inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.3

EVALUATION OF SOUND QUALITY OF CAR INTERIOR NOISE UNDER REAL DRIVING - THE DIFFERENCE OF SUBJECTIVE IMPRESSION BETWEEN DRIVER AND GUEST

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Keywords:
SOUND QUALITY, INSIDE VEHICLE, RUNNING CONDITION, DRIVER AND GUEST

ABSTRACT
The evaluation of sound quality of car interior noise will be different between a driver and a guest because the main task of the driver is to drive a car safely instead of judging the sound. On the other hand, the guest of a car has more free time to enjoy car interior noise. In order to investigate this difference under real car driving conditions, the real time response acquisition system was constructed utilizing a hand held personal computer for collecting time varying subjective evaluation on pleasantness, powerfulness, roughness and booming sensation. Each impression was judged by categories with five steps as like the usual SD method. The results obtained revealed that the impression of sound quality by driver was more moderate compared with that obtained by the guest seated at the rear seat.

1 - INTRODUCTION

In general, the evaluation of sound quality of car interior noise is conducted under a laboratory condition using recorded sound stimuli. This kind of approach has an advantage for the experimenter to ensure the reproducibility of the sound stimuli when they do evaluation tests with many subjects under the same sound exposure condition. But, under a real driving condition the driver and the guest of a car are exposed with seat and floor vibrations and see the passing sight around the car together with the exposure of interior noise. These factors other than noise itself may have an influence on the evaluation results. And the position of the seat where the subject is sitting and if he/she is a driver or a guest of a car may affect the evaluation results. In order to see these effects on sound quality evaluation, the test procedure under real driving condition must be employed. This paper describes the result of sound quality evaluation using cars under real driving to discuss the difference of the evaluation results obtained by the driver and by the guest seated behind the driver. Together with the subjective evaluations, the time variations of several sound quality parameters such as loudness, roughness, sharpness of the sound are calculated for discussing the relation between the subjective evaluations and objective metrics.

2 - APPARATUS FOR SUBJECTIVE EVALUATION

In order to obtain time dependent instantaneous subjective impression on sound quality of car interior noise, handheld personal computers installed a Visual Basic program developed at our laboratory for collecting subjective responses are used as input boxes. A computer with discrete ten key box is used for collecting impression of a guest sat on the rear seat (Fig. 1) and one with touch screen is used for collecting response of the driver (Fig. 2). For the driver seat, the computer is fixed on the stirring wheel by magic tapes. The numbers of sound quality attributes collected are four, namely, pleasantness, roughness, powerfulness and booming sensation. Each of these attributes is shown on the computer screen one after another after putting the category of the response into the computer by pressing the key or pushing the screen. The attributes have 5 categories relating polar adjective scales, i.e., pleasant − unpleasant, rough − smooth, unsatisfactory − powerful and not booming − booming. The representations how they appear on the computer screen are shown in Fig. 3.

Figure 1: Ten key box as an input box (guest).

3 - EXPERIMENT

Our main purpose for this experiment is to see the difference of the evaluated results on sound quality of real car interior noise under driving situation. Three passenger cars, i.e., cars A, B and C were used for this experiment. Car A: a FR (front engine rear drive) type medium sporty sedan with 4 cycle 6 cylinder gasoline engine, car B: a FF type (front engine front drive) small sedan with 4 cycle 4 cylinder gasoline engine and car C: a FF type medium sedan with 4 cycle 4 cylinder gasoline engine. 8 males and 1 female with normal hearing ability took part in this experiment as subjects. Two of them are riding in a car at one time as subjects one as the driver and the other as the guest sat on the rear seat. The subjects exchanged their roles as a driver and as a subject during the experiment. The total of twenty runs with three cars (6 runs for cars A and C, 8 runs for car B) were conducted. During the driving on a road the driver's and guest's impression on sound quality of car interior noise were collected by continuous semantic differential method in four attributes, i.e., pleasantness, roughness, powerfulness and booming sensation by utilizing hand held personal computers as the input device. The each run on a road was a set of 10 minutes real driving within a usual traffic. Together with the subjective evaluation, car interior noise was recorded binaurally by utilizing artificial head torso and the recorded sound signal was used for subsequent laboratory analysis on sound quality parameters, such as loudness, roughness etc. And the relation between the sound quality parameters and the subjective evaluation was examined.

