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Relationship between objective acoustic indices and subjective assessments for the quality of soundscapes

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Abstract

Different urban acoustics environments were evaluated using 31 recordings obtained using binaural techniques of recording and reproduction. The relationships of the perception of pleasantness/unpleasantness as described by a sample of 25 inhabitants of these urban environments with two psychoacoustic magnitudes (loudness and sharpness) and two traditional magnitudes (equivalent sound level in dB, L_{eq}, and equivalent sound level in dBA, L_{Aeq}) were analysed. A logistic regression model was considered to study the relationship between the objective acoustic indices mentioned above and the subjective descriptions of the urban soundscapes. A significant correlation between the perception of a soundscape as very unpleasant and the four objective indices considered for its acoustic characterization is found. No correlation was found between the objective indices and the pleasant soundscapes. L_{eq} was the objective index that explained a higher percentage of the variation of the very unpleasant answers. Moreover, L_{eq} was the only index that showed a significant correlation with the mean, maximum and minimum values for the items that respondents assigned to the recordings. Furthermore, it was the one with the highest coefficient of determination.

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1. Introduction

Due largely to urbanization, the environment in which people live most of their lives has undergone major changes in only a very short time, in evolutionary terms. These changes have been especially rapid since the Industrial Revolution ([1], [2], [3], [4]). Our acoustic environment is one aspect that has been altered so rapidly that, as a species, humans have had no time to adapt, and this lack of adaptation implies that humans are prone to many stressful situations [5] that can lead to psychological conflict and direct health problems (an extensive review of urban environmental noise and its psychological and physiological impact on people was published by the World Health Organization [6]. In particular, environmental noise-related concepts such as annoyance, noisiness, noise discomfort, disturbance, and unpleasantness, which would have been recognized only in very specific locations in the past, are commonplace today.

One can consider three basic approaches to the study of the acoustic environment and its influence on people's daily lives, psychology, and health [7]. In practice, these approaches are not always studied independently.

The first ('physical') approach is aimed at the objective evaluation of the acoustic environment and its comparison with certain reference values of sound levels, etc. ([8], [9]). This approach is the principal approach for making noise maps and forms the basis of many of the international regulations and guidelines. Nevertheless, the sound magnitudes measured in this approach (generally, the A-weighted equivalent sound levels, dBA), although used extensively, have only a weak relationship with the characteristics of human perception and are not based on the analysis of the signal domain frequency or the temporal structure of the sound (modulation, tonality, etc.). Many studies in different countries worldwide, from the beginning of the last century [10] to the present ([11], [12], [13]), have worked to achieve an objective characterization of these new urban soundscapes. Although the underlying motivation is the effect of sound on people, their physical focus means that human sensations are dealt with only secondarily.

The second ('psychophysical') approach is aimed specifically at studying the relationship between the sound environment and human sensations, in particular between the physical magnitudes associated with sound and people's responses. For instance, the objective variable ‘sound level’ is enriched with a subjective contribution (in terms of ‘annoyance’, ‘unpleasantness, ‘disturbance’, etc.) to allow for a characterization of aspects that negatively impact people's physical and psychological well-being. Studies of this kind began to be carried out only a couple of decades after the first work using the 'physical' approach [14]. Different characteristics of the sound, such as the source, its spectrum, its temporal structure, the perceptual context, and personal or socio-demographic characteristics, are now considered important ([15], [16], [17]). In nearly all studies of this kind, measurements of the A-weighted equivalent sound level (dBA) are still used to characterize the objective component of the sound level. However, two different sounds with the same noise level can produce very different sensations in the listener, and the question of the direct connection between sound pressure level and the effects of noise is currently a topic under reconsideration ([18], [19]). In this context, to understand how people are affected by and respond to today's soundscapes, it would appear advisable to use variables that take into account characteristics associated with the structure of the signal and with how the human ear perceives the sound, i.e., psychoacoustic magnitudes ([20], [21], [22], [23]).

Lastly, a third ('perceptual') approach has taken form somewhat more recently. The soundscape is treated principally as a source of information and an element of the interrelationship between people and their environment. The perceptual approach is aimed at identifying and describing the bases of the psychological processes that underlie people's appraisal of sound. Pioneering work in this line was performed by Schafer [24], and recently Raimbault et al. [20] described a partial union of this perceptual approach and the 'psychophysical' approach.

The present work, as well, while following mainly the 'psychophysical' approach, attempts to make a connection with 'perceptual' studies. An attempt was made to study the complex relations between objective and subjective magnitudes. The study of other important aspects such as the temporal or frequential structure is out of scope of this first analysis and it is left for future work. In particular, the relationships between objectively measured variables associated with the sound environment (the A-weighted sound level, loudness, and sharpness) and a subjective variable that characterizes people's responses (the sensation of pleasantness/unpleasantness) have been studied. Recent works on soundscapes considered a wide variety of objective variables and attempted to categorize different acoustic environments but without reference to the listeners’ subjective response ([25], [26]). Axelsson et al. [27], although consider objective parameters when describing a soundscape, they mainly focus their work on subjective attributes that describe this soundscape.

Various studies of the relationship between human perceptions and sound environments have been performed. Apart from their scientific interest, these studies are important technologically because psychoacoustic magnitudes (basically, loudness [28]) are ever more commonly being used to predict whether the sound generated by machinery will be acceptable to consumers [29]. These studies are also beginning to be used in other situations, such as work environments [30]. Generally, the associated human perception studied has not been the sensation of pleasantness/unpleasantness, but of annoyance, loudness, or noisiness ([29], [30], [31]).

The application of psychoacoustic magnitudes to the analysis of the urban sound environment has been less common. For example, even in studies ([32], [33]) that took a psychophysical approach to investigate the interaction between vision and hearing in people's sensation of pleasantness caused by the urban environment, no psychoacoustic variables were employed. Psychoacoustic magnitudes were used, however, in another work [20] where the approach was part perceptual and part psychophysical. This work found that the variable that gave the best results was loudness.

Recent works has shown that the assessment of urban soundscapes is quite complex and that many factors come into play, not only acoustic or visual. Raimbault et al. [20] conclude that it is quite difficult to match a unique acoustic descriptor with two cognitive representations of the same acoustic phenomenon. Lam et al. [34] found that the perception of a soundscape is influenced by the presence or absence of wanted and unwanted sounds. According to Jeon et al. [35], soundscape perceptions depend not only on acoustic comfort but also on visual images and day lighting. Pheasant et al. [36] reported that visual factors play an important role in auditory perception.

Although psychoacoustic magnitudes have been so little used to study the urban acoustic environment, in most of our cities it is nearly impossible to reduce sound levels to values that are recognized as innocuous for both the health and the quality of life of their inhabitants [6]. Given the essentially subjective nature of the dose-response relationship ([37], [38]), it appears important, and at times may be the only available option, to attempt to attain urban acoustic environments with sounds of high quality and levels that are not excessive ([8], [9]).

A broad variety of acoustic environments that could be considered to be typical of modern cities was selected for the present study. These environments were characterized by objective indices (L_{eq}, L_{Aeq}, loudness, and sharpness). The main objective of the present work is to study the potential relationships between these objective indices and the subjective responses evaluating the sensation of pleasantness/unpleasantness associated with those soundscapes. A complementary objective of the study was to evaluate the suitability of using psychoacoustic variables to evaluate people's pleasantness/unpleasantness response to a soundscape, rather than the traditional magnitudes L_{eq} or L_{Aeq}.

The study is organized as follows. Section 2 explains the data acquisition and the mathematical methods used for their analysis. The results obtained and their discussion is presented in section 3. The conclusions are shown in section 4.

