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LOUDNESS, ANNOYANCE AND MEASUREMENT OF A LOW FREQUENCY REPETITIVE IMPULSE NOISE

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INTRODUCTION AND PROBLEM

Sound pressure level and the spectral structure are, probably the most important characteristics of a noise that influence the psychological concepts, such as loudness and annoyance. However, other factors, particularly impulsiveness and duration can affect the relationship between the attributes and the physical descriptors of the noise.

Generally, the 'A' weighted sound pressure level gives a good correlation with the psychological assessments of community noises, however there are exceptions.

The aim of the present investigation is to examine one particular type of noise which has proven to be an exception. It is universally accepted that a sound pressure level in the low frequency range is not perceived to be as loud as a sound of equal level in the middle of the audio frequency range. It is, also, almost as well accepted that impulsive noises are perceived to be louder that continuous sounds. The question is what happens when a noise is a combination of low frequency and impulsiveness ? How is the loudness perceived and what is the relationship between the loudness and annoyance ? How can annoyance be measured ?

To attempt to answer these questions an experiment was arranged to obtain the response to a low frequency repetitive impulse noise compared to band limited pink noise. The free magnitude estimation method [1] was used.

THE EXPERIMENT

1) <u>The Stimuli</u>
Two stimuli types, at four different sound pressure levels were presented to the observers under free field conditions. The reference sound was a band limited pink noise,produced from a CEL 213 white/pink noise generator.

The low frequency repetitive impulse noise was a kick (bass) drum. This choice was made for the following reasons:
a) It is a type of noise, of the kind, that commonly causes complaint [2].
b) It is a 'real' sound.
c) It is a type of noise that has given a poor correlation between objective measures and subjective assessments [3].

To obtain a reliable, repeatable sound source a computer driven, digital drum machine was used. The spectral structure of the stimulusis shown in figure 1, and the temporal structure is shown in figure 2.
The repetition rate was set at 120 beats per minute or 2 Hz.

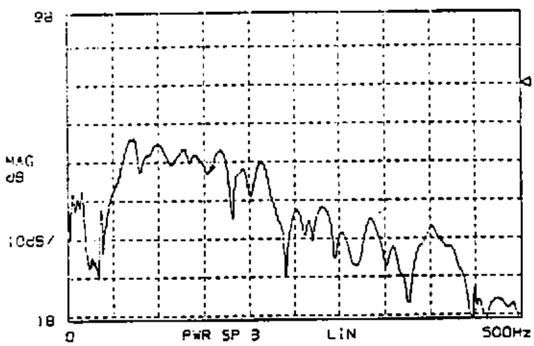

Figure 1. Averaged spectrum of the kick drum.

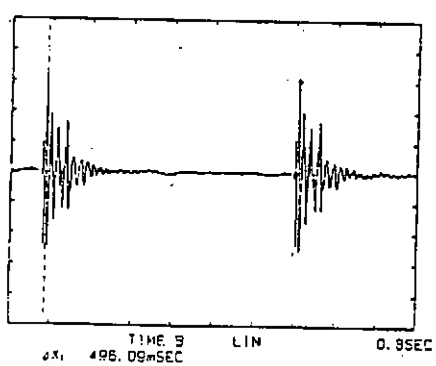

Figure 2. The kick drum in the time domain.

2) The Observers

Eighteen observers participated in the experiment, fourteen men and four women. The average age was 27 years. None had any known hearing defects and none had previously participated in this type of psychological experiment. All were students at The South Bank Polytechnic, London.

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3) The Experimental Design

The stimuli, each at four unweighted, equivalent continuous sound level (L_{eq}) of 80, 70, 60 and 50 dB, were presented to the observers in a random order. (with the exception of the reference level of 80 dB pink noise which was always presented first).

4) The Test Procedure

The observers were asked to tell how loud the reference sound seemed, by assigning any number to it that was appropriate. They then assigned proportional numbers to the other seven sounds, to reflect their subjective impression. The experiment was then repeated but 'annoying' was substituted for 'loud'. The definition of annoyance was based on that used by Berglund et al. [4] i.e. "After a hard day's work, you have just been comfortably seated in your chair and intend to read your newspaper." An addition was added to this imaginary situation, that " the noise would last for the whole of the evening" to cover the duration aspect of annoyance. This order, loudness first then annoyance, was reversed for every other observer,

RESULTS

After normalizing the data to a common modulus, the geometric mean was calculated The tabulated results are shown in table I, and the data is shown in a graphical form in figure 3.

