# Case-study evaluation of a low and vegetated noise barrier in an urban public space

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## ABSTRACT

To improve the sound environment along a popular esplanade in Lyon, France, a 1 m high vegetated noise barrier was erected to protect against noise from an adjacent road. The barrier was made of a metallic structure, filled with a substrate on which 40 plants per square meter were grown on both sides. The effect of the barrier was evaluated by acoustic measurements conducted before and after the barrier was erected, as well as, by a questionnaire study in which pedestrians were asked to assess the sound environment both behind and at the side of the barrier. The barrier reduced the sound pressure level from about 67 to 62 dB ($L_{Aeq}$), at sitting height (1.2 m), 3.5 m from the roadside. Questionnaires responses (n = 349) from the same location showed that the barrier reduced road-traffic noise annoyance, and increased the overall quality of the sound environment by making it slightly calmer and slightly more pleasant. However, these effects were fairly small and the sound environment was still perceived as annoying by most of the respondents. Overall, the result thus suggested that the barrier made the sound environment better but not good. Further work will include detailed psychoacoustic analysis of the questionnaire data, as well as listening experiments using binaural recordings from the site.

Keywords: Noise, Barrier, Annoyance

## 1. INTRODUCTION

Transportation noise is an increasing environmental problem in urban areas. It affects the health and well being of residents close to major roads, railways and flight paths [1]. In addition, it may reduce the quality of open public spaces and thereby their potential for promoting relaxation and stress recovery [2, 3].

Noise mitigation methods in public spaces need not only be acoustically efficient but also aesthetically attractive. Vegetated noise barriers is one example of a method that may reduce noise and at the same time increase the attractiveness of the location (e.g., [4]).

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The present study is a case-study evaluation of a low vegetated noise barrier, erected in central Lyon to protect a popular esplanade from road-traffic noise. The purpose of the evaluation was to determine the acoustic and psychoacoustic performance of the barrier. This was achieved by extensive acoustic measurements conducted before and after the barrier was erected, including binaural recordings to be used in subsequent listening experiments, as well as, by a questionnaire study in which pedestrians were asked to assess the sound environment both before and after the barrier was erected. This paper reports preliminary results from the sound level measurements and the questionnaire study.

## 2. METHOD

### 2.1 Noise Barrier

The barrier was erected along a popular esplanade in central Lyon, to protect against noise from a nearby road. The barrier was 1 m high, 14 m long and 40 cm thick. It was made of a metallic structure, filled with a substrate on which 40 plants per square meter were grown on both sides. The barrier was located at the roadside, see Figure 1.

Figure 1 – Left: Questionnaire respondents and acoustic measurement equipment behind the barrier (spot A, time 2). Right: Questionnaire respondent at the side of the barrier (spot B, time 2). Data was also collected at the same spots before the barrier was erected (time 1).

### 2.2 Study Design

Data was collected at two occasions, before the barrier was erected (time 1) and after it was erected (time 2). Each time, data was collected at two spots, at a place behind the barrier (spot A) and a place 20 m at the side of the barrier (spot B), see Figure 1. Thus, measurements could be compared at the same spot with and without barrier (same spot, different times) and at the same time with and without barrier (same time, different spots). There were different groups of questionnaire respondents at the two times, and each participant assessed the sound environment at both spots, A and B (counterbalanced order).

### 2.3 Acoustic Measurements

During data collection, 1/3-octave-band sound levels were measured continuously (time interval = 0.1 s) at both spot A and B at the same place were the questionnaires were filled in. These continuous measurements were documented by MP3 recordings. In addition, binaural and sound field recordings were conducted before and after the barrier was erected at various distances to the road.

### 2.4 Questionnaire

Research personnel from Acoucité Soundscape and Noise Observatory of Great Lyon were stationed at the two spots. Pedestrians that passed the spots was approached and asked to fill in a questionnaire. Fifty-five percent of the persons asked to participate agreed to do so. At time 1, 144 persons completed the questionnaire. Of these, 80 started at spot B followed by spot A, and 64 started at spot B followed by spot A. At time 2, 205 persons completed the questionnaire. Of these, 107 started at spot A followed by spot B, and 98 started at spot B followed by spot A. In total, 349 persons completed the questionnaire.

The questionnaire contained four parts. Part 1 and 2 were answered at the first place (A or B) and part 3 and 4 at the second place (A or B). The questions were taken from questionnaires used in previous Swedish studies on sound environments in city parks [3, 5]. The questions were translated to French and then back-translated to Swedish to check the quality of the translation.

Part 1 of the questionnaire contained six questions on how often the respondent visits the place, the purpose the present visit, and general questions on the perceived quality of the place with regard to environmental factors (view, sound, smell, and annoyance due to graffiti, traffic noise, etc).