2. Methods

A set of acoustic environments was recorded and reproduced using a binaural device in which the microphones were placed in the ear of the person making the recordings. The main advantage of this binaural device was its high fidelity in the reproduction of the recordings with respect to the actual situation in the listener's ears under the actual conditions of the acoustic environment ([39], [40]). The sound magnitudes measured by the binaural device in the ear of the respondent, as mentioned above, were L_{eq}, L_{Aeq}, loudness, and sharpness. Loudness is widely used as a psychoacoustic variable ([28], [31]), occasionally accompanied by sharpness, roughness, and tonality level [32]. The group of subjects whose responses were studied was chosen to be representative of the overall Spanish population with respect to age, gender, and level of education, although it was not an objective of the work to look for correlations with these variables.

2.1 Equipment

A binaural recording and playback device (Noise Book from Head Acoustics) was used. The device is fairly light and compact, consisting of a record-and-play unit connected to a computer, precision headphones for the binaural playback, and microphones for binaural recording integrated into the headphones. The aim is to record the sounds of the acoustic environment as closely as possible to the form in which a real subject would perceive them ([39], [40]).

2.2 Choice of the urban environments and the associated acoustic surroundings

As many recordings were made covering the variability of urban acoustic environments as was compatible with a reasonable number of sessions and total time that could be asked of the listeners. Thirty-one recordings lasting from 45 s to 3 min were made. The duration of each recording is not the same because it was attempted to capture the key features of each of the different sound environments fully. Moreover, the independence of the duration of the recordings with respect to the likelihood of answering the corresponding item was checked. To ensure that different kinds of urban environments were considered, the recordings were sorted into groups, and different measurements were made in each group. The definition of group was not strict, with some of the recordings being assignable to multiple groups because they contained various sources of noise. The purpose of this grouping was only for the convenience of organizing the data. The following is a broad classification of the noise sources into eight groups, according to the main noise source or the basic environment present:

1. Fairly saturated rush-hour traffic environments. (4 recordings)

2. Traffic environments combined with other environments. (4 recordings)
3. Urban green zones. (3 recordings)
4. Building or road work. (3 recordings)
5. Public transport station. (4 recordings)
6. Crowded spaces. (4 recordings)
7. Children. (3 recordings)
8. Other urban environments. (6 recordings)

2.3 Selection of the subjects

As mentioned in the Introduction, the selection of the 25 subjects who listened to the recordings and responded to a questionnaire took into account the socio-demographic characteristics of the overall Spanish population –age, gender, level of education, working status, and profession. These characteristics have been described in detail in a previous work [41], but the primary characteristics were:

- Gender: 13 (52 %) women, 12 (48 %) men.
- Age (years): range 19-78; median: 40; mean ± S.D.: 42.1 ± 17.3. The age distribution is shown in Figure 1.
- The level of education: the educational level varied from no formal studies (8%) to university graduates (16%).

2.4 The questionnaire

As indicated in the previous section, the first part of the questionnaire included questions regarding the subject's socio-demographic situation and certain physiological and psychological aspects. A free space was also provided for any other data that the subject considered to be relevant.

The second part consisted of items with closed Likert-scale responses about the pleasantness/unpleasantness of each recording of a soundscape. This type of scale has been shown to be optimal when the concept being studied is bipolar in nature, such as the present pleasantness/unpleasantness pair ([20], [42]). A Likert scale with seven responses was considered: 1: very unpleasant (*vu*); 2: quite unpleasant (*qu*); 3: somewhat unpleasant (*su*); 4: neither pleasant nor unpleasant (*n*); 5: somewhat pleasant (*sp*); 6: quite pleasant (*qp*); 7: very pleasant (*vp*) [in Spanish *1: muy agradable, 2: bastante agradable, 3: algo agradable, 4: ni agradable ni desagradable, 5: algo desagradable, 6: bastante desagradable, 7: muy desagradable*]. This scale, given its length, allowed analysing the subjective differences between similar recordings regarding objective characteristics. The number that accompanied the answer was used for subsequent numerical analysis.

2.5 Presentation of the recordings to the subjects

It was considered best that there be no order in the different recordings in terms of the kind of acoustic environment or of the different acoustic indices. A single random listening order was therefore prepared to be used for all the listeners. It was attempted to remove the influence of those aspects other than the sound characteristics on the perception of pleasure in a soundscape. In this sense, an order by level, type of environment or any order different from pure chance could call into doubt the results. Since the respondent should stop once made the audition and fill out a questionnaire associated with that hearing, it was considered that the order was not a factor in the development of this work. The element that was considered most important was that there was no clustering of sources, sound levels, etc. Furthermore, it has been proven that the duration of the recordings has no relation with the type of response, as said above.

The recordings were presented in three separate sessions, none of which lasted longer than 50 minutes. The sessions were conducted independently for each listener. In the first session, listeners were informed about the subsequent procedure of the listening sessions and about the contents of the questionnaire. The participants were then asked to respond to the first part of the questionnaire (socio-demographic situation, physiological and psychological aspects, and the free space) and, if they wished, they could begin auditions. Two more sessions were followed the initial session where respondents listened to the recordings. Listen to all recordings in a single session could tire the respondent and affect the results. All sessions for the same respondent were developed in less than a week. The questions corresponding to each recording were answered immediately after the audition. The number of recordings heard in each session depended on the subject (with the only constraint being that, as noted above, the entire session time was no longer than 50 minutes).

2.6 Statistical procedure

As previously stated, the initial goal was to analyse the relationship between the subjective variables obtained from the 7-items Likert scale proposed (described in section 2.4) to interviewees with respect to the objective variables of the different sound recordings (L_{eq}, L_{Aeq}, loudness, and sharpness) to study the physical variable that best explains the variation of different subjective variables.

The two variables considered were the following: (a) Dependent variable: proportion of people responding to the subjective item z_i for the x_i noise index value (with z_i = *vu, qu, su*...), (b) Independent variable: value of x_i = L_{eq}, L_{Aeq}, loudness or sharpness, registered for the different recordings. Each dependent variable (subjective item z_i) was analyzed in a different mathematical model for two purposes: First, to avoid building a global model with a low ratio between the noise level and the level of appreciation for the influence of a non-significant relationship between subjective items with the sound level; second, to analyse in more detail the effect of each item and to optimize the Likert scale. Considering this two points, the dependent variable was based on a binomial variable (success/failure).

Given the characteristics of the dependent variable, the regression model used was a logistic regression model ([43], [44]). A model based on the Verhulst logistic function [45] was proposed:

$$f = \frac{A}{1 + ke^{-\beta X}} . \qquad (1)$$

In logistic regression, the probability of a positive response or success (in our case, success was when the person, after hearing the noise, valued it as the item under study; i.e., if the relationship between L_{eq} and "*vu*" was our goal, if the subject answered "*vu*", then a positive response was considered) is a logistic function of the independent variable, where $A = 1$ and denoting $k = e^{-\alpha}$:

$$p = \frac{A}{1 + ke^{-\beta X}} = \frac{1}{1 + ke^{-\beta X}} = \frac{e^{\alpha + \beta X}}{1 + e^{\alpha + \beta X}} . \qquad (2)$$

In a sample with N_X observations, there would be a conditional binomial distribution for each value of the independent variable (in our case, 25 answers for each noise index value).

Instead of measuring the probability of success (p) or failure ($1 - p$), it was estimated when success is more probable than failure (odds, O) ([46], [47]):

$$O = \frac{p}{1 - p} . \qquad (3)$$

From the "odds", the logistic function of probability was:

$$O = e^{\alpha + \beta X} . \quad (4)$$

If logarithms are taken:

$$Y = \ln O = \alpha + \beta X . \quad (5)$$

There are several reasons to calculate the odds (Equation 3) and, from it to set out the model with the odds logarithm (Equation 5), rather than simply to set out it with the probability of success (*p*) or failure (1 - *p*) [44]. First, the range of variation of ln*O* is the set of all real numbers (from -∞ to + ∞), while for p or q the range is only from 0 to 1, and even if not set out with ln*O*, the odds variation range is from 0 to + ∞. Therefore, it should be no constraints with the logistic model coefficients that would complicate their estimation. Moreover, and more importantly, the coefficients are easily interpretable in terms of independence or association between the variables in the logistic model.

