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NOISE EFFECTS: RESEARCH PROSPECTS FOR THE FUTURE.

J.B. LARGE

INSTITUTE OF SOUND & VIBRATION RESEARCH, UNIVERSITY OF SOUTHAMPTON.

Over the past two decades a great number of papers have been written describing the effects of noise on people. Numerous studies have examined these effects using laboratory and field techniques; extensive reviews of the work are published (Refs.1,2,3). Noise effects fall into three categories

(i) interference with normal human activities;
(ii) health effects;
(iii) annoyance.

Of course, they do not fall easily into these compartments but such a division provides a useful framework to examine the state of our knowledge.

(i) Interference with normal human activities

A number of important effects are included in this category. Perhaps the most important is interference in speech communication. Speech characteristics are fairly well defined under normal environmental conditions the effects of background noise can be determined (see Fig.1. Ref.5). But there are many communication situations, some requiring a high degree of comprehension, in this area where more research is needed. For example, there is not yet an agreed method of assessing the effect of background noise in a classroom situation, a particularly serious problem for schools situated near a busy airport or motorway.

Interference with work has been another broad area of study. The general conclusion here appears to be that noise affects the quality rather than the quantity of the work output. This is true up to relatively high levels of background noise Leq90 dB(A) (Ref.3). There are so many varieties of work situations that such a generalisation is perhaps meaningless, and each situation needs to be individually assessed. The same comments apply to the effects of noise on rest and relaxation which appears to be little affected if the background level is steady at an Leq35 dB(A) or lower.

Sleep interference also falls into this category and category (ii). As in the case of work interference, sleep interference does not appear to present an environmental problem with steady background noise levels of $\not>$ 35 dB(A). If the background noise is variable in character then sleep interference can occur at lower levels, particularly during the initial and terminal stages of sleep. At background levels above an Leq80 dB(A) sleep becomes impossible for most people. But what are the consequences of sleep interference ? This is an area for consideration under health effects.

(ii) Health Effects

It has become fashionable to refer to the modern definition of health as the physical, psychological and social well-being of the population. For ease of categorisation, the last two factors are included in the third section of this paper. The study of health effects is broad and complex. For example, careful epidermiological studies are necessary to detect whether aircraft noise induces cardio-vascular effects, psychiatric-morbidity, or can inhibit foetal development. The results of various studies are reviewed in Refs. 2,3,4 & 6. In general the results can only be described as speculative but they cannot be ignored.

More universally significant are the potential effects of sleep disturbance on health. For many years laboratory studies have indicated that a range of physiological changes can be induced in subjects (Ref.3). But the connection between these phenomenon and real life situations have remained elusive. Data is now beginning to emerge from experiments in France (Ref.7) and elsewhere (Ref.6) on people living near airports, motorways and railways indicating potential health hazards. For example, the sleeping period may be shortened in high noise areas although more significantly the suppression of the deep sleep stages indicate a potential health hazard. Again these results are tentative but such far reaching implication must be vigorously pursued. In this respect an important contribution to our knowledge could be achieved if research could link laboratory and field physiological results to those obtained from questionnaire surveys in the field. Social survey data, to date, has not produced consistently identifiable results. For example, a re-analysis (unpublished) of the 1961 and 1967 Heathrow survey results indicate a higher correlation of night noise exposure with daytime orientated questions than those designed to help define sleep disturbance. These results would indicate that people are unable to make accurate judgements on such a complex issue.

(iii) Noise Induced Annoyance

Annoyance is an expression of dislike for noise combining physical, social and physiological dimensions. Many social surveys have been reported in the past twenty years, some to them of great scientific value, others have helped to obscure the truth. The plethora of indices and psycho-metric scales used in these studies have made the comparison of results extremely difficult. When comparisons have been attempted (Ref.8, 9) conclusions differ. Schultz concludes that results of different surveys have a high degree of similarity whereas Fields indicates greater sceptism if not disbelief. The Schultz presumption provides administrators and planners with a very convenient tool, a single continuous function relating human response with a physically defined noise exposure. That such a function could 'explain', with any degree of accuracy, the effects of environmental noise for all types of sources in any geo-political situation is difficult to envisage. For example, recent work surveying rural communities (Ref.10,11) indicates a substantial difference in the response to noise when compared with the results of a recent national road traffic and environmental survey sponsored by the Department of the Environment. There are also other examples both of field studies and laboratory simulations which make the assumption of a universal function difficult to support. But this data remains fragmented and cannot yet compete with the overwhelming convenience represented by the single function relationship.

