IMPROVEMENT OF DUMMY HEAD RECORDINGS REALISM WITH AN ADDITIONAL SUBWOOFER

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ABSTRACT

This study had the aim to assess the interest to add a sub-woofer emitting very low frequencies to binaural recordings through headphones. It had been carried out for interior noises of two trucks. Listeners were professional drivers of the manufacturer; they had to assess the realism of these recordings calling on their ability of memorizing the actual situation.
The results show the difficulty of this task. Nevertheless, the beneficial effect of the additional sub-woofer could be emphasized for one of the vehicles, the noise of which having its maximal energy in very low frequencies.

INTRODUCTION

The classical way of playing back binaural recordings foresees the unique use of high fidelity headphones. However, the low frequency content of signals can also be felt in the actual situation through the entire body (especially vibrations through the thorax) This mode of perception is obviously absent when listening through headphones. The increase of realism obtained by adding a sub-woofer to headphones has already been cited [1], [2] but not yet quantified. The purpose of this study was thus to precisely evaluate the increase of realism due to an additional sub-woofer.

EXPERIMENTAL SET-UP

The reference experimental set-up consists in the use of Sennheiser HD 600 headphones alone.
The tested one consists in using, in addition to these headphones, a sub-woofer (Altec Lansing DTS 182A), which emits the low frequency part of signals, defined as the low output of a cross-over filter (Altec Lansing 1632A), the high output being always directed towards the headphones. These headphones are open ones; therefore, the sound emitted by the sub-woofer is caught by the listener through his body and his ears.
This installation was made in the listening room of the laboratory. This room has small dimensions (3,65 *m* x 2,80 *m* x 2,65 *m*); as a consequence, its first mode is of a frequency of 45 Hz. The cross-over frequency had been fixed to 63 Hz, as it is necessary to correct the effect of the modes of the rooms in the global answer of the system.

The gains of the installation had then been adjusted so that transfer functions, measured from an acoustic dummy head (Bruel and Kjaer type 4100), are similar for the reference and the experimented set-ups (figure 1).

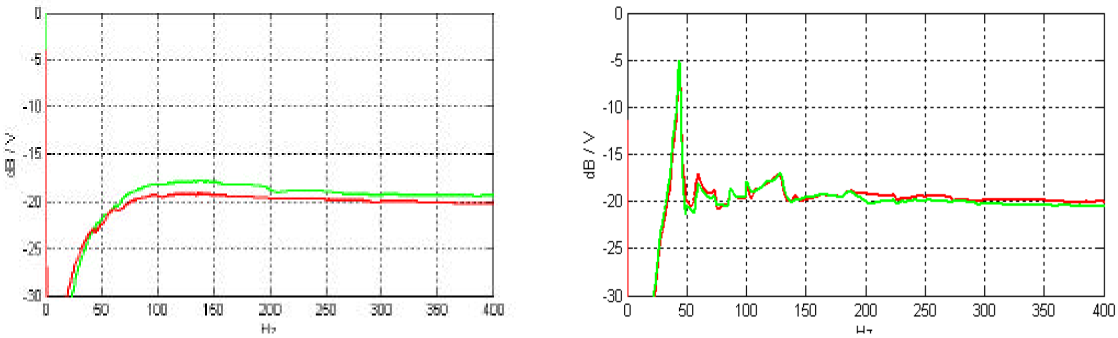

Fig. 1. Transfer functions of the set-ups. Left : headphones alones; Right : headphones and sub-woofer

Figure 1 (right) shows the effect of the first mode of the room (45 Hz), which has been corrected by an additional filtering of the signals which are to be reproduced by the whole installation (IIR filter, f_0 = 45 Hz, order 2, bandwidth 5 Hz and attenuation 12 dB, applied by the Sound Quality software from Mts).

EXPERIMENT

Stimuli

The interior noise of two trucks driving at a constant speed has been recorded with a BHM binaural probe from Head Acoustics (this probe is to be put on the driver's ears). Each of these signals was then filtered in four different ways so as to correct the influence of the measurement device (this being part of another study). So, a set of ten stimuli was prepared for each vehicle : five to be presented through headphones only, and five through headphones and subwoofer. The latter five stimuli corresponded to the five first ones, excepted they were filtered as described above, in order to eliminate the influence of the first acoustic mode of the room. The electrical gain has been adjusted so that the level of presentation of a signal corresponded to the real level measured in the cabin.

Procedure

Each listener participated to two series of listening tests (one by vehicle). First of all, they were given explanations concerning the type of vehicle and its accurate driving conditions : engine rpm and gearbox ratio. Each of the 10 stimuli was presented in a random order for each vehicle; an experimenter had to commute between the two possible modes of restitution. The listener had to assess the realism of the sequence he heard using a continuous scale graduated in an indicative way in 5 levels (from "completely unrealistic" to "very realistic") after listening tothe sound (that he could repeat as often as he wanted). He was also asked to explain his answer, giving the elements which allowed him to assess the realism of restitution, his comments being written down by the experimenter.

