



Hearing loss simulator for sound quality applications

Etienne PARIZET¹; Nicolas GRIMAUULT²; Samuel GARCIA²; Alexandra CORNEYLLIE²;

Laurent BROCOLINI¹

¹ Laboratoire Vibrations Acoustique INSA-Lyon

² Centre de Recherche en Neurosciences de Lyon

ABSTRACT

Most sound quality studies are conducted using normal hearing listeners, while many people suffer from mild to moderate hearing losses. On the other hand, recruiting subjects with a controlled hearing threshold can be difficult. To tackle this issue, a hearing loss simulator has been developed as part of the France funded AIDA project. This real-time simulator uses the approach proposed by Irino (2013). Using a gamachirp filters analysis, it aims at replicating the increase of hearing threshold, the widening of the auditory filters (depending of the level in the band) as well as the modification of the loudness curve. This simulator has been validated for speech intelligibility measurements. First of all, 76 people over 55 years old participated to the measurement of speech reception thresholds in cars. A sub-group of these participants suffered from hearing losses from 40 to 50 dB and were used as a reference group for the following. The experiment was replicated with 20 young normal-hearing participants - noise and speech being modified by the hearing loss simulator in order to replicate the averaged losses of the reference group. This simulator could be used to evaluate product sound qualities as perceived by hearing impaired customers.

Keywords: Speech intelligibility, hearing impairment. INCE Classification of Subjects Number(s): 63.3, 63.7

1. INTRODUCTION

The aim of the AIDA project is to increase the intelligibility of speech messages produced by a car (e.g. GPS messages) for drivers suffering from slight to mild hearing losses without hearing aid devices. Speech modification algorithms will be developed and the enhancement of intelligibility will have to be evaluated with listeners exhibiting a given hearing loss profile.

Unfortunately, recruiting such subjects can be very difficult. This is the reason why, as a first step of the project, a hearing loss simulator has been developed. The goal of this simulator is to modify sounds so that they can be presented to a normal hearing listener as if he had a given hearing loss.

This paper will present the simulator and a first evaluation of its accuracy.

2. HEARING LOSS SIMULATOR

Basic principles

The simulator is based on the approach proposed by Irino (1). The general idea is to combine a passive gammatone auditory filter with a high-pass filter. The cut-off frequency and gain of this second filter depend on the intensity computed at the output of the passive gammatone filter. On the contrary to the classical dynamic gammachirp auditory filterbank, the resulting filterbank is a bank of filters with lower gain and enlarged bandwidth for low level input signal. When combined with the real auditory filterbank of the listener, such a filter design is supposed to simulate a lesion of the outer inner cells and enables to simulate a moderate hearing loss from about 0 to 60 dB HL.

¹ etienne.parizet@insa-lyon.fr, laurent.brocolini@gmail.com

² nicolas.grimault@cnrs.fr, alexandra.corneyllie@cnrs.fr, samuel.garcia@cnrs.fr

Implementation

The implementation of the simulator is shown in figure 1. Computations are done in time-domain, in 32 frequency bands. Both the CPU and the GPU of the computer are used, as computations are time-consuming (and should be conducted in real-time).

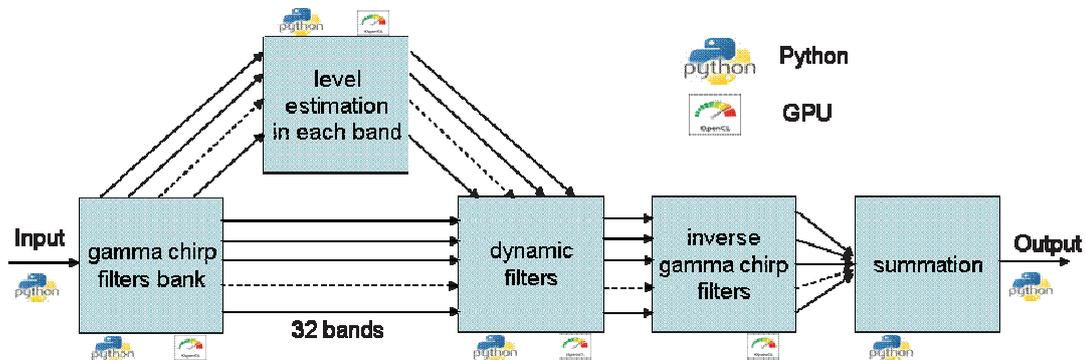


Figure 1 – Hearing loss simulator implementation

Two versions of the simulator exist. The first one can be used in a laboratory. In that case, the hearing loss simulator is inserted between the main computer running the experiment (e.g. speech intelligibility evaluation) and the headphone (or loudspeaker) used to present the stimuli to the participant. In this case, real time is not mandatory.

The second version is intended for in-situ applications. The participant has to get very high-quality active noise cancellation headphones, so as to be very well isolated from ambient noise. Two microphones located on the headphones (on the left and right side) record the outer noise; signals from these microphones are modified according to figure 1 and presented to the participant's ears using the loudspeakers of the headphones.

