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# THE EFFECTS OF IRREGULARITY AND INTERMITTENCY ON THE JUDGED ANNOYANCE OF IMPULSIVE NOISE

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## 1 INTRODUCTION

It is now generally accepted that, when impulsive noise is measured using the equivalent continuous A-weighted sound pressure level ($L_{Aeq}$), there is a need for a penalty to be applied to the measured level to take account of the enhanced annoyance of such a noise relative to more continuous noise. However, little work has been carried out to investigate various aspects of the noise signal in relation to the degree of annoyance.

A series of subjective experiments was conducted at the National Physical Laboratory as part of an evaluation of impulsive noise under contract to the Department of Environment (1). One of the effects to be investigated in that series of experiments was the effect of irregularity on the annoyance ratings. This then led to a later experiment to investigate the effect of intermittency on annoyance ratings.

This paper describes these two experiments investigating the effects of irregularity and intermittency on the judged annoyance of impulsive noise and assesses the significance of the data obtained from both experiments.

## 2 SUBJECTIVE EXPERIMENTS

### 2.1 Test Facilities

#### 2.1.1 *Listening Room*

The room was carpeted and furnished to give a reasonable simulation of domestic living room conditions and the background noise was steady at 25 dB(A).

#### 2.1.2 *Signal simulation and reproduction*

The experiments made use of both simulated impulsive noises and recordings of real noises. The simulations were obtained using digital synthesis software running on a

PRIME 300 minicomputer with a 12 bit digital-to-analogue converter. A white noise carrier signal was modulated to give a repeating envelope with sharp onset and exponential decay. The simulated impulsive noises and recordings of real noises were all stored on digital audio tape (Sony PCM F1) for eventual playback. The subjects were monitored by closed-circuit TV and the level of noise at the subject position was also monitored.

## 2.2 Irregularity Experiment

### 2.2.1 *Noises*

This experiment was designed to investigate the irregularity in the repetition rate. Six synthetic noises were used; the first three had a decay time of 100 ms and regular repetition rates of 1 Hz, 4 Hz and 8 Hz. The other three noises had the same decay time but with repetition rates varied randomly (rectangular distribution) in each of three ranges:

| Noise | Repetition rate range |
|---|---|
| Irregular 1 Hz | 0.2 Hz to 1 Hz |
| Irregular 4 Hz | 1 Hz to 4 Hz |
| Irregular 8 Hz | 4 Hz to 8 Hz |

Waveforms of all six noises are shown in Figure 1.

In addition to the synthetic noise, pile driver and traffic noise were also used. A master tape recording of a one-minute sample of each of these eight noises was made.

### 2.2.2 *Experimental design*

By digital copying from the master tape, four session tapes were made each containing a different randomised sequence of all eight noises plus a repeat of the traffic noise. Of the 24 subjects tested, 12 heard these tapes and 12 heard another

four corresponding tapes, with the same noises in reverse order.

2.2.3 *Test procedure*

Subjects were first given written instructions followed by a short practice session in which they heard a one-minute sample of each of the eight noises. Subjects then heard four tapes in four 15-minute sessions, each with twelve 1-minute noise exposures and with a 20-second period between each noise. They were asked to rate each noise using scoring sheets with the question, "how annoying would you find the noise if you heard it, at home, several times in the evening?" on a scale as follows:

NOT ANNOYING AT ALL 0 1 2 3 4 5 6 7 8 9 EXTREMELY ANNOYING

2.2.4 *Results and discussion*

A three-factor analysis of variance (level × regularity × repetition rate) was performed on the data.

The most important result was that irregularity was found to have no effect. The mean annoyance rating for each noise at each level is plotted in Figure 2 and shows that the annoyance ratings for the irregular rates are only marginally higher than those for the regular rates for the 1 Hz and 8 Hz cases, whilst the opposite is true for the 4 Hz case.

In an experiment conducted at ISVR, using sounds synthesised on the NPL computer system, which had either regular or irregular impulse levels and either regular or irregular repetition rates, Flindell and Rice (2) also observed no effect of irregularity on judged annoyance.

2.3 Intermittency Experiment

2.3.1 *Noises*

This experiment was designed to investigate the effect of intermittency on the

annoyance ratings. Two synthetic noises were used; the first was continuous impulsive noise with a decay time of 10 ms and repetition rate of 5 Hz. The second also had a decay time of 10 ms and repetition rate of 5 Hz but was presented in intermittent bursts. The pattern of intermittency is shown in Figure 3. The value of $L_{Aeq}$ was kept constant for both continuous and intermittent presentations. In addition to the synthetic noise, traffic noise was also used. A master tape recording of a 5-minute sample of each noise was made.

