inter•noise 96
25th Anniversary Congress – Liverpool
INCE: 63.1

SCALING ANNOYANCE OF STREET TRAFFIC NOISE AS A FUNCTION OF LOUDNESS AND SPEECH INTELLIGIBILITY

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1. INTRODUCTION

The psychoacoustic annoyance of sounds [1] can be derived from an aurally adequate sound analysis. This concept does, however, not consider the special situation in which a useful sound and a disturbing sound affect a person as happens with distortions of oral communication by noise.

Therefore, this study compares the psychoacoustic annoyance of a sound with the annoyance caused by the same sound in a situation in which there is also speech. As distortion, traffic noise is used which is one of the most common noise sources in our surrounding. The influence of a reduction of the speech intelligibility on the evaluation of disturbing noise is investigated.

2. MEASUREMENTS

As disturbing noise sources, two differently loud and dense, 9 minutes lasting sections of traffic noise were used. As speech material, words out of a rhyme test [4] are used, whose test lists consist of 100 different one-syllable words with a semantic meaning.

The level of the speech was determined as follows: all words were recorded A-weighted with a level recorder (recording speed 400 mm/s) and the peak level within each word was measured. The average value of these 100 maximum root mean square- (RMS-) values is regarded as the speech level.

In order to achieve different situations with respect to speech intelligibility; the speech level was varied during the hearing tests whereas the level of the respective traffic noise was not altered.

Table 1 shows the A-weighted speech levels used for the experiments. The different speech levels between soft and loud condition was to yield a wide range of intelligibility in both situations.

traffic noise levels	speech levels / dB(A)
soft : 64.5 dB(A)	64.5, 67.5, 72.5 and 77.5
loud: 74.0 dB(A)	58.5, 64.5, 67.5 and 78.5

Table 1. Speech levels for the different experiments.

10 subjects aged between 25 and 47 took part in the experiment.The sounds were offered to both ears (diotically) of eight test persons with normal hearing capabilities via free-fieldequalized electrodynamical headphones [5].

In the course of a session, the subjects had to write down the words which they had understood or could abstain if not so (open test). After each session, the test persons had to evaluate the overall annoyance just experienced. In different sessions, the psychoacoustic annoyance and the experienced loudness of the traffic noise without a simultaneously offered speech sample was assessed. In all tests, the line length method [3] was applied. In this method the test persons must mark their evaluation on the length of a line.

loudness of the traffic noise N_{5ST}	loudness of speech N_{maxN}
soft : 29.9 sone	14.2, 17.1, 25.3, 35.5 sone
loud: 48.2 sone	19.7, 14.2, 17.1, 37.8 sone

Table 2. Results of a loudness analysis of speech and noise.

The physical evaluation of the loudness of the disturbing traffic noises was carried out with a modem analyzing instrument including also features for loudness calculation for temporally variable sounds [5, 6] according to Zwickers method out of third-octave bands [2]. From the temporally variable loudness values of the disturbing noises a percentile statistics analysis was performed. A percentile value is the value which is exceeded in a certain amount of the measurement time. The loudness of speech (N_{maxN}) was determined for the speech levels as average value of the maximum loudness values of all words of a test list. Table 2 shows some results of the loudness analysis.

3. RESULTS

The percentile values gained from the loudness analysis of the traffic noise are shown in Fig. 1 together with the loudness-variations in time. One sound contains many quiet parts and is therefore called "quiet" traffic noise. It was recorded in a quiet residential area. The "louder" traffic noise was recorded at a highly frequented circle road. It is much more homogenous and contains considerably less loudness variations.

If the ratio N_5/N_{50} is defined as a measure of the variability of the sound, it amounts to 2.8 with "quiet" sound and only to 1.5 with a denser sound.

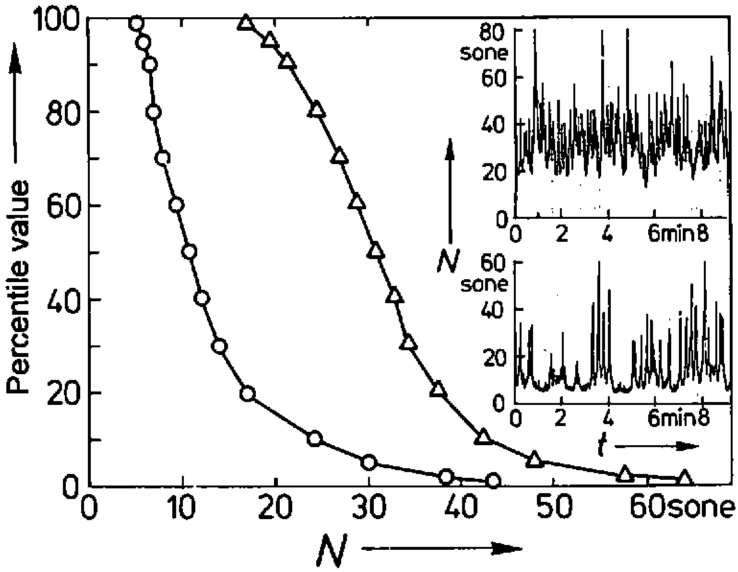

Fig. 1. Percentile statistics and loudness-variation in time for "loud" (triangles, at the top) and "quiet" (circles, at the bottom) traffic noise.