Part 2 contained four questions on the sound environment as perceived at the spot “right now”: (1) Identification of sounds from four categories of sounds: Sounds from humans, natural sounds (e.g., bird song), road-traffic noise, and other noises. For each category, the participant indicated to which degree the source was heard using the response alternatives “Never heard”, “Heard a little”, “Heard sometimes”, “Heard a lot” and “Completely dominating”. (2) Road-traffic noise annoyance was assessed on a five-point category scale, with the response alternatives “Extremely”, “Very”, “Moderately”, “Slightly” and “Not at all” (cf. [6]). (3) The overall sound environment was assessed using eight attributes: Pleasant (Agréable), Chaotic (Chaotique), Exciting (Excitant), Calm (Calme), Peaceful (Paisable), Annoying (Irritant), Eventful (Agité) and Monotonous (Monotone) (attributes selected from [7]). The eight attributes were presented as statements: “The sound environment is pleasant.”, “The sound environment is exciting.”, etc. The respondent indicated how much they agreed with the statements, by selecting one of the response alternatives “Disagree completely”, ”Disagree at large“, “Neither agree, nor disagree”, “Agree at large” and “Agree completely”. Finally, (4) the overall quality of the sound environment was assessed on a five-point bipolar category scale with the response alternatives “Very good”, “Good”, “Neither good, nor bad”, “Bad” and “Very bad”.

Part 3 contained the same questions as Part 2, but they were answered at the second place (spot A for those who started at spot B, and spot B for those who started at spot A).

Part 4 contained five background questions on the respondent’s age, sex, home town, noise sensitivity and hearing status.

The research personnel noted the time the questionnaire was handed over and the time when it was handed back. The average time for completing the whole questionnaire was 12 min.

## 3. RESULTS & DISCUSSION

### 3.1 Acoustic measurements

Simultanoeus sound level measurements behind and besides the barrier showed that it reduced the sound level with about 5 dBA at the point where the questionnaires were filled in (3.5 m from the road at the sitting height, 1.2 m), from about 67 dB $L_{\mathrm{Aeq,T}}$ besides the barrier to about 62 dB $L_{\mathrm{Aeq,T}}$ behind the barrier (measurement time, T, > 4 h). These are preliminary results. More detailed analyses of the acoustic measurements are in progress.

### 3.2 Questionnaire data

In this paper, we will focus on the noise annoyance and the sound quality questions from part 2 and 3 of the questionnaire. Comparison between the two spots may be conducted between subjects or within subjects. Between subject comparisons are only based on assessments made at the first spot, that is, using part 2 of the questionnaire, and compares assessments from respondents that started at spot A with assessments from those that started at spot B. In contrast, within-subject comparisons uses assessments from both part 2 and 3 of the questionnaire and compares assessments from the same respondents at spot A and B. Between subject analyses are presented first (Tables 1 & 2, Fig. 2), followed by a within subject analysis (Fig. 3).

Table 1 show the proportion of respondents extremely or very annoyed by road-traffic noise, separately for the four groups of respondents defined by the two data collection occasions (time 1 or 2) and the spots (A or B) at which the respondents first filled in the questionnaire.

The proportion of respondents that found the road-traffic noise annoying was slightly lower for those who assessed the noise behind the barrier (0.47) compared to those who assessed the noise without influence of the barrier (0.56-0.63). It should be noted, however, that the proportion annoyed respondents was close to 50 percent also behind the barrier, which shows that road-traffic noise still was a major problem at the place, at least at the point close to the road where the questionnaires were filled in.

Table 1 – Proportion of respondents that assessed the road-traffic noise as very or extremely annoying.

| Time | Spot A (barrier) | Spot B (no barrier) | $p^a$ |
|---|---|---|---|
| Time 1 (no barrier) | 0.63 (n = 78) | 0.56 (n = 64) | 0.49 |
| Time 2 (barrier) | **0.47 (n = 105)** | 0.58 (n = 97) | 0.12 |
| $p^b$ | 0.036 | 0.87 | |

*Footnote*. Numbers in bold refer to assessments of the sound environment behind the barrier; numbers in plain text refer to assessments without barrier. Due to internal response loss, the number, n, of respondents included in the analyses may be smaller than the number of respondents in the study.
[a] Fischer exact probability test (two-tailed) of the null-hypothesis of equal proportions at spot A and B.
[b] Fischer exact probability test (two-tailed) of the null-hypothesis of equal proportions at time 1 and time 2.

