Sensory evaluation of heating and air conditioning systems

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Abstract

Existing standards and models, such as ISO 7730 (1995) or Fanger works (1973), are not sufficient to characterise the satisfaction and pleasure of end-users provided by heating or air conditioning systems. For this reason Electricité de France (EDF) has initiated a project with the aim of using sensory evaluation in the designing of HVAC systems.

Sensory evaluation has been used for more than 25 years in the food industry, and now involves the cosmetics, telephone and car industries. It is based on a dual evaluation :

- sensation measurements carried out by a panel of trained experts,
- preference studies performed by a panel of consumers .

A correlation between the data of both studies is used to explain the preferences in terms of sensations (preference mapping).

The first experiments performed in 1999 and 2000 have provided lists of descriptors of thermal sensation and acoustic sensation associated with heating and cooling appliances. They show that it is possible to define reliable descriptors, to train a panel and to quantify these descriptors. It is also possible to draw the sensory profiles of different HVAC systems.

We also present the future experimental laboratory that EDF has decided to build, where the trained panels and naive consumers will evaluate the sensations and the preferences of real systems in 8 environmental chambers designed, furnished and decorated like offices and flats (realistic environmental chambers).

Keywords: ISO 7730, sensory evaluation, thermal sensation, acoustic sensation

1. Introduction

The existing standards for thermal comfort define criteria of not-uncomfortable conditions : ranges of temperature, humidity, air speed, etc. However they do not really give information about the satisfaction, pleasure and preferences of the end-users of HVAC systems. Different research studies have shown the influence of subjective features and interaction between sensations (Howell (1981), Rohles (1980, 1981))

One of the interests of our company is to understand and characterise the preferences of these end-users and to translate these subjective features into technical specifications for the new products under development (better perceived qualities). EDF has initiated a project whose objectives are to validate the relevance of Sensory Metrology in assessing the perception of HVAC systems, and to propose a new design process integrating the designers' constraints and the consumers' expectations.

2. What is sensory evaluation

Sensory evaluation techniques (Barthelemy et al. (1990)) have been used for more than 25 years in the food industry to characterise tastes and odours. Their actual goals were to achieve quality control of the products and were extended to the study of consumers' preferences and to the measurement of sensations. Now used for characterising touch, texture and sound ; sensory evaluation is applied in automotive industry, cosmetics, and in luxury industry.

These techniques are based on the assumption that the neurophysiological perception process can be roughly divided into three steps (" direct perception " model of W. Wundt (1874), G.T. Fechner (1860)) :

- an environmental phenomenon interacts with sensory receptors to create a stimulus (this phenomenon can be described by physical parameters such as temperature),
- the stimulus creates a nervous excitation that is transducted towards the sensory central nervous system (" objective part " of the sensation),
- the signal is integrated in the brain, a comparison with stored sensations is made and a hedonic judgement is given. This judgement is purely subjective because it refers to cultural, experimental elements associated with the subject. At this step, any response (verbal, behavioural, etc.) given by the subjects is global, both sensory and affective.

The basic assumption of sensory evaluation is that it is possible to perform objective measurements of sensations using a panel of people as an instrument , if they are correctly trained to reliably describe and quantify their sensations and to eliminate hedonic judgements. A panel is usually a group of 10 to 20 people. The final rating of a characteristic is the average of all the panelists' scores. To be considered as a reliable measure, the panel has to be reproducible. Training the panels leads to homogeneity and reproducibility in the ratings. These are the " sensory measurements ".

The complete sensory metrology approach involves another group of persons : the end-users. This group is more numerous (a minimum of 60 people is required), it must be representative of customers, who are as naive as possible on the topic studied. This group is not trained, the persons being merely questioned on their preferences. These are " hedonic studies ".

The combination of " hedonic studies " and " sensory measurements " leads to preference mapping that makes it possible to specify preferred sensory characteristics of products for given groups of end-users. See Figure 1.

The people taken from a trained panel are not representative of the end-users and thus can't perform the hedonic studies. Conversely a naive end-user is not able to evaluate and quantify the sensations since he has not been trained to do so (reliability, repeatability, reproducibility).