The most common and usual way to estimate the coefficients (α, β) is the method of maximum likelihood, which is to maximize the likelihood function of the sample ([48], [49]). This method will allow knowing how well the logistic regression model fits the data through the chi-square statistical.

Moreover, the least squares method was used to analyse the relationship between the dependent and independent variables. As shown in the expression 5, the dependent variable was "ln *O*" and the independent variable "*X*". This method will allow analysing the goodness of the model fit through the coefficient of determination (R-square) and the significance of it through the Fisher F test. Furthermore, the residual variance was calculated to contrast the above results.

The next goal, strongly related to the previous one, is to analyse the differences of the mean sound values that respondents assigned to each item. Therefore, it will allow analysing whether the 7-items scale used can significantly stratify sound values heard by the respondents. If this is not so, groups of homogeneous items will be grouped to improve the significance in the relations between sound and subjective variables, while achieving a significant stratification.

The strategy used was to transform the independent variable to a dependent variable and the dependent variable to a qualitative independent variable (factor). Thus, the logistic regression model became an ANOVA model in which the factor would be "people responding to item z_i", and the physical variable would be the response variable.

The mathematical model generated is as follows:

$$y_{ij} = \mu + \alpha_i + \varepsilon_{ij} \tag{6}$$

where:

$i = 1, \ldots, 7$ responses provided by individuals.

$j = 1, \ldots, 31$ are the recording.

y_{ij} is the measured value (L_{eq}, L_{Aeq}, loudness or sharpness).

μ is the mean value of the dependent variable.

α_i is the "people responding to item z_i" factor.

ε_{ij} is the random error.

However, since the random error showed significant differences (p-value < 0.001) from a normal distribution [$\varepsilon_{ij} \neq N(0,\sigma^2)$] and heteroscedasticity [$\sigma_m^2 \neq \sigma_n^2$ (*m* and *n* are the groups generated by the “people responding to item z_i” factor)] according to the Shapiro-Wilks and the Levene tests, respectively. Therefore the determination of the existence of significant differences in the mean values was performed using the nonparametric Kruskal-Wallis test [50] and the bootstrapping method [51]. To avoid any errors due to the use of data from the same population rather than from randomly selected data, the Holm correction [52] was used.

Finally, to studying the relationship between the proportion of successes for each item with regard to the sound index heard, all of the responses were analysed for a given sound index. This study was performed through an analysis of the linear relationship of the descriptive statistics (mean, maximum and minimum) obtained from the values of the items ($z_i = 1, ..., 7$) answered by the total of the 25 persons for that particular sound index heard (x_i).

3. Results and discussion

3.1 Logistic regression analysis

In this section, the relationship between the subjective variables of the items obtained from the 7-items Likert scale (as explained in section 2.4) with respect to the physical variables registered in the various recordings (L_{eq}, L_{Aeq}, loudness, and sharpness) will be analysed using a logistic regression (equation 5).

Figure 2 shows the values of the four acoustic magnitudes studied (L_{eq}, L_{Aeq}, loudness, and sharpness) for each of the recordings. It can be seen that there were no major differences between the two channels in the values of the sound indices of the recordings. Given this similarity and the lack of any standard procedure to estimate psychoacoustic magnitudes for binaural recordings, the means of the two channels were used to study the relationships between the acoustic variables and the sensation of pleasantness/unpleasantness of the different soundscapes. Also in this Figure 2 it can be seen how the sound indices present a strong association between them. To test this hypothesis the correlation coefficient was analysed. The results are shown in Table 1. Acoustics indices have a highly significant correlation, therefore, they cannot be proposed simultaneously to form part of the regression model because multicollinearity would occur.

Next, the relationship between the subjective variables and the physical ones is carried out through the regression model. The results are shown in Table 2. The following conclusions can be drawn:

- The logistic regression models used, in most cases, show a significant relationship between studied variables as indicated by the p-value obtained from the maximum likelihood method. However, only some linear regression models have a significant correlation coefficient.

- The response associated with the greater degree of unpleasantness (*vu*) presents the greatest chi-square value and, therefore, the highest level of significance. Figure 3 shows the functional relationship of this item (*vu*) relative to the physical variables L_{eq} and loudness. In addition, this item has a significant correlation coefficient with the different sound variables and a lower residual variance.
- The L_{eq} and L_{Aeq} sound indices are those with a greater chi-square value and a higher coefficient of determination regarding to the probability of answering the unpleasant items.

Perhaps some relationships between these variables exhibit low correlation coefficient and p-value > 0.05 due to the fact that the 7-items Likert scale is too wide. As a result, respondents would have hesitated to respond either item on recordings with similar sound values. One fact that supports this hypothesis, a hypothesis that will be discussed in the next section, are the values obtained for the "X in maximum derivative [ln(k)/β]" (Table 2). The ln(k)/β value indicates the value of the sound index that would be required in the model for 50% of the respondents answered the z_i item. The β/4 value indicates how increases the probability of answering the z_i item in the model at around ln(k)/β. For example, if the ln(k)/β value for the items "*vu*" and "*qu*" is analysed (Table 2), it can be seen how this value is greater for the item "*qu*" when this item has a lower degree of displeasure. That is, it takes a higher value of L_{eq} for half of the respondents say that the presented recording for hearing is quite annoying (*qu*) that to say it is very annoying (*vu*). This can be considered an endorsement that some items are not clearly differentiated by respondents, so after hearing a recording they assigned either item.

3.2 Analysis of averages sound values assigned to subjective variables

In this section, as it was have indicated above, it will be analysed the average sound values assigned by respondents to each of the items to detect possible homogeneous groups of items. To do this, it was used in the first place, the nonparametric Kruskal-Wallis test and the results show that sound average values assigned to the various items have highly significant differences (p-value <0.001).

Tested this, the next step was to perform multiple comparisons to establish the confidence intervals at a level of 95% of the mean values assigned to each item. That is, the recordings sound indices to which respondents assign the item "vu" or "qu" or "su"... were considered and compared their average values. Thus, it can be detected potential overlaps. For this, two methods were used: Kruskal-Wallis test with the Holm correction and bootstrapping. The results are shown in Figure 4. It can be concluded the following:

- Respondents distinguish better the sound values corresponding to unpleasant. Thus, the average sound indices of the recordings to which respondents have associated the item "*vu*" is significantly different from the items "*qu*" and "*su*" and these in turn differ from item "*n*". However, this does not apply for items that indicate pleasure: "*sp*", "*qp*" and "*vp*", that overlap each other and even, in some cases, include the item "*n*" (for the sound indices L_{Aeq}, loudness and sharpness).

- It is interesting to note the mean values of the L*Aeq* index pseudo-median. The mean values obtained for the “*sp*” and “*qp*” items are similar to those obtained for the “*su*” item, the mean value for the “*vp*” item is similar to that for the “*su*” item and the pseudo-median minimum value is obtained for the n item. Thus, the pseudo-median graph has a decompensated V-shape. Therefore, respondents feel as unpleasant the highest L_{Aeq} sound levels analyzed in this work. But when the L_{Aeq} level lower, respondents may feel both pleasure and displeasure and when levels are even lower vagueness in the pleasure or displeasure experienced by the respondents is found. This may be an indication that this noise index, so used in various acoustic studies related to noise and annoyance, may not be the most suitable to identify the level of pleasure related to a soundscape.

