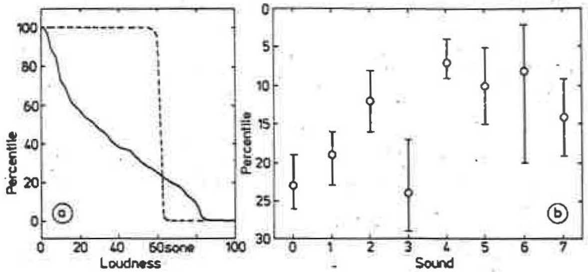

Fig. 3: Percentile loudness. (a) Distributions of truck noise (solid) and of continuous broadband noise (dashed). (b) Percentiles of physically measured loudness for same perceived loudness of test sound and continuous broadband noise.

are displayed in Fig. 3b, where the percentile numbers are plotted on a downward ordinate scale, in order to illustrate the 25%-values by the lower bar and the 75%-values by the upper bar connected with the circles, which stand for the 50%-values. For the sounds 0 through 7, the intersections of the distributions vary between percentiles of 7 and 24. Again, the sounds which produce large loudness near their end show small percentage numbers, i.e. the equivalent time invariant loudness lies near the maximum loudness of the test sound. On the other hand, for sounds 0, 1 and 3, which show more or less symmetric triangular shapes of their loudness-time-functions (see Fig. 1), the percentiles displayed in Fig. 3b lie around 20. This means that the loudness of passby-sounds of vehicles can be characterized by the percentile loudness around N_{20}, i.e. the loudness indicated by the meter which is exceeded in 20% of the measurement time.

REFERENCES

Fastl, H., Namba, S., and Kuwano, S.: Crosscultural study of loudness evaluation of road traffic noise and impulsive noise: Actual sounds and simulations. In: Proc. inter-noise'86, Vol. II, 825-830 (1986).
ISO 362: Acoustics-Measurement of noise emitted by accelerating road vehicles, Engineering method.
Namba, S., Kuwano, S. and Fastl, H.: On the loudness of impulsive noise and road traffic noise - a comparison between Japanese and German subjects. In: Transactions of the Commitee on Noise, The Acoust. Soc. of Japan N85-01-02 (1985).
Zwicker, E. und Feldtkeller, R.: Das Ohr als Nachrichtenempfänger. 2. erw. Auflage, Hirzel-Verlag, Stuttgart (1967).
Zwicker, E., Deuter, K. and Peisl, W.: Loudness meters based on ISO 532 B with large dynamic range. In: Proc. inter-noise'85, Vol. II, 1119-1122 (1985).

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HOW LOUD IS A PASSING VEHICLE ?

Hugo Fastl

Institute of Electroacoustics, Technical University München, Arcisstrasse 21, D-8000 München 2, F.R.Germany

INTRODUCTION

In ISO 362, the maximum A-weighted level, measured with the time constant "fast", is taken as an indication of the noise produced by an accelerating vehicle. Although the A-weighted level systematically underestimates the loudness of broadband sounds, intuitively the concept of maximum value may be regarded as an appropriate procedure. To check the validity of this concept, psychoacoustic loudness comparisons between the noise of a passing truck vs steady state broadband noise of same duration were performed. In addition, the passby-noise was simulated by broadband noise with temporal envelopes of different triangular shapes. These noises also were compared in loudness to steady state broadband noise of same duration. The results for same subjective loudness of triangularly shaped noises vs steady state noise are discussed in terms of level differences, measured by a sound level meter in accordance with IEC 651. Moreover, loudness differences, loudness ratios and percentiles of loudness are measured by a loudness meter (Zwicker et al. 1985) in accordance with ISO 532 B.

EXPERIMENTS AND RESULTS

Ten normal hearing subjects with an age between 25 and 40 years participated in the experiments, which were performed in a sound-proof booth. Sounds were presented diotically through electrodynamic earphones (Beyer DT 48) with free-field equalizer (Zwicker and Feldtkeller, 1967, p. 40). All sounds had the same duration of 8.8 s, and the same maximal A-weighted level (timeconstant "fast") of 87.8 dB(A). In Fig. 1, for all testsounds both the A-weighted level ("fast") and the loudness are given as a function of time. Sound 0, the original sound, stems from a truck, which passes under acceleration. Sound 1 shows nearly the same temporal envelope, which, however, is filled with uniform exciting noise (Zwicker and Feldtkeller 1967, p. 107), a

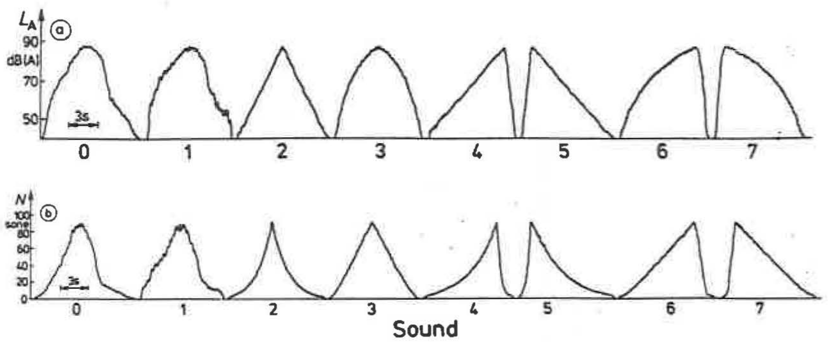

Fig. 1: Level- or loudness time functions of the test sounds. (a) A-weighted level "fast", IEC 651, (b) loudness ISO 532 B.

