THEORETICAL MODELS FOR RELATING ANNOYANCE TO NOISE LEVEL

Frank G. Krammer

Noise Pollution Control Section
Environment Ontario

ABSTRACT

Theoretical mathematical models are formulated to specify the relationship between human annoyance and levels of noise, based only on well confirmed assumptions. The proposed theories are consistent with descriptive models and appear capable of explaining the underlying mechanism as well as previously apparent discrepant findings.

THE MODELS

From experimentally supported theoretical assumptions discussed previously (Krammer, 1979b) and the assumption that a complex continuous sound is equivalent to the loudness of a reference stimulus (e.g. a 1-kHz tone) if both are equivalent on appropriately weighted sound levels, the following models of human reaction to sound level are derived, converting

(a) Sound level N to loudness L:

$$L = k10^{0.03N} = k\,(1.0715)^{N} \quad (1)$$

where k is an arbitrary scale factor.

(b) Sound level N to individual annoyance A:

$$A = a\,k\,10^{0.03N} + b = a\,k\,(1.0715)^{N} + b \quad (2)$$

where a is the asymptotic annoyance to loudness ratio, A/L, and b is the A-intercept of the curve relating annoyance to loudness. Preliminary experimental findings suggest that a is relatively constant and independent of type or quality of noise, but that b is a correction factor dependent on type and quality of noise (Berglund et al, 1976).

(c) Probability P or expected percentage 100P of individual or community reaction to noise R respectively, given the noise level (N):

$$P\ (R|N) = \int_{-\infty}^{N} \frac{1}{\sigma\sqrt{2\pi}} \exp\left[\frac{-(n-\mu)^2}{2\sigma^2}\right] dn \qquad (3)$$

where R is annoyance at or greater than a predefined criterion, and n is the random variable of the theoretical normal probability density function, with mean u and standard deviation o, which describes the probability density of the specific annoyance reaction at specific noise levels.

Parameters of these functions may be obtained from experimental work. Parameters included below are purposely approximate but may be more precisely specified as confindence in experimental observations increases. With substitution of available parameter estimates, the previous models may be somewhat simplified, e.g. converting:

(a) Sound level N to loudness L :

$$L\ (\text{in sones}) = 0.063\ (10^{0.03N}) \qquad (4)$$

where "0.063" is the scaling factor for the sone scale.

(b) Sound level N to annoyance A :

$$A\ (\text{re sones}) = 0.126\ (10^{0.03N}) + b \qquad (5)$$

where a=2 (from Eqn. B), approximated from the Berglund et al (1976) data, and the sone scale is implied. From this function it is obvious that the lower the noise level, the greater the relative contribution of the constant b, which may potentially be estimated from experimental data.

(c) Probability P or expected percentage 100 P of individual or community reaction R to noise level N :

$$P(R|N) = \int_{-\infty}^{N} 0.0307 \exp\left[\frac{-(n-79)^2}{338}\right] dn \qquad (6)$$

$$= \int_{-\infty}^{N} 0.0307\ (.997046^{(n-79)^2})\ dn$$

assuming R is a "highly annoyed" reaction and N is L_{dn}, both as defined by Schultz (1978a, 1978b).

DISCUSSION

The effect of time-varying properties of noise on human response has not yet been clarified and remains an area of continuing study and discussion (Seshagiri and Krammer, 1976; Hemingway and Krammer, 1977). Major studies examining the problem have arrived at opposite or no linear relationships between noise variability and annoyance. That is, both positive and negative relationships (Robinson, 1971; Bradley, 1977) have been reported. A recent study by Hemingway and Krammer (1977) has observed evidence of both relationships in the same study. A U- or inverted bell-shaped function has been proposed as a tentative working hypothesis (Hemingway and Krammer, 1977; Krammer, 1978) to describe human reaction to variability of noise level over time. Recent analyses (Krammer, 1979c), however, suggest that the form of this function may depend on noise source and time of day. In other words, the present working hypothesis requiring further testing is that both the time history function of noise levels and whether or not the exposed individual is awake or asleep may interactively affect annoyance ratings. Such factors are tentatively judged to be most effectively included in the source dependent term $\underline{b}$ of the annoyance model (Eqn. 2) for reasons that will be discussed in a later report.

CONCLUSIONS

Theoretical mathematical models derived only from basic assumptions appear to become reasonably complete when parameters are estimated from experimental data. In the equations relating annoyance to sound level, only one parameter is notably absent, but open to empirical estimation. In their present form, the discussed models provide plausible explanations of observations which have previously been considered unusual or discrepant, and allow for greater ease of generalization of future data. Potentially, they also provide a framework for the prediction of that portion of human reaction determined by the physical properties of noise.

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