VIII Congresso Ibero-americano de Acústica
1-3 outubro
Évora - Portugal
acústica 2012

INTEGRATION OF QUALITATIVE ASPECTS IN URBAN NOISE ASSESSMENTS

Sónia Antunes [1], Jorge Patrício [1], António Samagaio[2]

[1]Laboratório Nacional de Engenharia Civil
{ santunes@lnec.pt , jpatricio@lnec.pt }

[2] Universidade de Aveiro
samagaio@ua.pt

Abstract

To evaluate the human perception of road traffic noise reduction measures in urban areas, two surveys were developed. The first survey intends to evaluate the cognitive structure of individuals to noise while the second intends to study individual's perception about noise reduction measures.

In this paper the semi-structured interviews carried out, its content, structure and wording of the questions that were made for both surveys, are presented. A multidisciplinary approach was taken, with contributions in the fields of environmental psychology, statistics, acoustics and psychoacoustics.
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Keywords: Environmental noise, noise perception.

PACS no. 43.50.Sr

1 Introduction

There are numerous sound sources, fixed or mobile, temporary or permanent, that influence the acoustic environment of urban areas. However, road traffic noise is the most widespread and important in urban areas. In second and third place of importance, appear, respectively, air and railway traffic noise [1]. In urban areas, other important noise sources are industrial noise and the noise caused by construction works, although the latter is more unevenly distributed and has a temporary character. Finally, in urban areas there is a wide variety of other sources, resulting from human activity, and generally characterized by their sporadic nature, such as the sirens of ambulances, the system beeps caused by counter-intrusion and noise caused by systems of ventilation used in buildings. As a result of high density of population and the complexity of the urban environment, it is in the large cities that the noise sensitivity is higher. The coexistence of a sensitive occupation and noisy activities can lead to a conflict between the people and their perception environment.

Traditionally, the influence of noise on the quality of human life was studied focusing on the negative effects that this environmental descriptor causes, such as annoyance and sleep disturbance [2]. Another type of approach for the assessment of the acoustic environment is to take into account that the urban spaces include complex combinations of “pleasant and unpleasant” sounds, depending on their subjective evaluation. This classification is not only related with the sound intensity, but also with the context in which the sounds are perceived, and the social and cultural meanings attributed to them by individuals. Schafer introduced and developed the term soundscape [3] which translates an auditory standpoint of the urban environment - similarly as the shape and colors are linked with the visual landscape-, placing the human receiver in its center. In this context, the development of methodologies for the assessment of human perception of traffic noise is a fundamental aspect for the corresponding assessment of environmental noise.

2 Study description

In this work, two questionnaires were developed, one for assessing the cognitive structure of individuals to traffic noise and the second to the assessment of human perception of noise mitigation measures. The respective contents were based not only in the research literature, but also in the semi-structured interviews previously done. For their implementation, it was essential to use knowledge of environmental psychology, statistics, acoustics and psychoacoustics, and to take a multi-disciplinary approach.

Firstly, semi-structured pilot interviews were made, in order to assess the individual’s perceptions to road traffic noise in urban areas. This action proved to be essential, since it made possible the identification and classification of the most annoying noises sources in the resident’s scope for the 6 zones distributed along the area of interest (VCI). The content analysis of these interviews allowed the structuring of the two subsequent questionnaires. In addition, an idea about the perception road traffic noise mitigation measures already implemented was given, which in this case encompassed the placement of low noise pavement and the reduction of vehicles velocity.

