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Perception of noise annoyance reduction associated with acoustic screens.

Peiró-Torres, M. P.[1]
BECSA, S.A.U.
Ciudad del Transporte II. C/ Grecia, 31, Castellón (Spain)

Redondo, J.[2]
Universitat Politècnica de València. Instituto de Investigación para la Gestión Integrada de Zonas Costeras.
Paranimf 1, Grao de Gandia, Valencia (Spain)

López, J. J.[3]
Universitat Politècnica de València. ITEM Institute.
Camino de Vera s/n, Valencia (Spain)

Pereira, A.[4]
ISISE, Department of Civil Engineering. University of Coimbra.
Rua Luís Reis Santos, Pólo 2 da Universidade, Coimbra (Portugal)

Amado-Mendes, P.[4]
ISISE, Department of Civil Engineering. University of Coimbra.
Rua Luís Reis Santos, Pólo 2 da Universidade, Coimbra (Portugal)

Godinho, L.[4]
ISISE, Department of Civil Engineering. University of Coimbra.
Rua Luís Reis Santos, Pólo 2 da Universidade, Coimbra (Portugal)

ABSTRACT

This study describes the psychoacoustic experiment carried out in order to evaluate the rate of annoyance reduction obtained due to different Noise Reduction Devices (NRD). The respondents were subjected to different sound events representative of both road and railway traffic noise, as well as the same sound events auralized using a predefined set of filters obtained from a numerical model in order to simulate the attenuation obtained through the implementation of two different NRDs. Data obtained after a survey has been analysed to determine the relationship between this subjective rating of noise annoyance reduction and different intrinsic characteristics that evaluate the performance of NRDs.

Keywords: Sound quality, acoustic comfort, psychoacoustics, noise barriers.
I-INCE Classification of Subject Number: 79

Invited Communication

1. INTRODUCTION

In different fields of acoustics, mainly in architectural acoustics, several objective parameters have been proposed that aim to avoid the need of subjective assessments, as these are very complicated to develop and evaluate. The proof that these parameters are meant to take human perception into account is, on the one hand, that in the variables which depend on frequency, averaging is done in third octave bands or portion octave, i.e., that frequencies are considered logarithmically, like the human ear bahaves; on the other hand, in overall quantities, the use of weights such as A-weighting intended to simulate the human ear sound sensitivity regarding different frequencies. Thus, in the field of room acoustics there are many objective parameters with high correlation with other subjective ones that measure different aspects of the room acoustic quality. In the field of sound insulation, various parameters are used to measure the reduction degree of noise annoyance due to one or more walls. Finally, in environmental acoustics field, there are different parameters that measure the amount of annoyance, such as equivalent continuous weighted sound pressure level, or sound exposure level. Also, within this area, the sound performance of Noise Reducing Devices (NRD), such as acoustic screens, which is evaluated using parameters that are intended to measure, after all, perception of noise by humans.

The measurement of the acoustic characteristics of NRDs for road traffic noise is performed following procedures defined in different standards. We can distinguish three main groups: i) the laboratory measurement of intrinsic characteristics, ii) the measurement of these characteristics "in situ", and also iii) the measurement of extrinsic characteristics in the real state before and after placing the screen. In the first group, laboratory measurements are carried out following the standards:

EN 1793-1. Sound absorption (diffuse field) [2]
EN 1793-2. Airborne sound insulation (diffuse field) [3]

In the second group of measurements, "in situ", the procedures are described in the following standards:

EN 1793-4. Sound Diffraction (direct field) [4]
EN 1793-5. Sound reflection (direct field) [5]
EN 1793-6. Airborne sound insulation (direct field) [6]

Finally, the performance measurement of the installed screen is described in the standard:

ISO 10847: 1997. Determination "in situ" of insertion loss [7]

