not exist. In fact, other factors are involved.

4. Final Considerations

The four evaluated soundscapes were significantly different from each other with respect to magnitude and information content of sound, having created different social reactions towards them. Despite some drawbacks of this study, some conclusions were reached:

- Traffic noise had a negative influence on soundscapes in urban green areas, although some interviewees expressed favourable opinion about it;
- Acoustic comfort evaluation can not be based only on sound magnitude. People react to sound magnitude but other attributes also have a relevant influence on sound perception. The introduction of a pleasant sound can enhance the acoustic comfort considerably, even if the magnitude of sound is high;
- Green spaces seem to be important elements in creating pleasant soundscapes, as they might be *habitats* of several natural and human pleasant sounds.

In conclusion, urban planners have the challenge of changing the background and the foreground sounds in urban green areas, preferably replacing or masking mechanical sounds with natural sounds, while offering diverse urban soundscapes to increase people's choices.

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