For the assessment of the cognitive structure of individuals regarding road traffic noise: binaural recordings were conducted outdoors in the cities of Lisbon and Oporto. In Lisbon, binaural recordings were taken in areas such as the downtown, which are characterized by narrow streets (Ouro Street, Sound 9); an open square with compact traffic (Cais do Sodré, Sound 6); and, in the vicinity of an urban main road that crosses the city (2ª circular, near Telheiras, Sound 8). In Oporto, binaural recordings were taken in VCI (urban main road that circles the central area of Oporto and Vila Nova de Gaia), near the Foco area (Sound 4). Each binaural recording was edited in order to eliminate periods with major wind disturbances and unusual traffic sound, like ambulance sirens. Also binaural recordings of public transportation noise were taken. These samples integrate a train passing by (line Lisbon Cascais, Sound 3), old (Sound 5) and modern Lisbon Trams (Sound 11), modern city Bus (Sound 1), Oporto subway (Sound 10), and airplane passing by (Sound 2). Additionally, it was decided to integrate 2 samples of motorcycles passing by (a modern motorcycle with noise reduction device, Sound 12, and an old motorcycle, Sound 7) and a plane passing by. For mores details about these sounds see reference [1] (in Portuguese).

The 12 sounds were presented to 132 individuals of both sexes (voluntary participation), aged between 20 and 50 years. The sounds were reproduced using loudspeakers and a Power Point presentation. Before starting filling the response sheet, participants had always to perform a pre-test in order to become used with the sounds played and with the method of classification of 21 pairs of adjectives. Also, for each of the 12 sounds, physical and psychoacoustics parameters were calculated, such as the third octave bands noise spectrum, equivalent continuous sound level, A-weighted and linear, the loudness average spectrum and percentile levels (percentiles 5%, 10% and 50%), total loudness, sharpness and roughness.

The questionnaire about the perception of noise mitigation measures, have two distinct parts. The first part comprised a questionnaire with closed questions, in which several factors were evaluated, namely, factors associated with socio demographic, type of residence and its structure, noise exposure and noise-induced annoyance (standardized question according to the publication of ISO/TS 1566). This questionnaire also allowed to evaluate the noise sensitivity of respondents (according Weinstein scale), the assessment of different sources present in the area under study, as well as the evaluation of the main effects induced by noise and the type of strategies for dealing with noise annoyance (coping strategies). It was also asked participants to classify a set of statements about noise mitigation measures.

In the second part of the questionnaire a set of sounds associated with different noise mitigation measures were presented. These sounds resulted from a selection (and processing) of several audio recordings collected. It was used sounds recorded behind an absorbent noise barriers, known as "green barriers" (Figure 2, a)); behind noise barriers with perforated absorbent metal panels (Figure 2 b)), behind noise barriers with reflective metal panels and acrylic panels (Figure 2, d)) and sounds recorded behind acoustic barriers consisting of acrylic panels (Figure 2, c)). Since noise barriers can have characteristics of visual intrusion, was also integrated in this test the visual assessment of each noise barriers, by submitting their photographs and requesting the corresponding classification in terms of aesthetics and expected efficiency.

Regarding the evaluation of road pavements, audio recordings from a single passage of light vehicle (model Ford Focus, diesel) with a passing speed of 80 km/h, were used. In this case, taking into account the difficulty that humans have in sorting sounds with similar characteristics, it was asked to participants to compare the recording from a vehicle pass by in a dense asphalt concrete pavement (reference pavement, according to Standard ISO 11819 -1:1997), and the recording from the same vehicle passage in a low noise pavement, namely drainage asphalt, rubberized asphalt (closed moisture), thin layer (micro concrete), and rough asphalt.

Audio records relating for the same vehicle with different speeds (60, 80 and 100 km/h), were also present to the respondents. In this case, it was requested to sorting the sounds in accordance with the degree of pleasantness.

The participants in this survey have their homes nearby the VCI. The acoustic environment in these locations was essentially due to road traffic, having the noise spectrum dominant components in the low frequency range (200 Hz). The total duration of the survey was around 45 minutes. 21 persons participated in this study, 57.1% were male and 42.9% were women, aged from 20 years to over 80 years old.