Standard EN 1793-2 defines the noise reduction index, R_i, a parameter similar to the one used in field of sound insulation provided by separation elements. Of particular interest is the fact that the screens are usually classified according to an average of this parameter which, on one hand, adjusts the relevance of each frequency to the A-weighted curve and, on the other hand, takes into account the normalized traffic noise spectrum [8]. This parameter is called airborne sound insulation index:

$$DL_R = -10log\left|\frac{\sum_{i=1}^{18} 10^{0.1\,L_i}10^{0.1\,R_i}}{\sum_{i=1}^{18} 10^{0.1\,L_i}}\right| \qquad (1)$$

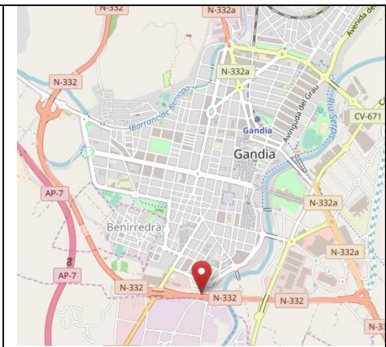
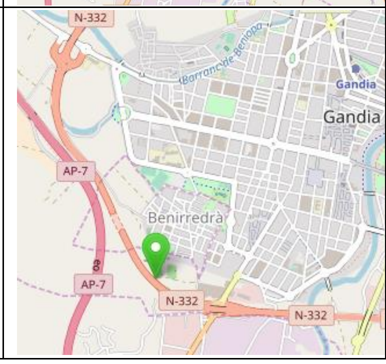
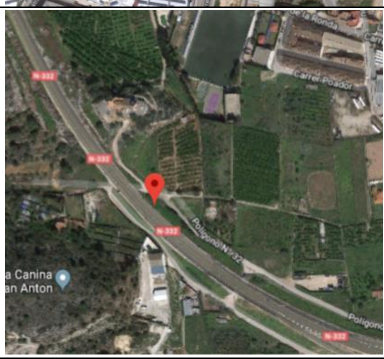
where L_i is the i-th level of normalized traffic noise for each third octave band [8]. It should be noted that acoustic screens are classified according to this parameter (DL_R). However, the performance of a screen depends not only on the provided sound insulation but also on the geometry of the problem, since the edge diffraction reduces significantly the performance of the screen. In other words, the DL_R indicates only a maximum limit but generally it does not exceed 25 dBA of reduction level on receivers.

In fact, the performance of a noise screen given by its sound insulation characteristics and by the geometry of the problem (topography, adjacent buildings, screen height, etc.) is established by ISO 10847 standard [7], where the insertion loss parameter is defined (D_{IL}), given by the noise level difference at the receivers with and without the noise screen, evaluated in dBA.

In this paper, the relationship between these parameters and the perception of annoyance reduction through a psychoacoustics experience is studied. This study aims to serve as a preliminary step to define an experiment in a larger scope.

2. PRELIMITARY EXPERIMENT

As a previous step to performing a psychoacoustic evaluation, a small experience has been carried out, limited in the types of noise screens, and in the number of individuals or the number of events considered. Several recordings were made, but only 6 of them were finally used. The 3 measuring points are listed below:

1.			Location: 38°57'23.6"N 0°11'07.1"W Date: 18:30, 29.11.2017 Road: N-332 Weather conditions: wet pavement
2.			Location: 38°57'29.7"N 0°11'42.1"W Date: 18:45, 29.11.2017 Road: N-332 Weather conditions: wet pavement

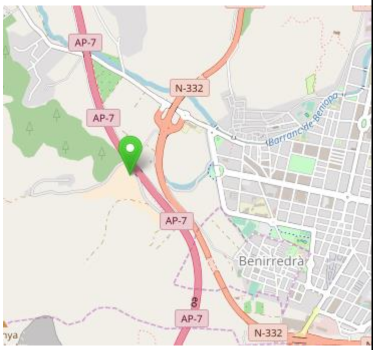
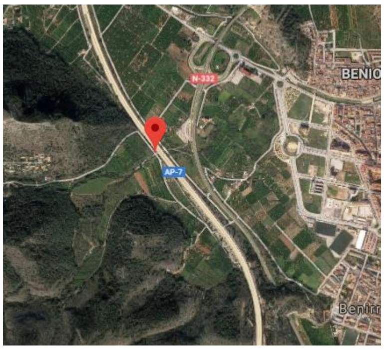
3.			Location: 38°58'02.9"N 0°12'15.2"W Date: 19:00, 20.01.2018 Road: AP-7 Weather conditions: dry pavement

Figure 1. Location of the measuring points.

