Timbre description of the sound of air-treatment systems for predicting acoustic comfort

A. Minard[a], A. Billon[b], B. Goujard[b], B. Robin[a], F. Fournier[a], J.-J. Embrechts[c], A. Sakout[b]
antoine.minard@univ-lr.fr
[a] CIAT, avenue Jean Falconnier, 01350 Culoz, France
[b] LaSIE, avenue Michel Crépeau, 17042 La Rochelle Cedex 1
[c] University of Liege – Acoustics Labo, Campus du Sart-Tilman, B28, B-4000 Liege 1, Belgium

ACOUSTICS 2012

Abstract

This study aims at defining reliable acoustic cues for the measure, characterization and prediction of the acoustic comfort of air-treatment systems (ATS). To meet customers' expectations, industrial products tend increasingly to follow a process of "sound design". In this process, the perceptual evaluation of sound quality is a necessary step to define acoustic specifications. In this context, this study aims at defining the main perceptual attributes of the sound of air-treatment systems in order to predict users' preferences. The timbre space of a sound dataset extracted from a large recording database was thus identified through a similarity experiment where participants were asked to rate the resemblance between each pair of sounds. The results of this experiment were analyzed with a Multidimensional Scaling (MDS) method in order to extract the main perceptual attributes. Finally, these attributes were linked to relevant audio features through a regression method in order to define a reliable computable metric of acoustic comfort. This study was conducted through the *Vaicteur Air*^{2} project supported by *OSEO*.

Similarity scaling experiment

Goal:

Whereas it is difficult for a listener to identify a sound's most relevant acoustic features, it is much easier to rate how much 2 sounds of the same kind are different from one another

Stimui :

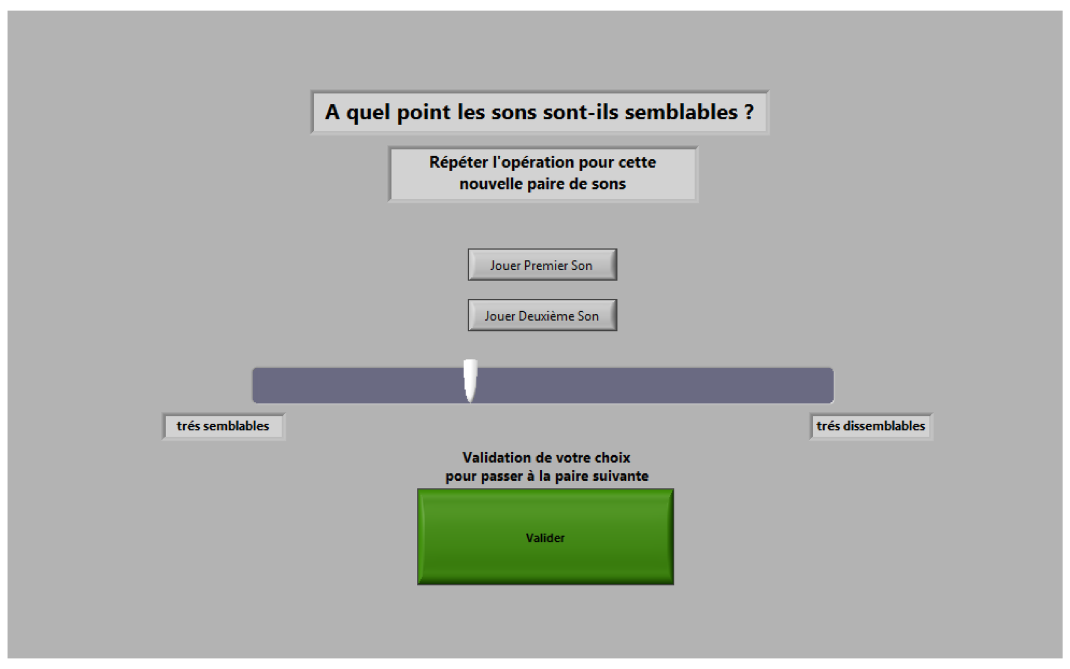
16 loudness-equalized monophonic sounds = 16 different ATSs

