Sensory evaluation of automotive fabrics: 
the contribution of categorization tasks and non verbal information to set-up a descriptive method of tactile properties

Agnès Giboreau a,*, Séverine Navarro a, Pauline Faye b, Jacqueline Dumortier c

a PSA Peugeot Citroën, DRIA/SARA/PVFH, 2 route de Gisy, 78943 Velizy, France
b LORE, 11 boulevard Pershing, 75017 Paris, France
c Trèves, Centre R&D, 5 rue E.Arquès, 51686 Reims, France

Received 11 July 2000; accepted 22 December 2000

Abstract

The works reported here show the selected approach used to build a powerful descriptive method of the touch of fabrics. First, naive consumers were asked to make classes of fabrics among 26 samples, based on their tactile similarities. MDS mapping showed a four-dimension perceptual space and the cluster analysis determined nine classes of typical touches, from which one exemplar was extracted for the following step. Second, internal experts from the textile domain were asked to describe the touch characteristics of these typical fabrics; they were also filmed while interviewed. Correspondence analysis and visioning of videos allowed us to identify the vocabulary and gestures used by experts for tactile description. Third, this information was used by the panel leader to drive the training sessions of the descriptive panel. The profile included nine terms and was applied to the analysis of 14 velvet-like fabrics. ANOVA and PCA results showed good panel performance and good discrimination of samples. Thus, the proposed complementary approach combining different tasks and different levels of expertise can be considered as a powerful methodology to successfully set-up accurate sensory profiling methods. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Tactile properties; Fabrics; Descriptive analysis; Expertise level; Sensory methodology

1. Introduction

In a car, a driver or passenger is exposed to a wide variety of stimuli. These signals of course depend on the vehicle itself (engine, architecture, components) but also on the driving situation (speed, gear level), the road characteristics (coating, bends), the environment (urban or rural area, temperature, hygrometry). Global perception and multi-sensory information are essential for hedonic studies of car interiors and detailed studies of separate elements are technically important to define and develop target industrial products. Among all, visual and tactile properties of the compartment strongly contribute to the first overall quality judgment a consumer has as he/she visits the car in a show-room. Towards this latter objective, textile components (from seats, door and roof panels) constitute one of our working axes.

These two senses are particularly involved in textile perception: sight for color, pattern, appearance and touch with hand and body contacts. The final touch depends on the yarn as well as on the processes (spinning, weaving, knitting). Finishing also plays an important role on the handle of a textile: chemical operations, raising, shearing, calandering, embossing. Touch properties are essential for material specifications both in fashion and in other textile domains, although most of the time they are subjectively evaluated. Hollins, Faldowski, Rao and Young (1997) used a categorization task to examine the subjective tactile dimensions of various texture stimuli, such as wood, sandpaper, velvet. From an analytical point of view, physical and sensory methods are sometimes cited for tactile description of materials. On one hand, instrumental machines have been developed since the 1970s (Kawabata, Niwa, & Fumei, 1972). One machine, called KES (Kawabata Evaluation System) uses physical objective means (compression, bending, extension, shear) to predict sensory dimensions (dry, thick, rough, warm...). One the other hand, sensory terms are also described in published
work. The most cited dimensions are softness versus harshness and the global description of the “hand” of a fabric (Ali & Begum, 1994; Bigue-Bueno & Renner, 1999; Bogaty, Hollies, & Harris, 1956). Civille and Dus (1990) developed a detailed terminology for papers and fabrics, using both tactile and sound approaches. However, no specific publication has been encountered on automotive fabrics.

The present paper shows the approach PSA Peugeot Citroën settled on when starting the studies of tactile properties of fabrics, together with Trèves, a major car fabric supplier. The general aim of these works is to better understand the final consumers: how do they perceive the touch of a fabric in the car interior? what type of tactile profile are they expecting? how the perceived quality can be optimized?

Thus, the objective of our works was to set-up a descriptive tactile method, which is discussed hereby. The selected approach aims to include both naive and expert perceptions in the definition of the trained panel sensory method. By this way, we expect to have a powerful descriptive method in terms of consumer perception (and choice) and in terms of design (and technical communication). This tool is to be used in various R&D studies: competitor comparisons, technical experiments on yarn quality, processes, finishing.

The study is based on three steps:

Part I. Tactile categorization by naive subjects: various automotive fabrics are presented blind to naive consumers who are asked to make classes according to the touch properties of the samples. The aim of this part is to determine which fabrics are perceived as similar and which are perceived as typical.

