Kano's satisfaction model applied to External Preference Mapping : a new way to handle non linear relationships between hedonic evaluations and product characteristics

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Summary

In order to deal with non linear dependence relationships between sensory characteristics and hedonic appreciation, we applied Kano's model (1984) to External Preference Mapping methodology. By considering separately satisfaction and dissatisfaction, we proposed to classify the sensory attributes according to Kano's typology. We identify attributes that contribute only to satisfaction, those which contribute only to dissatisfaction and those which contribute to both. Therefore, this new information for each key sensory attributes leads to more straightforward recommendations for Development and Marketing departments.

Keywords: preference mapping, product optimisation, PLS regression, satisfaction, dissatisfaction.

INTRODUCTION

External Preference Mapping (EPM) is used in food industry as a tool for leading product renovation. EPM aims at identifying the most important product attributes to explain and predict preference of a homogeneous consumer group.

We must state that these important attributes found by EPM can not be distinguished as influencing only satisfaction, or only dissatisfaction or both. But, in some cases, we strongly believe that sensory attributes driving preference, are not the same as those driving rejection. For example, a mouldy taste in a yoghurt conducts to the reject of the product. Whereas, an absence of mouldy taste, may not ensure a high level of satisfaction, considering that the particular attribute is a undesirable feature for this product.

Learning from the Quality management discipline, to gain and keep new customers, companies has to understand its customers needs and expectations. Particularly, Kano's model (1984) considers that satisfaction and dissatisfaction are two independent construct in minds and should be considered separately. Working with social science theories on satisfaction, developed by Frederick Herzberg, Kano concludes that relationship between fulfilment of a need and satisfaction or dissatisfaction experienced is not necessarily linear. Product requirements are thus sorted into distinct classes. Each class exhibits a different relationship with respect to satisfaction and/or dissatisfaction, depending on whether certain product requirements are completely fulfilled, only partially met, or go unserved.

In his model, Kano (1984) distinguishes at least three types of product attributes:

- *Must-be attributes* These attributes correspond to the basic requirements of a product. If these requirements are not fulfilled, consumers will be extremely dissatisfied. On the other hand, their fulfilment will not increase his satisfaction, but only lead to a state of "not dissatisfied".
- *Performance attributes*. Depending on the level of their fulfilment by a product, these requirements can satisfy or dissatisfy consumers.
- *Attractive attributes* These attributes are the product requirements which have the greatest influence on how satisfied a consumer will be with a given product. Fulfilling these requirements can lead to more than proportional satisfaction. If they are not met, however, there is no felling of dissatisfaction.

Considering the 'product requirements' as the sensory attributes of the products, Kano Model can be used to explore non-linear relationship between hedonic appreciation and product characteristics. Thus, analogy between Kano model and EPM becomes more obvious. We can, for example, imagine that acidity perception for yoghurt as a must-be attribute. This implies that product having high scores for acidity will leads to dissatisfying products whereas low scores for acidity don't necessarily ensure satisfaction.
In order to fully evaluate the relevance of Kano's theory applied to EPM, we state the following hypotheses:

- A satisfying product has no defects. Must-be and performance attributes get satisfied. Fulfilling attractive attributes also required.
- A dissatisfying product supposes that one or several must-be or performance attributes are not fulfilled. Even if some attractive attributes are fulfilled, their influence on satisfaction are cancelled since this product doesn't satisfied basic needs.

Purpose of this study is to propose a way to classify the key sensory attributes identified by EPM, into "attractive", "must-be" or "performance" attributes by decoupling satisfying products from dissatisfying products for each consumer.

DATA SETS

Sensory Evaluation

Eleven chocolate biscuits selected from the market place were rated for P=29 attributes by 16 trained judges on a 60 points scale. Each product was tested twice, using a sequential latin square (MacFie et al, 1989). The design's factor effects that were swept out are : replication effect, judge effect; first position effect; first-order carry-over effect (exepted for the first position); judge*product interaction; and judge*replication interaction. Adjusted means correspond to overall mean added to direct product effects. The obtained average attributes constitute the explanatory variables, X, of the following model.

Consumer test

This study involves Q=78 French consumers aged from 18 to 65. They evaluate 11 chocolate biscuits one at a time, in 2 sessions and were are asked to score on a 10 points Likert-Type Scale their degree of liking for each product. Presentation order of products is balanced using a Latin Square of Williams. Thus, all order effects of presentation and first order of carry-over effect are controlled.
At the end of the sessions, each consumer is asked to report on the hedonic scale the score above which he would accept to consume again a product of the tested category. Thus, we consider this score as an individual threshold of satisfaction for the tested product category. For a given consumer, products having scores above his threshold are considered as satisfying products whereas, products having scores below his threshold are considered as dissatisfying products. By asking each consumer his threshold, we avoid biais due to individual use of the scale (i.e. some consumers use only the upper or lower part of scale) and biais due to the tested product category (i.e. Threshold of satisfaction may not be the same for biscuits than for vegetables due to different levels of pleasure induced).