Taking into account these results, those adjacent items whose average sound value was not significantly different (p-value> 0.05) were clustered. Two possibilities were considered. One possibility was to make 4 groups: 1 (very unpleasant), 2-3 (moderately unpleasant), 4 (neither pleasant nor unpleasant), and 5-6-7 (pleasant to some degree). The other possibility was to group in 3 items: 1 (very unpleasant), 2-3 (moderately unpleasant), 4-5-6-7 (not unpleasant). Therefore, the new nomenclature to be used is:

- 4 items:

1. "*vu*" (very unpleasant): "*vu*" (very unpleasant)
2. "*mu*" (moderately unpleasant): "*qu*" (quite unpleasant) + "*su*" (somewhat unpleasant)
3. "*n*" (neither pleasant nor unpleasant): "*n*" (neither pleasant nor unpleasant)
4. "*p*" (pleasant to some degree): "*sp*" (somewhat pleasant) + "*qp*" (quite pleasant) + "*vp*" (very pleasant).

- 3 items:

1. "*vu*" (very unpleasant): "*vu*" (very unpleasant)
2. "*mu*" (moderately unpleasant): "*qu*" (quite unpleasant) + "*su*" (somewhat unpleasant)
3. "*nu*" (not unpleasant): "*n*" (neither pleasant nor unpleasant)+ "*sp*" (somewhat pleasant) + "*qp*" (quite pleasant) + "*vp*" (very pleasant).

As was the case for the 7-items Likert scale, the random error (equation 6) for the new items was not normally distributed and exhibit heteroscedasticity (p-value < 0.001), as a result of applying the Shapiro and the Levene tests. Thus, non-parametric tests were used to compare the new items mean values. The Krukal-Wallis test was used and, as for the 7-items scale, the new items have significant differences (p-value <0.0001).

Then, following the above procedure, multiple comparisons were performed using Kruskal-Wallis test and bootstrapping techniques. Table 3 shows the homogeneous group analysis. In the case of the 4-items scale, the results are shown in

Table 3(a). Items that have the same letter are homogeneous groups, i.e., they do not show significant differences in the mean sound values recorded. Therefore, considering this, the Leq is the only index that presents significant differences in items 1 (a), 2 (b), 3 (c) and 4 (d) for the Kruskal-Wallis test and the bootstrapping method. Items that have different letter are those with significant differences in the mean sound values recorded. Sharpness fails to differentiate between the four items with either method. LAeq and loudness achieve to differentiate between the four items significantly with at least one of the two methods used for a confidence level of 95%. Lastly, in Table 3(b) for the 3-items scale, all the groups were differentiated significantly. According to these results, Leq is still the best sound index to distinguish between the different subjective options.

Once differentiated significantly heterogeneous groups of items, the goodness of fit of the new relationship between subjective variables and noise variables was analysed using equation 5, i.e., it was raised again the first objective of the work. The results are shown in Table 4 (a) and (b).

With respect to Table 4(a) that shows the results of clustering in 4 items, the “X in maximum derivative [ln(k)/β]” column shows again that respondents could hesitate in the answer in the case of the items “*n*” and “*p*”. Moreover, only the item "*vu*" presents a significant correlation coefficient with the four objective indices, as happened in the case of 7 items. The sound index that accounts for a larger fraction of the variability of respondents' answers to the item "*vu*" is L_{eq} followed by L_{Aeq}. Sharpness and loudness explain a lower fraction of the variability of respondents' answers.

Finally, if the results of Table 4(b) are analysed, the “X in maximum derivative [ln(k)/β]” column shows an expected order in the answer. Besides, the answers for the item "*nu*" showed a significant correlation coefficient in addition to the item "*vu*". In the case of "*vu*", the analysis is similar to the 4-items scale. When considering the response "*nu*", again is the L_{eq} index which explains a greater percentage of the variability in the responses, followed closely by L_{Aeq}. In this case the variability explained by loudness and sharpness is clearly lower. Therefore, the scale of displeasure would be formed by the items "*vu*" and "*mu*" and the rest would be grouped within the scale "*nu*". If in a further analysis the items "*vu*" and "*mu*" were grouped, the significance of the new grouped item would be lost. It can be found examples of two options on a displeasure scale in the literature, for example, the %HA and %A ([53], [54]) and, also, it can be seen how sometimes divided into three the displeasure scale generated worse adjustments with regard to actual data [55].

Thus, the objective sound indices used in this work are suitable to achieve to some extent the aim of assessing whether a soundscape will be pleasant or unpleasant. But the scale used to characterize the level of pleasantness or unpleasantness of the soundscape should be reduced (3 items), and thus it can be estimated if the landscape will be very unpleasant or will not be unpleasant. In addition, the psychoacoustic indices are worse than the traditional ones, and among these, the most suitable is L_{eq}.

3.3 Descriptive analysis of the overall survey respondents

In this section, the linear relationship between the descriptive statistics (mean, maximum, and minimum) obtained from the values of the items answered (y_i = 1, ..., 7) for the total of 25 people and the value of the sound index (x_i) will be analysed. The results are shown in Table 5. The maximum value corresponds to the maximum level of pleasantness assigned by any of the respondents to the sound presented in the interview, and the minimum value corresponds to the minimum value of pleasantness (maximum value of unpleasantness).

From this analysis, L_{eq} is the only acoustic index that presents a significant correlation coefficient with the three descriptive statistics. Moreover, it is the index that explains the higher degree of variability for these descriptive statistics (greater R value). L_{Aeq} presents a significant correlation coefficient with the descriptive statistics mean and minimum, like loudness and sharpness, but L_{Aeq} is the index that explains the lower degree of variability of these two statistics.

In summary, this analysis supports the goodness of the L_{eq} index to significantly relate the response given by respondents.

4. Conclusions

Some conclusions can be drawn from the above results and analyses.

According to the logistic regression model used for the analysis of a 7-items Likert scale, the relationship between the subjective item for the higher negative characterization of the soundscape and the objective indices is highly significant (p-value < 0.01) only for Leq and significant for the other indices (p-value < 0.05). Thus, the model indicates that Leq is the objective variable that explains the higher level of variation when a sound environment is perceived as very unpleasant. If the objective variables are ordered based on their degree of explanation of the variability of the subjective variable of higher unpleasantness, from highest to lowest, the order would be Leq, LAeq, sharpness, and loudness. Furthermore, with respect to the subjective variables associated with a high positive characterization of the soundscape, there is no correlation between them and the objective indices.

However, a subjective 7-items scale is too wide. So, we proceeded to group the respondents' answers on a 4-items scale and another 3-items scale. In the case of the 4-items scale, only correlation is found between the four objective indices and the response "very unpleasant", being L_{eq} the objective index that explains a greater proportion of the variability of that response. In the case of the 3-items scale, there is correlation between the four objective indices and the responses "very unpleasant" and "not unpleasant". In both cases, it is L_{eq} the index that explains the higher percentage of variation for these answers.

Lastly, with regard to the analysis of the linear correlation between the descriptive statistics (mean, maximum, and minimum) and the objective acoustic indices, L_{eq} is the only acoustic index that correlate with the three descriptive statistics.

The other three indices correlate with mean and minimum but never with maximum. L_{eq} always explains a higher degree of variability of these descriptive statistics.

References

[1] Lefebvre, H. La révolution urbaine: Gallimard, Collection Idées, Paris (1970).

[2] Merrington, J. Town and Country in the Transition to Capitalism, New Left Review **93,** 1975, 71-92 (1975).

[3] De Vries, J. European Urbanization 1500-1800. Harvard Univ. Press, Cambridge (1984).

[4] United Nations (UN); Population Division. World urbanization prospects: The 2001 revision. UN, New York (2002).

[5] Seyle H. A syndrome produced by diverse nocuous agents. Nature **138**, 32 (1936).

[6] World Health Organization (WHO). Guidelines for Community Noise. (Eds. Berglund, B.; Lindvall, T.; Schwela D.H. and Goh, K.T.) Geneva (1999).

[7] López Barrio I, Carles JL. La calidad sonora de Valencia. Espacios sonoros representativos, Fundación Bancaixa, Valencia, Spain (1997).

[8] Organization for Economic Cooperation and Development (OECD). Report Fighting Noise. OECD Publications, Paris (1986).

[9] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the

assessment and management of environmental noise. Official Journal L 189, 18/07/2002 P. 0012-0026.