Apparatus :

- GUI Labview 2010
- Interface audio RME Fireface 800
- Casque audio Sennheiser HD650

Procedure:

Each possible pair of sounds (120 pairs) is presented to the listener who has to rate its similarity with a slider on a continuous scale



MultiDimensional Scaling analysis [1]

Context:

- Similarity matrix: distances between the sounds = perceptual similarities
- N element in a common geometrical space $\Rightarrow N-1$ dimensions required

Goal:

Model all distances with a space of much lower dimensionality, (2 or 3)

Models:

- MDSCAL - single model
  $\Rightarrow$ Rotationally invariant space
- INDSCAL - weighted model [2]: applies weightings to the dimensions
  $\Rightarrow$ The space is no longer rotationally invariant
  $\Rightarrow$ The dimensions are perceptually meaningfull

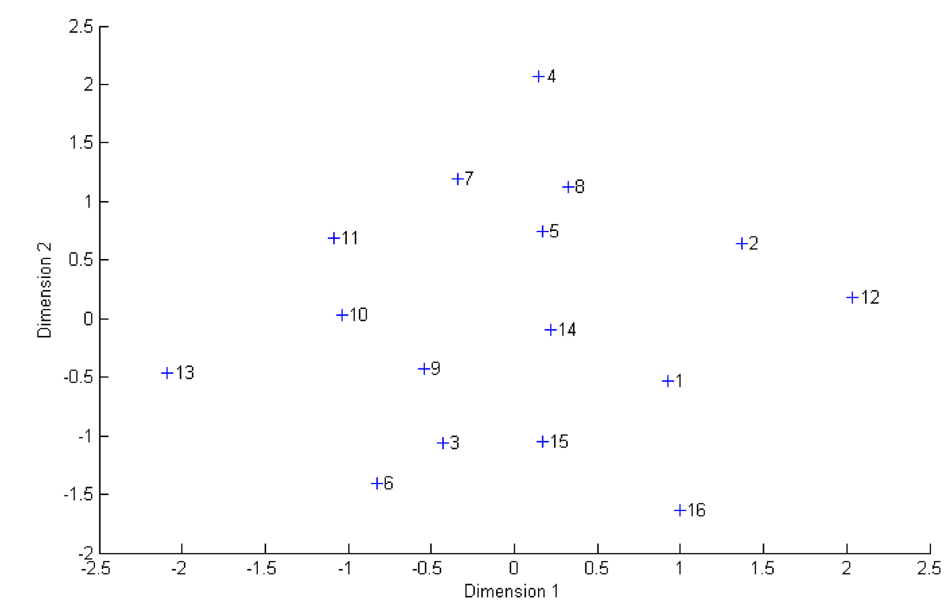
MDSCAL model

$$d_{ij} = \sqrt{\sum_{r=1}^{R} (x_{ir} - x_{jr})^2}$$

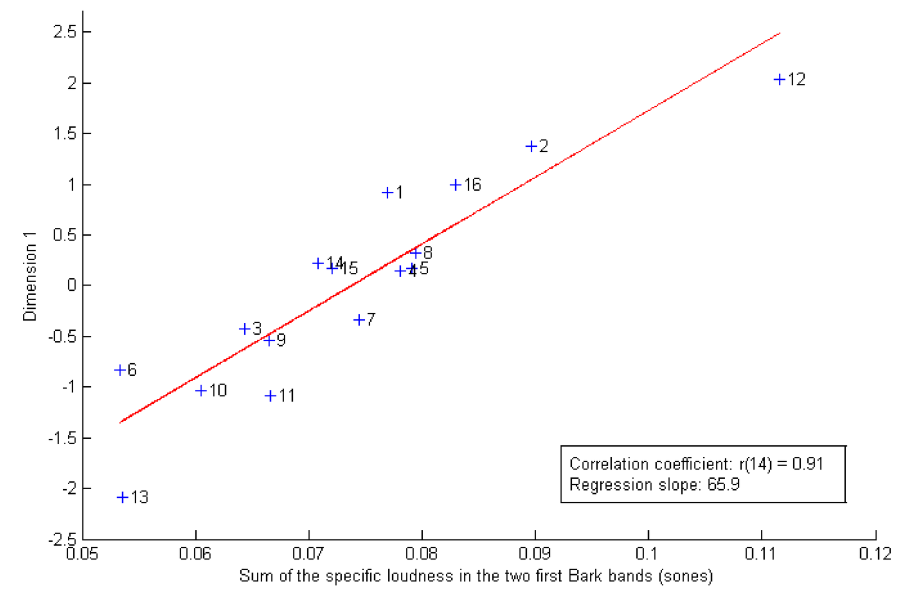
INDSCAL model

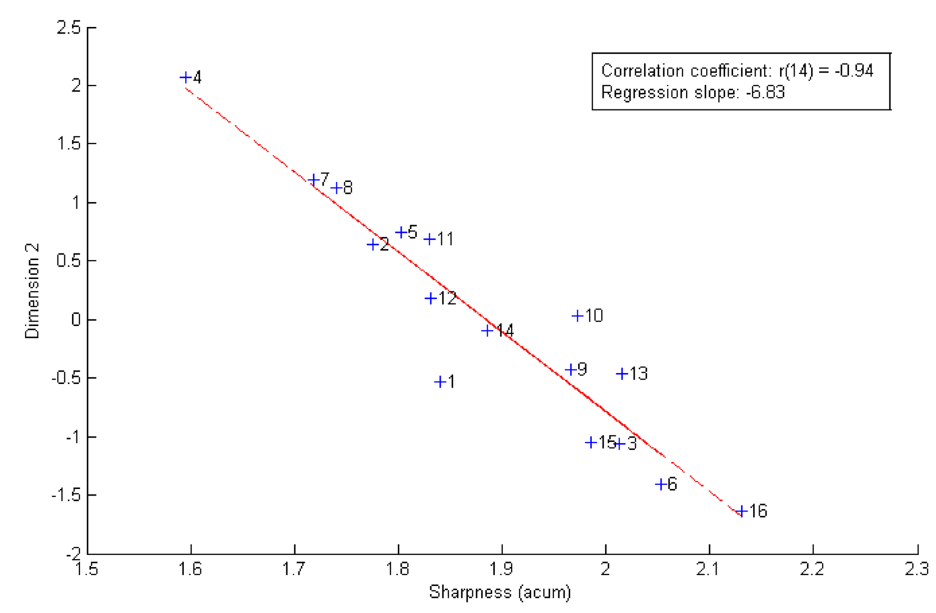
$$d_{ijn} = \sqrt{\sum_{r=1}^{R} w_{nr} \cdot (x_{ir} - x_{jr})^2}$$

Results



Psychoacoustic descriptors [3]	Dim. 1	Dim. 2
Spectrual centroid (perceptual modeling)	r(*df*=14) = -0.36	r(*df*=14) = **-0.88**
Spectral Spread (perceptual modeling)	-0.61	**-0.80**
Sharpness	-0.28	**-0.94**
N(1)	**0.84**	0.22
N(2)	**0.89**	0.36
N(1) + N(2)	**0.91**	0.31





Conclusions & further work

Conclusions:

- The MDS analysis of perceptual distances measured through a similarity scaling experiment raised a 2-dimensional timbre space
- Correlation calculations indicate that these 2 dimensions correspond respectively to the loudness in the two first Bark bands (*i.e.* between 0 and 200 Hz), and to sharpness

Further work:

- The perceptual dimensions identified here and their associated psychoacoustic descriptors need to be included into ATS acoustic comfort modeling
  $\Rightarrow$ Perceptual experiments aiming to measure hedonic preferences among the sounds.

Références

[1] J. Grey: Multidimensional perceptual scaling of musical timbres. J. Acoust. Soc. Am. **61**(5) (1977) 1270-1277.

[2] J. D. Carroll, J. J. Chang: Analysis of individual differences in multidimensional scaling via an n-way generalization of "Eckart-Young" decomposition. Psychometrika **35**(3) (1970) 283-319.

[3] E. Zwicker, H. Fastl: Psychoacoustics: Facts and models. Springer, New York, 1990.