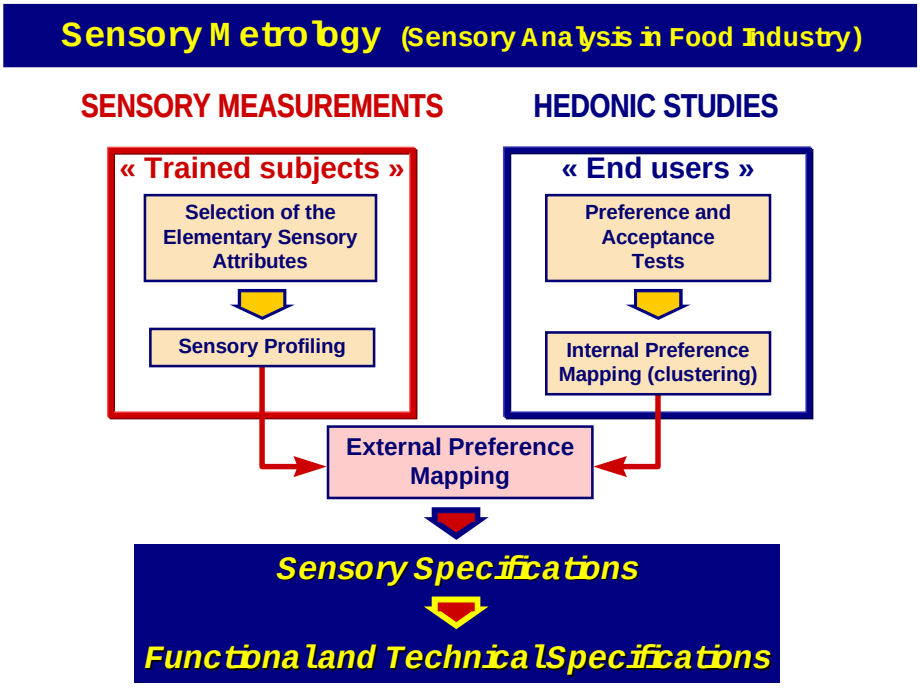

Figure 1 : Sensory Metrology methodology

3.First experiments done by EDF

We first verified that it is possible to describe the perceived thermal sensations when standing in front of HVAC appliances.
We then carried out the following steps for descriptive analysis :

- selection of the panel
- determination of the sensory attributes
- panel training
- evaluation of the perceived effects of HVAC appliances

A specific experimental protocol was defined for the descriptive analysis of thermal sensation, see table 1. Each judge had a fixed activity level (remaining still, standing in front of the product at a given distance) and clothing (0.5 Clo). Before the test, each judge spent 15 minutes in a conditioning chamber with a fixed air temperature (24°C), then he was led blindfold in front of the various products.

Each person had to test all the products twice, at different times (reproducibility), blindfolded to avoid any influence of visual perception of the products, one product at a time.

The experimental conditions involved were : 5 heating and 4 cooling appliances fixed on one side of an environmental chamber, we had the same Resultant Temperature in the centre of the environmental chamber for all appliances (19°C or 24°C for the heating systems, 24°C and 29°C for the cooling systems).

The panel was composed of 6 judges whom were trained for 2 weeks.

TEST CONDITIONS	
Conditioning of the judge	15 minutes in the conditioning chamber at 24 °C
Activity and position of the judge	Standing still at 0.5 m or 1 m in front of the appliance (2 positions) Blindfold
Clothing	0.5 clo
Temperature in the test room	19 °C and 24 °C for heating appliances 24 °C and 29 °C for cooling appliances
Room dimensions	5 m x 4 m x 2.50 m
Repetitions	2 evaluations

Table 1 : test conditions performed for the descriptive analysis.

At the time of writing this article, we have not yet carried out the hedonic study.

4. Results of the descriptive study

A list of descriptors of the thermal sensation was generated by the panel. 15 terms were defined, with internal references and specific definitions being obtained by the panel itself.

10 of the descriptors described the sensations (such as “perceived temperature”, “intensity of radiation”, “continuity of perception” ...) they were rated from 0 to 10 on a 11-points linear scale. 5 descriptors indicating the localisation of the perception on the body (head, legs ...) were binary descriptors. The judges were asked to chose their own rating, considering that the set of appliances has to be rated on a same scale (no sensation should give a 0 score and the highest sensation should give a score of 10). The panel was trained on these descriptors to get reproducible and homogeneous ratings.

Figures 2 and 3 show examples of results, presented for the heating appliances. In figure 2, the descriptors are on the x-axis, the mean value of the rating of the panel on the y-axis, each curve presents a different appliance. Names of the appliances and descriptors are coded.