Listeners

19 professional drivers from Volvo - Renault VI participated to the experiment. These people are in charge of the subjective assessment of the overall performances of lorries under development, and spent a large part of their time in driving. Thus, they seemed to have the best internal sound image of vehicles, which allowed them to carry out the required task in the best way.

Three of the 19 individuals hadn't the required experience to assess one of the vehicles, so these ones only achieved half of the test. Three others were also acoustic experts of the company.

RESULTS

Difficulty of the task

It appeared that the assessment of the realism of stimuli is very difficult even for professional drivers ! This is shown on figure 2 which presents the different listeners answers (coded between 0 : totally unrealistic and 1 very realistic) for one of the signals.

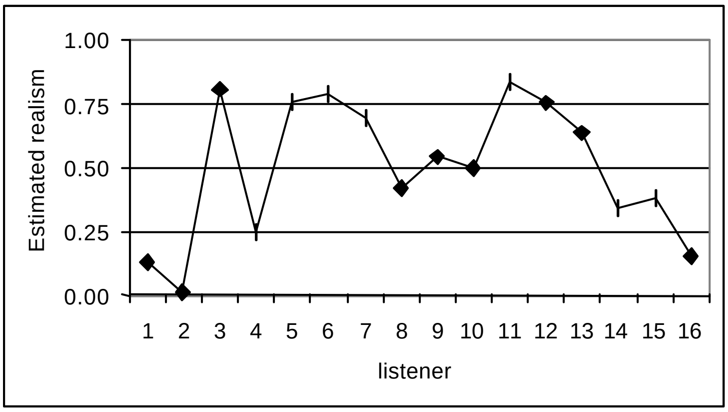

Fig. 2. Individual answers for one stimulus

This difficulty is also visible with a strong order effect : the answers given for each stimulus depend on the order according to which vehicles are presented to the listener. This effect is represented on figure 3 for one of the trucks. Stimuli are referenced by numbers, indicating the filtering (0 corresponding to no filtering) and by the *sw* suffix indicating the use of the additional sub-woofer. The black diamonds curve is the average over drivers who had to evaluate that vehicle first; the open diamond one is the average over the other half of the jury, who was presented the stimuli corresponding to the other truck first.

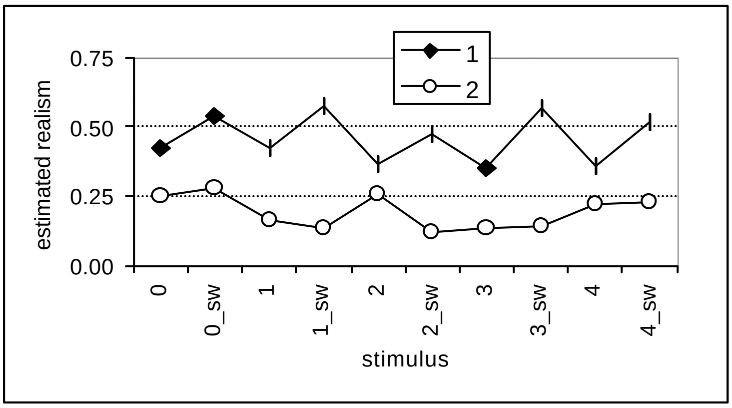

Fig. 3. Average realism for a vehicle whether it has been assessed in a first or in a second step.

Individual results have been weighted by a number between 0 and 1 so as to take into account the different driving experience of each tester. One of the consequences of this weighting is to suppress the order effect (figure 4). This can be an indication that the order effect can be controlled by the experience of the listener.

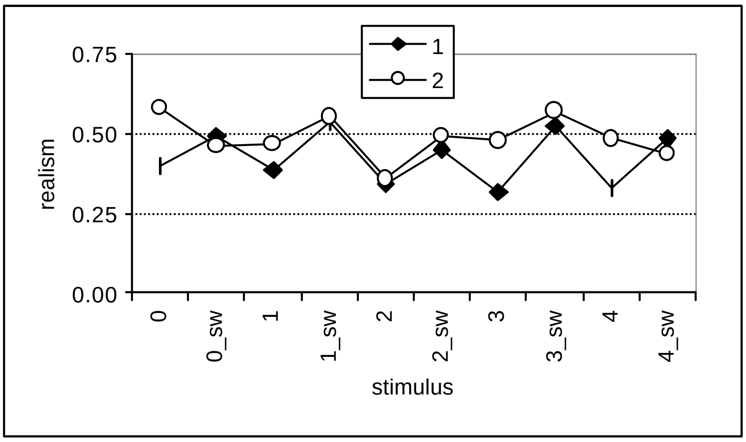

Fig. 4. Average realism of the vehicle in figure 3 after weighting of individual results.