Recommendation

Both national and international considerations require that some norm or reference function should be recognised. An example of this type of planning in the U.K. is the use by the Government of the Noise & Number Index (NNI) a Heathrow index, used to examine the impact of various air transportation strategies at all civil aviation airports in   If decision makers were prepared to accept a universal dose-response relationship suitable for large scale strategy planning but also recognise that local conditions could move the response ± 10 dB on either side of this function, this recognition would provide a basis for sensible and sensitive environmental judgements. Decision making would then exist at two levels, regional decisions of a major strategic nature would be resolved using the agreed universal function, but local problems would be examined through an agreed social survey procedure, Fig. 1. The results would include the attitudinal and other social factors which undoubtedly reflect the 'annoyance' of the community. The effect of changes in the noise environment could also be quickly determined if current research by Rice and others (Ref.4, 2) can establish the link between field studies and laboratory measurements. Such an approach to the assessment of noise annoyance requires the acceptance of a method for producing results rather than agreed tabulated criteria. The development of a standard survey method requires careful discussion and research before any recommendation could be made but this should not deter its development.

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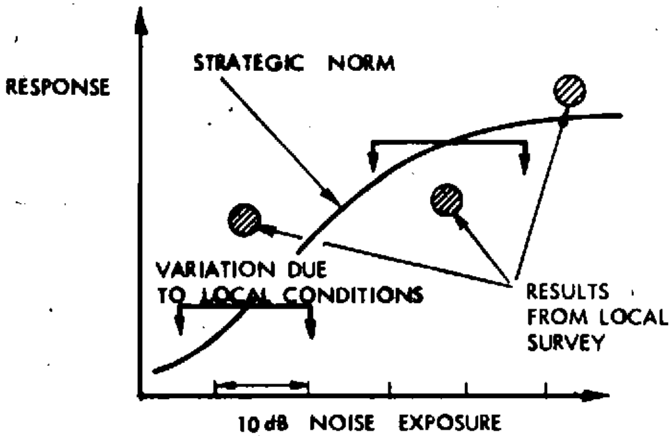

FIG 1. VARIATION IN LOCAL COMMUNITY RESPONSE ABOUT RECOGNIZED RESPONSE NORM.

AN INTERACTIVE ANNOYANCE MODEL FOR MULTIPLE NOISE SOURCES AND ITS RELEVANCE TO NOISE ANNOYANCE CRITERIA

C. A. POWELL

NASA LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA, U.S.A.

Introduction

Although a single dose-response relationship for community noise annoyance as proposed by Schultz (1) is conceptually appealing, considerable evidence indicates that equal noise exposures do not evoke equal annoyance reactions. It has been found (2-4) that people react differently to different noise sources and to different temporal patterns for a given noise source. It has also been found (4) that an energy model is not sufficient to explain total annoyance response to combined noise. This paper presents a model which considers the summation and inhibition of noise sources. In addition, experimental verification of the model and its relevance to annoyance criteria based on single or unique dose-response relationships are discussed.