2.3.2 *Experimental design*

Four session tapes were made by digital copying from the master tapes. One of these tapes was a practice tape consisting of a 1-minute sample of each of the continuous impulsive noise, intermittent impulsive noise preceded and followed by a 1-minute sample of the low-variability traffic noise. The other session tapes were as follows:

Tape A - low-variability traffic noise
Tape B - continuous impulsive noise
Tape C - intermittent impulsive noise

The three noises, each at four possible values of $L_{Aeq}$ - 35, 45, 55 and 65 dB - were presented in twelve 5-minute periods to 24 subjects, tested singly. The order of presentation of the noises to each subject was determined by a repeated 12 by 12 Latin Square design.

2.3.3 *Test procedure*

Subjects were first given written instructions followed by a short practice session in which they heard a 1-minute sample of each of the impulsive noises and two one-minute samples of the traffic noise. Subjects were then presented with the twelve 5-minute samples in three blocks. Each noise was rated using the same method of scoring as in the irregularity experiment.

2.3.4 *Results and discussion*

An analysis of variance was performed on the individual response data. This indicated a significant difference between the intermittent and continuous impulsive noises at all except the lowest level used. The mean annoyance rating for each noise at each of the four levels is plotted in Figure 4. Regression equations relating mean annoyance rating to $L_{Aeq}$ were calculated and used to derive values of the impulse penalty of each noise relative to traffic noise (see Berry (1) for method). The results are shown below.

Impulse Penalty (dB(A))

| Level | Continuous Impulsive | Intermittent Impulsive |
|---|---|---|
| 35 | 12.2 | 13.0 |
| 45 | 11.0 | 9.1 |
| 55 | 9.8 | 5.2 |
| 65 | 8.6 | 1.4 |

## 3 CONCLUSIONS

Subjects in a simulated living room environment have made numerical category scale judgements on the annoyance of various noise exposures. The results indicate that over a wide range (0.2 to 8 Hz), irregularity in repetition rate had no significant effect on judged annoyance. Intermittent impulsive noise was found to be significantly less annoying than continuous impulsive noise, with the impulse penalty at the highest level being reduced by 7 dB.

## 4 REFERENCES

1. B F BERRY, 1987. *The evaluation of impulsive noise.* NPL Report Ac 111.
2. I H FLINDELL and C G RICE, 1986. *1984–1985 Joint CEC Project on annoyance due to impulse noise. Laboratory studies.* ISVR Memorandum 677.

