Perceptual and physical evaluation of loudspeakers

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Introduction

Although listening is the final goal of sound reproduction, normalized measurements used nowadays to compare loudspeakers do not take into account our perception of audio sources. Aiming to a wider assessment of reproduced sound, we decided to evaluate a panel of loudspeakers in two parallel ways: physical measurements and perceptual ones. We look for relationships between these two approaches, examining the way they differentiate loudspeakers. This paper presents our protocol and preliminary results.

Protocol

Many studies have already been done on the perception of reproduced sound. It led to the publication of recommendations concerning listening tests on loudspeakers [1], [2].

The perception of the sound radiated by a loudspeaker is greatly influenced by the room in which it is used, by the positions of loudspeaker and listener, by the chosen musical excerpt and sound level. All these parameters have to be rigorously controlled for loudspeakers to be tested in the same conditions and listening tests to be valid. Moreover, if one wants to evaluate differences between loudspeakers directly, they have to be compared one just after the other due to our short auditory memory. As our final goal is to find relationships between the physical and perceptual approaches, physical measurements have to be done in strictly the same environment as psychoacoustical ones, and preferably at the same time, as we would be sure to measure the same sound field along both approaches.

To deal with all these constraints, we decided to record loudspeakers at one single position in a usual room, and to run listening tests using headphones. Both the recording phase and the reproduction using headphones introduce distortions into the signal to be delivered to the ears of the listener. But these distortions are the same for each loudspeaker and we aim to measure the relative differences among loudspeakers, not their absolute qualities. This protocol allows physical measurements to be done while recording. During psychoacoustical tests, we can switch between loudspeakers in few seconds. Because of the listening through headphones, the spatial dimension of sound reproduction is not investigated. So, our study focuses on the restitution of timbre.

Experimental conditions

We recorded twelve different loudspeakers, using various musical excerpts and recording techniques. We ran the psychoacoustical experiments using three recording techniques: stereo AB ORTF, stereo MS , and mono omnidirectional recordings. Three musical excerpts were chosen: Kan'nida (percussion, 1.7 s.), Mc Coy Tyner (jazz, 3.3 s.) and Vivaldi (symphonic orchestra, 4.7 s.).

There were five listening tests. The first set of three tests involved stereo AB ORTF recordings, with one excerpt by test. The second set of two tests kept only the excerpt Kan'nida and used stereo MS recordings for one test and mono omnidirectional recordings for the other.

Each test consisted in the evaluation of perceptual similarities between the recordings of the loudspeakers. The twelve recordings were presented by pairs to the listener, in random order. The listener had to quantify the similarities within each pair by adjusting a cursor on a line whose end points were labelled "very similar" and "very dissimilar". For each test, the recordings were equalized in overall loudness, as judged by the experimenters. Twenty-seven normal-hearing listeners took part in the first set of tests, and fifteen of them were involved in the second set. None of the listeners was trained to loudspeaker comparison.

It must be noticed that we found such short musical excerpts very suitable for the evaluation of (dis)similarities.

Results of psychoacoustical experiments

The similarity data were analysed using a multidimensional-scaling technique [3]. The result is a two-dimensional auditory space (Figure 1), showing that listeners have used two main perceptual attributes or dimensions to differentiate the loudspeakers.

The auditory space is stable through the different musical excerpts and recording techniques: the two dimensions remain the same in every cases. The fact that relative positions of loudspeakers are slightly changing between the various spaces is not a surprise. It shows the influence of both the excerpt and the recording technique. This influence has been confirmed by an analysis of variance (ANOVA).

As expected, one can notice that the loudspeakers 7 and 8, two loudspeakers of the same model, stand very close together in the auditory space.

Only the relative positions of loudspeakers 2 and 5 are greatly changed, as seen on the space corresponding to the omnidirectional monophonic recording. We think this might be explained by specificities [4]. Further analysis using a more powerful MDS program is required.