STATISTICAL ANALYSIS

For a given cluster of consumers, EPM consists in regressing hedonic data, Y, against product sensory descriptive data, X. Most of the time, regressors are strongly intercorrelated and number of regressors is larger than number of observations. To solve this problem, Martens et al (1983) proposed to use PLS regression to perform EPM because it alternately computes orthogonal sensory components (t_1, t_2, …, t_h) that both summarize main sensory differences between products and explain the original variance accounted for hedonic responses.

Nevertheless, relationship between sensory description and overall liking is often non-linear, that is why we elected to study a new nonlinear PLS extension. We propose, in accordance with Kano's theory, to two distinct models to explain separately satisfaction and dissatisfaction.

Considering the satisfaction threshold y_{Ti}, for consumer i, we propose to replace variable Yi representing the original hedonic scores with new variables representing separately his satisfaction (Y_{1i}) and his dissatisfaction (Y_{2i}). We define Y_{1i} and Y_{2i} for consumer i, as followed:

For j = 1,….N, with N = number of products.

If $Y_{ij} \geq y_{Ti}$ then $Y_{1ij} = Y_{1ij} - y_{Ti}$ and $Y_{2ij} = 0$

Or, if $Y_{ij} \leq y_{Ti}$ then $Y_{1ij} = 0$ and $Y_{2ij} = -(y_{Ti} - Y_{1ij})$

Yi
1
2
3
4
5
6
7
8

→

Yi1	Yi2
0	-3
0	-2
0	-1
0	0
1	0
2	0
3	0
4	0

Example of Yi transformation ($y_{Ti} = 4$)

We then perform 2 distinct PLS2 Regression. X, the sensory attributes matrix, is the independent variable and the new hedonic matrixes Y_1 and Y_2 on the other are the two separated dependent variables.

PERFORMANCE CRITERIA AND INTERPRETATION RULES

We calculated the *Variable Importance for Projection* (VIP) of Wold (1994) to summarise each variable contribution to the model. VIP describes which X variables characterise the X block well and which variables correlate with Y. VIP values summarise the overall contribution of each X_i to the PLS model, summed over all components and weighted according to the Y variation accounted for by each component. VIP is calculated as follows:

$$VIP_j = \sqrt{\frac{p * \sum_{l=1}^{h} \sum_{i=1}^{Q} \left(R^2(y_i, t_l) * w_{lj}^2\right)}{\sum_{i=1}^{Q} R^2(y_i; t_1 \ldots t_h)}}$$

Each X_j is classified in one of Kano's typology according to its VIP value and its coefficients signs for both Y_1 and Y_2 modelling. We consider descriptors with VIPj superior to 1 as relevant to explain variability of the response (Tenenhaus, 1998) and will make conclusions only for those sensory attributes. In order to classify attributes into Kano's typology we implement the following decision rules:

- Attributes only relevant to Y_1 modelling are attractive attributes
- Attributes only relevant to Y_2 modelling are must be attributes
- Attributes relevant to both Y_1 and Y_2 modelling are performance attributes

We compared this approach with the classical statistical analysis consisting in modelling originals variables Y with a PLS 2 regression on X.
The three methods are compared considering the percentage of the hedonic responses' variability, R^2. But, explained hedonic variance naturally increases with the number of retained sensory components leading to overfitting of the data. To avoid this, Predictive Residual Sum of Squares (PRESS) is calculated for each model. We, thus, select, for each model, a correct number of components by optimizing both R^2 and PRESS values.

RESULTS

In order to consider the diversity of individuals preferences, we performed Agglomerative Hierarchical Clustering (Gordon, 1991) on consumer data (NxQ) centred by consumer. Two groups of consumers are clearly shown. Hedonic means of each product were estimated for each group, yelding two hedonic responses (Fig 1)

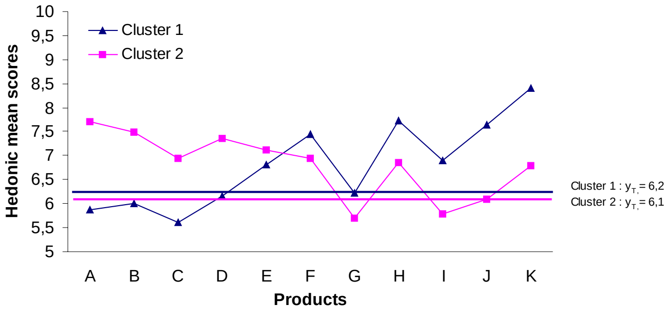

Fig 1 : Adjusted hedonic means scores estimated by product and means satisfaction thresholds for each class of consumers. Each letter represents one product.