3 Results

3.1 Noise evaluation of the cognitive structure of individuals

In the Portuguese language there is not a tradition in applying the Semantic differential technique with sound stimulus. So a bibliographic research was made on the words used in others countries. The words have been sorted and their respective context has been analyzed to find more detailed information on their use. Also, surveys were made to people (acousticians and non experts) in order to ask them to use their own words for sound samples description. The semantic differential profile for the 12 sounds is presented in Figure 1. From the analysis of this figure, the audio recording corresponding to the city bus passing by (Sound 1), is in the point of view of connotative meaning essentially classified as uncomfortable, annoying, but also as disharmonious, irritating, noisy, unpleasant, and strong. The corresponding scale for this assessment focuses on the intensity value equal to five. The airplane passing by (Sound 2) is identified by almost all participants, as annoying, loud and unpleasant (intensity level equal to 6.5). However, adjectives like high, uncomfortable, noisy and irritating can also be used to characterize the passage of an airplane. The train passing by (Sound 3) is more identified with the adjectives unpleasant, loud, annoying, uncomfortable, irritating and strong (intensity ranging between five and six). Regarding the audio recording associated with road traffic in the VCI (Sound 4), adjectives like unpleasant, annoying, high, uncomfortable, strong and noisy are used (intensity scale equal to six). For the sound of the old Lisbon tram passing by (Sound 5) the following adjectives were used: unpleasant, annoying, uncomfortable, loud, irritating, rough and strong (intensity scale equal to five). The sound on the audio recording recorded at the Cais do Sodre Square (Sound 6), is mainly described by adjectives: annoying, noisy, unpleasant, uncomfortable, disharmonious, loud, irritating, strong and rough (intensity level of five). The passage of an old motorcycle (Sound 7), whose exhaust noise is significant, was essentially classified by all participants as irritating, rough and strong (intensity level equal to six). However, adjectives such as annoying, loud, uncomfortable, noisy, disharmonious, were also used to characterize this sound. Regarding the audio recording associated with the road traffic of 2ªCircular (Sound 8), in Lisbon, adjectives like annoying, uncomfortable, noisy, disharmonious, unpleasant, irritating were used.

With regard to the sound recorded at Ouro Street (Sound 9), in Lisbon, it is better identified as unpleasant, loud, annoying, uncomfortable, and strong (intensity level equal to six). However adjectives as noisy, irritating and unacceptable can also be used. The Oporto subway passing by (Sound 10) audio recording was classified as slightly uncomfortable, boring and irritating annoying (intensity level of 4). The audio recording associated with the modern Lisbon Tram passing by (Sound 11), is essentially described by the adjectives unpleasant, loud, annoying, uncomfortable and strong (intensity level close to six). Finally, the sound of a motorcycle with exhaust noise silencer (Sound 12), is essentially characterized by the adjectives dull and muffed (intensity score between 4 and 5).

The airplane passing by is the sound for which a more depreciative assessment is associated. It is described as the most unpleasant, uncomfortable, annoying, strong and high. Then, it follows the sounds of the Lisbon modern Tram and Old motorcycle passing by and VCI road traffic noise. At the other extreme there are the sounds associated with road traffic at Cais do Sodre, and the sound associated with the Oporto subway. Regarding the temporal structure, the sound considered as the most irregular, inconstant and unstable is the sound associated with the old motorcycle passing by.