3. INTELLIGIBILITY EXPERIMENT

Two experiments were conducted in order to evaluate the accuracy of the simulator. Both used a french version of the Four Alternative Auditory Feature Test (2, 3). The four alternative features were words differing in their final consonant (9x4 presentations for each S/N ratio).

First experiment

Three noises recorded in a car were used. The speed of the car was 50, 90 or 130 km/h; noise level being respectively 47, 57 and 54 dB(A) (the second one being louder as the car drove on a rough road).

76 participants were recruited, most of them on an age criterion (older than 55); 10 additional subjects were younger but suspected to have hearing losses. First of all, their tonal hearing thresholds were measured (for reasons of speed, thresholds lower than 20 dB were not looked for, as hearing ability can be considered as normal up to this value). Then, speech-reception threshold was measured in each of the three noises and in silence.

Listeners were characterized by their Best Pure Tone Average at 0.5, 1, 2 and 4 kHz (BEPTA) and can be separated in three groups :

- in the first one (39 people), the averaged BEPTA was 22.3 dB HL;
- in the second one (25 people), the averaged BEPTA was 30 dB HL
- in the third one (12 people), the averaged BEPTA was 40 dB HL.

No age difference appeared between these groups (the averaged ages being 63, 66 and 62).

Averaged thresholds, computed over the three groups, are shown in figure 2.

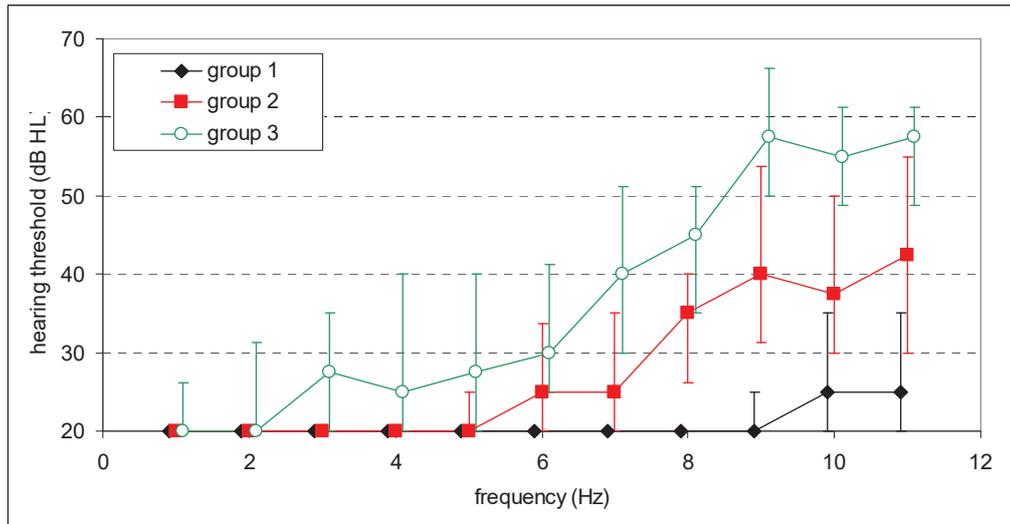


Figure 2 – Averaged hearing thresholds

As it could be expected, speech-reception thresholds showed the same trends (figure 3). The increase of SRTs between groups 1 and 3 are 12 dB in silence condition and between 8 and 10 dB in noisy conditions.

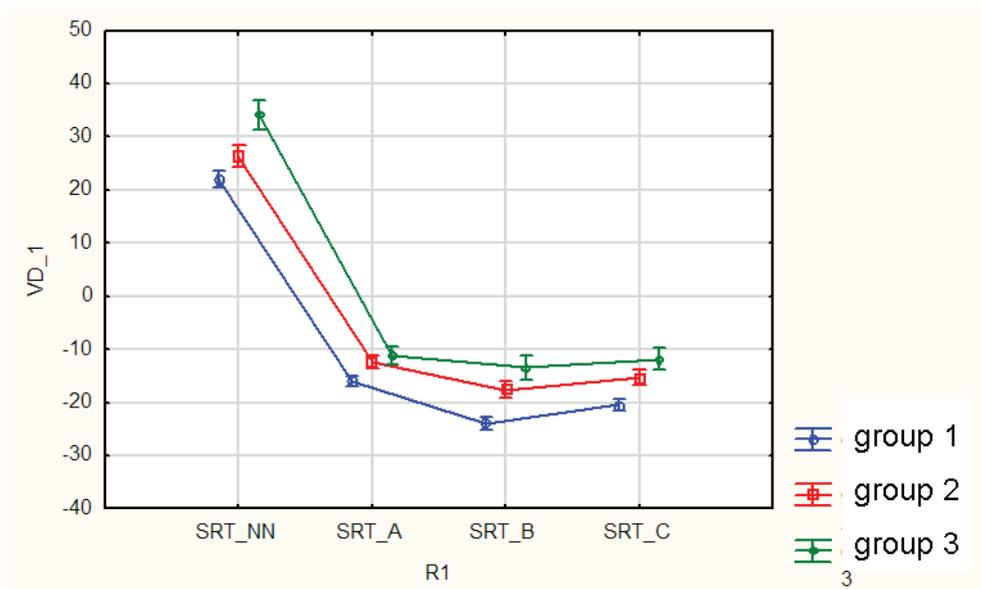


Figure 3 – Speech reception thresholds, computed over the three groups of participants