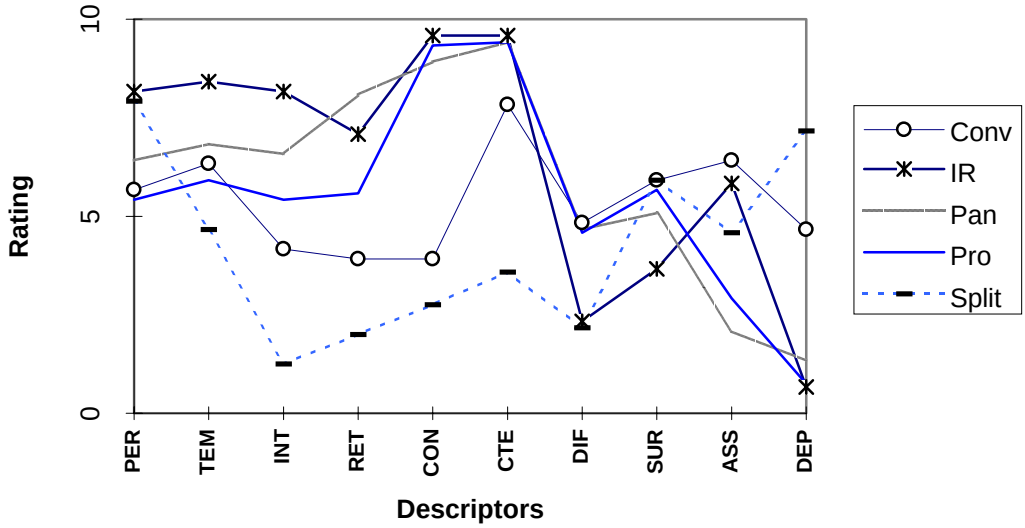

Figure 2 : Example of rating of the 10 first descriptors for 5 heating appliances

We can comment on some of theses descriptors. For instance, *INT* represents the " intensity of perceived radiation " (the reference given is solar heating). We see that the IR (Infrared) appliance gives a very high score compared with the Split system which has a very low rating.

In Figure 3, presenting a principal component analysis, lines show the directions of the descriptors and each ellipsoid gathers the various experiments performed with the same appliance (different distances of evaluation and room temperatures).

We can notice that, for example, the sensations perceived in front of the appliance coded **CONV** are highly influenced by the room temperature and the distance of perception whereas those in front of the appliance coded **SPM** (Split System) are not so much. For the latter, the descriptor *DEP* is very representative of the thermal sensations.

In such a study, the reliability criteria are: reproducibility of the judges, homogeneity of the panel and discrimination of the products. Although the panel was small, these requirements were met.

