Sensory evaluation of air-conditioning noise: Sound design and psychoacoutic evaluation

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The aim of the psychoacoustic study presented here was to characterize listeners' preferences for a set of sounds produced by different models and brands of indoor air-conditiong units. In addition, some synthetic sounds were created on the basis of interpolation among recorded sound samples and were integrated into the set. The approach consisted first in determining the multidimensional perceptual space as well as the corresponding physical space representative of the sound set. Then the preferences for different classes of subjects were related to the physical space.

INTRODUCTION

Concerning the characterization of the quality (timbre) and preference associated with a sound object, it is important to define the appropriate techniques in order to allow designers to define the acoustic properties of a product based on perceptual data derived from human listeners. In addition, certain acoustic aspects contribute in a significant way to the auditory image projected by the object that produces them and are important for emphasizing its identity and functionality.

In order to determine the salient perceptual and acoustic properties of a sound source which are not known in advance, a dissimilarity experiment and multidimensional scaling (MDS) program CLASCAL [1] are use at Ircam.

A first step (§1) consists in determining the perceptual attributes common to a panel of listeners that are used to compare sounds to one another. The MDS yields a spatial model that can be represented graphically and which reveals the perceptual structure underlying the listeners' judgments in terms of continuous dimensions shared by all the sound samples and specific features (specificities) of each sound. In addition, the CLASCAL program output also allows an analysis of different judement strategies used by listeners, corresponding to their grouping into latent classes.

The next step (§2) is to do an acoustic analysis which attempts to determine the acoustic and psychoacoustic parameters of the sound signals that are correlated with the positions of the samples along the perceptual dimensions determined in the previous step. At this point, the method provides the physical parameters that are perceptualy salient for the sound source studied. This parameters can then be used by the sound designer to change significantly the timbre of the source.

In a further step (§3), we migth be interested in the preference jugdments among the sounds studied. In the last stage of the method used here, the degree of preference associated with each sound is evaluated as a function of the perceptually significant acoustic parameters revealed previously. Finaly, this latter knowledge provides the sound designer with an interesting tool to produce new sounds according to perceptual properties.

The focus of this article is to explore sound quality and to characterize listeners' preferences for a set of sounds produced by different models and brands of indoor air-conditiong units using the global approch just described. The details of the experimental methods and data analysis techniques will not be presented but can be found in a previous article [2].

1. PERCEPTUAL DISSIMILARTY

Forty three sounds of different models and brands of indoor air-conditiong units were recorded in a sound proof room with a sound reference used to calibrate the sound level for headphone presentation in the laboratory.

In order to create synthetic sounds and to select sounds from among those recorded for the main study, two first experiments were performed. Sound selection was made by a group of five subjects. A categorization experiment and a cluster analysis were performed.

Finally, 18 sounds were chosen to represent the different sound classes obtained from the analysis. Then, the same group of subjects performed a dissimilarity experiment : all 153 different pairs between the 18 sounds were presented in a random order. For each pair, a dissimilarity judgment was made by moving a cursor between "very similar" and "very different" endpoints on a continuous rating scale. The MDS analysis using direct judgments of dissimilarity among stimuli revealed a three-dimensional space to represent the 18 sounds. The number of subjects used was not enough to obtain a stable space and thus to determine the identity of the dimensions. However, the main idea here was to get a global overview of the sound distribution and to pre-determine the position of four synthetic sounds created on the basis of interpolation among pairs of sounds belonging to this space. Finaly, a set of 15 sounds from the previous 18-sound corpus were kept, and the 4 synthetic sounds were integrated into the set

With this set of 19 sounds, a new dissimiliraty experiment was performed using 50 subjects. The MDS analysis shows that the best spatial model had three common dimensions and specifities. The analysis also revealed two latent classes of subjects giving a different weight to each dimension. Figure 1 shows the distribution of the sounds along the two first dimensions. The sounds numbered 1, 2, 3, and 4 are positioned at the expected locations by interpolation. This result suggests that it is possible to design a sound according to the perceptual characteristics extracted from a perceptual space.

2. ACOUSTIC ANALYSIS

Once the perceptual configuration is obtained, it is important to give an acoustic interpretation in the form of a systematic relationship between the stimulus characteristics and the locations in the space. In Table 1 are presented the correlation coefficients between the perceptual dimensions and the physical or psychoacoustic parameters for each sample group. The three dimensions are correlated with the ratio of the noisy part of the spectrum to the harmonic part (RAT), with the spectral center of gravity (SCG) and with loudness (LOU).

3. PREFERENCE ANALYSIS

All 171 pairs of different sounds were presented to a group of 100 subjects in a random order. On each trial the subject heard a pair of sounds only once and had to choose which sound was preferred. This phase of the study attempts to construct the map of the "utility" to the preference as a function of the objective acoustic and psychoacoustic parameters (RAT, SCG, LOU) that perceptually characterize the sounds. The analysis [3] revealed that, in terms of preference, two classes of listeners can be distinguished. For one, preference varied primarily with loudness, whereas for the other it varied more with SCG and RAT. On the other hand, for one class the preference grows with the parameter RAT, and for the other class, it decreases with RAT. This tendency is confirmed for another group of 99 subjects tested in a different laboratory.

CONCLUSION

The method used in this study provided fruitful results to characterize the sound quality and the preference of different homogeneous sound sources. In addition, the method can be used as an objective tool for sound design.

RÉFÉRENCES

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	Dim. 1	Dim. 2	Dim. 3
RAT	**-0.97****	0.11	-0.26
SCG	-0.32	**0.73****	-0.15
LOU	0.26	0.04	**0.84****

Tab.1 : Best correlated parameters (dl=17, * $p < 0.05$, ** $p < 0.01$)

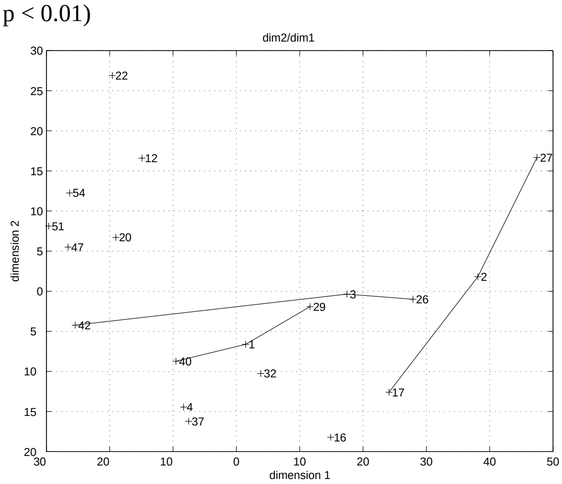

Fig1 : Two first dimensions of the three dimensional perceptual space of the indoor air-conditiong units; featuring the synthetic sounds numbered (1, 2, 3, 4).