4 - EXPERIMENTAL RESULTS

A part of the experimental results were shown in Figs. 4, 5, 6 and 7 for the driver 1 and the guest 1 and in Figs. 8, 9, 10 and 11 for the driver 2 and the guest 2. By carefully watching the results, the following tendency could be confirmed, i.e., the total numbers of evaluation by drivers were less than those obtained by the guests. The average number for the drivers was 21 times while the one for the guests was 31 times during the total of 20 runs each with 10 minutes continuous driving. This was because the drivers had to safely drive a car, so their attentions were paid more for driving and relatively shorter time was used for evaluation on sound quality than with the guests. The guests had more time to hear well about the car interior noise. This will be true at anytime concerning how many times the driver and the guest evaluate their impression on sound quality.

This relation was reflected on the evaluation of pleasantness-unpleasantness of car interior noise in Figs 4 and 8. The evaluations by the drivers 1 and 2 took lower scores in unpleasantness compared with those obtained by the guests 1 and 2. In this sense, the driver's response on unpleasantness was rather moderate. On the contrary, from the viewpoint of the guests, they had a tendency to respond severely.

Figure 2: Touch screen as an input box (driver).

5 - RELATION BETWEEN SUBJECTIVE EVALUATION AND METRICS

20 binaurally recorded car interior noises with their duration time 10 minutes were analyzed in terms of psycho-acoustical parameters such as loudness, sharpness, roughness (modulation) and roughness (hearing model) with respect to time and the relation between the psycho-acoustical parameters and the subjective evaluations were examined [1].

In the calculation of correlation coefficient, the total numbers of evaluations in terms of pleasantness, roughness, powerfulness and booming sensation over subjects mixed together for three cars respectively. So, the total numbers of the subjective evaluations for the drivers were 140, 167 and 114 for cars A, B and C respectively. Those for the guests sat on the back seat were 217, 236 and 171 for cars A, B and C respectively.

	unpleasantness		**roughness**		**powerfulness**		**booming sensation**	
	driver	**guest**	**driver**	**guest**	**driver**	**guest**	**driver**	**guest**
loudness	0,447	**0,721**	0,481	**0,693**	**0,581**	**0,744**	**0,510**	**0,556**
sharpness	-0,373	-0,461	-0,368	-0,397	-0,439	-0,474	-0,385	-0,307
dBA	0,333	**0,693**	0,490	**0,656**	**0,545**	**0,719**	0,499	**0,561**
roughness (m)	0,432	**0,686**	0,448	**0,681**	**0,551**	**0,719**	0,479	**0,541**
roughness (h)	0,472	**0,589**	0,428	**0,597**	**0,515**	**0,647**	0,478	0,448

Table 1: Correlation coefficient between subjective evaluation and metrics (car A).

	unpleasantness		**roughness**		**powerfulness**		**booming sensation**	
	driver	**guest**	**driver**	**guest**	**driver**	**guest**	**driver**	**guest**
loudness	**0,638**	**0,708**	0,387	0,453	**0,814**	**0,755**	0,043	0,187
sharpness	0,127	0,226	0,090	0,043	0,035	0,100	-0,116	-0,049
dBA	0,257	0,446	0,185	0,383	**0,670**	**0,632**	0,078	0,157
roughness (m)	**0,600**	**0,684**	0,359	0,425	**0,804**	**0,739**	0,052	0,168
roughness (h)	0,485	**0,597**	0,373	0,362	**0,704**	**0,635**	0,127	0,190

Table 2: Correlation coefficient between subjective evaluation and metrics (car B).