Second experiment

In the second experiment, 24 normal hearing listeners aged from 20 to 26 were recruited (except for one of them who was 35). Speech reception thresholds were measured for two of the previous noises only (50 and 130 km/h). This was done in two conditions : in the first one, the hearing loss simulator was not used, which provided values representing the actual hearing ability of subjects. In the second condition, the hearing simulator was used to simulate the mean hearing loss of the third group of subjects in exp. 1.

Results are summarized in figure 4.

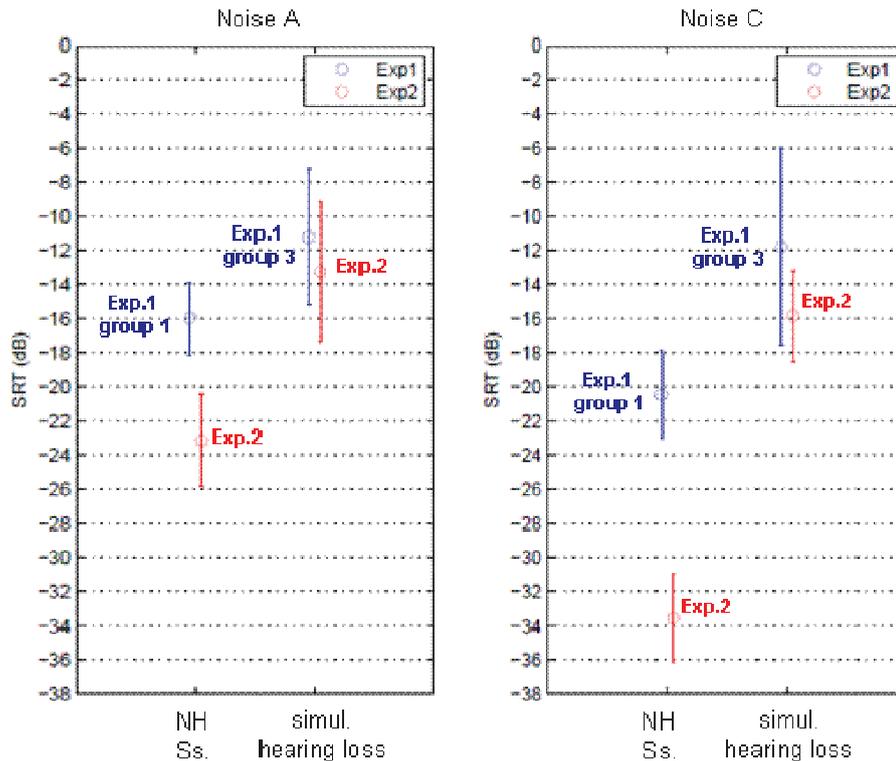


Figure 4 – Comparison of the results of the two experiments.

In this figure, blue data represent SRTs obtained in the first experiment, for the first group of subjects (normal hearing listeners) and the third one (hearing impaired listeners). Red data represent SRTs obtained in the second experiment, without (on the left size of each panel) and with the simulation of the averaged loss of the third group.

The main finding is that the simulator allowed to get data close to the one of real hearing impaired subjects.

On the other hand, there is a clear difference between the "normal-hearing" results measured in the two experiments. Two hypothesis can be made to account for this difference :

- hearing threshold is probably close to 0 dB HL for the young normal hearing subjects of the second experiment. In the first one, thresholds lower than 20 dB HL were not looked for. But, because of the averaged age of exp. 1 participants, it can be expected that their threshold is higher than 0 dB HL;
- age increases SRT, whatever the hearing threshold (approx. 3 to 5 dB, as measured by Fuellgrabe et al. (4)).

4. CONCLUSIONS

The efficiency of the simulator has been evaluated using speech-reception threshold measurements. In the following, other experiments will evaluate how this simulator modifies psychoacoustic parameters of normal hearing persons (e.g. auditory filter bandwidth or cochlear input-output function).

This simulator could also be used for sound quality applications. In most studies, listeners have normal hearing, while the industrial product can be used by older people. As these studies may require a high number of participants, the simulator will provide an easy way to evaluate the perception of sound quality by people suffering from presbycusis.

Such a simulator enables to compare several hearing loss profiles within the same listeners and reduces the inter subject variability.

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