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ANNOYANCE AND IMPULSIVITY JUDGMENTS OF ENVIRONMENTAL NOISES

C G Swift, I H Flindell and C G Rice

ISVR, University of Southampton

INTRODUCTION

This study was part of a joint European research programme into community response to impulsive noise. Existing national and international standards assume that the annoyance of impulsive sounds can be assessed by subjective judgment. If the sound is judged impulsive, a penalty is added to the measured level. The aim of this particular study was to investigate the relationship between annoyance and subjective impulsivity of a representative range of impulsive and non-impulsive sounds. The study provided subjective data for comparison with physical analyses of the sounds. These physical analyses were carried out at the National Physical Laboratories [1] and the Institut fur Medizinische Psychologie [2]. The overall goal of the programme was to develop guidelines for the assessment, regulation, and control of impulsive noise in the community.

A pilot and a main study were carried out in a simulated domestic sitting room listening facility, using repeated measures experimental designs. This was done to isolate the sounds from their situational context as heard in real life, and to control for the different noise sensitivities of the subjects. The pilot study used synthesized impulsive sounds to investigate the relationship between subjective response and signal envelope shape. The intention was to differentiate between physical descriptors which take account of envelope parameters (rise time and rise rate), and others which take account of the deviation in envelope level. The main study used representative sounds that had been recorded in the community. Twenty sounds were used from a catalogue of forty that had been recorded by members of the European team and used in a previous study [3]. The sounds were replayed in both forward and reverse directions to manipulate the signal envelope shape while keeping constant as many as possible of the other sound attributes.

EXPERIMENTAL METHOD

Both the pilot study and the main study were carried out in the Subjective Listening Suite at the ISVR. The volunteer experimental subjects were all between 18 and 30 years old. Screening audiometry ensured that they all had hearing thresholds below 20 dB in the range 250 Hz to 8 kHz for each ear. The male/female splits for both the pilot and main studies were such that the minority sex formed at least 25% of the whole.

All the sounds were recorded on digital audio tape and were presented to the subjects in the living room by means of concealed loudspeakers. Only one subject was in the room at a time. Sound levels were measured at the subject's head position in the absence of the subject. A substantially flat frequency response, meeting a 10 dB tolerance over the range of 80 Hz to 10 kHz, was obtained using a graphic equaliser.

Annoyance and impulsivity questionnaires were used to record the subjects' responses in both the pilot and the main study. The annoyance questionnaire asked, "How annoying would you find the noise you have just heard if you heard it indoors at home?", and was rated on a ten-point, unipolar scale from "not annoying at all" to "extremely annoying". Impulsivity was rated either "yes" or "no" in response to the question "Would you say the noise you have just heard is clearly impulsive?". Previous studies [3][4] indicated that impulsivity judgments might be influenced by having both questions on the same questionnaire sheet. In order to overcome this influence, the judgments in this study were made in two separate blocks: either all the annoyance judgments were made first and then the impulsivity judgments once those were complete, or the impulsivity block first and then the annoyance.

Pilot Study Design

Triangular envelope impulses were synthesised, and superimposed on background noise. The study used three envelope shapes (referred to as "shapes"), four impulse durations ("durations"), and three impulse equivalent maximum level to background level ratios ("I/B"), as shown below.

Shapes:	fast	rise	with	slow	decay
	medium	rise	with	medium	decay
	slow	rise	with	slow	decay
Durations:	53, 95, 180, and 350 milliseconds				
I/B:	0, 10, and 20 dB				

These give 36 different combinations. Both impulse and background sounds were synthesized by shaping random noise to have a long term spectrum representative of continuous road traffic noise. The combined sounds were each fifteen seconds long, the impulses being repeated at a rate of 1 Hz.

Twenty-four subjects took part in the pilot study. Each subject first rated all 36 combination sounds for annoyance with both 50 L_{Aeq} and 60 L_{Aeq} background sound levels (making 72 annoyance ratings in all). They then rated all 36 sounds for impulsivity with a background level of 55 L_{Aeq} (making a further 36 ratings).