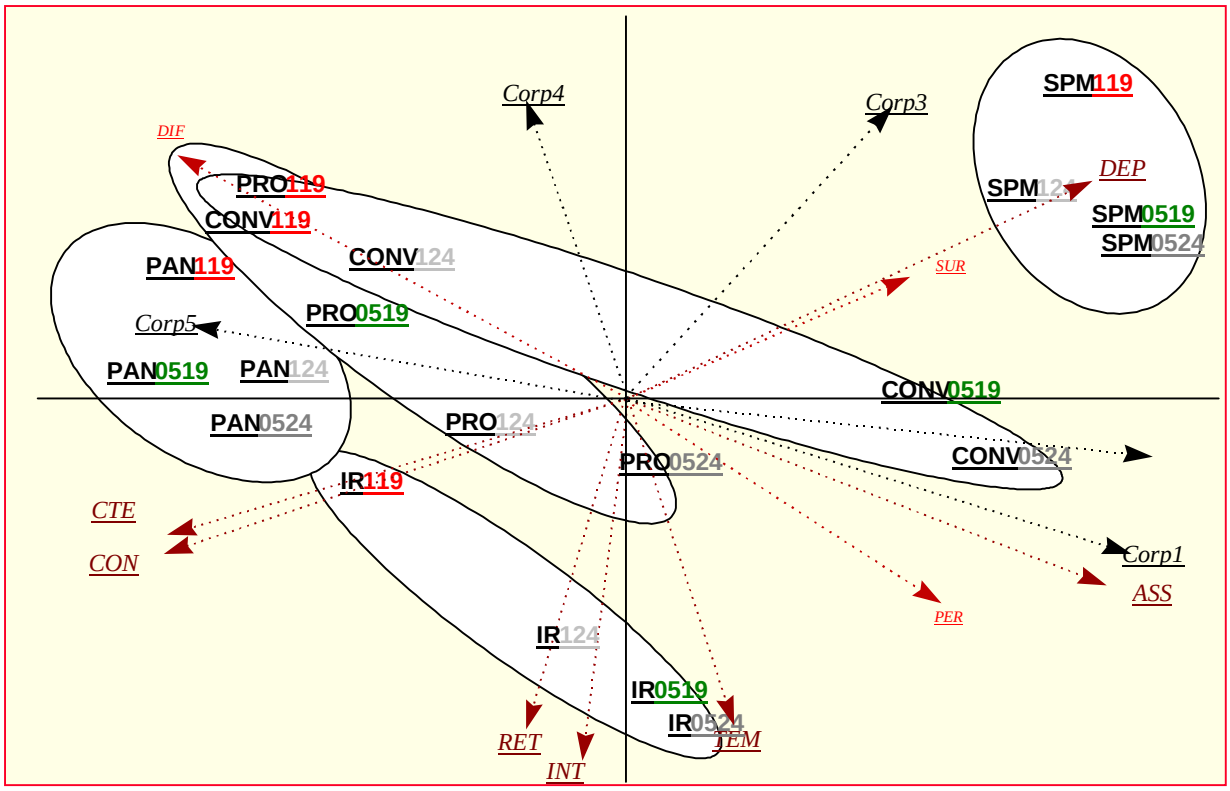

Figure 3 : Sensory Mapping - Result of Principal Component Analysis of all the ratings

The next steps are to train a larger panel with a view to have a more reliable descriptive analysis and to carry out hedonic studies with a large group of consumers. For that, we are now building a new experimental laboratory which is thermally controlled but also furnished in a realistic way (See Figure 4). It is composed of 6 small test rooms (15 m²) and 2 large rooms (25 m²), surrounded by environmental zones able to simulate outdoor (from -15 to +40°C) and indoor environment (between +10 and +35°C). The reference zone will be used to conditioned the people before each test. In each room, integrated heating and cooling systems (indicated in block letters) will be installed, and also mobile appliances.

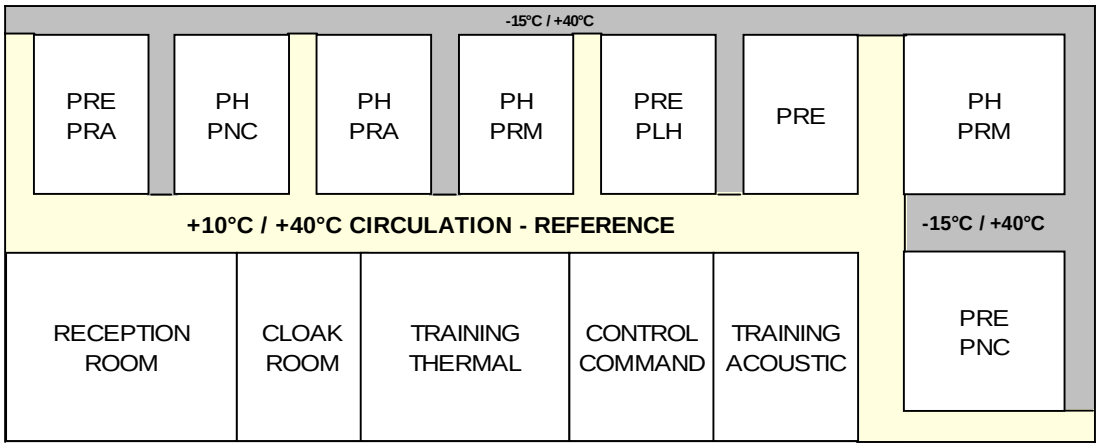

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Figure 4 : schematic representation of the sensory metrology laboratory. Integrated heating and cooling systems : PRE : electrically heated floor, PRA : electrically heated ceiling, PH : water cooled floor, PNC capillary water cooled ceiling, PLH : water cooled ceiling, PRM : modulary electrically heated ceiling.

5. Conclusion

In this study we have shown that it is possible to define sensory descriptors and to train a panel of judges to quantify thermal sensations and we have carried out a first evaluation of real HVAC appliances.
The next steps are to train a larger panel with a view to have a more reliable descriptive analysis and to carry out hedonic studies with a large group of consumers.

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