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Sensometrics approaches in sensory and consumer research

El Mostafa Qannari

During the last few years, significant advances have been achieved in sensory and consumer research. Accordingly, sensometrics which is devoted to the analysis of data arising from this research field has also made significant progress. A review of recent advances in the statistical treatment of sensory and preference data is outlined. Problem areas are identified and avenues for future investigations are suggested.

Address
StatSC, ONIRIS, INRA, 44322 Nantes, France

Corresponding author: Qannari, El Mostafa (elmostafa.qannari@oniris-nantes.fr)

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Introduction

Sensometrics can be defined as the application of statistics and, more generally, mathematics and computer science to sensory and consumer studies. It encompasses a set of tools that can be used in product development, quality insurance, market research and consumer choice.

In the last three decades or so, statisticians and sensory analysts have benefited from the exchange of knowledge across their respective disciplines. On the one hand, this made it possible for the statisticians to extend the range of application of several statistical methods and inspire the development of new techniques. On the other hand, the practitioners in consumer and sensory analysis not only were stimulated by gaining new insights to their own disciplinary endeavors through the application of sensometrics tools, but also to add new material and new techniques for data collection to the evolving knowledge in their field.

The purpose of the paper is to present an overview of recent advances in the statistical treatment of sensory and preference data in response to the growing interest and the needs in this field. We also attempt to answer the question whether the sensometricians are sufficiently prepared to meet the new challenges in a world where new generations of computers and devices for data collection together with new analytical techniques such as meta-analysis, interactive electronic databases, machine learning and new channels of communication (*e.g.*, social networks) . . . are constantly shaping our way of working, if not our way of thinking.

Discrimination tests and sensory profiling

The traditional view of sensory analysis defined a clear-cut division of the evaluation tests in analytical procedures (trained panels) and hedonic tests (consumer panels). Nowadays, the dividing line between these two facets of sensory analysis tends to blur [1]. Because of this shift, few achievements in sensometrics have been accomplished these last three years or so regarding the statistical treatment of data from discrimination tests and sensory profiling. However, the research work that aimed at expanding the range of Thurstonian models to several discrimination, rating and ranking tests stands out [2•,3•]. The Thurstonian approach, based on Thurstone's categorical judgment model is one of those multifaceted theories that can be linked to various concepts such as the latent class models [4], signal detection models, and generalized linear models. It was demonstrated how the Thurstonian framework provides a fecund theoretical background to compare efficiency in terms of power and precision of several methods such as assessing the degree of difference tests. Of particular interest to sensometrics is the so called d-prime which stands as a standardized measure of perceptual difference between two products and thus makes it possible to compare the efficiency of several procedures of evaluation and techniques of analysis. The basic d-prime calculations are implemented in the free and open source software R-package (Christensen R, Brockhoff PB 2016, sensR—An R-package for sensory discrimination. http://www.cran.r-project.org/package=sensR/). Another noteworthy development related to the Thurstonian approach concerns the Tetrad and A not A tests [5,6]. In particular, it was reported that the Tetrad test enjoys a high power and, in some cases, requires only one third of the sample size needed by the triangle test. For a comprehensive overview of discrimination and difference testing, we refer to the book by Jian Bi [7].

Another praiseworthy investigation regarding sensory profiling concerns the introduction of an analysis of

variance model called the Mixed Assessor Model (MAM) that takes into account the variations among the assessors in the range of rating the products [8]. The efficiency of this new model in comparison to the traditional one was tested on the basis of a meta study of 8619 sensory attributes from 369 sensory profile datasets contained in SensoBase (www.sensobase.fr). It turned out that the MAM better highlighted the differences among the products and gained over the conventional approach in 8% of the cases. Notwithstanding this relatively small percentage which does not seem to indicate that MAM is a clear winner, we should not overlook that this model makes it possible to shed more light on the assessors' performance. Let us also pinpoint, in passing, the interest of Sensobase as a tool of validation of models. Not only has this database made it possible to compare several strategies of analysis on a large scale but also to infer from the information available on the assessors and the products some cognitive and behavioral explanations as to why the assessors vary from each other. For instance, it was reported that the scaling effect was more shown for panelists over sixty years old and smokers, and it was also observed that this scaling effect was higher for aroma and flavor compared to texture and appearance [9].

Preference mapping

Understandably, preference mapping has always been an active field of research. This encompasses several techniques applied to sensory and hedonic data for a better understanding of consumers' liking and product optimization. A critical review of the common methods of analysis used in this context is given in [10••]. Classically, the so-called external preference mapping consisted in a two steps procedure: (i) depicting the products on a perceptual space obtained from the sensory variables, (ii) regressing the preference data onto this space. In the recent developments, research was more concentrated on defining a one step procedure and unveiling nonlinear links between the sensory and hedonic data. An attempt to achieve this goal consisted in seeking, by means of a PLS regression, an optimal perceptual space that takes account of quadratic relationships between hedonic and sensory data [11]. Alternative strategies, still in a fledgling phase, advocated using machine learning tools such as neural networks and support vector machines to analyze preference data taking account of external information [12]. Other noteworthy strategies of analysis of preference and sensory data that take account of nonlinear relationships among the variables fit within the framework of regression/classification trees and random forests [13]. A regression or classification tree consists in recursively partitioning the observations by setting up a simple prediction model or rule (*e.g.*, sweetness > 5.4) at each node of the hierarchically organized partition. In random forest, one grows several regression/classification trees which are conjointly used to predict the response variable at hand (*e.g.*, by means of a majority vote). The rationale behind the random forest is to correct for the tendency of the individual regression or classification trees to overfit the data. As a matter of fact, random forests are part of the so-called ensemble learning paradigm which consists of relying on several prediction models to achieve a better prediction performance than could be obtained by each individual model [14]. These data mining techniques are likely to attract a growing interest among sensometricians because of their intuitive appeal and because they open up new possibilities to effectively handle the data.

Ennis and Ennis [10] criticized the general approach of external mapping on the ground that the external variables (*e.g.*, sensory variables) may not drive the consumers liking or may account for only a small part of the drivers of likings. These authors advocated using the hedonic data as the cornerstone of the analysis. In this context, the strategies of analysis that fit under the umbrella of unfolding methods are intuitively appealing and easy to interpret [15]. These models yield a perceptual space where products and ideal products for the various consumers can be simultaneously depicted with the understanding that the distances between the products and the consumers reflect how the products are far removed from the ideal products of those consumers. The progress on the unfolding methods has been so far hindered by the fact that very often these methods lead to degenerate solutions, that is, not meaningful perceptual maps. Strategies of analysis to counteract this problem were recently proposed [16].

All the methods discussed above mainly focus on the relationships between hedonic data and intrinsic properties of the products (*e.g.*, sensory or physico-chemical properties). An interesting discussion of recent methodologies for combining intrinsic and extrinsic properties (*e.g.*, price, packaging) in consumer studies is reported in [17•]. Besides an overview of methods of investigation such as conjoint analysis, hedonic testing and rapid methods, this study also provides directions for future research.

Consumers' segmentation

Consumers have different likings and different drivers of liking. Therefore, the division of a panel of consumers into homogeneous clusters is an intuitive demand and a pressing need. The consumers' expectations are better met and the marketing efforts are better rewarded if the companies target specific groups of consumers with products that best appeal to them and develop marketing strategies that are more relevant to each segment. From a statistical point of view, segmentation can help set up tailored models to increase the effectiveness of strategies that aim at uncovering liking drivers and understanding consumers' behavior. This idea is better illustrated by the finite mixture models also known as Latent Class Analysis (LCA). These models encompass statistical methods for