Pilot Study Results

The effects on the annoyance ratings of background level, impulse to background ratio (I/B), and impulse duration were all statistically significant, but the effects of envelope shape were not. The effects on the impulsivity ratings of I/B and envelope shape were significant, but the effects of impulse duration were not. Thus annoyance was significantly affected by duration and not shape, whereas subjective impulsivity was affected by shape and not duration. After allowing for the effects of background level, there was a relatively strong relationship between annoyance and subjective impulsivity (see Figure 1). However, this relationship was confounded by a much stronger correlation between annoyance and the overall L_{Aeq}. A plot of annoyance against the increment of the overall L_{Aeq} over the background level (50 or 60L_{Aeq}) is shown in Figure 2.

Subjective impulsivity was quite highly correlated with this increment. As a result, it was not possible to determine whether the observed relationship between annoyance and subjective impulsivity was due to this correlation, or whether it was due to any underlying relationship between annoyance and subjective impulsivity.

Main Study Design

The pilot study showed differences between annoyance and subjective impulsivity in terms of their relationships with impulse duration and envelope shape. It was important to determine whether the same result would hold for real sounds. Therefore, all the sounds in the main study were reproduced at a constant L_{Aeq} of 55 dB in order to eliminate sound level as a confounding factor.

In a previous study [3], a sound was defined as "Objectively impulsive" if a difference greater than 4 dB was found between the true L_{Aeq} and a 'pseudo-L_{Aeq}', measured using an impulse time-weighting. Twenty sounds were chosen to represent the following four groups:

GROUP A:	Objectively impulsive,	Subjective impulsivity > 50%
GROUP B:	Objectively not impulsive,	Subjective impulsivity > 50%
GROUP C:	Objectively impulsive,	Subjective impulsivity < 50%
GROUP D:	Objectively not impulsive,	Subjective impulsivity < 50%

The sounds chosen are listed in Table 1. A sample lasting approximately 14 seconds was taken from each of the sounds. These samples were replayed forwards and backwards, equalised using a graphic equaliser, and recorded on to digital audio tape. Forty subjects took part in the main study. Twenty subjects rated all forty sounds for annoyance first. When the sounds were replayed (in a different order), the subjects were asked to rate them for impulsivity. The other twenty subjects were asked to rate the sounds for impulsivity first and subsequently for annoyance.

Main Study Results

Rating annoyance first or second had no significant effect on the annoyance ratings. An analysis of variance showed that the impulsivity ratings were significantly different if the subject had previously rated for annoyance. Because of their inexperience with the concept of "impulsivity", some subjects may have confused the impulsivity scale with the annoyance scale. Such a subject would think that if he had previously rated the sound highly annoying, he should also rate it as clearly impulsive; conversely, not annoying implied not impulsive. The subjects who rated impulsivity first would not confuse the two scales, but would be forced to make judgments based on their own understanding of impulsivity.

The effects on both the annoyance ratings and the subjective impulsivity ratings of sound and direction (forward or reverse) were statistically significant. Preferred, non-industrial sounds such as birdsong were rated low for annoyance and for subjective impulsivity, despite having high impulsivity when measured on objective scales. A further group of clearly recognisable sounds, such as church bells, outdoor tennis and car doors slamming were rated much less annoying when played forwards than when reversed. Presumably this was a result of their recognisability. For many of the remaining sounds, reversal tended to slightly increase annoyance while reducing subjective impulsivity. There was generally very little relationship between annoyance and subjective impulsivity (see Figure 3).

All the sounds were analysed in terms of a number of simple physical descriptors. One descriptor that had been suggested by previous studies was the difference between a 'pseudo-L_{Aeq}', measured using an impulse time-weighting, and the true L_{Aeq} (abbreviated to "$L_{Aeq}I-L_{Aeq}S$"). It had been suggested that when this metric exceeded 4 dB, the sound should be classed as "impulsive". However, this study showed only a very slight relationship between $L_{Aeq}I-L_{Aeq}S$ and subjective impulsivity, and absolutely no relationship between $L_{Aeq}I-L_{Aeq}S$ and annoyance. The relationships between the ratings and other simple physical measures were also investigated. These included percentile measures and peak level. No single physical descriptor was found which could reliably predict annoyance or subjective impulsivity for the entire data set.