[10] Free EE. Measurements of the street noise in New York city. Physical Review **27**, 507 (1926).

[11] Chakrabarty D, Santra SC, Mukherjee A, Roy B, Das P. Status of road traffic noise in Calcutta metropolis, India. J. Acoust. Soc. Am. **101**, 943-949 (1997).

[12] Sommerhoff J, Recuero M, Suárez E Community noise survey of the city of Valdivia, Chile. App. Acoust. **6**, 643-656 (2004)

[13] Rey Gozalo G, Barrigón Morillas JM, Gómez Escobar V. Analysis of noise exposure in two small towns. Acta Acustica united with Acustica **98**, 884-893 (2012).

[14] Fields JM. An updated catalog of 521 social surveys of resident' reactions to environmental noise (1943-2000), NASA Center for AeroSpace Information (CASI), Hanover (2001).

[15] Griffiths ID, Raw GJ. Adaptation to changes in traffic noise exposure. J. Sound and Vibration **132**, 331-336 (1989).

[16] Fields JM. Effect of personal and situational variables on noise annoyance: With special reference to implication for En Route Noise. NASA, Atlanta (1992).

[17] Barrigón Morillas JM, Gómez Escobar V, Rey Gozalo G. Noise source analyses in the acoustical environment of the medieval centre of Cáceres (Spain). Applied Acoustics **74**, 526-534 (2013).

[18] Schulte-Fortkamp B., Fiebig A. Soundscape analysis in a residential area: an evaluation of noise and people’s mind. Acustica-Acta Acustica; **92**, 875-880 (2006).

[19] Gómez Escobar V, Barrigón Morillas JM, Rey Gozalo G, Vaquero JM, Méndez Sierra JA, Vílchez-Gómez R, Carmona del Río FJ. Acoustical environment of the medieval centre of Cáceres (Spain). Applied Acoustics **73**, 673-685 (2012)

[20] Raimbault M, Lavandier C., Bérengier M. Ambient sound assessment of urban environments: field studies in two French cities. App. Acoustics **64**, 1241-1256 (2003).

[21] Brambilla G., Maffei L. Responses to noise in urban parks and in rural quiet areas. Acustica-Acta Acustica **92**, 881-886 (2006).

[22] Bullen, R. Modelling soundscapes. Acoustics Australia **38**, 94 (2010).

[23] Houg, CM. Note on the applications of a simple acoustic immersion index. Acoustics Australia **38**, 87-93 (2010).

[24] Schafer RM. The tuning of the world. A.A.Knopf, New York (1977).

[25] Rychtarikova M, Vermeir G. Soundscape categorization on the basis of objective acoustical parameters. Applied Acoustics **74**, 240-247 (2013).

[26] Yang M, Kang J. Psychoacoustical evaluation of natural and urban sounds in soundscapes. The Journal of the Acoustical Society of America **134**, 840-851 (2013).

[27] Axelsson O, Nilsson ME, Berglund B, A principal components model of soundscape perception. Journal of the Acoustical Society of America **128**, 2836-2846 (2010).

[28] Zwicker E., Fastl H. Psychoacoustics. Facts and Models. Springer-Verlag, Germany (1999).

[29] Tang SK, Wong, MY. On noise indices for domestic air conditioners. J. Sound and Vibration **274**, 1-12 (2004).

[30] Ayr U, Cirillo E, Fato I, Martellotta F. A new approach to assessing the performance of noise indices in buildings. App. Acoust. **64**, 129-145 (2003).

[31] Trapenskas D, Johansson Ö. Noise annoyance evaluation in a steel plant using binaural technology. Acustica-Acta Acustica **89**, 889-899 (2003).

[32] Viollon S, Lavandier C, Drake C. Influence of visual setting on sound ratings in an urban environment. App. Acoust. **63**, 493-511 (2002).

[33] Watts, G.R., Pheasant, R.J., Horoshenkov, K.V. Predicting perceived tranquillity in urban parks spaces, Environment and Planning B: Planning and Design 2011, **38**, 585 - 594

[34] Lam KC, Brown AL, Marafa L,Chau KC. Human preference for countryside soundscapes. Acta Acustica united with Acustica **96**, 463-471 (2010).

[35] Jeon JY, Lee PJ, Hong JY, Cabrera D. Non-auditory factors affecting urban soundscape evaluation. J. of de Acoustic Soc. Am. **130**, 3761-3770 (2011).

[36] Pheasant RJ, Fisher MN, Watts GR, Whitaker DJ, Horoshenkov KV. The importance of auditory-visual interaction in the construction of 'tranquil space'. Journal of Environmental Psychology **30**, 501-509 (2010).

[37] Schultz IJ. Synthesis of social surveys on noise annoyance. J. of de Acoustic Soc. Am. **64**, 377-405 (1978).

[38] Job RFS. Community response to noise: A review of factors influencing the relationship between exposure and reactions. J. Acoustic Soc. Am. **83**, 991-1001 (1988).

[39] Møller H. Fundamental of binaural technology. App. Acoust. **36**, 171-218 (1992).

[40] Hotehama T, Sato S, Ando Y. Dissimilarity judgments in relation to temporal and spatial factors for the sound field in an existing hall. J. Sound and Vibration **258**, 429-441 (2002).

[41] Barrigón Morillas JM, Palma Amador B, Vílchez-Gómez R, Gómez Escobar V, Méndez Sierra JA, Vaquero JM. La calidad sonora en los ambientes urbanos y su relación con algunos parámetros acústicos. Revista Española de Acústica **34**: (2003)

[42] Kawai K, Yano T. Relation between the overall impression of the sound environment and types and the loudness of environmental sounds. Journal of Sound and Vibration **250**, 41-46 (2002).

[43] Kleinbaum, DG. 1994. Logistic Regression: A Self-Learning Text. New York: Springer-Verlag

[44] Hosmer, DW, Lemeshow, S. 2000. Applied Logistic Regression, 2nd ed. New York: John Wiley and Sons

[45] Verhulst P-F. Notice sur la loi que la population poursuit dans son accroissement. Correspondance mathématique et physique **10**, 113-121 (1838).

[46] Cornfield J. A Method for Estimating Comparative Rates from Clinical Data. Applications to Cancer of the Lung, Breast, and Cervix. Journal of the National Cancer Institute **11**: 1269-1275 (1951).

[47] Mosteller F. Association and Estimation in Contingency Tables. Journal of the American Statistical Association (American Statistical Association) **63** (321): 1-28 (1968).

[48] Albert A, Anderson JA. On the existence of maximum likelihood estimates in logistic models. Biometrika **71**, 1-10 (1984).

[49] Menard S. Coefficients of determination for multiple logistic regression analysis. The American Statistician **51**, 17-24 (2000).

[50] Kruskal WH, Wallis WA. Use of ranks in one-criterion variance analysis. Journal of American Statistical Association **47**, 583-621 (1952).

[51] Efron B. Bootstrap methods: Another look at the jackknife. The Annals of Statistics **7**, 1-26 (1979).

[52] Holm S. A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics **6**, 65-70 (1979).

[53] Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental Health Perspectives **109**, 409-416 (2001).

[54] ISO 1996-1: 2003. Description, measurement and assessment of environmental noise. Part 1: basis quantities and assessment procedures. Switzerland: International Organization for Standardization; 2003.

[55] Rey Gozalo G, Barrigón Morillas JM, Gómez Escobar V. Analyzing nocturnal noise stratification. Science of the Total Environment 479-480, 39-47 (2014).

TABLE CAPTIONS

Table 1.– Spearman's correlation coefficient. (**) p-value <0.01; (***) p-value < 0.001.

Table 2.– Measure of the goodness of fit (χ^2) and the relationship (R-square) between the subjective variables (7 items) and the acoustic magnitudes (L_{eq}, L_{Aeq}, loudness and sharpness) using maximum likelihood and least squares methods, respectively.

