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"NOISE AND LOUDNESS EVALUATION".

THE ROLE OF LABORATORY EXPERIMENTATION IN THE FORMULATION OF NOISE CRITERIA

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INTRODUCTION

In order to attempt prediction of the annoyance reactions of communities exposed to noise, contributions from the physical characteristics of the exposure (perceived noisiness) and the altitudinal and environmental activities of the observer (psycho-social variables) must be included in the criterion.

A working definition of perceived noisiness (after Kryter (1)) is "the subjective impression of the unwantedness of a not unexpected, non-pain or fear producing sound as part of one's environment". Description terms such as disturbing, unwantedness, unacceptableness, objectionableness or noisiness fit the total attribute of 'perceived noisiness' and are fairly consistently used by subjects in psychological judgement tests. Rating scale units which may be used to express perceived noisiness are PNdB, EPNdB, dBA, etc.

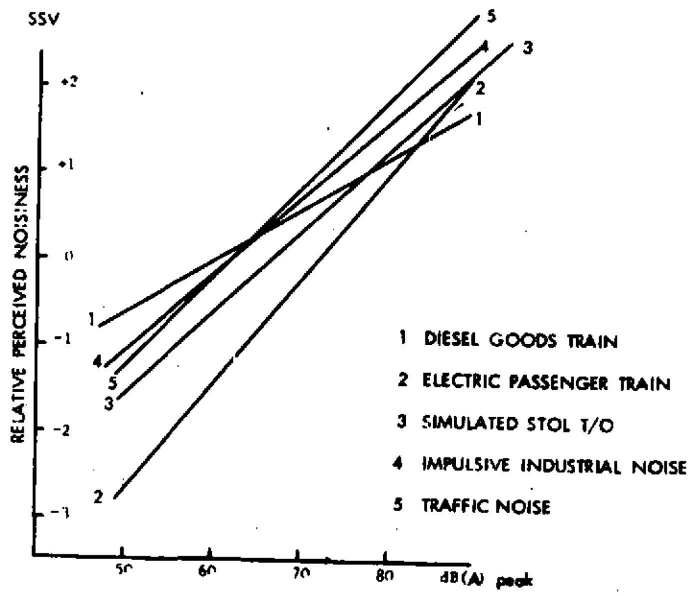
Annoyance on the other hand (after Borsky (2)) is defined as being a feeling of displeasure associated with any agent or condition realised or believed by an individual or a group to be adversely affecting them. While it is often useful or necessary from an analytical point of view to focus attention on a single environmental agent - (such as noise for example) it should be recognised that the single agent appears in real life as one of a complex of environmental stresses. Annoyance, therefore, includes both perceived noisiness and psycho-social variables, and may be expressed in terms of relationships such as NNI, TNI, etc.

Whilst there is little doubt that perceived noisiness judgements can be made in the laboratory, some doubt has been cast on the validity of similar annoyance studies. More recently, however, it has become apparent that provided the experiment is adequately designed, useful indicators of weakness in community annoyance criteria may be studied in the laboratory.

The purpose of this paper is to concentrate on the perceived noisiness components of community noise criteria, and to show that useful contributions towards our understanding of the 'noise problem' may be achieved if closer account is taken of the inadequacies shown by existing rating scale units. It should be noted that the 'noise problem' is not limited to the reactions of noise exposed 'communities'; the noise 'sources' themselves are being increasingly subjected to control and legislative procedures. These restrictions often impose high development, production and operating costs, and in consequence, when required to meet obligatory noise standards, the rating scale unit used should not be seen to favour one 'source' rather than another.

PROBLEM DEFINITION

Any comprehensive urban noise model ideally requires a physical expression of the noise in terms of a unit for which equal magnitudes represent equal subjective responses. At present whilst it seems that the choice of an 'A' weighted unit might be as convenient as any, it is also a well-known fact that sounds of equal dBA, L_{eq}, L_{NP} for example do not evoke equal perceived noisiness or annoyance responses. A recent in-house perceived noisiness laboratory experiment illustrates this point quite clearly (see figure).



SUBJECTIVE REACTION TO DIFFERENT COMMUNITY NOISES.

These corrections are ideally suited to being investigated under laboratory conditions as they exclude the emotive overtones which precipitate annoyance reactions and concentrate more on relative comparisons of the different noise characteristics. Straightforward perceived noisiness comparisons of the physical characteristics of noise therefore result, and these are of particular value to the 'source' problem where greater accuracy is required (e.g. noise certification of aircraft, vehicle noise regulation, etc. to within ± 0.5 dB) than the ± 10 dB acceptable in normal 'community' studies.

EPNL DETERMINATION BY DIRECT SUBJECTIVE TEST

For the purposes of aircraft noise certification the EPNL unit is used (3), although it is generally agreed that EPNL may be imperfect and in need of further revision. The development of a direct rather than a calculated method for determining the EPNL has arisen in order to fulfil the need for a jury concept for rating aircraft noise (3). The approach has been to devise a method (4) which would directly assess the EPNL of an aircraft (hereinafter denoted 'TEST AIRCRAFT') by a psychoacoustic test, wherein a jury of subjects determine the level of the noise of the test aircraft relative to that of present operational aircraft (hereinafter denoted 'STANDARD AIRCRAFT'). This direct or 'operational definition' of EPNL takes the form of a numerical correction factor which can be applied to the basic engineering calculation of the EPNL of the test aircraft; it does not take the form of a revised method of computing EPNL from the physical characteristics of the sounds used.

