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URBAN NOISE MEASUREMENT AND EVALUATION

UNITS FOR THE ASSESSMENT OF NUISANCE DUE TO TRAFFIC NOISE IN A SPEECH ENVIRONMENT

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INTRODUCTION

A laboratory study of nuisance due to traffic noises in a speech environment has recently been carried out (1), in which it was suggested that $L_{10\%}$ dBA might be the most suitable unit for relating the indoor intrusion caused by the traffic noise to its physical characteristics.

Further analyses of these results enabled other physical parameters of the noises to be taken into account, and these in turn led to the formulation of a 'goodness factor' which enabled the efficiency of the different rating scale units to be re-assessed.

The model used is particularly important in assessing the claims of such units as $L_{10\%}$, L_{eq} and L_{NP} in the formulation of the optimum unit for use in the general assessment of urban noise.

LABORATORY STUDY

The study was designed to investigate the effects which a variety of traffic noise situations have on the appreciation of speech in a controlled environment. Subjects were asked to adjust the intensity level of an intruding time-varying traffic noise signal until they considered it to be just "unacceptable" for relaxed listening to speech. A criterion of speech interference was not used, rather subjects were asked to select the level at which the traffic noise just began to be noticeably unacceptable.

The traffic signals were representative of sounds produced indoors near roads with varying percentages of heavy vehicles superimposed upon a high flow of light vehicles. Three conditions were chosen (12%, 4% and 1.3% heavy vehicles in a 6000 v/hr light traffic flow) at each of two peak-steady noise levels (5 dB and 20 dB) and two durations (20 dB down points of 5 and 15 seconds). The thirteenth condition was the steady light traffic flow of 6000 v/hr. The speech signals were thirteen separate male voice recordings of short stories of topical interest.

Each of the 13 test situations was to be presented to each subject. In order to balance out the possible effects due to different speech recordings or to changes in the subject's tolerance during a test session a 3-way balanced design was needed. This ensured that each noise situation was paired an equal number of times with each and every speech recording, and was presented an equal number of times in each and every presentation order position.

These requirements were achieved by using a design based on two 13 x 13 balanced Graeco-Latin squares, which required 13 speech signals and 26 subjects. The Graeco-Latin square design is shown in Table 1; subjects 1-13 received treatments in rows as indicated; subjects 14-21 received the reverse order of treatments within the same rows as subjects 1-13 respectively.

Subject No.	Presentation Order 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10 th	11 th	12 th	13 th
I	1m	2ℓ	13a	3k	12b	4j	11c	5i	10d	6h	9e	7g	8f
II	2a	3m	1b	4ℓ	13c	5k	12d	6j	11e	7i	10f	8h	9g
III	3b	4a	2c	5m	1d	6ℓ	13e	7k	12f	8j	11g	9i	10h
IV	4c	5b	3d	6a	2e	7m	1f	8ℓ	13g	9k	12h	10j	11i
V	5d	6c	4e	7b	3f	8a	2g	9m	1h	10ℓ	13i	11k	12j
VI	6e	7d	5f	8c	4g	9b	3h	10a	2i	11m	1j	12ℓ	13k
VII	7f	8e	6g	9d	5h	10c	4i	11b	3j	12a	2k	13m	1ℓ
VIII	8g	9f	7h	10e	6i	11d	5j	12c	4k	13b	3ℓ	1a	2m
IX	9h	10g	8i	11f	7j	12e	6k	13d	5ℓ	1c	4m	2b	3a
X	10i	11h	9j	12g	8k	13f	7ℓ	1e	6m	2d	5a	3c	4b
XI	11j	12i	10k	13h	9ℓ	1g	8m	2f	7a	3e	6b	4d	5c
XII	12k	13j	11ℓ	1i	10m	2h	9a	3g	8b	4f	7c	5e	6d
XIII	13ℓ	1k	12m	2j	11a	3i	10b	4h	9c	5g	8d	6f	7e

1-13 - 13 test signals; a-m - 13 speech recordings; I-XII - 13 subjects.

TABLE 1. Graeco-Latin Square Design.

The settings of the attenuator controlling the traffic noise level chosen by each subject as his "just acceptable" level for each test situation were noted. These were related to physical means of the test signals made both as heard in the listening chamber (in the absence of a subject) and in the equivalent outside facade position, using real time analysis and computational facilities. Over eighty rating scale units were evaluated to see which 'best' related the physical characteristics of the noises to the judged subjective responses. The criterion of 'best' is not easy to define, but in the context of the study it was considered that it was not unreasonable to expect the 'ideal unit' to be one which would give the same numerical value for all thirteen noise signals when subjectively lined up at the average levels chosen by subjects. The results obtained for a selection of units in terms of both F-ratio and standard deviations are shown in Table II.

Although the $L_{10\%}$ dBA measure at the facade of the building appears to be the most appropriate unit and supports the Noise Advisory Council's recommendation based on Building Research Station researches, it is clear that none of the units examined comes close to being 'ideal'; in particular all 'F' ratios from the analysis of variance are significant which indicates the inability of any of the units to satisfactorily account for the physical characteristics in the noises when judged to be subjectively equal.