Modelling results indicate that R^2 for Y_2 modelling (0.49 for cluster 1 and 0.59 for Cluster 2) are superior to R2 for Y_1 modelling (0.48 for cluster 1 and 0.47 for Cluster 2). We conclude that dissatisfaction is better explained than satisfaction. We may interpret this results by supposing that when evaluating products, consumers think more easily in term of what they don't want than in term of what they really want.

Figure 2 and 3 show VIP plot per attribute for cluster 1 and 2. Only VIP superior to 1 are mentioned. Each attribute is associated to 3 values of VIP considering Y_1 modelling (Satisfaction), Y_2 modelling (Dissatisfaction) or Y modelling (Reference). One sensory attribute, is associated to its sign (+) or (-) in one of the three model. Interpretation of the coefficient sign for a given sensory attribute is expressed as followed:

- Positive coefficient for Y_1, respectively Y_2, means that high perception of this sensory attribute leads to high consumer satisfaction, respectively absence of consumer dissatisfaction.
- Negative coefficient for Y_1, respectively Y_2, means that high perception of this sensory attribute leads to absence of consumer satisfaction, respectively high consumer dissatisfaction.

First cluster of consumer

Satisfaction threshold mean score for cluster 1 is 6.2. Thus, in average, consumers of cluster 1 won't consume again products A, B, C, D and G whose mean scores are bellowed 6.2. Whereas Products E, F, H, I, J and K can be consumed again. Fig 2 shows for each attribute, its values of VIP superior or equal to 1 considering Y_1 modelling (Satisfaction), Y_2 modelling (Dissatisfaction) or Y modelling

(Reference) for cluster 1. Thus we classify sensory attributes following Kano typology as follows:

Must be attributes that only contribute to dissatisfaction are sour, crunchy, fat and melting. For example, products having pronounced fat perception, like product B and G, are dissatisfying. This is in accordance with the corresponding negative sign of Y_2 model coefficient. But, in contrast, products having relatively low scores for fat perception are not necessarily satisfying products like A (i.e. dissatisfying product). This supposes that product A doesn't fulfilled all must be (or performance) attributes that penalised it on all other attributes.
Attractive attributes that only contribute to satisfaction are hard, granular, cereal taste, cereal perception, sticky cereal, nuts, grilled, granular, chocolate chips and cocoa. For example, products with pronounced cereal taste lead to high predicted score for Y_1 provided that these products fulfils must be and performance attributes.
Performance attributes for cluster 1 are sticky, coco, milk, caramel and butter. These attributes are straightforwardly interpretable. For example caramel flavour classified as a performance attribute influence both Y_1 and Y_2. The highest the score for caramel intensity, the best the product is predicted.

We notice that most of the attractive and must be attributes are not put in evidence by the reference method. But performance sensory attributes that contribute to both satisfaction (Y_1 modelling) and dissatisfaction (Y_2 modelling) are also relevant to Y modelling. We conclude that reference method only deliver partial information on attributes influences and can not distinguished between must be, performance, and attractive attributes.

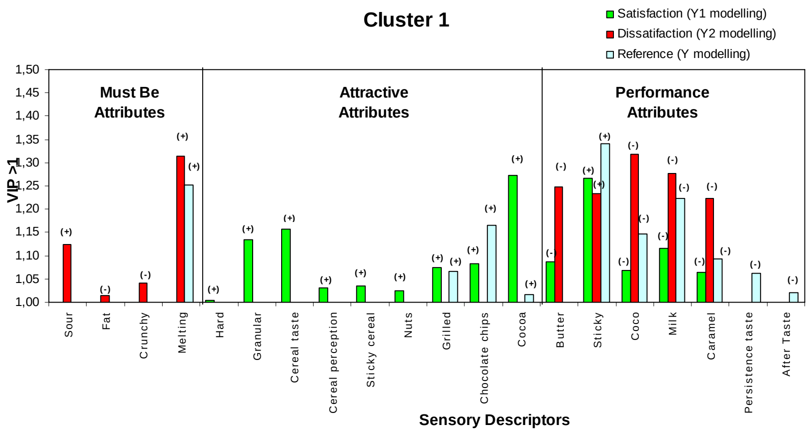

Fig 2: VIP plot per descriptor for the first cluster of consumer. Only VIP>1 are shown. Each sensory descriptor is associated to 3 values of VIP considering Y_1 modelling (Satisfaction), Y_2 modelling (Dissatisfaction) or Y modelling (Reference). For each sensory descriptor, (+) means a positive coefficient in the considering model and (-), a negative coefficient in the considering model.

