inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 63.2

ROAD NOISE SUBJECTIVE ASSESSMENT IN CARS

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1. INTRODUCTION

Road noise is an important part of the overall noise in a car; it may be due to the tires themselves, or to the whole car structure which is excited by irregularities of the pavement, through the tires. The behaviour of the car's structure is very complex; its improvement needs sophisticated experimental tools [2]. Therefore, the knowledge of sound perception can help to focus on a solution which will really be appreciated by customers. The goal of this study is to determine the important perceptual characteristics of road noise and to find accurate physical parameters of its quality.

2. PRELIMINARY EXPERIMENT

Sound stimuli
8 cars, driving at different speeds (50, 70 and 90 km/h) on a smooth and a rough road, were used. These cars were from different sizes (small cars, medium size and luxury ones). Some of them were equipped with 3 sets of tires (Original Equipment and 2 other sets). The recordings were realised with a dummy head, located on the front passenger's seat.
Procedure
The whole recording database was too important to be correctly studied, so that it was decided first to evaluate the importance of tires and cars parameters. Two pair comparison tests were conducted. In the first one, the three medium size cars, equipped with their OE tires, were compared for different speed and road surface conditions. In the second one, three different sets of tires were compared, when mounted on one of these three cars.

18 people took part in the two listening tests. They listened to the stimuli through electrostatic headphones in a quiet room. The duration of

each sound of a pair was 10 s; the two sounds were separated by a 250 ms pause. The listener had to select the most annoying sound, using a five levels scale and to freely explain his answer.

Results

The preference probabilities of each pair were computed in the two cases. They lead to a global annoyance score for each of the 3 sounds. Theses scores are shown in table 1 (cars) and table 2 (tires). The significant distance between two scores, which depends on the number of sounds and listeners [1], is 11.

	Car n°1	Car n°2	Car n°3
Smooth 50 km/h	2.5	17	25.5
Smooth 70 km/h	2.5	18	21.5
Smooth 90 km/h	1.5	19.5	24
Rough 70 km/h	3.5	12	29.5

Table 1 : Annoyance scores for cars with OE tires

	Tire n°1	Tire n°2	Tire n°3
Smooth 50 km/h	11.5	13.5	20
Smooth 90 km/h	14.4	16.5	14.1
Rough 70 km/h	15.5	21	8.5
Rough 90 km/h	21.5	18	2.5

Table 2 : Annoyance scores for tires on car n°1

It can be seen that :

- tires are not often different in a significant way. This is only the case on a rough road, where a tire is better than the two other ones, the more so as speed is increasing. But this tire is a special one, designed for snowy roads and very soft; road irregularities are damped by this tire.
- differences between cars are more important. On a smooth road, these differences do not depend on speed; there is a sort of vehicle timbre for road noise, which is in accordance with a previous study [4].

3. MAIN EXPERIMENT

Procedure

The 8 sounds recorded in the cars driving at 70 km/h on a rough road were selected in that experiment. A semantic differential pair comparison method was used; 6 sound features were chosen according to what listeners have said in the previous experiment : Annoying, Loud, Regular, Dull, Rich and Cosy. As half a matrix was studied, each listener had to listen to 28 pairs. The test was driven by a PC computer, which sent instructions to a DAT recorder, showed the features to the listener as 6 scales on the screen, and recorded his answers in a file.

15 people took part in this experiment. Some of them (5) worked in the NVH team. The reliability of each listener was computed (as the number of circular triads for the whole set of sound features), so that two of them were taken out of the jury.

Annoyance results

As in the previous experiment, the preference probability of each pair and the annoyance score of each sound were computed. These scores are shown in table 3; the significant distance is 15.

	S1	S2	M1	M2	M3	L1	L2	L3
Score	59	90	28	63	42	45	55	39

Table 3 : Annoyance scores (S : small size, M : medium size, L : luxury)

It can be seen that differences between cars are very important and are not strongly correlated to the size of the car.

Comparison with the preliminary experiment

The 3 medium-size cars were compared twice for the 70 km/h rough road situation : once in their own context (preliminary experiment) and once in the context of the 8 cars (main experiment). Moreover, the listeners were not the same for the two tests. Nevertheles, the annoyance preferences probabilities between these three cars were very similar (Table 4), which proves the robustness of the subjective evaluation.

	M1 / M2	M1 / M3	M2 / M3
Prelim. exp.	0.77	1	0.95
Main exp.	0.64	0.74	0.7

Table 4 : Annoyance pref. probabilities for the three medium-size cars

Correlation between annoyance and the other sound features

In figure 1 is shown the relation between annoyance and loudness, as averaged for the 13 listeners; each point is one of the 28 pairs. The correlation is very strong (R = 0.96).

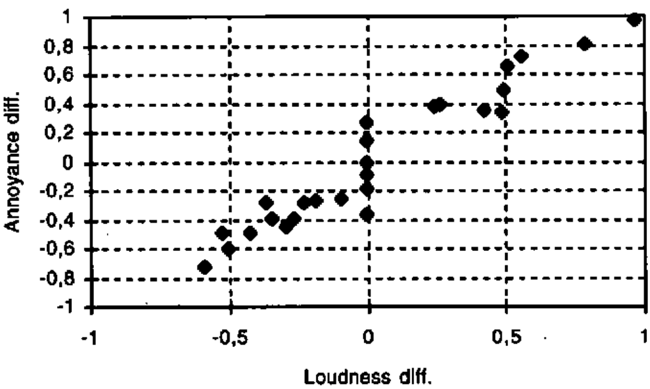

Fig. 1 : Relation between subjective loudness and annoyance

When the individual correlations between these two sound features are computed, two groups of listeners can be distinguished. In the first one (strong correlation), people have only used loudness to evaluate annoyance. In the second one, the correlations are weaker, which means that such listeners can use other parameters. 6 people belong to that second group and 4 of them are from the NVH department; therefore, this effect is related to the experience of listeners.

Description of subjective loudness

For each of the 8 sounds, were computed the overall A-weighted level and the Phone level, from the ISO-532 defined Zwicker's loudness. Then the differences in the 28 pairs were compared to the differences of subjective loudness.

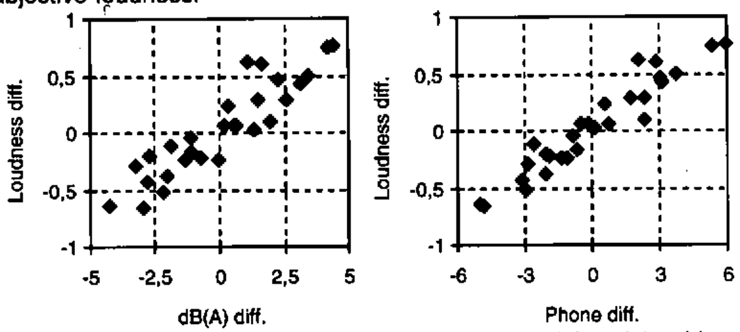

Figure 2 : Relation between subjective loudness and A-weighted level (left) and Phone (Right)

The correlation is slightly better for Zwicker's loudness than for A-weigthed level ($R = 0.95$ for the former, $R = 0.9$ for the latter). Nevertheless, it can be seen that A-weighted level can be used to get a first indication of subjective loudness. This rather good accuracy, which may not exist in ther cases of inside cars' noise [3], may be due to the fact that all these noises have a rather similar frequency content [5].

Aknowledgements

This work has been helped by the European Community (Brite program BE-7796).

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