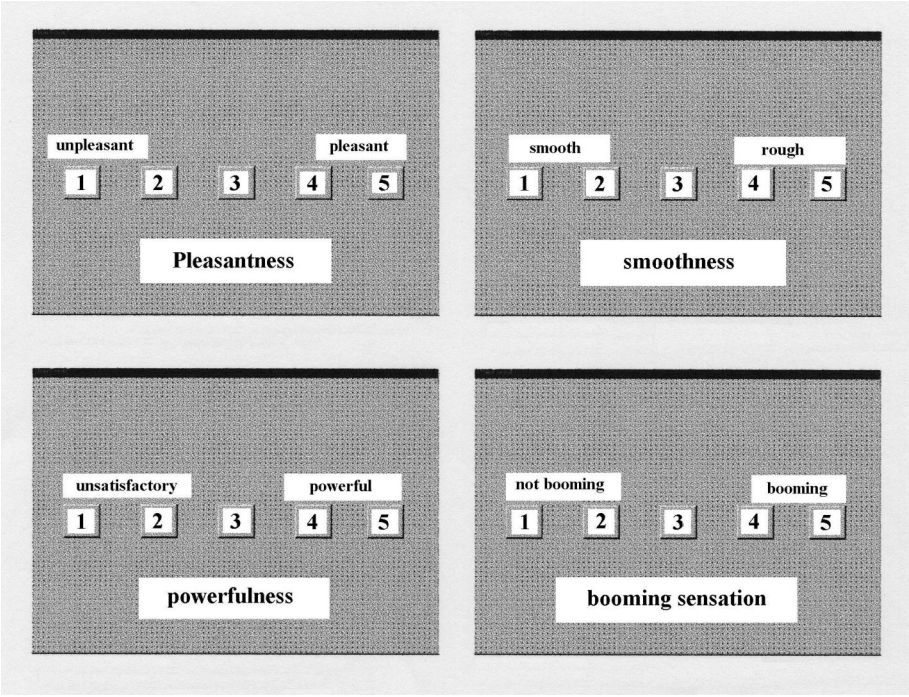

Figure 3: Representation of computer screen for the subjective evaluation.

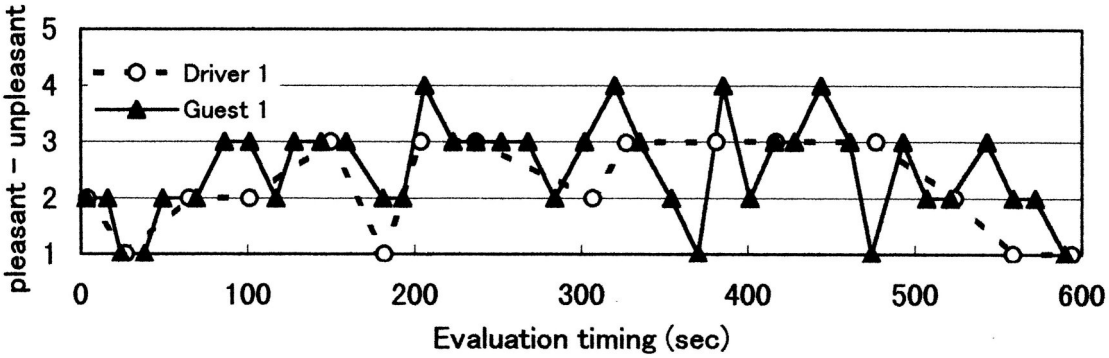

Figure 4: Subjective evaluation on pleasantness for driver 1 and guest 1 in a car A.

	unpleasantness		**roughness**		**powerfulness**		**booming sensation**	
	driver	guest	driver	guest	driver	guest	driver	guest
loudness	0,461	**0,59**	0,496	**0,520**	**0,687**	**0,719**	0,176	0,376
sharpness	0,052	0,176	0,138	0,132	-0,080	0,091	-0,027	-0,128
dBA	0,287	0,481	0,490	0,377	**0,553**	0,479	0,306	0,362
roughness (m)	0,493	**0,602**	0,488	**0,525**	**0,676**	**0,735**	0,129	0,355
roughness (h)	0,432	**0,500**	0,372	**0,509**	**0,610**	**0,707**	0,114	0,323

Table 3: Correlation coefficient between subjective evaluation and metrics (car C).