DISCUSSION

Of the other favoured units which are often reported in the literature L_{eq} was well rated provided it was calculated using the energy mean or by using the B & K Noise Dose Meter. L_{NP} was not as successful, nor were NNI or TNI. Of particular interest however are the approximated formula (based on the assumption that noise levels from road traffic are normally distributed) which are used in the calculation of L_{eq_3} and L_{NP_1} and L_{NP_2} (see Table II). Not all the traffic noises were normally distributed and that by using such approximations, larger F ratios were obtained. The implication of this point in the real life environment should not go unnoticed. Further examination of the analysis of variance tables showed that

TABLE II. 'F' values (and standard deviations) of selected units.

Measured as heard inside	dBA	dBB	dBD
$L_{10\%}$ Statistical Distribution Analyser	5.5(1.8)	7.5 (2.1)	7.3 (2.0)
Peak Level Recorder	9.2(2.3)	7.7 (2.1)	7.3 (2.0)
Max. integrated ½ sec.	9.6(2.3)	8.1 (2.2)	7.6 (2.1)
$L_{50\%}$	69.7(6.3)		
L_{eq_1} = Energy mean	6.6(1.9)		
L_{eq_2} = Dosemeter	7.9(2.1)		
$L_{eq_3} = L_{50} + (L_{10}-L_{90})^2/57$	36.5(4.5)		
$L_{NP_1} = L_{eq_3} + (L_{10} - L_{90})$	30.0(4.1)		
$L_{NP_2} = L_{eq_3} + 2.56\sigma$	21.8(3.5)		
$L_{NP_3} = L_{eq_2} + 2.56\sigma$	34.9(4.5)		
$NNI = PNL_{max} + 15 \log N - 20$	58.2(5.7)	($N = \frac{720}{I+1}$, I = peak interval (secs))	
PNL_{max}	7.5(2.1)		
$TNI = L_{90} + 4(L_{10}-L_{90}) - 30$	590.6(18.3)		
Measured outside	**dBA**	**dBB**	**dBD**
$L_{10\%}$ Statistical Distribution Analyser	4.5 (1.6)	5.2 (1.7)	5.3 (1.7)
Peak level recorder	9.5 (2.3)	9.0 (2.3)	9.1 (2.3)
Levels of Significance	5%, F = 1.8	: 1%, F = 2.3	

the temporal distribution of the traffic noises are not well accounted for by the existing units. The somewhat regular occurrence of the noises enabled an interval correction to be added to the peak values. This empirical correction takes the form $n \log_{10}(I/m)$ where n and m are integers and I is the time interval in seconds between the pass-by peaks. The final unit becomes

$$dBI = dB_p - 5 \log_{10}\left(\frac{I'}{5}\right)$$

where dB_p is the peak rating scale unit value, and $I' = I$ for $I' \geq 5$ secs and $I' = 5$ for $I' < 5$ secs.

Table III shows that this condition lined up the test signals with a non-significant scatter that could be attributed to random error, suggesting that a peak or maximum measure coupled with a rate of occurrence correction might be the best unit solution. However, how much the regularity of the signals affected subjects' judgements is not known, and in practice freely flowing traffic with varying concentrations of heavies is not regular. Bunching occurs causing a randomness which may be very hard to physically define, although under certain circumstances, such as 'worst mode', these conditions might be quantifiable.

GOODNESS FACTOR MODEL

The 'ideal unit' concept previously defined may not necessarily be the correct way of identifying the physical rating scale unit which best describes the subjective reactions to the noises concerned.

Consideration should also be given to the way in which the unit is sensitive to changes in the physical characteristics of the noises. If the noises in this study were lined up on their background levels ($L_{90\%}$) the approximate ranges covered when measured by different units were: L_{eq} - 12 dB, $L_{10\%}$ - 17dB, Peak and NNI - 20 dB, L_{NP} - 25 dB, TNI - 55 dB.

TABLE III. Interval corrected 'F' ratios using peak measures as heard indoors.

Source of Variation	d of f	dBAI	dBA Peak	PNLI	PNL max
NOISE	12	1.6	9.2	1.0	7.5
Interval (I)	2	0.2	43.8	0.1	39.1
Peak (P)	1	5.0	1.7	0.4	0.4
Duration (D)	1	4.8	4.1	0.1	0.1
RESIDUAL	276				

1% levels of significance F(12,276) 2.3; F(2,276) 4.7; F(1,176) 6.7.

This infers that units such as TNI and L_{NP} can much more sensitively measure changes in noise characteristic than do L_{eq} or $L_{10\%}$. Because this is a desirable quality in a noise unit more account should be taken of this fact. It is therefore proposed that the best unit is the one whose 'Goodness Factor' (GF) is the smallest where

$$GF = \frac{\sigma \text{ of unit values at subjective equality levels}}{\sigma \text{ of unit values of the noise set}} = \sigma_s/\sigma_p$$

The best unit measure is therefore the one which allows maximum flexibility and sensitivity of physical measurement (i.e. large σ_p) with minimum subjective scatter (i.e. small σ_s). Application of the goodness factor to a selection of the results of the traffic noise study yields the values shown in Table IV.