Model of Summation and Inhibition

Stevens (5) proposed that the presence of an inhibiting stimulus produces a power transformation on the general psychophysical law. Two different power group transformations are used in the present model development as shown in Figure 1. If two noise sources exist so that the uninhibited subjective magnitude of annoyance of each is given by ψ_1 and ψ_2, the inhibited subjective magnitude of one, ψ_1', depends on its uninhibited magnitude and its relative magnitude with respect to ψ_2. In the three regions shown in Figure 1, the following relationships are assumed. In region I, ψ_1' is highly inhibited and

$$\log \psi_1' = a \log b + (1+c)\cdot \log \psi_1 \text{ for } \psi_1 \le \psi_2 \tag{1}$$

where a, b, and c are constants for a given ψ_2. In region II, ψ_1' is less inhibited and

$$\log \psi_1' = d \log e + (1+f)\cdot \log \psi_1 \text{ for } \psi_2 \le \psi_1 \le g\psi_2 \tag{2}$$

where d, e, and f (f<c) are constants for a given ψ_2. The constant g is the ratio of ψ_2 to ψ_1 at the point beyond which no inhibition is provided. Therefore, in region III

$$\log \psi_1' = \log \psi_1 \quad \text{for} \quad g\psi_2 \le \psi_1 \tag{3}$$

Assuming continuity at the boundaries of each region and reciprocity of inhibition effects between ψ_1 and ψ_2, the total subjective magnitude, ψ_T, for the two sources combined can be reduced to a form with only three unknown constants, c, f, and g. Using the notation that ψ_M is the greater of ψ_1 and ψ_2 and ψ_m is the lesser of ψ_1 and ψ_2, the reduced form is given by

$$\psi_T = (1/g)^f\cdot(\psi_M/\psi_m)^f\cdot\psi_M + (1/g)^f(\psi_m/\psi_M)^c\cdot\psi_m \tag{4}$$

$$\text{for} \quad \psi_M/\psi_m < g$$

and

$$\psi_T = \psi_M + (1/g)^f \cdot (\psi_m/\psi_M)^c \cdot \psi_m \quad \text{for} \quad \psi_M/\psi_m \geq g \qquad (5)$$

The relationship of subjective magnitudes ψ_T, ψ_M, and ψ_m are analogous to the sone and noy concepts for loudness and noisiness calculation procedures. Successful applications of the relationships thereby require experimental determination of constants, g, f, and c, an appropriate standard condition, and transfer relationships from noise level to subjective magnitudes for different sources. The following section will describe an experiment which provided these items and experimental verification of the model for combined aircraft and traffic noise.

Experimental Verification of the Model

Aircraft and traffic noise recordings were presented to subjects in a simulated living room environment. A total of 17 noise conditions were used, 4 levels each of separate aircraft and traffic noise and 9 factorial combinations (3 levels each) of mixed aircraft and traffic noise. Each aircraft noise condition consisted of eight flyovers in a 15-minute time period. Each traffic noise condition was heavy-flow roadtraffic (σ = 1.3 dB) also of 15-minute duration. The L_{eq} values for the separate conditions were 30, 40, 50, and 60 dB. The L_{eq} values for the components of the mixed conditions were 40, 50, and 60 dB.

Subjects (16 groups of 4) made a single annoyance judgment to each session of noise using a numerical category scale while engaged in a leisure activity (reading, knitting, etc.). Each subject group was exposed to three each of the separate aircraft and traffic conditions and three of the combined noise conditions.

Mean annoyance responses are presented in Figure 2 as related to the total L_{eq} of the noise conditions. The solid and dashed lines represent polynomial fits to the separate traffic and aircraft conditions. Large deviations of the combined conditions from the trends of the separate conditions are obvious.

Mean responses were converted to subjective magnitudes by assigning the subjective magnitude of 1.00 to the traffic annoyance response at L_{eq}-40dB and assuming a 10dB doubling relationship between level and subjective magnitude. A polynomial fit of these data for the separate traffic conditions provided the necessary transfer function.

A comparison of the data with the model is provided in Figure 3. Both have been normalized to the separate aircraft subjective magnitude at the same level as used in the combined condition. The functional relationship for the model was determined by a least squares fit for the coefficients of equations (4) and (5) (g = 2.56, f = 0.169, c = 1.34) to the experimental data. The model explained 85 percent of the total variance (not normalized) in the subjective magnitudes of the combined conditions. Comparison with other models, simple summation, and energy-type summation of subjective magnitudes, produced considerably less explained variance, 39 percent and 63 percent, respectively. The large difference between the present model and a simple summation model is indicative of the importance of inhibition. The difference between the present model and an energy summation model will be considered in the following section.