DISCUSSION

The data do not support the common assumption that annoyance can be predicted by taking subjective impulsivity into account. There appears to be no simple causal relationship between annoyance and subjective impulsivity. Experimentally changing certain characteristics of both real and synthesized, impulsive and non-impulsive sounds can affect the annoyance and subjective impulsivity of those sounds in opposite directions. The only possible explanation for this finding is that there are many reasons for any one sound to be rated more annoying than another when presented at the same L_{Aeq}. Subjective impulsivity, if too narrowly defined by the subjects in any particular experiment, is only likely to be one of those possible reasons. Other causal factors for increased annoyance could be temporal or spectral irregularity, or even undesired contextual associations. In the context of industrial or shooting sounds, impulsivity ratings are not as important as annoyance ratings, since we are seeking to reduce the annoyance that these noises cause in the community. This study shows that further investigation of subjective impulsivity would not increase our understanding of annoyance in this context. Industrial sounds, if not strictly impulsive, will usually be tonal, irregular, or attention demanding in some other way, in comparison with a blander sound such as distant road traffic. Physical descriptors should take account of many or all of those factors that are associated with increased annoyance due to the impulsive nature of a sound, and not be constrained merely to subjective impulsivity, as this is wholly inadequate as a predictor of annoyance by itself.

RECOMMENDATIONS

The implications for guidelines for noise assessment, regulation, and control are as follows. In most cases, the L_{Aeq} contributions from each noise source will adequately explain the community annoyance response. However, in some cases there may be second order effects which cause increased annoyance. This would make it necessary to invoke statistical measures of the short term variability of the noise [1]. If the annoyance observed was still not adequately explained, it would then be necessary to invoke time-varying spectral measures using advanced digital signal processing techniques [2]. Thus a system would be adopted with the following hierarchy:

i) Combined values of L_{Aeq} from all contributing noise sources
ii) Statistical measures of short-term variability of the envelope
iii) Time-varying spectral measures.

In order to define the boundary conditions for such a measurement scheme, a field validation study needs to be conducted. Such a study should be based on open interview survey techniques, and should be applied (with appropriate controls) to sites with a well known complaint history.

REFERENCES

[1] B F Berry 1989 Proceedings of 13th ICA, Belgrade, "Recent advances in the measurement and rating of impulsive noise".

[2] R Bisping 1989 Proceedings of 13th ICA, Belgrade, "Steady versus impulsive noises: spectral parameters and subjective ratings".

[3] P Wright, I H Flindell 1988 Contract Report No. 88/8, "ISVR Laboratory Studies - Phase 1a.

[4] Official journal of the European Communities 33/23 7.3.1.

TABLE 1

Group	Sounds	Forwards			Reverse		
		LAI-LAS	Imp	Annoy	LAI-LAS	Imp	Annoy
A	Piledriver	10.4	95.0	7.625	11/2	87.5	7.300
	G55	8.9	97.5	7.550	9.2	87.5	6.925
	Outdoor Tennis	8.8	77.5	4.725	9.3	77.5	5.350
	Car Doors	7.9	72.5	4.375	8.6	80.0	6.400
	Scrapyard	6.9	67.5	5.750	6.8	52.5	6.075
	G55T55	4.8	80.0	6.050	5.4	37.5	6.250
	Church Bells	4.6	92.5	3.725	4.3	72.5	6.300
	Telephone	4.3	87.5	6.575	4.1	82.5	8.100
	Sawing Machine	4.2	90.0	7.000	4.5	70.0	6.550
B	Typewriter	3.6	97.5	6.100	4.0	90.0	6.375
	Fire Alarm	3.5	95.0	7.525	3.7	100.0	8.350
	Metal Beating	2.8	95.0	7.375	3.1	75.0	7.350
	Road Drill	1.7	95.0	7.875	2.4	82.5	7.300
	Lawnmower	1.1	77.5	6.900	0.9	72.5	7.000
C	Birdsong	4.8	25.0	1.200	5.4	32.5	1.600
	Drophammer	4.3	42.5	5.475	5.0	22.5	5.700
D	Diesel Taxi	2.9	30.0	4.900	3.2	22.5	5.225
	Boat Diesel	1.5	27.5	5.275	1.5	32.5	5.125
	T55	1.5	7.5	5.700	1.5	5.0	5.300
	Air Compressor	0.9	42.5	6.300	0.7	40.0	6.325