TABLE IV. Goodness Factor Results.

Unit	σ_s	σ_p	$GF = \sigma_s/\sigma_p$
$L_{10\%}$ dBA	1.8	5.8	.31
Peak dBA	2.3	7.2	.32
L_{NP_2}	3.5	8.9	.39
L_{eq_1}	1.9	4.6	.41
L_{eq_2}	2.1	4.4	.48
TNI^2	18.3	24.2	.76
NNI	5.7	6.6	.87

These results change the rank ordering suggested in Table II, most noticeable being the relegation of L_{eq}. L_{NP} now ranks slightly superior to L_{eq} and this result needs further consideration in the light of recent trends towards the adoption of L_{eq} as national units in other European countries and in the USA.

Of considerable importance in the present context of traffic noise, however, is the vindication of the choice of $L_{10\%}$ dBA, which appears to be favoured however the units are assessed, apart from dBAI.

Reference

(1) ISVR Wolfson Unit Consultation Report 1542 (May 1972). A laboratory study of nuisance due to traffic noise in a speech environment. University of Southampton.

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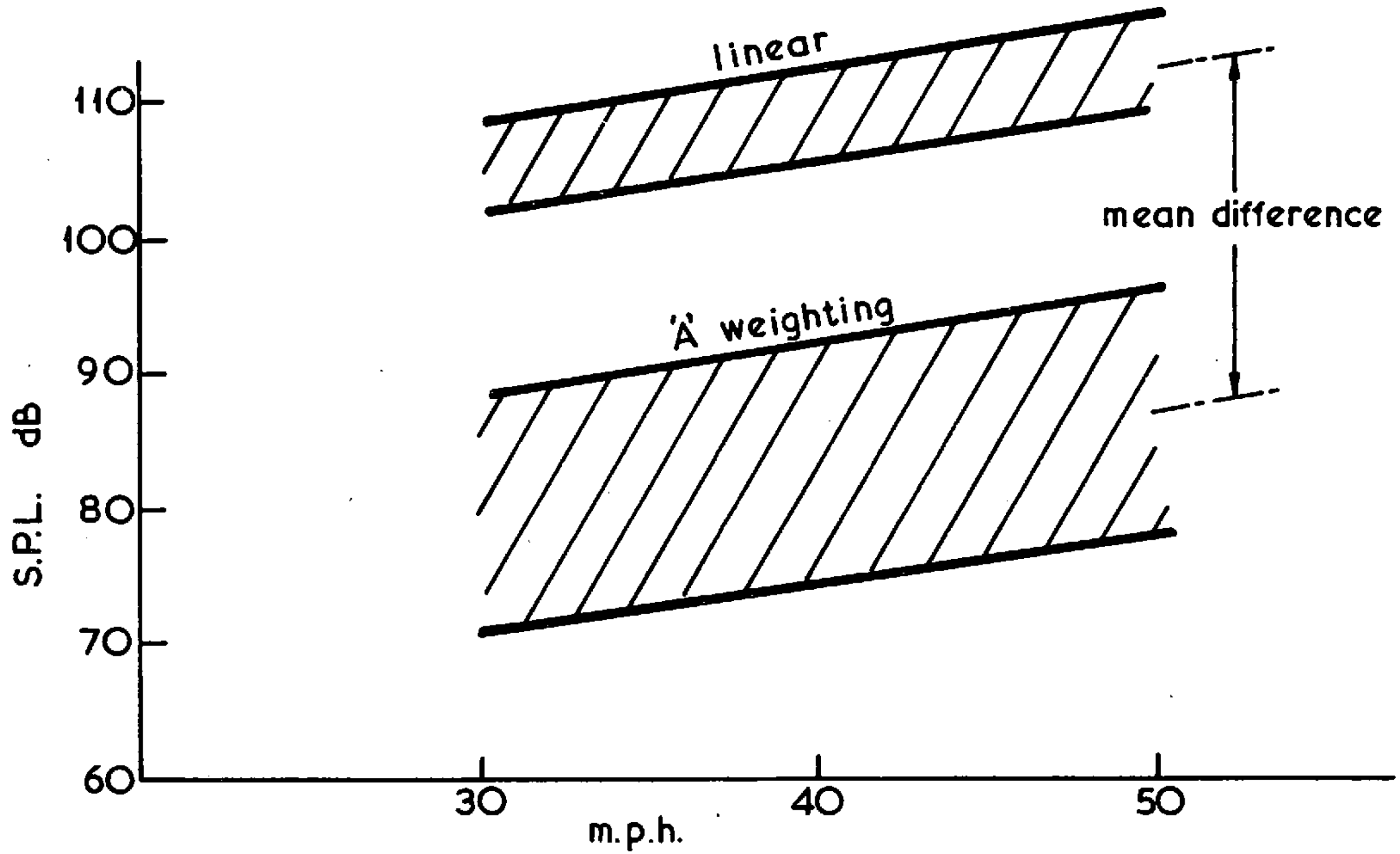

Fig. 4 Distribution of linear and 'A' weighted noise levels in lorry cabs.