EXAMPLES OF OTHER LABORATORY RELEVANT STUDIES

Other in-house laboratory studies dealing with perceived noisiness and annoyance studies include: investigation of the trade-off effects of aircraft noise and number in NNI; importance of durational aspects of transportation noise pass-bys (aircraft, traffic and trains); subjective gain in a quiet truck programme (does an engineering calculated noise reduction of 10 dBA represent a greater or lesser perceived noise reduction?); extension of the equal noisiness contours to 20 Hz; effectiveness of different rating scale units in predicting levels at which different traffic noises start to interfere with the ability to relax and enjoy listening to the spoken word; judgements of aircraft noise in varying traffic noise backgrounds. The psycho-physical methods used in these studies have included numerical category scaling, magnitude estimation, method of adjustment and constant stimuli differences. Other pressing problems include the true subjective impact of aircraft retrofit and the sub-sonic noise of Concorde.

CONCLUSIONS

The concept of the 'subjective correction' to rating scale units is one that carries with it great attraction, because it allows a unit to be chosen on political rather than scientific merit. Laboratory experiments lend themselves very well to this task of correcting the chosen units, because they enable 'perceived noisiness' judgements to be made with great precision, the results of which may then be incorporated into annoyance criteria.

When considerable efforts are currently being made to unify subjective reactions to all types of community noise by such schemes as L_{eq} and L_{NP}, it seems obvious that such 'subjective corrections' could improve the claims of these units by reducing some of their inherent error. That psycho-social variables appear to dominate noise exposure terms in the formulation of noise criteria is no excuse for neglecting to attempt their obvious need for correction. In fact in the legislative control of 'source' noise the manufacturers should have a moral, if not legal right to a jury concept laboratory test of their product, if they felt it was being unfairly penalised by inadequacies in the measurement unit.

REFERENCES

(1) K.D. Kryter — The Effects of Noise on Man. Academic Press, New York and London. 1970.

(2) P.N. Borsky — Sonic Boom Exposure Effects II.4 Annoyance Reactions. J. Sound Vib, 20 (4), 527.

(3) Federal Aviation Regulations. Noise Standards. Type certification of aircraft. Volume III. Pt. 36 in Federal Register 34 FR 19025. 1969.

(4) Effective Perceived Noise Level Determination by Direct Laboratory Test. SAE Research Project Committee R-6. Report on Test No. 8. Society of Automotive Engineers, Inc. New York. 1972.

ACKNOWLEDGEMENTS

The EPNL determination by direct laboratory test formed part of a research programme carried out for the R6 Committee of the Society of Automotive Engineers Inc, New York, the experimental design for which was based on original concepts by Dr. Warren S. Torgerson of the John Hopkins University, Baltimore. Some of the other ideas expressed have formulated from discussions held with Dr. James D. Mabey and Hugh J. Parry of MAN-Acoustics and Noise, Inc. Seattle.

Experimental and Validatory Experiments

The method of adjustment procedure used required subjects to listen to a pair of sounds, and then adjust the presentation level of one of them until they are both judged to be subjectively equal. To obtain the experimental result described below the TEST aircraft will be the fixed level sounds and the STANDARD aircraft will be the VARIABLE level sounds. The validatory result requires that the standard sounds be compared with themselves and each other, so that FIXED LEVEL STANDARD sounds replace the test sounds used to obtain the primary result. Once each subject has completed his adjustment of the variable sound in a particular pair, his single estimate of the EPNL for the fixed sound is the value by the engineering calculation of the EPNL of the variable sound. These estimates are compiled across subjects and experimental stimuli so that final mean values can be determined. If the mean value shows any systematic bias with the engineering calculated value of EPNL for the Test aircraft, then an operational definition of EPNL will have been obtained. If a constant error exists in the experimental procedure, it would be expected to exhibit itself in the validatory result.

Aircraft Flyover Noise Recordings

The Test aircraft was a nacelle treated DC 8, 6 recordings of which were obtained at the approximate approach to landing FAA noise certification point. The five Standard in-service aircraft comprised a BAC 1-11, DC-9, DC-8, VC 10 and B 707, recordings of which were specially obtained in January 1971 at the approximate approach to landing FAA noise certification point at London (Heathrow) Airport.

Test Designs

Graeco-Latin and Youden Square balanced designs were used throughout so that complete exclusion of all experimental biases was achieved. 120 and 100 subjects were required for the experimental and validatory tests respectively, although by careful choice of treatments sufficient accuracy was maintained with half those numbers. Each subject judged only five pairs of aircraft.

Results

Three hundred $(\$i - T_j)_K$ values were used in the analyses of the experimental result. $\$i$ is the Kth subject's single estimate of the EPNL of the jth Test aircraft and is the EPNL of the ith variable Standard aircraft at the judged equality setting. The overall mean difference was 0.93 EPNL with a standard error of 0.24 EPNL. This means that compared to currently operating aircraft the nacelle treated DC-8 aircraft is underated (or the unit is in error) by 0.9 ± 0.2 EPNL.

The overall mean difference for the validatory result was -0.02 EPNL with a standard error of 0.23 EPNL. This result confirms that the bias of 0.9 EPNL shown in the experimental result is real, and not due to the experimental procedures.

Of major importance is the accuracy with which subjective corrections to rating scale units can be achieved. In the example discussed although the overall unit error was only of the order of 1 dB, other situations give much larger differences (see figure). The experimental data obtained in these studies has enabled several further analyses to be carried out. These are described in detail in reference 3. In particular analyses of variance technique have enabled individual differences between TEST and STANDARD aircraft to be emphasised. The sensitivity of the experimental design enabled differences in recording techniques and locations to be clearly identified. Subsidiary experiments also investigated the influence of instructions, of indicator lights, of start level, and the time placement of flyovers on the tape loop pairs.