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Figure 2

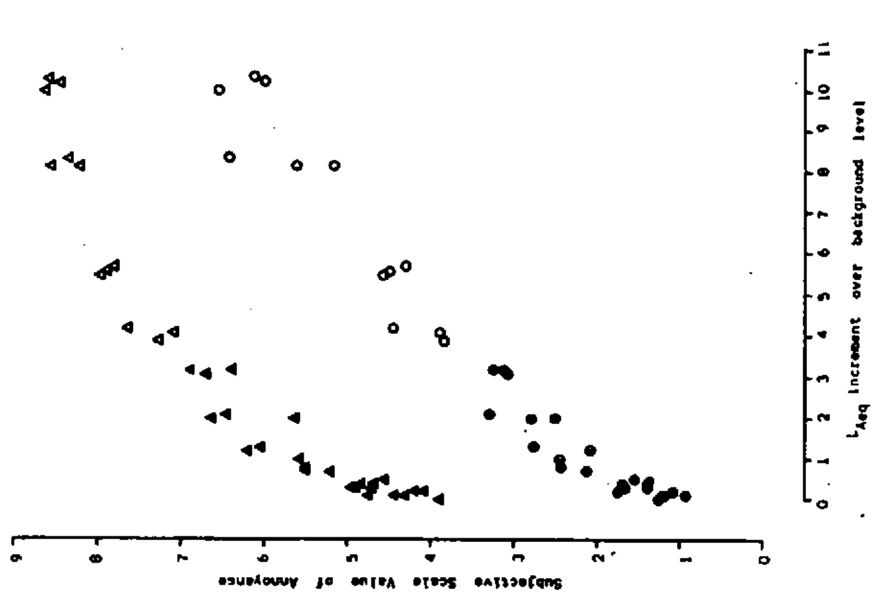


Figure 1

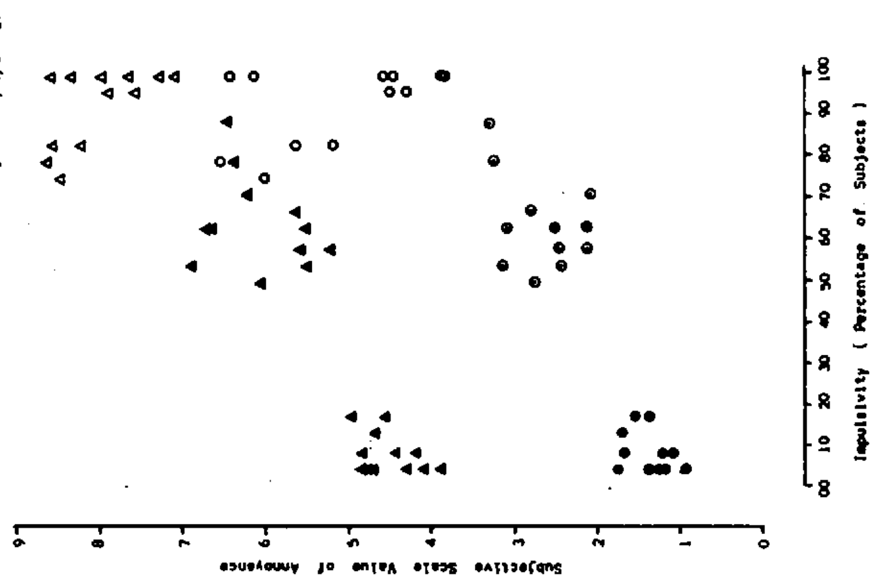
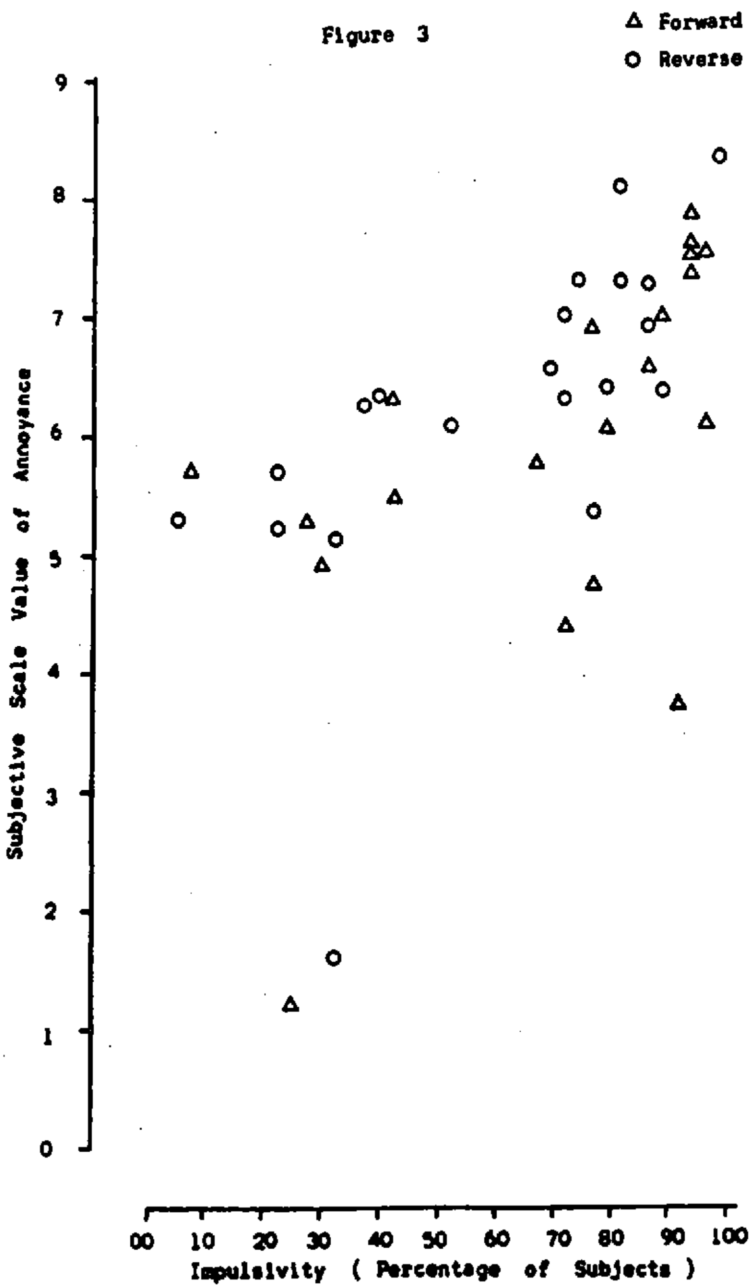


Figure 3


Δ Forward
O Reverse
Subjective Scale Value of Annoyance
0
1
2
3
4
5
6
7
8
9
00
10
20
30
40
50
60
70
80
90
100
Impulsivity (Percentage of Subjects)

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LOUDNESS OF LOW FREQUENCY IMPULSES

C W Dilworth

Department of Applied Acoustics, University of Salford

An investigation was made into the loudness of low frequency blasts, such as those generated by quarry blasting. A sealed booth, suitable for the simulation of impulses with a low frequency content, was available for the testing.

The booth was shown to be extremely susceptible to reflections and resonances within it. To try and eliminate these, the booth was lined with an absorbent.

A test method was devised whereby the effect of varying the delay between the individual impulses which make up a blast on the blast's subjective loudness could be investigated. The method used a paired comparison technique, and required a reference with which the test blasts were compared.

Due to the nature of the booth and the signals under test the reference signal chosen was a 20 Hz triangular wave. A level in phons could not readily be attached to this. Therefore a separate set of subjective tests was carried out, equating the reference to a sinusoidal wave, for which a level could be found.

The results obtained from the testing enable a set of equal loudness curves to be constructed. These show the effect of varying the peak over-pressure and the delay between individual impulses on the loudness of a low frequency blast.