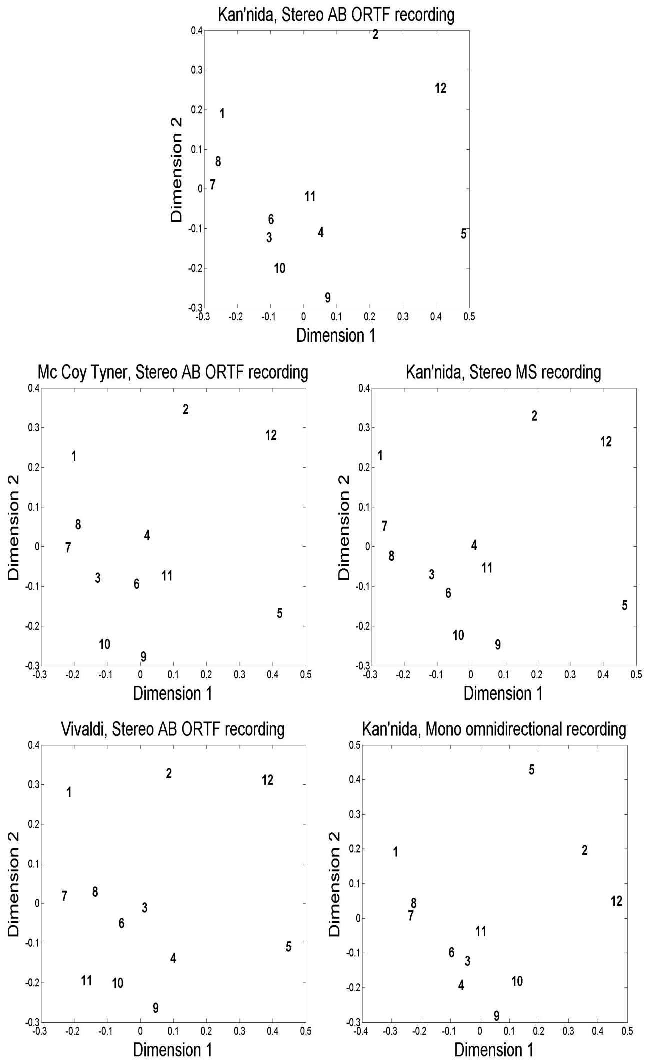

Figure 1: Discrimination of loudspeakers by perceptual measurements. Auditory spaces obtained for the different recordings, each number corresponds to a loudspeaker.

Preliminary physical measurements

As preliminary physical measurements, we used a program evaluating the loudness of non-stationary sounds [5] on the recordings used during the listening tests. For each recording, we determined the percentile loudness N10, i.e. the loudness reached or exceeded 10% of the time, within each critical band. Figure 2 shows how the resulting curves or "profiles" differentiate loudspeakers.

We defined two "geometrical" attributes from these curves. The first one is the slope of the linear regression of the curve between the critical bands 2 and 15 (corresponding to the frequency range 90-4500 Hz). It can be seen as an evaluation of the "bass-medium balance". The second one is the centroid of the curve between the critical bands 5 and 15 (frequency range 355-4500 Hz), corresponding to the "centroid of medium frequencies". The first attribute orders the loudspeakers in the same way as dimension 1 of the auditory spaces of Figure 1, and the second attribute seems to explain the distribution along dimension 2. These are only preliminary results and more investigations have to be done for this physical approach.

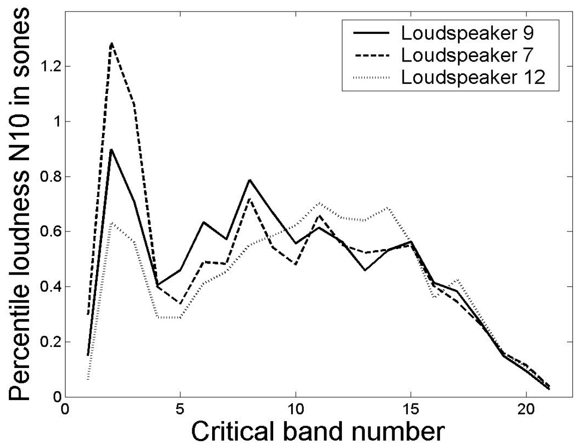

Figure 2: Discrimination of loudspeakers by preliminary physical measurements.

Conclusion

Listeners can differentiate loudspeakers even comparing them through headphones. Our protocol offers strict control of experimental conditions and is fully compatible with physical measurements. It is particularly useful for the direct evaluation of differences between many loudspeakers. Our first listening tests showed that listeners have used two perceptual attributes to differentiate loudspeakers. These attributes were independent of the tested recording techniques and musical excerpts. Our protocol seems suitable for further investigations at least on these two dimensions. Our preliminary physical measurements link these dimensions to the "bass-medium balance" and the "centroid of medium frequencies".

Acknowledgement

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