Part II. Interview and observation of specialists: samples showing typical touch are presented to specialists of the car textile domain. They are asked to describe the touch properties of the fabrics and they are filmed to allow the analysis of their gestures. The aim of this part is to integrate the expert know-how from the semantic and gesture points of view.

Part III. Sensory profiling with a trained panel: results from parts I and II are used by the panel leader to set-up the descriptive vocabulary and associated definitions and procedures of evaluation. Then, the developed sensory method is applied to the characterization of a group of automotive fabrics.

2. Materials and methods

2.1. Samples

Fabrics (26 samples) with different tactile properties are selected to represent the current automotive market regarding the seat application only. They cover various yarn qualities and various technologies. They all have a 2 mm foam support, in a A4 format (21 × 29.7 cm). They are presented blind to avoid any visual influence. Table 1 gives codes, characteristics of the fabrics and their use in the three phases of the study.

2.2. Tactile categorization by naive subjects

Considering the relatively high number of samples to evaluate, the objective of the first step is to know whether all the fabrics exhibit specific touch properties or not. Thus, based on categorization theory of object perception, the existence of classes of similar touch is explored with naive subjects.

2.2.1. Subjects

Twelve persons from the company with no specific training nor professional experience in fabrics are invited to participate in the categorization test (five females and seven males).

2.2.2. Procedure

Due to supplying constraints, 23 fabrics out of the selected 26 are used in this phase (see Table 1). The test consists of the categorization of the samples according to their tactile properties: panelists are asked to sort the samples into mutually exclusive groups based on their tactile similarities. No constraint is given of the number of classes to make.

Fabrics are hidden behind a curtain under which the subject puts his/her hands. Two sessions are conducted in the same conditions with the same subjects, on 2 different days.

2.2.3. Data analysis

The assumption underlying this method is that samples occurring in the same group are more similar than samples occurring in different groups (Popper & Heymann, 1996). The categorization results are transformed into quantitative scorings: for each of the two replications, the sorting data for any individual consists of a matrix of 0 and 1, indicating whether the subject grouped two products together or not. Individual similarity matrices are summed for all assessors and all evaluations: the similarity $S_{ij}$ of two samples, $i$ and $j$, varies from 0 to 24 (12 subjects×two replicates). The dissimilarity is then obtained by $(24 - S_{ij})$ and is considered as a distance between samples.

First, Classical MultiDimensional Scaling (CMDS) allows the construction an Euclidean space in which the points configuration fits the distance between samples the best. The non-metric Alternating Least-Square sCALing (ALSCAL) algorithm is performed on the dissimilarity matrix using SPSS Software (version 10.0, SPSS, Paris, F).

Two parameters indicate the degree of fit between the original data and the final configuration and allow to
select the number of dimensions of the MDS model: the ‘STRESS’ and the RSQ.

The STRESS, often termed Kruskal’S stress, is a ‘badness-of-fit’: a lower STRESS means a better fit. It is defined by the following formula:

$$\text{Stress} = \left( \frac{\sum_{i} \sum_{j} (d_{ij} - \hat{d}_{ij})^2}{\sum_{i} \sum_{j} d_{ij}^2} \right)^{1/2}$$

where $d_{ij}$ represents the distance between $i$ and $j$ in the MDS space and $\hat{d}_{ij}$ the distance that fits the dissimilarity between $i$ and $j$ the best.

The RSQ is a correlation coefficient between dissimilarity (original data) and distance (calculated). A closed to 1 RSQ means a better fit.

Second, fabrics are segmented by cluster analysis (Hierarchical Ascending Classification with square Euclidean distance and Ward’s method) on the products coordinates on the MDS dimensions. This analysis groups together samples that have close coordinates in the multidimensional space, meaning that they are similarly perceived by the subjects. The histogram of the level index indicates the loss of inertia when an additional class is considered in the partition. An important gap on the histogram indicates the index corresponding to the number of classes that have to be kept (Lebart, Morineau, & Piron, 1997). SPAD software (version 4, Cisia-Ceresta, Paris, F) is used to perform this analysis.

2.3. Part II. Interview and observation of specialists

Considering the existing expertise of professionals in our companies, the objective of the second step is to extract the sensory know-how from internal experiences. Thus, gestures and vocabulary to explore and describe the touch of fabrics are studied from face to face filmed interviews of experts.