The recorded sounds were modified to simulate the effect of two different types of noise barriers. For this purpose, a third octave band filter was applied with D_{IL} values obtained by a numerical simulation, with more details available in [9]. Since, in general, manufacturers only provide sound insulation measures in third octave bands with centre frequencies from 125Hz to 4000Hz, the original sound, which was also shown to respondents, was filtered to remove frequencies outside this range. Figure 2 illustrates the characteristic parameters of the two noise screens considered. We can see that, although noise reduction (R_i) provided by the screens is clearly different, the final performance (D_{IL}) is quite similar for the two screens.

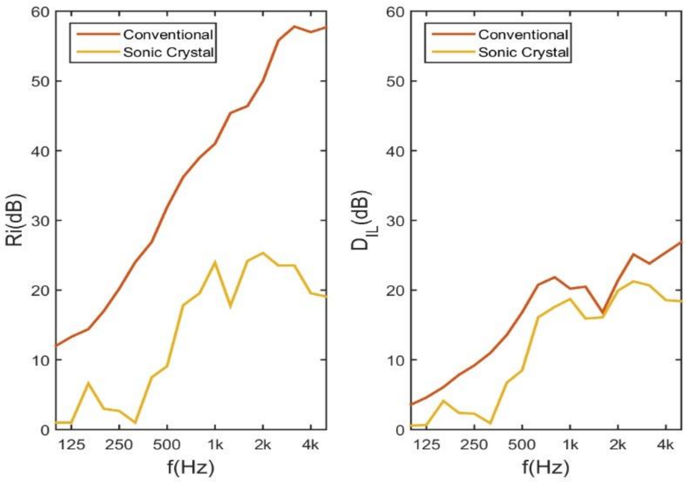


Figure 2. Most representative parameters of the acoustic performance of the evaluated noise screens (R_i and D_{IL}).

Following the recommendations of ISO 15666 [10], respondents were asked to rate the degree of annoyance on a numerical scale of 11 points (from 0 to 10). Figure 3 illustrates the convergence of the answers corresponding to one of sounds evaluated. It can be seen that, about 15 surveys, the value hardly oscillates. Finally, 40 surveys were considered. All subjects were previously examined by an audiometry test to rule out any hearing defect.

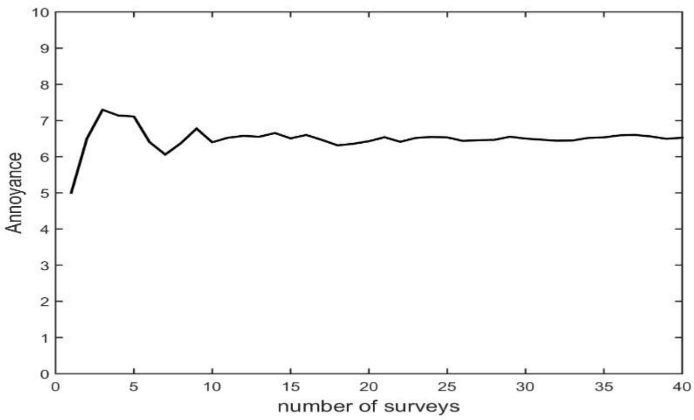


Figure 3. Convergence of the results for one of the evaluated sounds. The results are considered reliable enough for 40 individuals.

First, to verify the coherence of the measurements, the degree of annoyance of all sound events (original sound, filtered according to conventional noise barrier and filtered according to sonic crystal screen) is represented as a function of the sound pressure level expressed in dBA (figure 4). A high correlation between both magnitudes can be observed, as expected. Then, the results of the experiment are considered to be reliable enough.