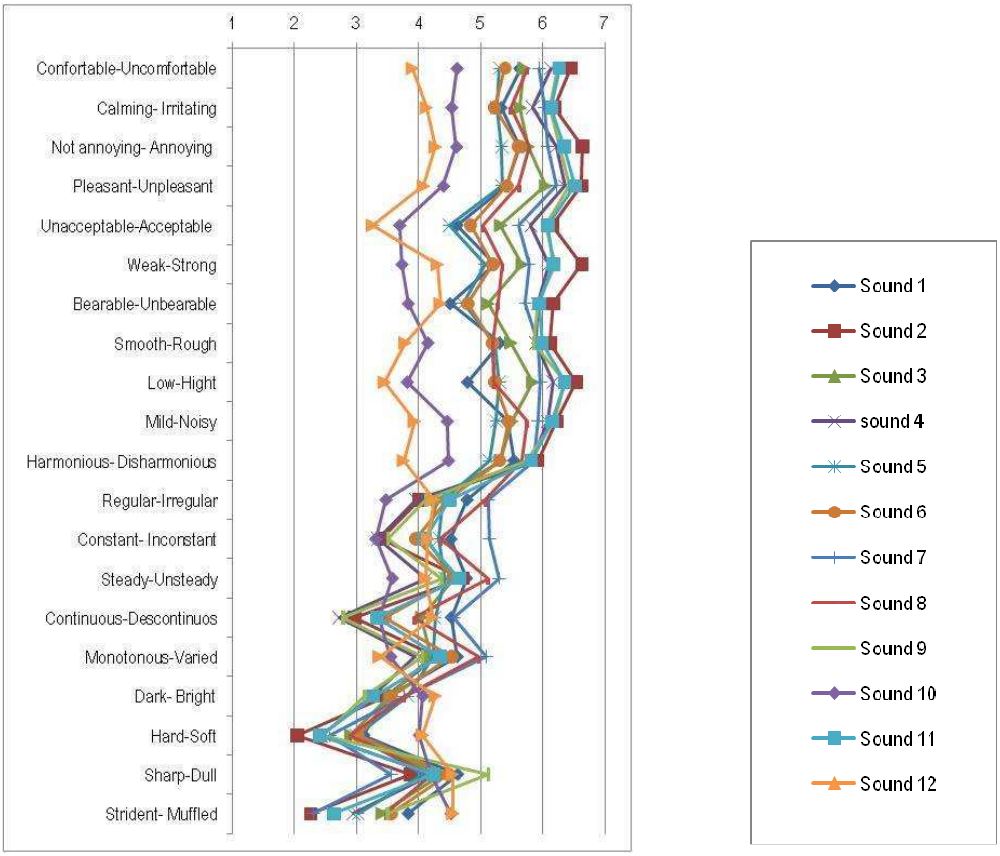

Figure 1 – Semantic differential profile

Principal component analysis was carried out using SPSS v.15 with varimax rotation (with Kaiser normalization) on the semantic differential adjective pairs in order to extract the number of factors present in the data, and to identify which descriptors highly affects each factor. Table 2 presents the results of the principal components analysis for all 12 sounds. In this case, four factors were extracted explaining 75% of the variance. The first factor summarizes the meanings contained in various variables among which the adjectives pairs Comfortable-Uncomfortable, Calming- Irritating, Not annoying- Annoying, Pleasant-Unpleasant have highest loadings. This factor indicates a qualitative assessment in terms of assessment and intensity, noting the inclusion of pairs like Low- Height and Weak-Strong in this factor. The Cronbach's alpha equals 0.95 for this factor. The second factor includes aspects mainly related to the scales Regular-Irregular, Constant-Inconstant, Steady-Unsteady, and Continuous-Discontinuous. A value of Cronbach alpha of 0.89 was found. The third factor, comparatively smaller than the previous ones, is mostly represented by the scales Dark-Bright and Hard-Soft (in this case the Cronbach alpha is equal to 0.79). Finally, the fourth factor is characterized by adjectives Sharp-Dull and Strident- Muffled, with a Cronbach alpha equal to 0.3.

The following names seem more appropriate for the appointment of these four factors: Qualitative Assessment (factor 1), Temporal Stability (factor 2), Power (factor 3) and Timbre (factor 4).). For this analysis the pair Exciting-Boring was taken out.

As regards the breakdown of sounds related to road traffic noise, for those audio recordings that have had a duration exceeding 30 seconds (Sounds 4, 6, 8 and 9), the same factor structure that explains 75% of the variance was found. The first factor summarizes the meanings in various scales, including the pairs: Not annoying- Annoying, Calming- Irritating, Comfortable-Uncomfortable, Unacceptable-Acceptable, and the highest loadings. As in the previous case, it is interesting to note that this factor enables a qualitative evaluation in terms of assessment and intensity. For this factor the value of Cronbach's alpha equals 0.93. The second factor includes aspects mainly related to the scales Regular-Irregular, Constant- Inconstant, Stable-Unstable, Continuous-Discontinuous, which is linked to an alpha Cronbach of 0.89. The third factor (Cronbach's alpha equal to 0.75), comparatively smaller than previous ones, is mostly represented by the scales Dark-Bright and Hard-Soft. Finally, the fourth factor is characterized by the adjectives Sharp-Dull and Strident- Muffled, with a Cronbach alfa equal to 0.3. As in the previous case, the factors were named as: Qualitative Assessment (factor 1), Temporal Stability (factor 2), Power (factor 3) and Timbre (factor 4). In this analysis, four factors extracted explain 75% of the variance.