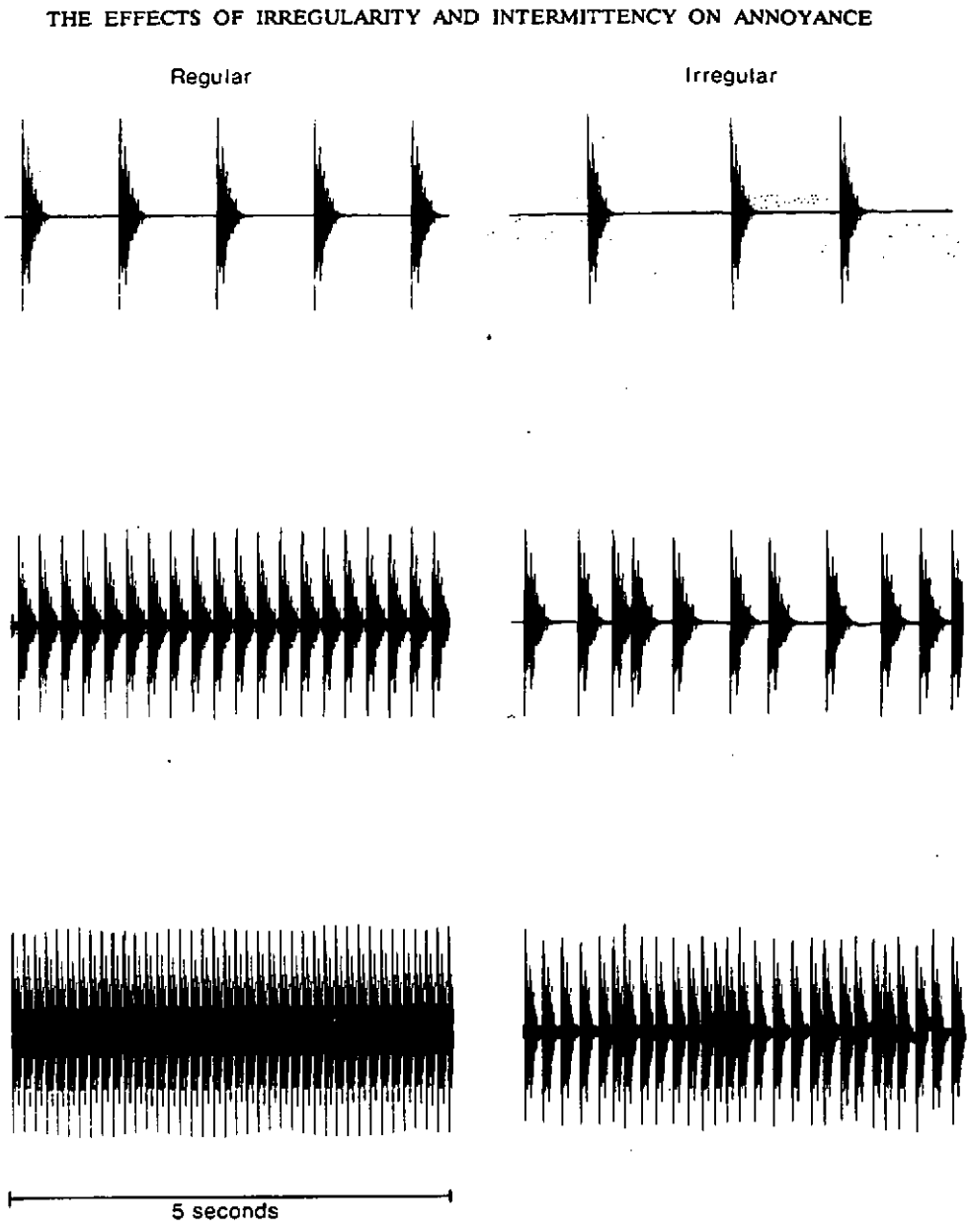


Figure 1. Waveforms of synthetic noises; irregularity experiment

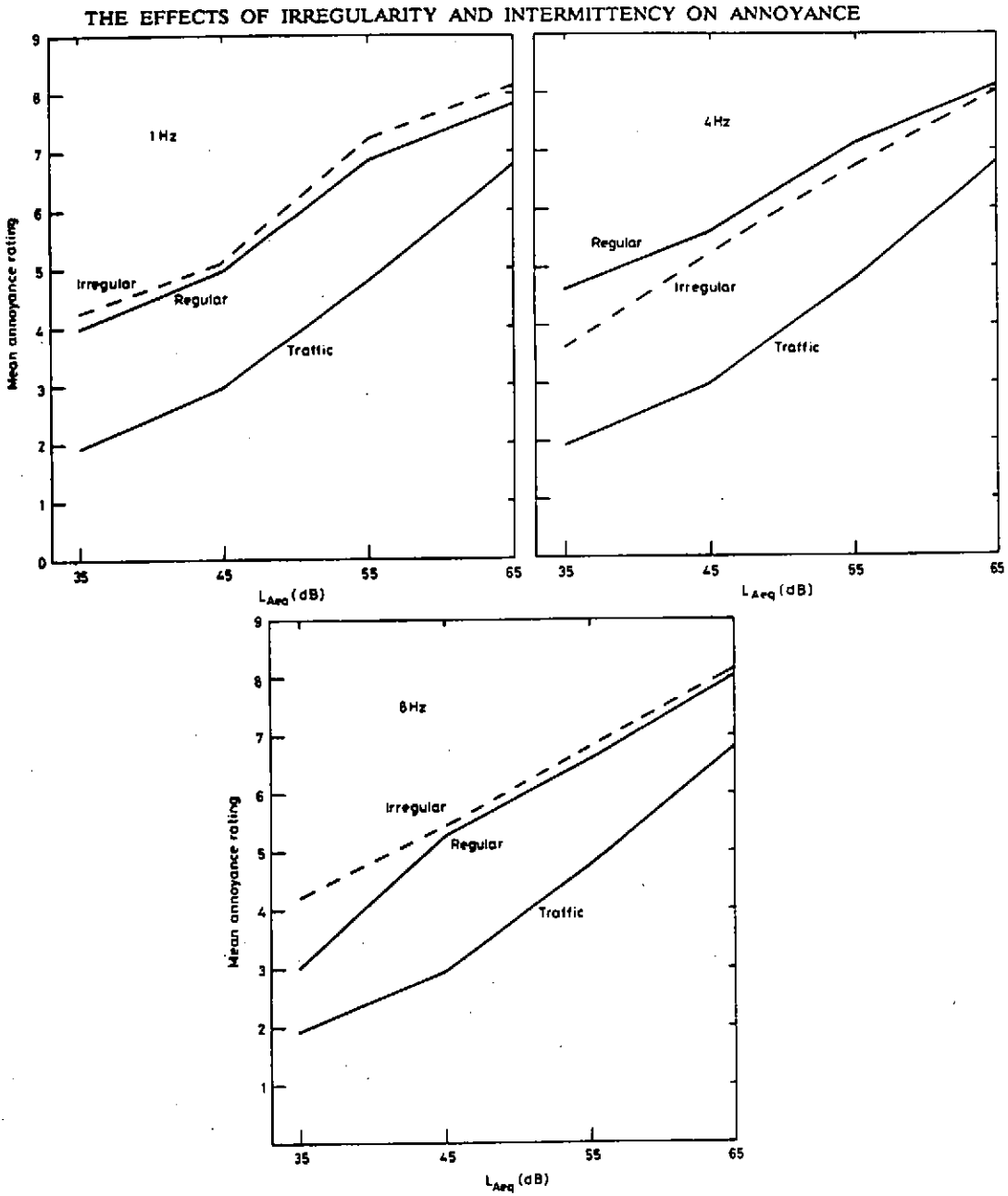


Figure 2. Mean annoyance rating and $L_{Aeq}$; irregularity experiment