Table 2 – Proportion of respondents that assessed the sound environment as good or very good.

| Time | Spot A (barrier) | Spot B (no barrier) | $p^a$ |
|---|---|---|---|
| Time 1 (no barrier) | 0.10 (n = 79) | 0.10 (n = 63) | >0.99 |
| Time 2 (barrier) | **0.20 (n = 107)** | 0.07 (n = 96) | 0.014 |
| $p^b$ | 0.10 | 0.77 | |

*Footnote*. Numbers in bold refer to assessments of the sound environment behind the barrier; numbers in plain text refer to assessments without barrier. Due to internal response loss, the number of respondents, n, included in the analyses may be smaller than the number of respondents in the study.
[a] Fischer exact probability test (two-tailed) of the null-hypothesis of equal proportions at spot A and B.
[b] Fischer exact probability test (two-tailed) of the null-hypothesis of equal proportions at time 1 and time 2.

The proportions of respondents that found the sound environment good or very good were low, as might be expected for assessment conducted close to a busy road (Table 2). Still, the proportion was higher for those who assessed the noise behind the barrier (0.20) compared to those who assessed the noise without influence of the barrier (0.07-0.10). These results agree with the pattern of result for noise annoyance, which suggested that the barrier made the sound environment better but not good.

Figure 2 shows mean values of assessment of the sound environment on eight attributes, separately for the same groups as in Table 1 and 2. The mean values for the group who assessed the sound environment behind the barrier (green circles) was similar to those who assessed it without barrier (open symbols). The sound environment behind the barrier was slightly more pleasant, calm and peaceful and slightly less annoying and eventful than without the barrier. However, these differences were very small and not statistically significant (one-way MANOVA).

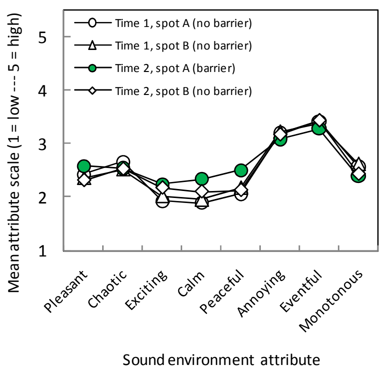


Figure 2 – Mean values of assessments of the sound environment on eight attributes, separately for assessments behind the barrier (green circles) and assessment without barrier (open symbols).

Figure 3 shows within-subject comparison between attributes, as mean differences with error bars (95 % confidence intervals). In this analysis, the differences between assessments of the sound environment with and without barrier (green circles) were clearly discernible and statistically significant for most attributes (most confidence intervals do not cross the line y = 0). The sound environment behind the barrier was assessed as more pleasant, calm and uneventful and as less chaotic, annoying and eventful than the environment without barrier. The differences were fairly small, less than one scale point (green circles), but considerably larger than the corresponding differences for those who participated before the barrier was erected (open circles). Thus, the observed difference was not related to other differences between the two spots, because the differences at time 1, without barrier, were close to zero. These results suggest that the barrier had an effect on how participants assessed the sound environment with and without the barrier. It is not, however, possible to estimate how much of this effect that was due to changes in the sound environment and how much was due to visual and other aspects of the barrier.

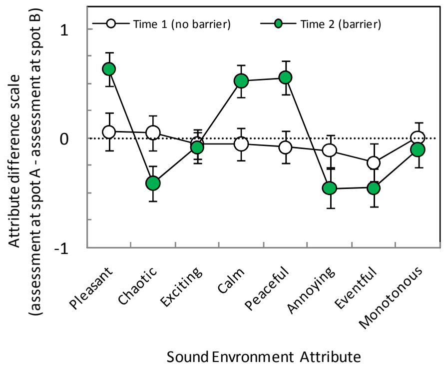


Figure 3 – Mean difference values of assessments of the sound environment at spot A and B on eight attributes, separately for respondents who assessed the sound environment at time 2, when the barrier was present at spot A (green circles) and for respondents who assessed the sound environment at time 1, before the barrier was erected (open symbols).

## 4. CONCLUSIONS

This paper reports preliminary results from a case-study evaluation of a vegetated barrier erected to protect an esplanade from road-traffic noise. The barrier reduced the sound pressure level with about 5 dB ($L_{Aeq}$), at sitting height (1.2 m), 3.5 m from the roadside. Questionnaires responses from the same location showed that the barrier reduced road-traffic noise annoyance, and increased the overall quality of the sound environment by making it slightly calmer and slightly more pleasant. However, these effects were fairly small and the sound environment was still perceived as annoying by most of the respondents. Further work will include listening experiments using binaural recordings at the site, and detailed psychoacoustic analysis of the questionnaire data, comparing individual questionnaire responses with acoustic measurements conducted during the time each questionnaire was filled in.

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