Table 3.– Homogeneous groups resulting from the multiple comparisons of the mean values of the different items through the Kruskal-Wallis test with the Holm correction and bootstrapping technique. (a) 4-items scale; (b) 3-items scale.

Table 4.– Measure of the goodness of fit (χ^2) and the relationship (R-square) between the subjective variables and the acoustic magnitudes (L_{eq}, L_{Aeq}, loudness and sharpness) using maximum likelihood and least squares methods, respectively. (a) 4-items scale; (b) 3-items scale.

Table 5.– Kendall correlation coefficient (R) for the descriptive statistics of the items answered for a given noise level. (*) p-value < 0.05; (**) p-value < 0.01; (***) p-value < 0.001.

Acoustics index	L_{eq}	L_{Aeq}	Loudness
L_{Aeq}	0.846 (***)		
Loudness	0.775 (***)	0.838 (***)	
Sharpness	0.649 (***)	0.565 (**)	0.689 (***)

Table 1

Noise Index	**Item**	**Maximum Likelihood Method**				**Least Square Method**		
		Maximum derivative (β/4)	**X in maximum derivative ln(k)/β**	χ^2	**p-value**	**R-square**	**p-value**	**Residual variance**
$\mathbf{L_{eq}}$	*vu*	0.040	105.09	72.48	< 0.001 (***)	0.52	0.008 (**)	0.43
	qu	0.019	108.75	36.33	< 0.001 (***)	0.04	0.398	1.14
	su	0.017	107.87	34.61	< 0.001 (***)	0.09	0.164	0.78
	n	-0.008	62.06	17.71	< 0.001 (***)	0.11	0.075	1.37
	sp	-0.016	56.53	44.75	< 0.001 (***)	0.23	0.030 (*)	0.82
	qp	-0.008	11.12	7.29	0.007 (**)	0.26	0.064	0.99
	vp	-0.011	8.12	6.66	0.010 (**)	0.03	0.656	1.17
$\mathbf{L_{Aeq}}$	*vu*	0.033	101.11	58.61	< 0.001 (***)	0.42	0.023 (*)	0.52
	qu	0.013	110.48	21.71	< 0.001 (***)	0.04	0.434	1.14
	su	0.011	113.31	16.50	< 0.001 (***)	0.04	0.385	0.83
	n	-0.008	52.40	14.51	< 0.001 (***)	0.10	0.088	1.39
	sp	-0.014	45.58	32.40	< 0.001 (***)	0.25	0.020 (*)	0.79
	qp	-0.006	-25.11	3.28	0.070	0.19	0.120	1.08
	vp	-0.009	-13.82	3.86	0.049 (*)	0.05	0.5819	1.15
Loudness	*vu*	0.006	173.00	43.64	< 0.001 (***)	0.33	0.049 (*)	0.60
	qu	0.002	320.26	4.00	0.045 (*)	0.09	0.214	1.08
	su	0.001	316.77	3.49	0.062	$4.07\cdot10^{-7}$	0.998	0.86
	n	-0.002	-71.94	4.75	0.029 (*)	0.02	0.452	1.51
	sp	-0.007	-23.85	24.60	< 0.001 (***)	0.11	0.144	0.95
	qp	-0.005	-92.53	7.60	0.006 (**)	0.21	0.097	1.05
	vp	-0.013	-30.44	15.53	< 0.001 (***)	$3.76\cdot10^{-3}$	0.876	1.20
Sharpness	*vu*	0.206	6.78	49.69	< 0.001 (***)	0.37	0.037 (*)	0.57
	qu	0.061	10.38	5.37	0.020 (*)	0.08	0.262	1.10
	su	0.047	11.44	3.40	0.065	$4.54\cdot10^{-3}$	0.760	0.85
	n	-0.090	1.07	12.49	< 0.001 (***)	0.03	0.377	1.50
	sp	-0.128	-0.15	12.60	< 0.001 (***)	0.06	0.301	1.00
	qp	-0.180	-0.39	11.36	< 0.001 (***)	0.16	0.159	1.12
	vp	-0.125	-3.59	2.87	0.090	0.02	0.739	1.18

Table 2

(a)

Method	Acoustic index	Item			
		1	2	3	4
Kruskal-Wallis	L_{eq}	a	b	c	d
	L_{Aeq}	a	b	c	c
	Loudness	a	b	c	d
	Sharpness	a	b	c	c
Bootstrap	L_{eq}	a	b	c	d
	L_{Aeq}	a	b	c	d
	Loudness	a	b	c	c
	Sharpness	a	b	c	c

(b)

Method	Acoustic index	Item		
		1	2	3
Kruskal-Wallis & bootsrap	L_{eq}	a	b	c
	L_{Aeq}	a	b	c
	Loudness	a	b	c
	Sharpness	a	b	c

Table 3

(a)

Noise Index	Item	Maximum Likelihood Method				Least Square Method		
		Maximum derivative (β/4)	**X in maximum derivative ln(k)/β**	χ^2	**p-value**	**R-square**	**p-value**	**Residual variance**
L_{eq}	*vu*	0.040	105.09	72.48	< 0.001 (***)	0.52	0.008 (**)	0.43
	mu	0.025	92.16	91.57	< 0.001 (***)	0.10	0.138	2.06
	n	-0.008	62.06	17.71	< 0.001 (***)	0.11	0.075	1.37
	p	-0.019	70.44	74.53	< 0.001 (***)	0.11	0.131	5.97
L_{Aeq}	*vu*	0.033	101.11	58.61	< 0.001 (***)	0.42	0.023 (*)	0.52
	mu	0.015	88.80	47.63	< 0.001 (***)	0.05	0.310	2.18
	n	-0.008	52.40	14.51	< 0.001 (***)	0.10	0.088	1.39
	p	-0.014	58.93	45.14	< 0.001 (***)	0.08	0.180	6.12
Loudness	*vu*	0.006	173.00	43.64	< 0.001 (***)	0.33	0.049 (*)	0.60
	mu	0.002	132.31	9.80	0.002 (**)	$1.80 \cdot 10^{-4}$	0.952	2.30
	n	-0.002	-71.94	4.75	0.029 (*)	0.02	0.452	1.51
	p	-0.008	7.95	51.24	< 0.001 (***)	0.07	0.207	6.18
Sharpness	*vu*	0.206	6.78	49.69	< 0.001 (***)	0.37	0.037 (*)	0.57
	mu	0.073	5.68	11.27	< 0.001 (***)	0.01	0.682	2.28
	n	-0.090	1.07	12.49	< 0.001 (***)	0.03	0.377	1.50
	p	-0.178	1.69	32.51	< 0.001 (***)	0.01	0.617	6.60

(b)

Noise Index	Item	Maximum Likelihood Method				Least Square Method		
		Maximum derivative (β/4)	**X in maximum derivative ln(k)/β**	χ^2	**p-value**	**R-square**	**p-value**	**Residual variance**
L_{eq}	*vu*	0.040	105.09	72.48	< 0.001 (***)	0.52	0.008 (**)	0.43
	mu	0.025	92.16	91.57	< 0.001 (***)	0.10	0.138	2.06
	nu	-0.038	87.40	174.07	< 0.001 (***)	0.44	< 0.001 (***)	8.07
L_{Aeq}	*vu*	0.033	101.11	58.61	< 0.001 (***)	0.42	0.023 (*)	0.52
	mu	0.015	88.80	47.63	< 0.001 (***)	0.05	0.310	2.18
	nu	-0.024	81.29	101.38	< 0.001 (***)	0.30	0.001 (**)	10.05
Loudness	*vu*	0.006	173.00	43.64	< 0.001 (***)	0.33	0.049 (*)	0.60
	mu	0.002	132.31	9.80	0.002 (**)	$1.80 \cdot 10^{-4}$	0.952	2.30
	nu	-0.006	59.15	52.81	< 0.001 (***)	0.15	< 0.001 (***)	12.21
Sharpness	*vu*	0.206	6.78	49.69	< 0.001 (***)	0.37	0.037 (*)	0.57
	mu	0.073	5.68	11.27	< 0.001 (***)	0.01	0.682	2.28
	nu	-0.196	3.64	60.47	< 0.001 (***)	0.13	0.046 (*)	12.55

Table 4

	L_{eq}		**L_{Aeq}**		**Loudness**		**Sharpness**	
	R	p-value	R	p-value	R	p-value	R	p-value
Mean	-0.52	<0.001 (***)	-0.35	0.006 (**)	-0.39	0.002 (**)	-0.40	0.002 (**)
Maximum	-0.37	0.008 (**)	-0.20	0.143	-0.27	0.050	-0.26	0.062
Minimum	-0.63	<0.001 (***)	-0.41	0.003 (**)	-0.46	0.001 (**)	-0.48	0.001 (**)

Table 5

FIGURE CAPTIONS

Figure 1.– Age distribution of the respondents.