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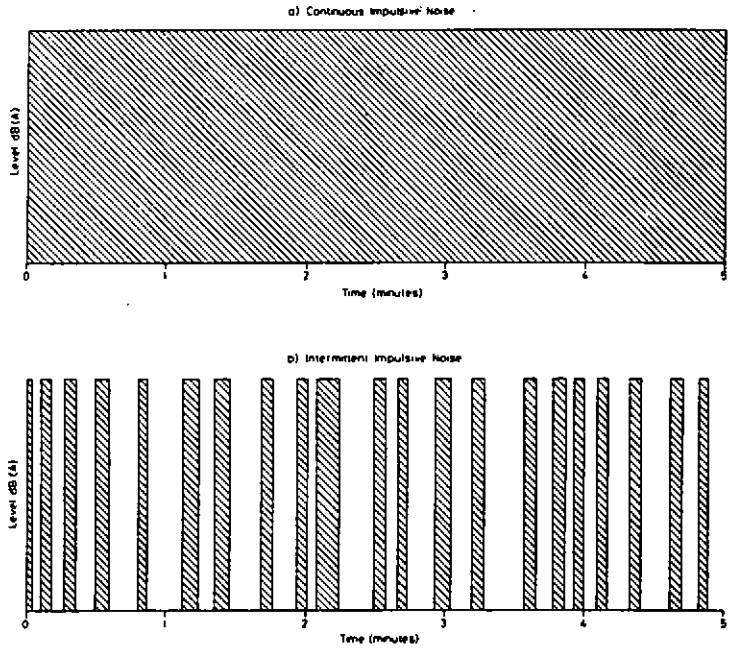


Figure 3. Time patterns of continuous and intermittent impulsive noise

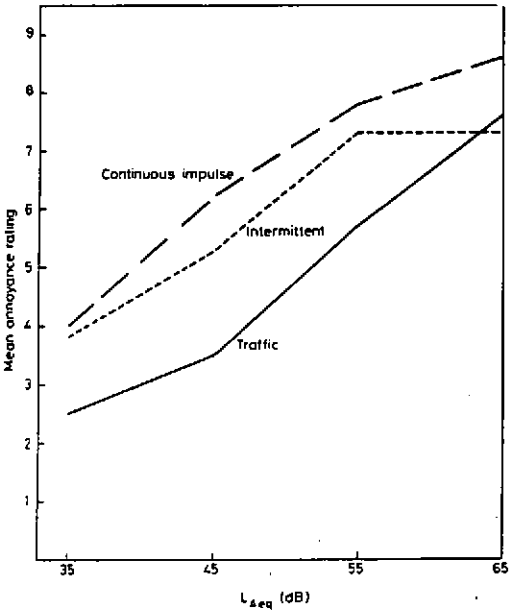


Figure 4 Mean annoyance rating and $L_{Aeq}$; intermittency experiment