Table 2 – Component Component Matrix(a): 12 sounds average

Average : 12 sounds	Component			
	1	2	3	4
Comfortable-Uncomfortable	0,93			
Calming- Irritating	0,92			
Not annoying- Annoying	0,90			
Pleasant-Unpleasant	0,90			
Acceptable-Unacceptable	0,81	0,27		
Weak-Strong	0,80	0,25		
Bearable-Unbearable	0,80	0,20		
Smooth-Rough	0,80		-0,27	
Low-High	0,79			
Mild-Noisy	0,78			
Harmonious- Disharmonious	0,73		-0,23	
Regular-Irregular	0,08	0,91		
Constant- Inconstant	0,11	0,90		
Steady-Unsteady	0,15	0,86		
Continuous-Discontinues	0,06	0,79	0,20	
Monotonous-Varied	0,03	0,74		-0,37
Dark- Bright	-0,17		0,91	
Hard-Soft	-0,53		0,72	
Sharp-Dull	0,10			0,85
Strident- Muffled	-0,47			0,58

Regarding the breakdown of sounds related to the vehicles passing by (Sounds 1,5,7,11,12), it appears that the relevant factor structure is slightly different, increasing their number by 1, which may suggest a slight difference in the evaluation of emerging sounds, from those related to the background noise. These extracted 5 factors explain about 74% of the variance. The first factor (Cronbach's alpha equals 0.89) summarizes the meanings in different scales, from which the pairs Not annoying-Annoying, Comfortable-Uncomfortable, Pleasant-Unpleasant have the highest loadings.

Again, this factor indicates a qualitative evaluation in terms of assessment and intensity. The second factor (Cronbach alpha of 0.8) includes aspects mainly related to the scales Constant-Inconstant, Regular-Irregular, Continuous-Discontinuous. The third factor (Cronbach's alpha equals 0.89), comparatively smaller than the previous ones, is mostly represented by the adjectives pairs Muffled-Strident and Monotonous-Varied. The last two factors are represented by one pair only, namely the factor of 4 by the pair Dark-Bright, and the factor 5 by the pair Sharp-Dull. The following names seem to be appropriate for these five factors: Qualitative Assessment (factor 1), Temporal Stability (factor 2), Variation (factor 3), Power (factor 4) and Timbre (factor 5).

3.2 Assessment of noise mitigation measures

For the statements relating to the expectations of effectiveness in noise attenuation provided by acoustic barriers, namely “the construction of a noise barrier near your home will improve your quality of life”, it has been found that most respondents agree with this statement, especially those with higher annoyance during the day. However, for the statement "The introduction of a noise barrier will eliminate road traffic noise at my home", it was noted that there were two main groups with opposite responses. This result suggests the importance of public information and participation in the choice of noise mitigation measures. Regarding the type of material used in the acoustic barrier, most respondents (66.7%) believe that near their residences, the barrier must incorporate transparent panels, whilst 28.6% have no opinion on this. When asked about the main benefit due to the construction of an acoustic barrier near their residence, 19 individuals (90.5%) reported the rnoise eduction as major consequence.

Regarding the psychoacoustic tests, Figure 2 presents four photos that were viewed by the respondents, and their associated numbering. In total, three different classifications were requested with this set of photographs, namely, sortings according to visual effectiveness in noise attenuation, the degree of visual preference and audiovisual effectiveness.