Figure 2.– Values of acoustic variables for the 31 recordings in the right and left channels: (a) L_{eq}; (b) L_{Aeq}; (c) loudness; (d) sharpness.

Figure 3.– Logistic and linear relationship between variables (a) L_{eq} and "*vu*" and (b) loudness and "*vu*".

Figure 4.– (Pseudo) median and the 95 percent confidence interval of the acoustic indices of the recordings for the 7-items Likert scale.

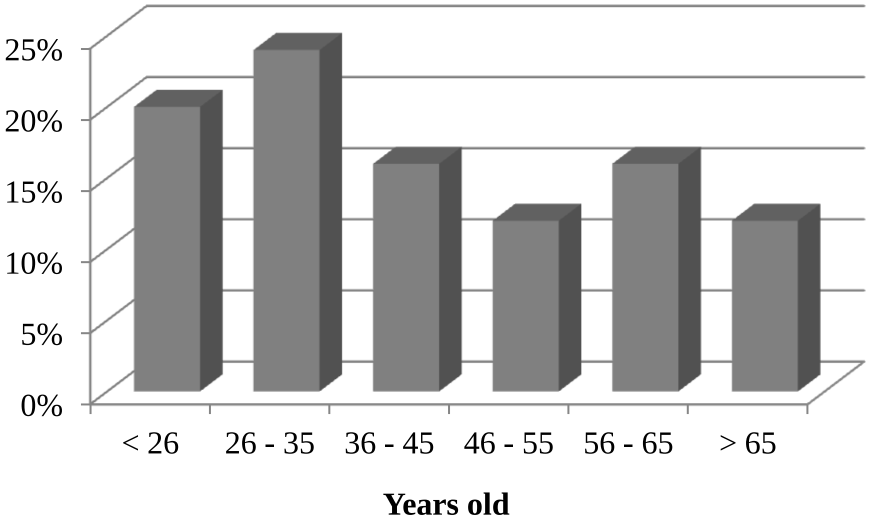

Figure 1

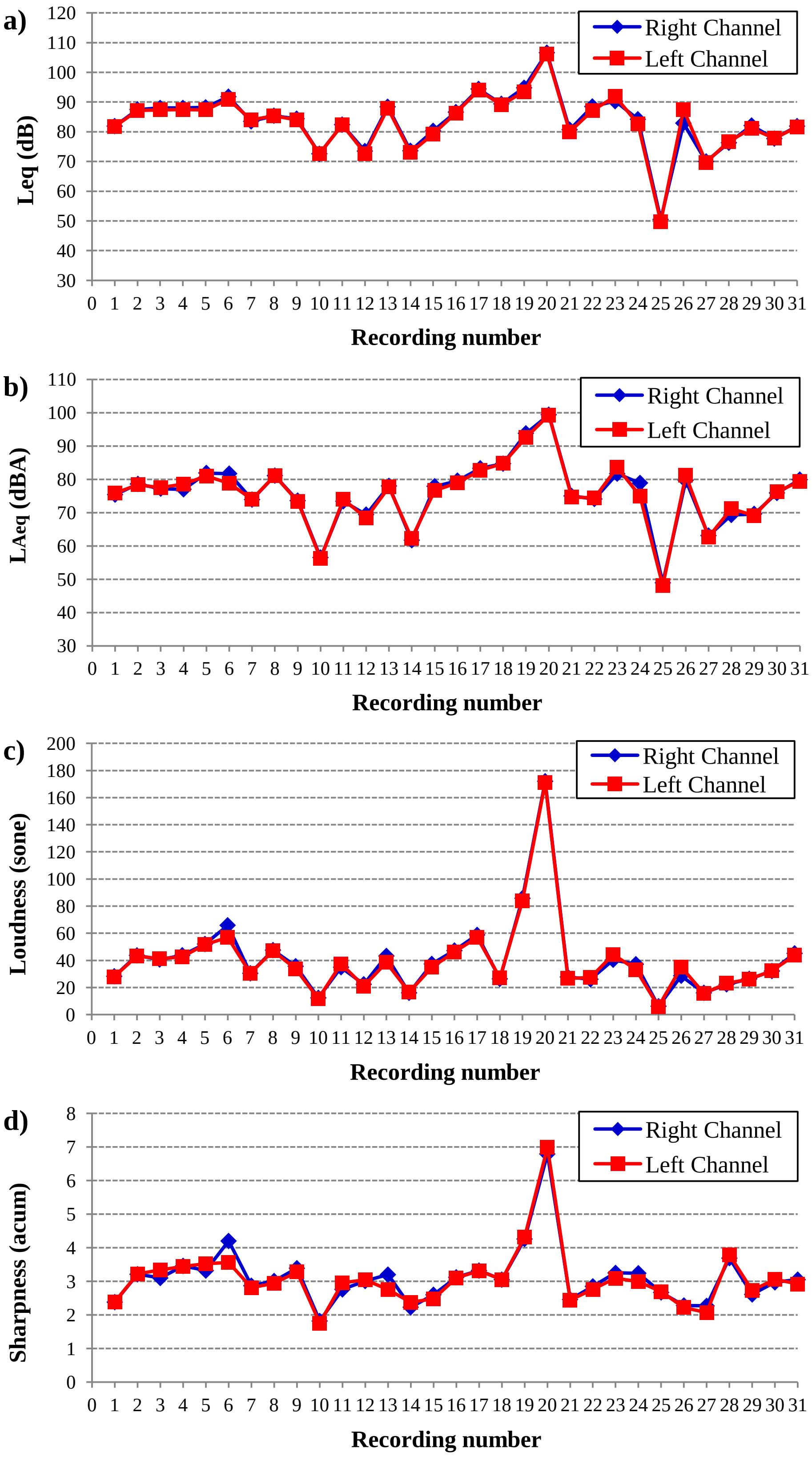
a)
Leq (dB)
120
110
100
90
80
70
60
50
40
30
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Recording number
Right Channel
Left Channel
b)
LAeq (dBA)
110
100
90
80
70
60
50
40
30
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Recording number
Right Channel
Left Channel
c)
Loudness (sone)
200
180
160
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Recording number
Right Channel
Left Channel
d)
Sharpness (acum)
8
7
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Recording number
Right Channel
Left Channel

