Spectrum Contrast and Noise Annoyance

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Abstract: The tested hypothesis states that the hearing system is able to detect changes in the relative amplitude of the partials. The present study investigates if the hearing system is able to scan the frequency spectrum more thoroughly and pick up subtle information contained in it. It was assumed that this activity of the hearing system needs more precise description and results of its functioning can be traced in experimental data about perceived annoyance of noise. The experimental results show the best correlation between the reported annoyance and calculated values for the spectrum contrast defined as a sum of two components: the average absolute value of the second derivative calculated on a weighted and unweighted loudness pattern. The specific loudness was weighted by the function introduced by Aures in his sharpness calculation.

LOUDNESS PATTERN AND SHARPNESS IN DIFFERENT MODELS OF NOISE ANNOYANCE

Based on the loudness pattern [i.e., specific loudness as a function of critical-band rate expressed in channel numbers (according to DIN 45652)] different values of loudness can be calculated. The most often used is total loudness (ZwL), (applied to the stationary noises) and the loudness measures related to the statistical loudness distribution (applied when loudness varies strongly as a function of time). N10 is a statistical loudness measure where the number 10 refers to the percentage of time during which a given loudness is exceeded. The differences in total loudness, for example, explain the existence of so-called “railway bonus” (2), while N10 index occurs in Zwicker's formula for unbiased annoyance (UBA), as a component of the annoyance (6). According to the environmental approach to noise annoyance (5) one of the annoyance components is the annoying loudness. It is defined as the difference between the loudness of the noise and the background sound that contributes to subject's assessment of noise annoyance. Annoying loudness represents the relative measure of noise loudness. In the case of single noise presented to the subject without background noise, the average absolute value of the derivative can be used as such a relative measure of annoying loudness.

Traditional accounts consider only a single parameter, loudness, as the determinant of annoyance. This approach encounters problems with reports that certain types of noise are considered annoying despite their low loudness values. In literature the term intrusiveness is frequently used as a surrogate for annoyance produced by low-level noise exposure (3). However, in the environmental approach to noise annoyance (5) intrusiveness is defined as the attribute of noise which depends primarily on the quality of noise and is independent of its sound pressure level. Intrusiveness (IN) depends primarily on sharpness. It represents the difference between the sharpness of the noise and the sharpness of the background sound. In the formula for sharpness [according to Aures’s model (1)] specific loudness for certain critical band is multiplied by the weighting function g’(z). This function is defined as follows:

\[ g'(z) = 0.0165 \exp\left(\frac{0.171z}{\text{Bark}}\right) \]  

(1)

When a single noise is regarded the average absolute value of the derivative calculated on the weighted loudness pattern (according to the weighting function in Eq. 1), this may represent a measure of the intrusiveness of noise.

THE FIRST AND SECOND DERIVATIVE AS A MEASURE OF SPECTRUM CONTRAST

The average absolute values of the derivative, calculated both on the weighted and unweighted loudness pattern are regarded as the measure of spectrum contrast. The values calculated on the weighted loudness pattern should relate to the intrusiveness of sound (relative sharpness) while the values calculated on unweighted loudness pattern should correspond to the annoying loudness of the noise (relative loudness). It seems that both the first and second derivative may influence the perception of noise. The average absolute value of the first derivative represents the average rate of change in specific loudness calculated with the critical band rate as a variable. The higher the value the bigger is the average change in loudness (or weighted loudness) per one critical band rate occurring in the loudness pattern. This value is responsible

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for the magnitude of fluctuation of loudness or weighted loudness in the loudness pattern (in musical acoustics, this phenomenon is called 'jaggedness' of the spectrum (4)). The average absolute value of the second derivative refers to the average value of steepness of these changes in loudness per one critical band rate. The higher the value the bigger difference in steepness of the loudness changes (or weighted loudness changes) per one critical band occurring in the loudness pattern. In this study, two average absolute values of the first derivative and two average absolute values of the second derivative were calculated both for weighted and unweighted loudness patterns from the two similar equations:

\[ |b'(z)| = \frac{1}{n} \sum \left| N_{w}'(z_1) + \ldots + N_{w}'(z_n) \right| \]

and

\[ |b''(z)| = \frac{1}{n} \sum \left| N_{w}''(z_1) + \ldots + N_{w}''(z_n) \right| \]

where \( N_{w}'(z) \) and \( N_{w}''(z) \) were defined as the first and a second derivative calculated on loudness pattern with a critical-band rate expressed in channel numbers as a variable. In calculations for weighted loudness pattern in Equation (2) the values \( \sigma_{w}'(z) \), \( \sigma_{w}''(z) \), \( N_{w}'(z) \), \( N_{w}''(z) \), and \( N_{w}(z) \) replaced the unweighted values, without the symbol 'w'.

**COMPARISON OF THE SUBJECTIVE DATA WITH DIFFERENT NOISE ANNOYANCE INDICES**

The results of 2-dimensional MDPREF solution for 14 noises and 8 subjects are shown in Figure 1. The noises are presented as points and marked by letters from A to M, each subject should be viewed as a vector, a line which is drawn from the origin of the plot to each subject point marked from s1 to s8. In addition, the UBA, ZwL, and the four average absolute values of the first and second derivative calculated on weighted 1DW, 2DW and unweighted 1D, 2D loudness pattern are presented in this figure as 'potential subjects'. Finally, two measures of the spectrum contrast SC1 (based on the average absolute value of the first derivative) and SC2 (based on the average absolute value of the second derivative) were constructed and also presented in the Figure 1. These measures represent the summation of the annoying loudness component (1D and 2D) and intrusiveness (1DW and 2DW) and are: SC1=1D+1DW, and SC2=2D+2DW.

![Figure 1. Results of annoyance assessment](image)

The experimental results show that the best fit between the reported annoyance and calculated values was obtained for the SC2 value which is the measure of spectrum contrast calculated as a sum of the 2D and 2DW values. 2D represents annoying loudness and 2DW represents the intrusiveness, two components of the noise annoyance.

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**REFERENCES**


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