(a) (b) (c) (d)

Figure 2 – Noise barriers photos: (a) Photo 1 (green barrier); (b) Photo 2 (metal barrier); (c) Photo 3 (acrylic barrier) e (d) Photo 4(mixed barrier)

Figure 3 presents the scores given by the respondents to the visual effectiveness rating. For this purpose, it was suggested to order the photos in accordance with the expectations of noise attenuation provided by the barrier, taking into account only the visual appearance. For this rating, respondents had only information about the (panel) materials of each acoustic barrier. In this case, the ordering was as follows (from most effective to least effective: is as follows): photo 3, photo 4, photo 2 and finally photo 1.

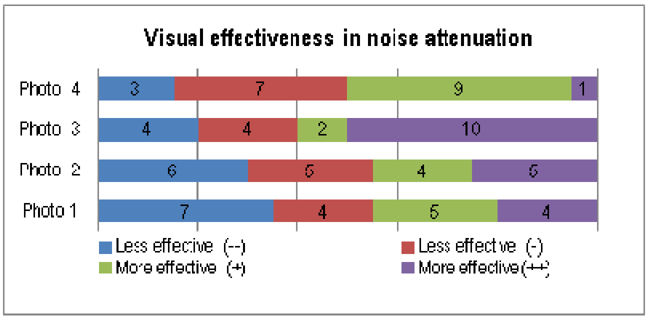

Figure 3 – Rating of the four photos according to visual effectiveness in noise attenuation

When asked about the aesthetic pleasantness provided by each acoustic barrier, participants' responses are presented in Figure 4. The sequence of photos from the most pleasant to less agreeable is: photo 3, photo 4, photo 1 and photo 2. When these photos were presented together with each audio recording (approximately during 60 seconds), the sorting, as regards the effectiveness of each barrier, is as follows (from most effective to least effective): photo 4; photo 3; photo 1 and photo 2, as showed in Figure 5.

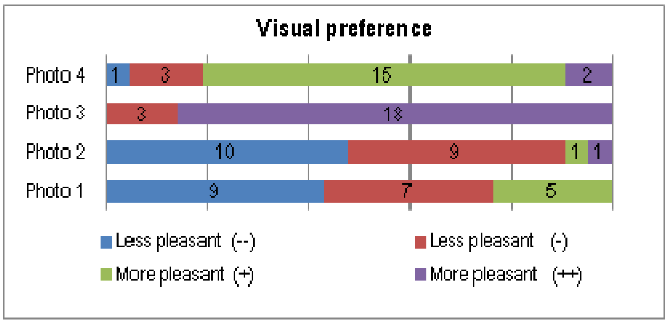

Figure 4 – Rating of nose barriers according to visual preference

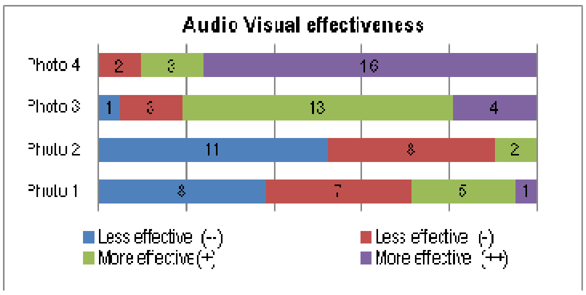

Figure 5 – Rating of noise barriers according to audio visual effectiveness

Figure 6 shows the results obtained when comparing the audio records relating to vehicle pass by in different types of road pavements and corresponding passage in a dense asphalt concrete pavement (velocity of 80 km/h, in both cases). It can be noted that the most part of individuals prefer the audio recording associated with the vehicle passing in a thin layer (micro concrete), and in second place the audio recording associated with vehicle passing by in drainage asphalt. To a lesser extent, the sound associated with the vehicle pass by in rubberized asphalt (closed moisture). At last place of preference is the vehicle pass by on a rough asphalt pavement.