The assessment of the annoyance for the different presentations with and without language is shown in Fig. 2. In Fig. 2a the psychoacoustic annoyance is compared with the perceived loudness. The loudness of a denser traffic noise is given with an average of 83 % of the line length whereas the quieter noise gets only 50 %. This corresponds with a loudness ratio of 1.66. This ratio can be well reconstructed by the quotient of the physically measured percentile values N_5 (compare Fig. 1.). This results confirms that for the assessment of the loudness of a transient sounds over a longer time period, the loudest events are determining the evaluation of noise immissions as described by the literature [3, 7].

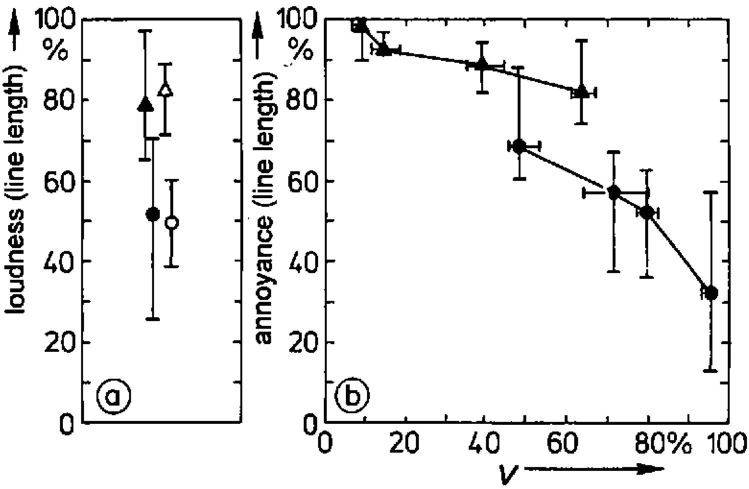

Fig. 2. Medians and interquartile ranges of the a) psychoacoustic annoyance (filled symbols) and of the loudness (open symbols), b) annoyance as function of the achieved speech intelligibility v (medians and interquartile ranges), for "loud" (triangles, at the top) and "quiet" (circles, at the bottom) traffic noise.

The assessment of psychoacoustic annoyance differs only slightly from the assessment of loudness but has stronger fluctuations. If the traffic noise is presented together with speech with different level distances of speech and noise (Fig. 2b), the speech intelligibility changes.

With a quiet traffic noise, an average between 48,5 % and 95,5 % of the words are correctly understood. Worse cases of intelligibility were not investigated as the examples with quiet traffic noise contained many very quiet parts and it therefore did not make sense to decrease the speech level further.

With the louder traffic noise, between 9 % and 64 % of the words were correctly taken down. It was not possible to achieve a better speech intelligibility because the extremely loud speech which would have been necessary cannot be accepted as natural.

With a decreasing intelligibility *v*, for both noise examples the annoyance increases. With the "quieter" traffic noise, the influence of the speech intelligibility is more pronounced. If only 48 % of the words are correctly understood, the annoyance increases to 68 % of the line length. For a very good speech intelligibility, the annoyance decreases as can be expected; this decrease is, however, connected with strong fluctuations.

With the "loud", denser traffic noise, the decrease of the annoyance shows a less declining curve. The annoyance remains, however, between 25 % and 30 % above the one of the quiet traffic noise. If the annoyance in view of a worse speech intelligibility is compared with the unbiased annoyance, the average difference amounts to approx. 18 %.

If the annoyance values of Fig. 2b are entered logarithmically above the quotient of the speech loudness (N_{maxN}) with the percentile loudness N_{5ST} (see Tab. 1) of the traffic sounds, Fig. 3 is developed.

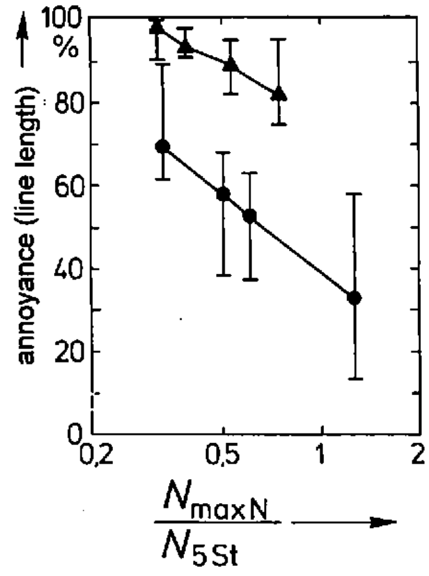

Fig. 3. Medians and interquartile ranges of the annoyance for "loud" (triangles, at the top) and "quiet" (circles, at the bottom) traffic noise as function of the speech-noise-loudness-ratio (N_{maxN}/N_{5ST}).

It is obvious that with the "quiet" traffic noise, the annoyance rises linear by 18.5 % and for the "loud" traffic noise by 13 % per halving of the speed to noise loudness ratios. The ratio of the signal loudness and the loudness of the noise therefore represents a good measure in order to describe an increase of the annoyance with a decrease of the speech intelligibility.

For the absolute value of the annoyance, the temporal structure of the disturbing noise is of essential importance.

4. CONCLUSIONS

Without the aspect of speech recognition the loudness of the noise is again the prominent criterion of the psychoacoustic annoyance [1]. The subjective assessment is governed by the loudest events of the noise and can therefore be simulated by the evaluation of the percentile loudness N_5 measured with a loudness meter.

If street traffic noise interferes with speech it can be generally stated that with a decrease of speech intelligibility an increase of the annoyance is perceived. This effect is most conspicuous if the disturbing noise is a very dense, variable sound.

As it is known that for both traffic noises with very bad speech intelligibility the annoyance lies by about 18 % above the one without speech presentation, the annoyance for any signal to noise ratios can be calculated from the loudness ratios of speech and noise.

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