On the whole, the correlation for guests took higher values than that for drivers. Unpleasantness, roughness and powerfulness of the car interior noise related with loudness, dBA, roughness (m) and roughness (h). Booming sensation related with loudness, dBA and roughness (m).

6 - CONCLUSIONS

- The computer program for continuous SD method was developed and this method was applied for sound quality evaluation on car interior noise under real driving.

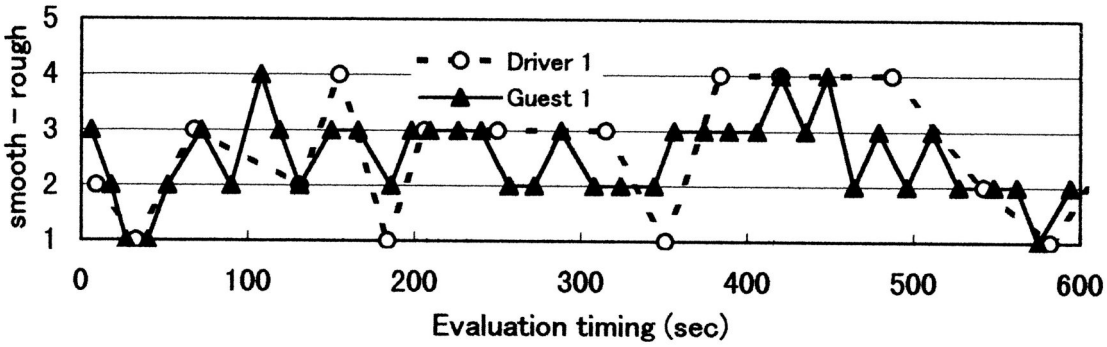

Figure 5: Subjective evaluation on roughens for driver 1 and guest 1 in a car A.

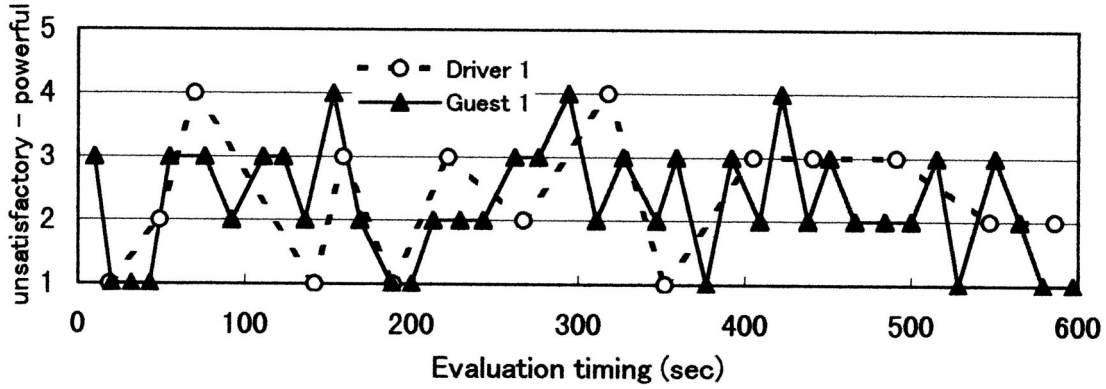

Figure 6: Subjective evaluation on powerfulness for driver 1 and guest 1 in a car A.

- The numbers of evaluations by a driver was smaller than that by a guest.
- Evaluations on unpleasantness was more severe by a guest and those by a driver was rather moderate.
- Correlation by guests were greater than those by drivers in general.