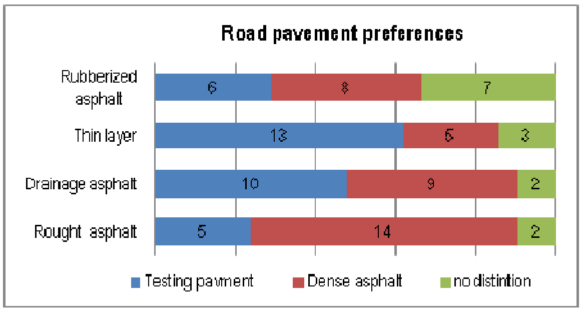

Figure 6 - Preferences expressed by individuals for vehicle pass by in different road pavement (rubberized asphalt; thin layer; drainage asphalt, rough asphalt)

For the audio records associated with the vehicle pass by in drainage asphalt with different speeds (100, 80 and 60 Km/h), it has been found that respondents preferred the recordings associated with lower velocities.

3.3 Association between physical and perception data

Table 3 presents all the significant nonparametric associations between the pairs of adjectives (qualitative appraisal) and the corresponding physical and psychoacoustics parameters of the audio recordings, for the 12 sounds. This nonparametric association was assessed in terms of bivariate correlation coefficients, namely the Spearman Rho. This coefficient measures the correlation between qualitative variables (ordinal and nominal), and provides information about the intensity and direction of the relationship, ranging between -1 and 1.

Relating association between the noise barriers audio visual effectiveness and the physical parameters and of audio recordings it could be seen a close agreement between the subjective ranking assigned by respondents, and the weighted sound level A and the 5% loudness. Regarding the audio recordings from a vehicle pass by, it was noted a correlation between the subjective rating and the maximum value of loudness.

4 Final remarks and conclusions

One of the sounds classified in a more depreciative way was the recording from the old motorcycle (Sound 7), corresponding to a passing by of one motorcycle with significant exhaust noise. On the opposite side, the less depreciative sound is the one related to the modern motorcycle with a noise reduction device (Sound 12).These opposite result suggests the importance of awareness campaigns and noise monitoring of vehicles. For the sounds associated with recordings of road traffic noise with a duration exceeding 30 seconds (Sounds 4, 6, 8 and 9), it is interesting to note that the recordings associated with roads that crosses a compact urbanization (with buildings on both sides), are less appreciated. This is the case of Ouro Street (Sound 9), whose classification is comparable to road traffic from VCI (also with a compact urbanization structure nearby).

Table 3 – Significative associations ($p<0,01$) between adjectives and physical parameters

Pairs of adjectives	Physical parameters	Psychoacoustics parameters
Acceptable-Unacceptable	SPL_A (ρ_S=0,92); SPLC (ρ_S=0,82);	S(ρ_S=0,71); LN (ρ_S=0,94);LN_5 (ρ_S=0,94); LN_{10} (ρ_S=0,94); LN_{50} (ρ_S=0,89);
Pleasant- Unpleasant	SPL_L (ρ_S=0,8); SPL_A(ρ_S=0,89); SPL_C (ρ_S=0,87)	LN (ρ_S=0,89);LN_5 (ρ_S=0,82); LN_{10} (ρ_S=0,86); LN_{50} (ρ_S=0,85);
Calming- Irritating	SPL_A(ρ_S=0,77); SPL_C (ρ_S=0,72)	LN (ρ_S=0,8);LN_5 (ρ_S=0,8); LN_{10} (ρ_S=0,86); LN_{50} (ρ_S=0,75);
Not annoying- Annoying	SPL_A(ρ_S=0,75); SPL_C (ρ_S=0,78)	LN (ρ_S=0,75);LN_5 (ρ_S=0,78); LN_{10} (ρ_S=0,78)
Bearable-Unbearable	SPL_A(ρ_S=0,75); SPL_L(ρ_S=0,73);SPL_A(ρ_S=0,92); SPL_C (ρ_S=0,86)	LN (ρ_S=0,94); LN_5(ρ_S=0,91); LN_{10} (ρ_S=0,94); LN_{50} (ρ_S=0,87)
Mild-Noisy	SPL_A(ρ_S=0,7)	LN_5 (ρ_S=0,78); LN_{10} (ρ_S=0,78);
Weak-Strong Low - Height	SPL_A(ρ_S=0,91); SPL_C (ρ_S=0,81) SPL_L(ρ_S=0,8); SPL_A(ρ_S=0,96); SPL_C (ρ_S=0,87)	S(ρ_S=0,71); LN (ρ_S=0,93);LN_5 (ρ_S=0,94); LN_{10} (ρ_S=0,94); LN_{10} (ρ_S=0,94); LN_{50} (ρ_S=0,89); S(ρ_S=0,78); LN (ρ_S=0,93);LN_5 (ρ_S=0,96); LN_{10} (ρ_S=0,96); LN_{50} (ρ_S=0,96);
Muffled- Strident	SPL_L(ρ_S=-0,71); SPL_A(ρ_S=-0,87); SPL_C (ρ_S=-0,82)	LN(ρ_S=-0,87); LN_5 (ρ_S=-0,79); LN_{10} (ρ_S=-0,83); LN_{50} (ρ_S=-0,81);
Smooth-Rough	SPL_A(ρ_S=0,91); SPL_C (ρ_S=0,85); SPL_L(ρ_S=0,75)	LN (ρ_S=0,91);LN_5 (ρ_S=0,91); LN_{10} (ρ_S=0,91); LN_{50} (ρ_S=0,91);
Hard-Soft	SPL_L(ρ_S=-0,77); SPL_A(ρ_S=-0,87); SPL_C (ρ_S=-0,88)	LN (ρ_S=-0,87);LN_{10} (ρ_S=-0,91); LN_{50} (ρ_S=-0,83);