Relevance of the Model to Noise Annoyance Criteria

In the following example, it is assumed that one noise exists at 60 L_{dn} and that community annoyance of this source is adequately represented by the Schultz (1) model. Figure 4 represents the percentage highly annoyed if an additional noise at various levels is combined with the first. The solid line represents a strict energy model of combined noise annoyance and does not provide for annoyance differences between sources or inhibition. The dashed lines represent predicted annoyance based on the present model allowing for differences in annoyance between sources. If the additional (second) source produces effectively 10dB more annoyance than the same level of the fixed source (D = 10dB), the increase in percentage highly annoyed over the energy model is obvious. Even for the case where the two sources have equal annoyance potential at the same level, D = 0dB, the present model predicts significantly more annoyance than the energy model if the additional source is at or near the level of the fixed source (60 L_{dn}).

The example illustrates the possibility for large differences in percentage highly annoyed between communities of equal noise exposure in terms of L_{dn}. The example also exemplifies the care which should be exercised in physical measurements for community noise annoyance surveys. The grouping of respondents into broad categories of noise exposure could completely obscure the true nature of the interaction between noise sources.

The determination of the true nature of annoyance to combined noise sources will most probably have to rely on data from a large number of surveys. As a consequence, cooperative efforts for standardization and comparability between surveys, such as outlined in reference (6) are of utmost importance.

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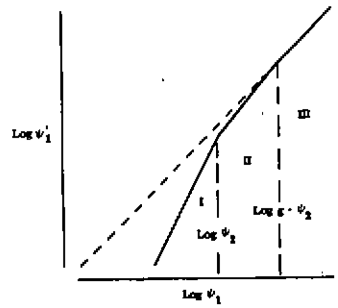

Figure 1.- Power group transformations for inhibition.

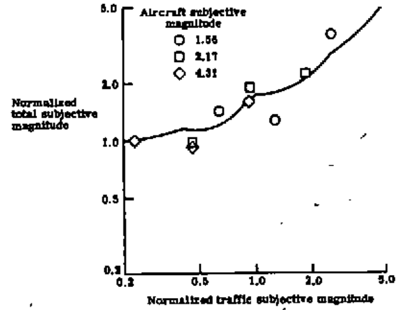

Figure 3.- Comparison of model and experimental data normalized to the aircraft subjective magnitude.

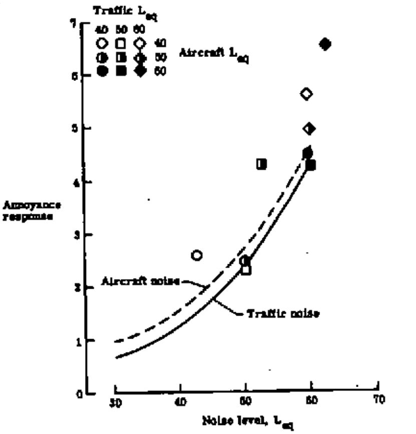

Figure 2.- Annoyance response to experimental noise conditions.

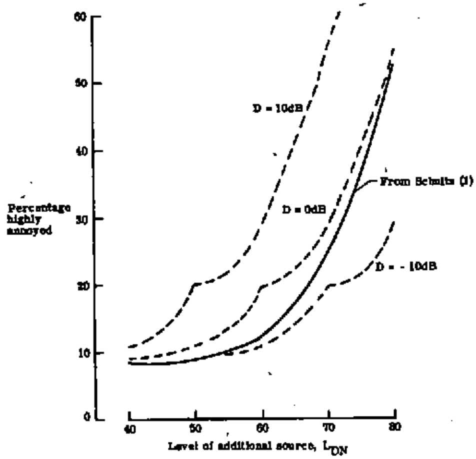

Figure 4.- Effects of the combination of a noise source at L_{DN} 60 and an additional noise source.