Figure 2

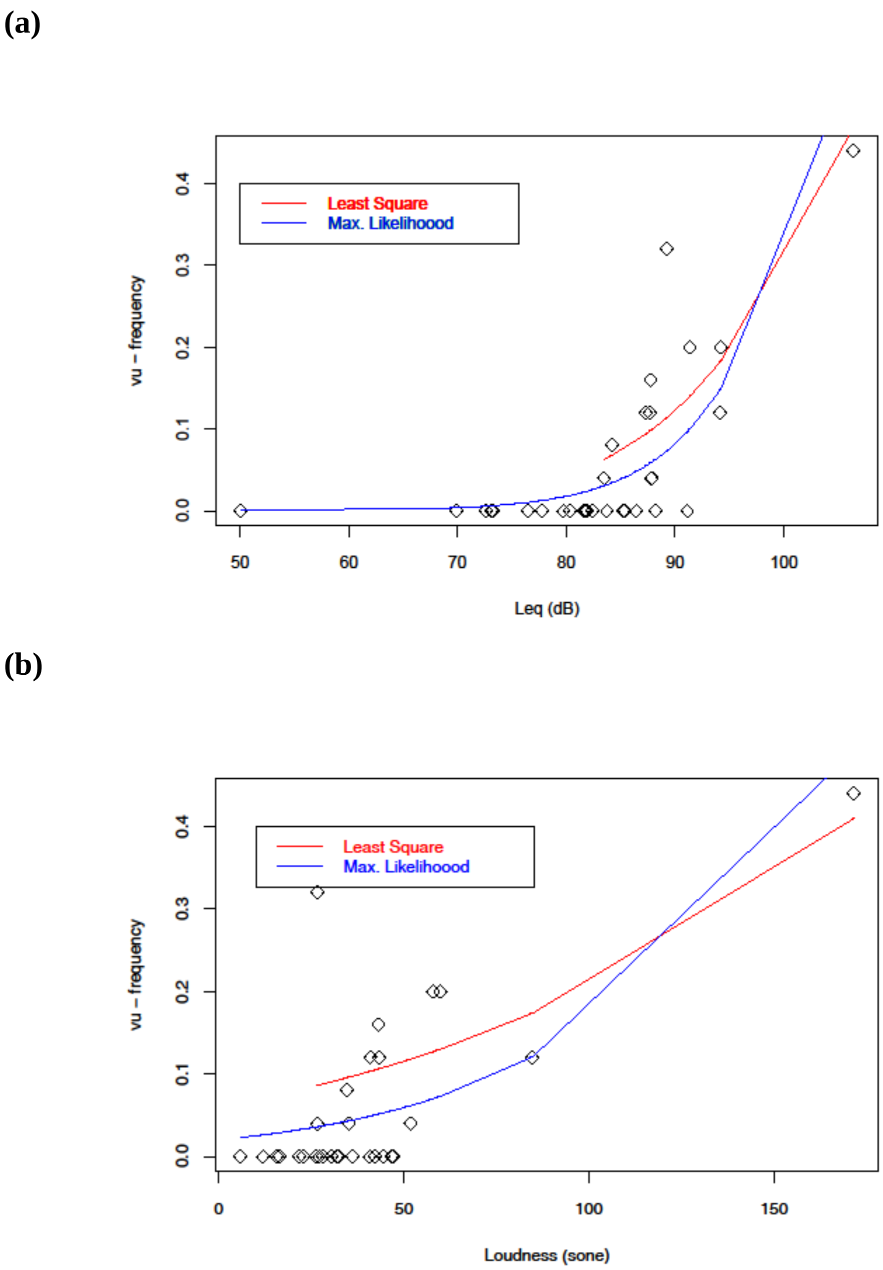
(a)
Least Square
Max. Likelihoood
vu – frequency
0.0
0.1
0.2
0.3
0.4
50
60
70
80
90
100
Leq (dB)
(b)
Least Square
Max. Likelihoood
vu – frequency
0.0
0.1
0.2
0.3
0.4
0
50
100
150
Loudness (sone)

Figure 3

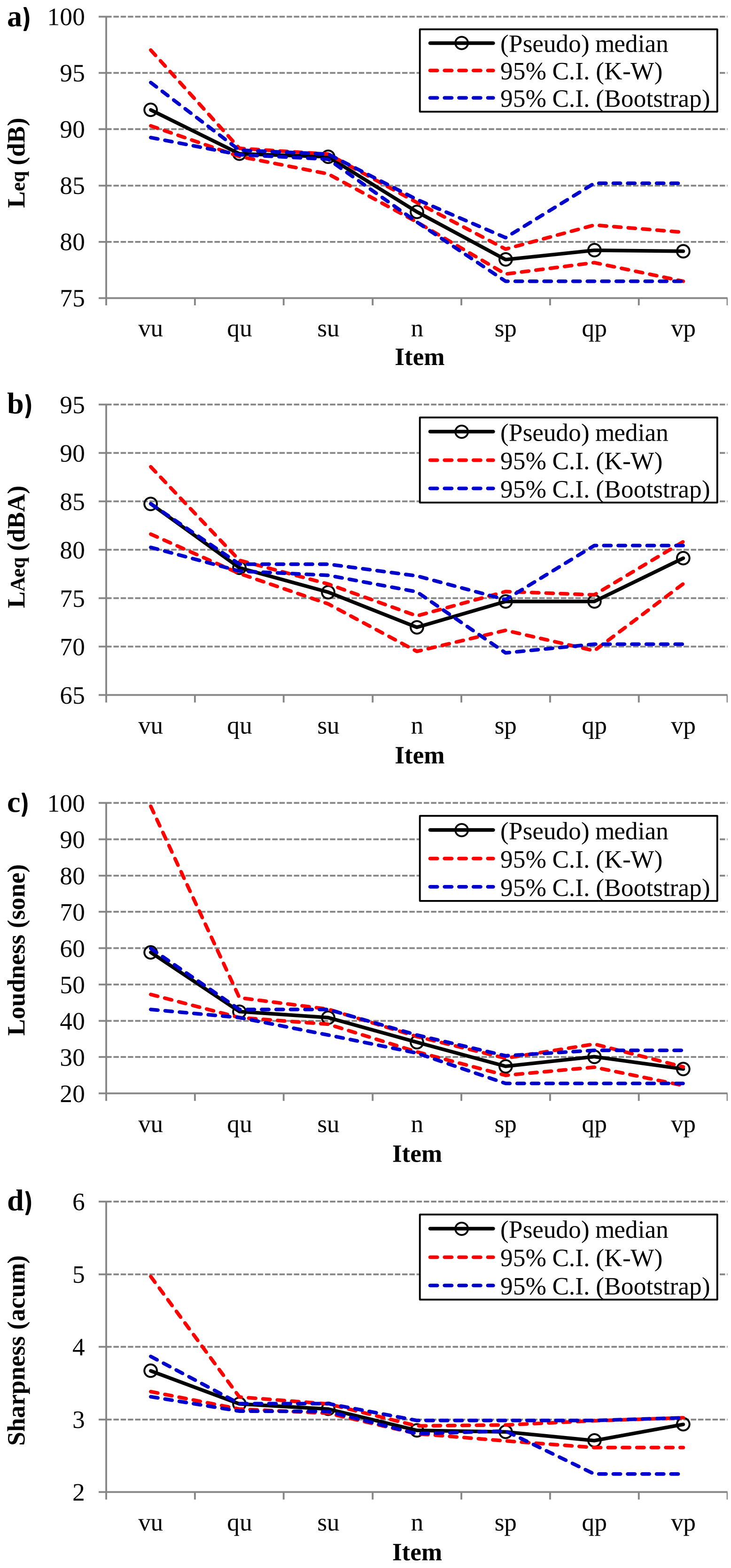
a)
100
95
90
85
80
75
Leq (dB)
(Pseudo) median
95% C.I. (K-W)
95% C.I. (Bootstrap)
vu
qu
su
n
sp
qp
vp
Item
b)
95
90
85
80
75
70
65
LAeq (dBA)
(Pseudo) median
95% C.I. (K-W)
95% C.I. (Bootstrap)
vu
qu
su
n
sp
qp
vp
Item
c)
100
90
80
70
60
50
40
30
20
Loudness (sone)
(Pseudo) median
95% C.I. (K-W)
95% C.I. (Bootstrap)
vu
qu
su
n
sp
qp
vp
Item
d)
6
5
4
3
2
Sharpness (acum)
(Pseudo) median
95% C.I. (K-W)
95% C.I. (Bootstrap)
vu
qu
su
n
sp
qp
vp
Item

Figure 4