Regarding the principal component analysis carried out, it is interesting to note that the second emerging factor, is the one related to the temporal structure of the signal. This happens when an analysis of all 12 sounds is done, as well as when carrying out a breakdown of sounds corresponding to road traffic noise. It appears that the sounds corresponding to just one passing by of vehicles are generally rated as more irregular, more inconstant and unstable. There is also an additional factor in the principal component analysis, which is appointed by variation in this study. In this context, it is possible to suggest a different mode of evaluation between sounds with a more solid structure (like background noise), from sounds related with isolated acoustic events.

Regarding the association between the perceptual (set of pairs of adjectives) and physical and psycho acoustical data, it has been found that the factor qualitative assessment showed largest number of significant associations. Especially with the parameters loudness, percentiles loudness, and the equivalent continuous sound level A-weighted (C-weighted in some cases). This is the cases of the pairs: Acceptable-Unacceptable, Bearable-Unbearable, Mild-Noisy, Weak-Strong, Low-High, Smooth-Rough.

For the factor Temporal structure, there were no significant associations found between pairs of adjectives used, and the physical and psychoacoustic measures. However, for the potency factor (which is associated with the pair Hard-Soft), there is a strong negative association, because whenever "softer" the sound is, the lower the intensity of the physical and psychoacoustics are, especially in terms of equivalent continuous sound level, A weighted, and loudness.

For the noise mitigation measures in the propagation path, one of the important aspects regarding the noise barriers effectiveness it is not only related with the noise attenuation, but also with the subjective opinion of individuals. In fact, for planning more effective noise mitigation measures, the public assessment of noise perception and pre-established concepts associated with the respective noise reduction measure, becomes essential.

In the context of noise mitigation measures at the receiver, namely enhancing the sound insulation of walls and the introduction of double glazing, it was found that this type of measure is satisfactory and effective. However, as these types of measures do not reduce exterior noise, many respondents reported some dissatisfaction arising from the fact that they can not open the windows because of the noise, particularly during the summer.

The use of computer resources, such as the ones presented in this work, with the presentation of sounds through headphones and corresponding visualization, if necessary, can be an important tool for raising awareness, information disseminating and the assessment of the perception of noise mitigation measures. This work could be done within the public participation in the framework of environmental impact studies.

The results of this work show the importance of working methodology in order to obtain a more suitable noise reduction, aiming to an effective noise level reduction in the scope of the suitable perception of individuals. This type of methodology can also contribute to a more widespread acceptance of the noise mitigation measures.

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