Second cluster of consumer

Satisfaction threshold mean score for cluster 2 is equal to 6.1. Thus, they probably not consume again products are G, I, and J. On the other hand Products A, B, C, D, E F, H, and K may be consumed again. Identically to cluster 2 we identify influence of each attribute on satisfaction and dissatisfaction. Then, we classify them into Kano's typology. Results are illustrated in Fig 3.

Must be attributes that only contribute to dissatisfaction are melting, honey, chocolate chips, vanilla, and warming. For example, products having weak honey perception, are predicted as dissatisfying. This is in accordance with the corresponding positive sign of the Y_2 model coefficient.
Attractive attributes that only contribute to satisfaction are cocoa, coco, caramel, sour, persistence taste, after taste, sticky, sweet and crumbly. For example, products with pronounced coco flavor lead to satisfying products provided that these products fulfils must be and performance attributes.
Performance attributes for cluster 2 are fat, hard, cereal perception, sticky cereal, nuts and cereals taste.

Once again, we notice on Fig 3. that most of the attractive and must be attributes are not put in evidence by the reference method. Only performance sensory attributes are relevant to Y modelling. This confirms that reference method only deliver partial information on attributes influences and can not distinguished between must be, performance, and attractive attributes.

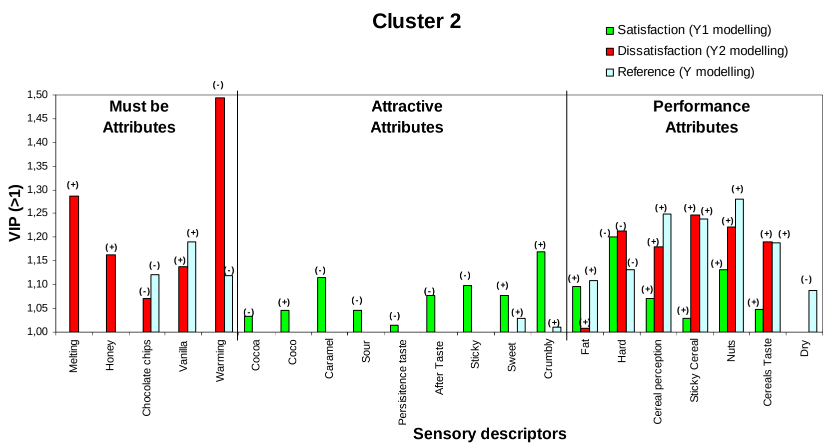

Fig 3: VIP plot per descriptor for the second cluster of consumer. Only VIP>1 are shown. Each sensory descriptor is associated to 3 values of VIP considering Y_1 modelling (Satisfaction), Y_2 modelling (Dissatisfaction) or Y modelling (Reference). For each sensory descriptor, (+) means a positive coefficient in the considering model and (-), a negative coefficient in the considering model.

Conclusion

Even if results must be confirmed with other case studies, this work highlights the relevance of Kano's theory applied to EPM in finding all key sensory attributes and interpreting their influence on satisfaction and dissatisfaction. The advantages are clearly expressed by Matzler and Hinterhuber (1998):

- Product attributes are better understood: sensory attributes which have the greatest influence on consumer's satisfaction are identified. Classifying product attributes into must-be, performance and attractive attributes can be used to focus on.
- Priorities for product development. It is, for example, useless to invest in improving must-be attributes which are already at a satisfactory level but better to improve performance or attractive attributes as they have a greater influence on consumer's level of satisfaction.
- Discovering and fulfilling attractive attributes creates a wide range of possibilities for differentiation. A product which merely satisfies must-be and performance attributes is perceived as average and therefore interchangeable.

References :

Gordon A.D. (1991). *Classification*, 2nd edition Chapman &Hall.

Kano N. (1984). Attractive quality and must-be quality, *The Journal of the Japanese Society for Quality Control*, April, pp. 39-48.

MacFie H.J., Bratchell N., Greenhoff K. et Vallis L.V. (1989). Designs to balance the effect of order of presentation and first order carry-over effects in Hall Tests. *Journal of Sensory Studies*, 4, 129-148.

Martens, M., Martens, H., & Wold, S. (1983). Preference of cauliflower related to sensory descriptive variables by partial least squares (PLS) Regression. *Journal of the science of food and agriculture*, 34, 715-724.

Matzler K. and Hinterhuber H.H. (1998). How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment, *Technovation*, vol. 18, no. 1, pp. 25-38.

Tenenhaus M. (1998). *La régression PLS*. Technip, Paris.

Wold, S. (1994), PLS for Multivariate Linear Modeling, *QSAR: Chemometric Methods in Molecular Design. Methods and Principles in Medicinal Chemistry*, ed. H. van de Waterbeemd, Weinheim, Germany: Verlag-Chemie.