REFERENCES

1. **E.Zwicker, H.Fastl**, *Psychoacoustics, Facts and Models*, Springer-Verlag, 1990

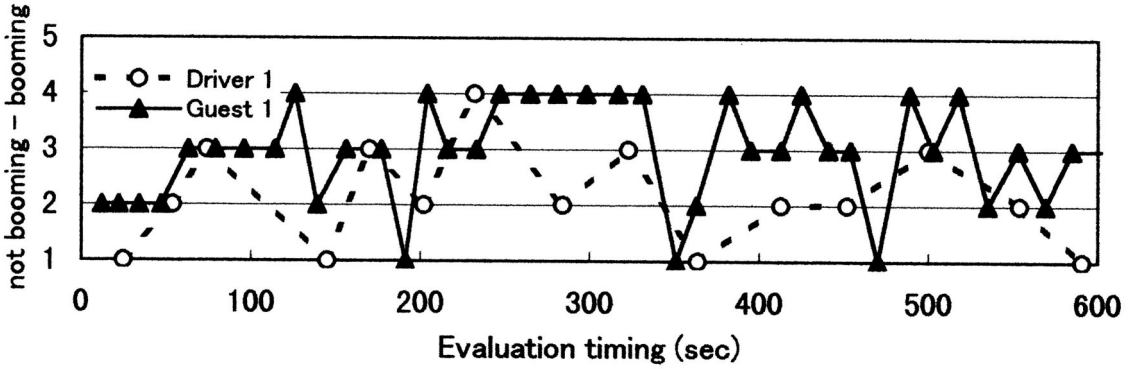

Figure 7: Subjective evaluation on booming sensation for driver 1 and guest 1 in a car A.

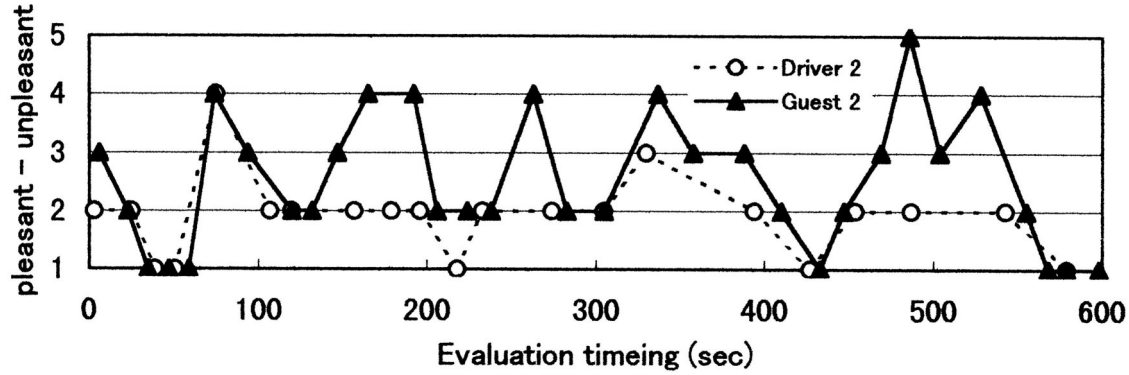

Figure 8: Subjective evaluation on pleasantness for driver 2 and guest 2 in a car A.