L_{eq} (dB)	GEOMETRIC MEAN			
	LOUDNESS		ANNOYANCE	
	pink	drum	pink	drum
80	77.5	75.9	88.3	89.8
70	48.7	45.2	60.5	57.7
60	25.3	26.7	35.9	39.5
50	15.2	15.7	20.0	27.3

Table I. Physical descriptor and subjective response.

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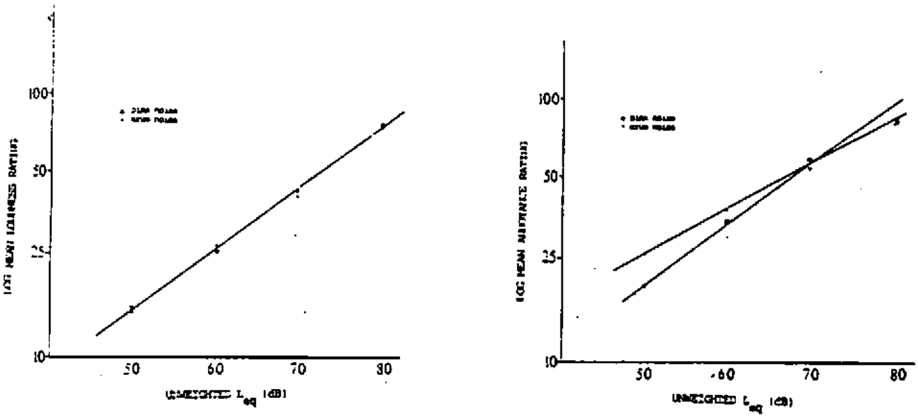

Figure 3. The psychophysical power functions fitted to the data for pink noise and drum noise for both attributes. a) loudness, b) annoyance.

CONCLUSIONS

In this experiment the two stimuli were perceived to be approximately equally as loud for a equal change in the unweighted L_{eq}. The curve shown in figure 3 a shows that the sensation magnitude M grows as a power function of the stimulus magnitude p. This conforms to the psychophysical power law [1] which states:

$$M = k p^n$$

Where the constant k depends on the modulus the data was normalized to.In this case it is 162.5. The value of the exponent n is more important and determines the slope of the gragh.In this case the value of n was found to be 0.46.

With annoyance, however the two attributes do not have the same slope. The exponent for annoyance of pink noise is close to the exponent of the loudness data, at 0.49. This indicates that a physical measurement of loudness will,also be a good basis for assessing annoyance.

For the drum stimulus, however the psychophysical exponent is much smaller,thus indicating that the decrease in annoyance is less rapid for a decreasing sound pressure level, than a loudness measure predicts.This is shown more profoundly on a plot of the annoyance-to-loudness ratio as a function of loudness (figure 4)

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This low exponent value (0.34) has a significant influence on the practical measurements of noise annoyance and this is examined in detail by Scannell 1988 [5], however, basicaly it indicates that a correction factor, that is inversely proportional to the sound pressure level, is required to give a good correlation between the physical measurement and the human response.

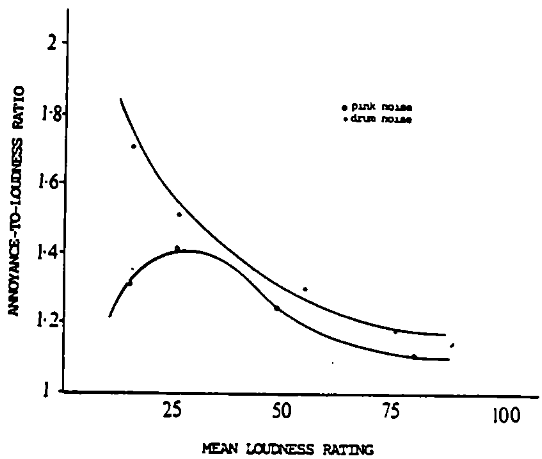

Figure 4. The annoyance-to- loudness ratio as a function of loudness for pink noise and a low frequency repetitive impulse noise.

ACKNOWLEDGMENTS

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REFERENCES

[1] Stevens, S.S. Psychophysics, Wiley-Interscience New York, 1975.
[2]Leventhall, H.G. 'Discotheque Noise', Noise Control & Vibration Reduction, May 1974.
[3] Scannell, K. 'Annoyance and Measurement of a low level, low frequency repetitive impulsive noise' Unpublished dissertation, South Bank Polytechnic, Summer 1987.
[4] Berglund, B., Berglund, U., and Lindvall, T. 'Scaling loudness,noisiness and annoyance of aircraft noise', J. Acoust. Soc. Am. 57, 1975.
[5] Scannell K. 'The equivalent annoyance level as an objective assessment of entertainment noise.' Proc. IOA Vol. 10 1988