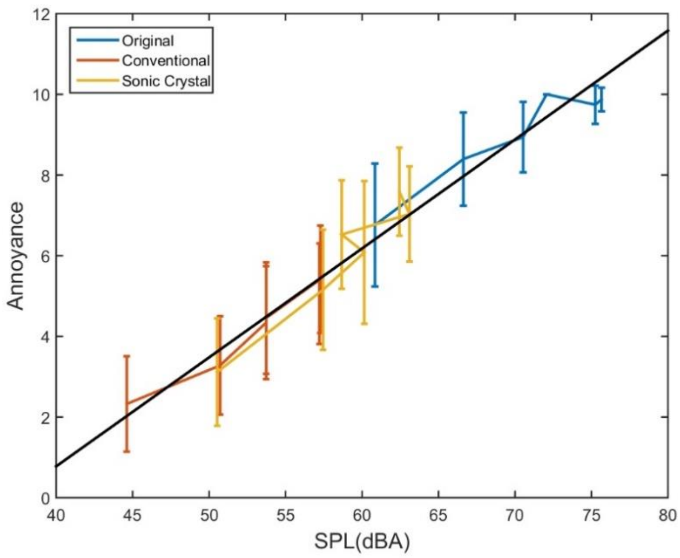


Figure 4. Relationship between annoyance and sound pressure level in dBA. A high correlation between the two magnitudes is observed, as expected.

Then, in Figure 5, the relationship between perceived annoyance and the sound pressure level of the original sound in dBA is represented. It can be seen that, the annoyance in the case of sonic crystal acoustic screen is always significantly above the conventional screen. In other words, this new technology has not yet been able to match the performance of a conventional acoustic barrier, however this new technology offers additional advantages such as the lower visual impact and reducing wind load or water flow, and thus makes it possible to reduce the foundation required for installation and allows drainage of the infrastructure.

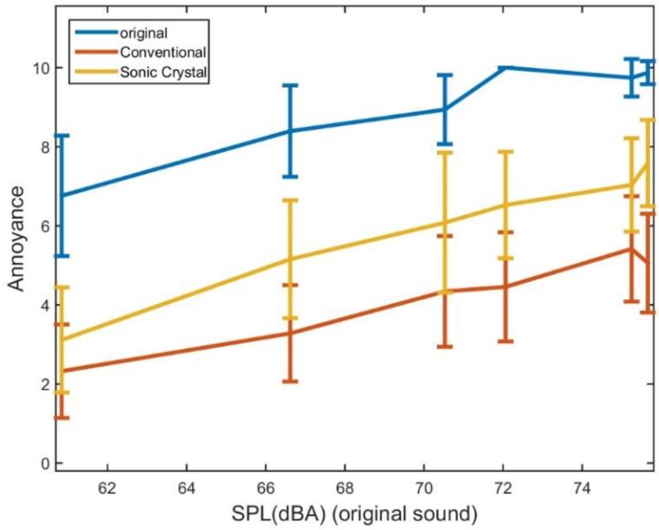


Figure 5. Relationship between annoyance and the sound pressure level of original sound in dBA.