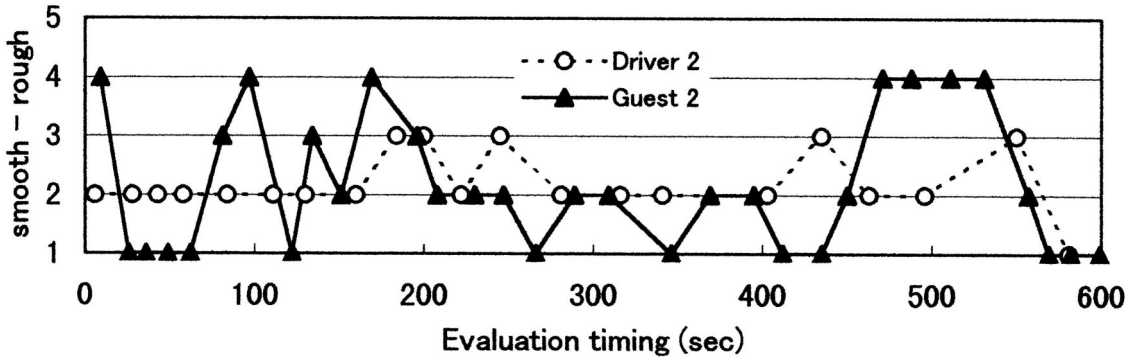

Figure 9: Subjective evaluation on roughens for driver 2 and guest 2 in a car A.

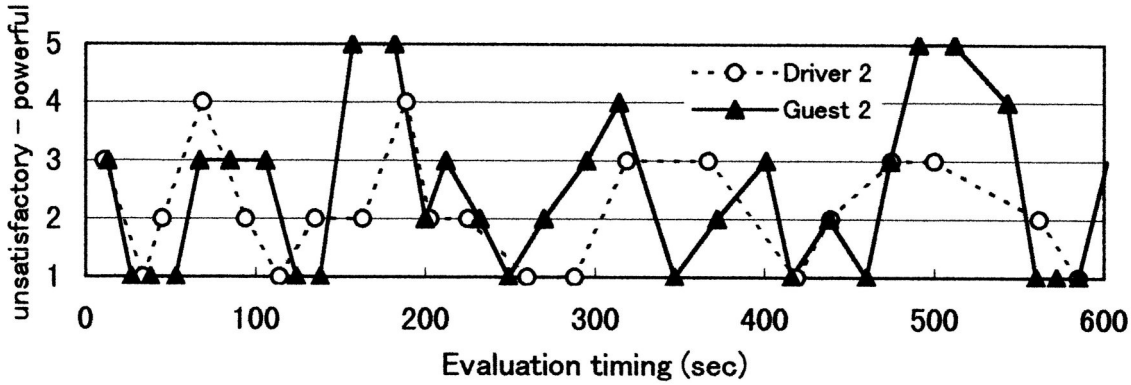

Figure 10: Subjective evaluation on powerfulness for driver 2 and guest 2 in a car A.

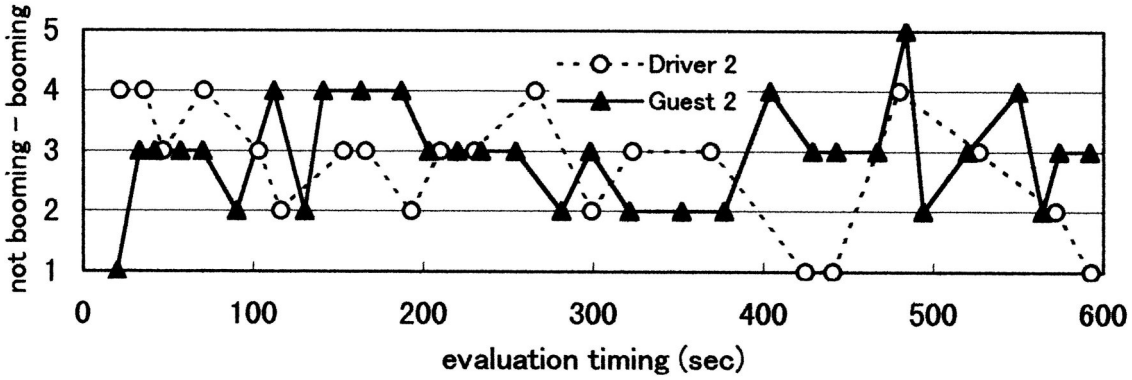

Figure 11: Subjective evaluation on booming sensation for driver 2 and guest 2 in a car A.