Influence of the additional sub-woofer

The difference of averaged estimated realism between the complete installation and headphones alone has been computed (table A) for each vehicle and filtering.

Filtering	Veh. A	Veh. B
0	0.05	0.01
1	0.10	0.18
2	0.05	0.14
3	0.12	0.22
4	0.00	0.14

Table A. Improvement of realism when using the additional sub-woofer

The use of the sub-woofer doesn't improve the realism of the signals recorded in vehicle A; this is confirmed by an ANOVA of the results (the increases are not significant). But its contribution is highly significant for vehicle B. ($F_{(1;8)}$ = 20,88, $p<0.005$).

This difference between the vehicles can be linked to frequency contents being different from signals : vehicle B has much more important levels in low frequencies (figure 5).

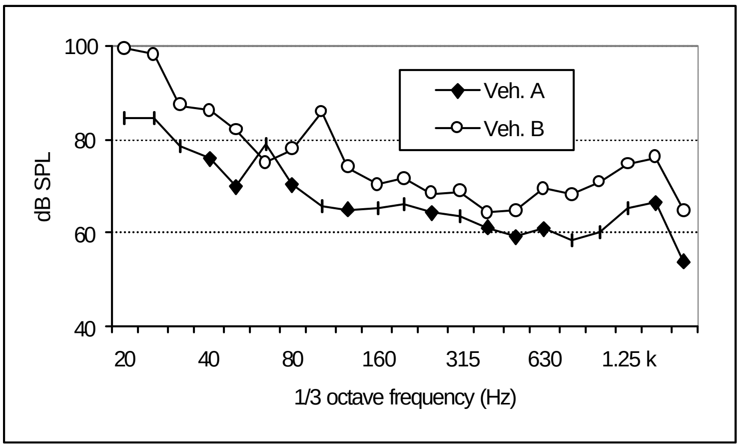

Fig. 5. Spectra of 1/3 octave for both noises (binaural average)

Exploitation of listeners’ comments

Listeners’ comments, written down during the experiment, have been roughly analyzed by counting the numbers of both positive and negative verbal units (that is to say mentioning favorable or unfavorable sound aspects to the estimated realism). The difference between these two numbers gives an indication of the average realism of the stimulus. These values have been computed without weighting from listeners. The comparison between the obtained values shows the increase of the realism which has already been mentioned (figure 6) for each filtering with the headphones alone and using the additional sub-woofer.

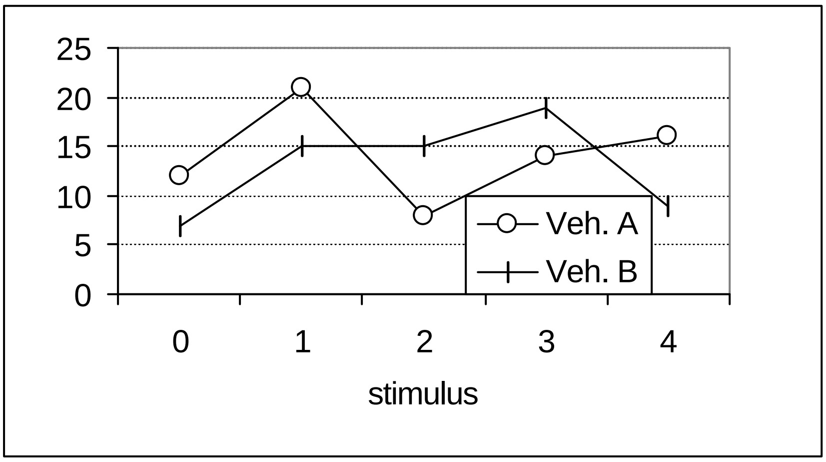

Fig. 6. Increase of realism through the additional sub-woofer considered from listeners’ comments.

Paradoxically, the comments that were made when hearing sounds through headphones only often emphasized a too high level of low frequencies. This was not the case when the same signal was heard with the contribution of the sub-woofer, even if physical levels, measured to the ears of the listener, were similar in both situations (figure 1). .This auditory sensation can thus be explained because of the absence of sensations through the body, revealing the importance of this mode of perception.

CONCLUSION

This study shows the interest to use an additional sub-woofer in addition to the headphones usually used for the restitution of binaural recordings. It allows to significantly improve the realism of sound occurrences presented to listeners, when signals have particularly high levels in the first thirds of octave of the auditory spectrum. (more than 85 dB).

The impact of this increase of realism on the subjective appreciation of sounds remains to be assessed. Will the hierarchy be different if the listening test is conducted with or without the use of this subwoofer ?

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