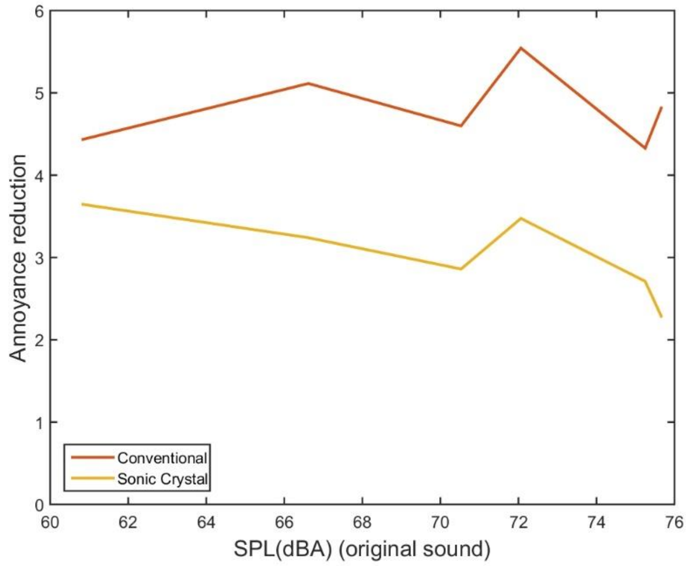


Figure 6. Reduction of annoyance due to conventional acoustic barrier and sonic crystal acoustic screen.

Finally, figure 6 shows the reduction of annoyance due to each of the noise screens. From these results, the high correlation between the perceptual magnitude with the magnitude that is used to characterize the performance of the screen, such as DL_R or D_{IL}, is clearly observed. The main conclusion is that the perceived annoyance depends on the sound pressure level of the original sound. This raises two important aspects to consider in the design of the further experiments. On the one hand, the need not to mix sounds of different levels; on the other hand, the reduction of annoyance has been calculated as the difference between annoyances with and without screen, however, from the data obtained by these previous surveys, the measure of the annoyance directly in the survey is considered.

Also, it is worth noting that the differences measured between the two noise screens are greater than those which might be expected, having in mind the slight differences in the insertion loss of both structures (Figure 2).

3. EXPERIMENT DESIGN

The experience presented in the previous section has allowed anticipating the difficulties, limitations, scope, etc., of a future experiment in which the relationship between objective variables used to measure the acoustic performance of screens and the reduction of annoyance due to them are taken into account. In this section we propose the most relevant details on the design of the experiment to be carried out for this purpose.

First, the number of respondents should be equal to or greater than that of the previous study. It is estimated that 60 is an adequate number of respondents. As in previous experiences, an audiometry has been determined as necessary in order to rule out respondents' hearing defects. In addition, to check the validity of the evaluations, all events must be approved twice by each listener to determine the consistency of their answers and to decide whether or not they are taken into account in the subsequent analysis.

Three types of noise barriers will be compared, two of which are already included in the previous study. The third one will be a hypothetical noise barrier with perfect sound insulation, i. e. its performance will be given exclusively by edge diffraction. Only two different sound events will be taken so as not to increase the test too much. These events will be chosen in such a way that their dependencies are as different as possible, but adapted in intensity so that the A-weighted sound pressure level is the same.

A range of different insertion loss values in each of the three cases will be considered, taking two different barrier heights and two receiver distances.

Finally, it should be kept in mind that, unlike the previous experience, the aim is to measure the reduction of annoyance directly and not to calculate a reduction of annoyance. Therefore, before going on to listen to each of the sound events, the respondents will hear the reference, i.e. the original sound. This could result in an excessive duration of the test, so sounds of short duration (a few seconds) will be chosen.

Also included in the survey will be a phase of learning how to use the application taking note of the time required for each answer, and it will be analysed if it is necessary to discard the last questions of the test due to the fatigue of the respondent.

Once the test has been carried out, an extensive statistical study of the results will be carried out and a comparison will be made between the different global parameters of frequency weighting values associated with insertion loss levels.

4. CONCLUSIONS

In this paper we have presented the design of a small perceptual experiment that allowed studying the validity of the parameters used to characterize the performance of acoustic screens from a perceptual point of view.

This research is expected to validate or suggest improvements to the criteria currently established for this purpose. Depending on whether the results agree or disagree with these values, the study should be extended to more cases, taking into account other parameters, such as different noise sources or meteorological conditions.

In the performed test, it was found that both the sound insulation values and the insertion loss values established by the standards do not justify the differences found in the reduction annoyance perceived due to different types of screens.

In a future work, the results of the new perception experiment will be presented, which will include the improvements presented in this paper.

5. ACKNOWLEDGEMENTS

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