Perception of sounds emitted by vacuum Cleaners

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Introduction

The noise emitted by an object is a source of objective and subjective information. Namely, it is a way to know whether the system properly works or not (objective information) and to estimate its quality (subjective information).

In the particular case of the vacuum cleaner, the subjective information related to the impression of power shall remain, and the annoyance linked to different criteria (sound pressure level, sharpness…) shall be minimize.

The purpose of these perceptive tests was to determine how listeners assess the impression of both efficiency and pleasantness of vacuum cleaners' sounds.

Stimuli recording conditions

Sounds were recorded in a room (3*2*2.5m), with wallpaper and fitted carpet on the floor.

A preliminary session of listening tests showed that each of the 8 models of vacuum cleaners had its own tone. The position of the dummy head (type 4100) Bruel et Kjaer® did not seem to influence tone very much while recording. Therefore, the recording position did not generate any confusion between different models, one position was freely chosen for all recordings.

While recording, the tube and the hose were placed to the right of the dummy head, the motor was behind it, and the nozzle laid on carpet (defined by CEI 60704-2-1) was ahead.

All the stimuli were filtered in order to correct the transfer function of the headphones (Sennheiser HD600) and the presence of the dummy head pinna. Thus, the listener's concha was the only element to intervene when the signal was presented.

Tests: Pleasantness, efficiency

The task of each subject was to supply an estimation of both pleasantness and efficiency of 8 different models of vacuum cleaners .

The jury consisted of 61 listeners (of whom 70% were women), half of them living in a flat. They were between 25 and 65 years old (distributed with homogeneity).

Listeners answered on a continuous scale on a Matlab user's interface. They could listen sounds as much as they wanted. An absolute scale was used.

The whole group used the same strategy to assess pleasantness.

The whole group can be divided (using K-means method) into two sub-groups which have their own estimation strategies on the impression of efficiency.

The following figures show the mean values of pleasantness and efficiency for each sub-population.

It appears that one sub population (fig 1) is able to estimate efficiency through the sound. In fact, the dynamic of its responses is higher than the other population's (Fig 2). The second sub population stays in a neutral position. The sub population which is able to feel efficiency, assesses it in opposition of pleasantness (coefficient of correlation = -0.8)

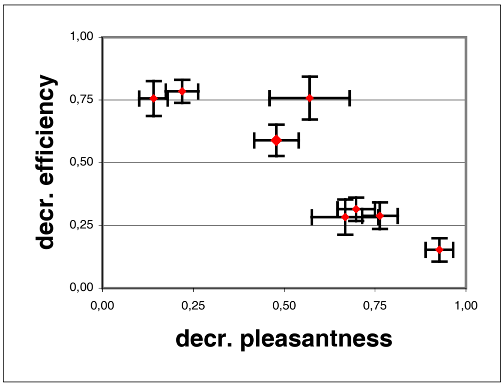

Fig 1 decr. efficiency, decr. pleasantness (34 listeners).

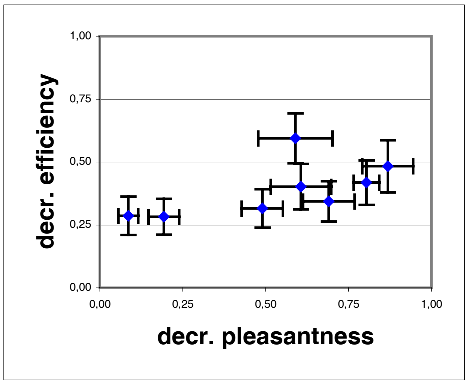

Fig 2 decr. efficiency, decr. pleasantness (27 listeners).

The efficiency of a vacuum cleaner cannot be evoked, without being to the detriment of pleasantness. This means that improving the impression of efficiency cannot be done by sound design.

The creation of Agreement response models thanks to classical sound parameters (sharpness, tonality, loudness, pressure level…) was not reliable.

Experimental design

During the previous test, 3 perceptive dimensions could be noticed in the pleasantness assessment. An experimental design was used to study them.

- Sound pressure level
- Medium –high balance
- Tonality component

To study the relative contribution of these 3 factors, an original sound was artificially altered. A L_9 (3 factors, 3 levels) experimental design was built.

- 1st factor: sound pressure level: -XdB, 0dB, XdB (confidential results)
- 2nd factor: balance medium high: -6dB >2000Hz, no modification, +6dB >2000Hz
- 3rd factor: Tonal component (4100Hz), no modification, +9dB, +18dB

The use of fractional experimental design allows to decrease the number of presented sounds from 27 down to 9 [2].

The jury consisted of 6o Students. Listeners answered on a discrete scale (5 choices) on a Matlab user's interface. They could listen sounds as much as they wanted.

The difficulty of this test lead to use paired comparison method. Pairs were presented according to Ross's series[1] after a first random permutation of the signals order, which allowed to avoid repetitions for the successive permutations of pairs.

The low standard deviation of the average response shows that the whole group of listeners used the same strategy to assess the pleasantness. Moreover the circular error rate is very low, the population did not seem to have difficulties to answer this test. [3] An analysis of variance gives the contribution for each factor. The sound pressure level describes 85% of the variance, the Medium-high balance 12%, the tonal component 2.5%. The residual contribution is 0.5% (possible interactions, statistical noise).

A threshold effect is seems to appear. Namely the contribution of the tonality component lead to depreciate the sound only for the highest level of this factor (+18dB).

It must be underline that experimental designs are based on an additive model and do not give continuous representation of the factors effects.

Seek for interactions

A cross-analysis of variance has been done to find significant interactions between factors. On one hand, no interaction highlighted between SPL and Balance Medium-high.

On the other hand, an interaction appears between the tonality component and the other factors. The contribution of this interaction represents half of the contribution of the third factor itself.

Since the contribution of the last factor was already low regarding the pressure level and the medium high balance, interactions with it could be neglected.

Summary

To conclude, an improvement of the efficiency impression of a Vacuum Cleaner's sound is not feasible. An experiment designs gives us contribution of different perceptive dimension in this sound.

References

[1] David H.A. Method of paired comparisons, Charles Griffin&Company LTD, 1988

[2] Alexis J. Pratique industrielle des plans d'expérience. AFNOR, 1995

[3] Parizet E, Paired Comparison Listening Tests and Circular Error Rates, Acustica — Acta Acustica 2002;88:594-598