broadband noise much like pink noise. This specific broadband noise was used throughout for sounds 1 to 7. While in previous experiments (Namba et al. 1985, Fastl et al. 1986), simulated sounds were generated in an apparatus called PSCS Mark II available at Osaka University, this time the envelope of the truck noise was obtained by rectifying and low pass filtering and was multiplied with broadband noise. Sound 2 has symmetrical triangular shape in level with 4.4 s rise and 4.4 s decay. Sound 3 shows symmetrical triangular envelope in loudness with 4.4 s rise and decay. Sound 4 exhibits 7.8 s rise and 1 s decay both linear in level, whereas sound 5 has 1 s rise and 7.8 s decay. Sound 6 has an envelope with 7.8 s rise and 1 s decay whereas sound 7 shows 1 s rise and 7.8 s decay, all linear in loudness. The envelopes of sounds 2 through 7 were calculated in a computer, D/A converted and multiplied with the broadband noise. Each of the test sounds 0 through 7 was paired with continuous broadband noise of 8.8 s duration. The level of this comparison sound was varied in 2 dB-steps between 76 and 92 dB(A). After the presentation of one pair of testsound and comparison sound, the subject had to answer with "yes" or "no" to the question: "Is the second sound of the pair louder than the first sound?" Each sound pair was compared in loudness three times by each subject. From the resulting 30 datapoints at each level of the comparison sound psychometric functions of the "yes" responses were calculated. Their 25%, 50% and 75%-values are given in Fig. 2. In Fig. 2a, the A-weighted SPL of the comparison sound is plotted for the different test sounds 0 through 7. The 50%-values (circles) show A-weighted levels between 83.6 and 86.5 dB(A). This means that for same equivalent time invariant loudness, the level of continuous broadband noise is by about 2 to 4 dB lower than the maximum level of broadband noise with triangular envelope. Fig. 2b shows the results in terms of loudness measured by a loudness meter (Zwicker et al. 1985). Despite the same maximal A-weighted level, the maximum loudness indicated for the truck (sound 0) is some-

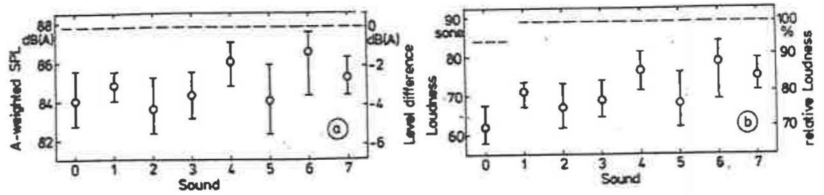

Fig. 2: A-weighted level (a) and loudness (b) of continuous broadband noise (circles), which produces the same equivalent time invariant loudness as the test sounds 0 through 7 (dashed).

what smaller (84 sone) than the maximum loudness (89 sone) indicated for the broadband noises (sounds 1 through 7). This difference is due to the different spectra of original sound and simulations. For same perceived loudness, i.e. equivalent time invariant loudness, the physically indicated loudness of the continuous broadband noise reaches between 75.3% and 88.2% of the maximum loudness indicated for the sounds with triangular envelope. The highest values are found for sounds 4 and 6 which show - because of their asymmetric shape - large loudness values near the end of the stimulus (see Fig. 1). This result indicates that for loudness evaluation of sounds with durations of several seconds, the ear may use a weighting function which "forgets" gradually the loudness heard some seconds before.

The meaning of the results in terms of percentile loudness is explained by Fig. 3. The percentile loudness is that particular value of the loudness indicated by the meter, which is reached or exceeded in x% of the measurement time. In Fig. 3a, the percentiles are shown for the original truck noise (solid) as well as for the continuous broadband noise of equivalent time invariant loudness (dashed). As expected for a continuous sound, the distribution for the comparison sound (dashed) shows a very steep slope, i.e. during all the measurement time, a loudness around 60 sone shows up. For the truck-sound, however, a gradually decreasing distribution of percentile loudness is found (solid), which is typical for sounds with temporal envelopes of triangular shape. The crossing point of both distributions occurs at a percentile of 23. This means that for same perceived loudness of the truck and the continuous broadband noise, the physically measured loudness of the truck, which is exceeded in 23% of the measurement time, is not fully reflected in the perception. In other words, not the maximum of the loudness of the truck indicated by the meter accounts for its equivalent time invariant loudness, but an indicated loudness value which is by about 23% down from the maximum. In the same way as shown in Fig. 3a for the truck-noise and the 50%-value of the psychometric function for the continuous broadband noise, the intersections of the distributions of percentile loudness were determined for all sounds and the 25% and 75% values of the psychometric functions as well. The results