2.3.1. Subjects

Sixteen specialists of fabrics of Trèves and PSA Peugeot Citroën are interviewed (seven females and nine males). They come from various departments involved in the textile area: marketing, design, development, quality control. Subjects are blindfolded during all the interview.
2.3.2. Procedure

Eleven typical fabrics are chosen from the categorization results to be representative of existing touches. Four pairs of fabrics are also used in this phase to present pairs of close tactile properties (see Table 1).

First, the typical fabrics are given one by one in a random order and subjects are asked to describe their touch characteristics.

Then, each pair is presented in a random order and subjects are asked to describe the tactile similarities and dissimilarities between the two samples.

At the end of the test, complementary questions are asked in order to get more information about imprecise gestures or definitions, if any.

With the approval of the participant, all the interview is filmed with a miniature camera (30 x 10 x 10 mm) in order to analyze sequences of gestures in detail. An outside observer takes note on gestures and comments.

2.3.3. Data analysis

On one hand, the words mentioned by the specialists are listed and their occurrences are counted for each sample. The terms whose occurrences never exceed one or two are removed from the data set.

In order to study the relationships between words and fabrics, a Correspondence Analysis is performed on the word occurrences for each sample. The results is a map which plots words and fabrics in a chi-square metric.

Then, a Cluster Analysis is realized on the words coordinates on the factorial space dimensions in order to determine the groups of terms which characterize the fabrics the best. The histogram of the level index is used to choose the number of classes.

On the other hand, gestures are studied from the videotapes. Due to the large variability of encountered gestures, no statistical analysis is conducted. The interpretation is qualitative: all gestures are reported by two experimenters. They gather similar gestures into families. Classes of most used gestures are then selected by mutual agreement.

2.4. Part III. Sensory profiling of velvet-like fabrics

Information from Part I and Part II is used to build the sensory methodology regarding the samples space, the vocabulary and the procedure of evaluation. As a result of Part I, the original group of the 26 fabrics is divided into two sub-groups: fabrics with a ‘flat aspect’ (mainly woven and warp knitted) and the velvet-type fabrics. Only the study of the latter group is described herein (14 samples as indicated in Table 1).

2.4.1. Subjects

Twelve persons (five females and seven males) are selected to constitute an external trained panel coming all year long 2 x 2 h a week. Recruitment is based on several criteria: sensory ability (triangle tests on samples with small tactile differences), logical aptitudes (scoring of black amount in geometrical shapes on a linear scale, see Meilgaard, Civille, & Carr, 1991), group behavior (discussion to consensually elicit terms describing the aspect of plastic samples), availability and interest (interviews). The selected subjects are given a 12 h instruction with the presentation of the objectives of sensory evaluation, basic information on sensory physiology, and practice of several common tests. The panel is 6 month experienced when the current study starts. Only 10 out of the 12 panelists participate in this study.

A specific training is conducted on the touch of fabrics, organized as follow:

- two sessions to generate descriptors;
- five sessions to select definitions, gestures and references for each tactile attribute; and
- eight sessions to practice scaling through pair comparison tests, ranking tests and sensory profiling.

About half the exercises are individual tasks and half are group discussions to compare results and reach a consensus. The training specifically devoted to velvet-type fabrics represents about 15 h.

2.4.2. Procedure

The categories of descriptive terms given by the textile experts and their most observed gestures are used by the panel leader as a help to conduct panel discussions. The final list of terms includes nine attributes: rigid, deep, relief (frequency), rough 1, rough 2, bouncy, elastic, mobile, compact.

Each attribute is precisely defined as well as its associated gesture and fabric references for minimum and maximum of the scale. For example, the attribute ‘deep’ is defined as the depth of the unevenness and is evaluated by gently moving the fingertips over the surface of the fabric, without any pressure. POL is the reference for the low anchor of the scale and BOL for the high anchor.

The exact definitions and procedures of evaluation are kept confidential. An overall presentation of the active part of the hand and of the type of gesture is given for all attributes in Table 2.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Active part</th>
<th>Type of gesture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td>Hand</td>
<td>Large/pressure/movement</td>
</tr>
<tr>
<td>Deep</td>
<td>Fingertips</td>
<td>Small/no pressure/movement</td>
</tr>
<tr>
<td>Relief (frequency)</td>
<td>Fingertips</td>
<td>Small/no pressure/movement</td>
</tr>
<tr>
<td>Rough 1</td>
<td>Hand</td>
<td>Small/no pressure/movement</td>
</tr>
<tr>
<td>Rough 2</td>
<td>Hand</td>
<td>Small/no pressure/movement</td>
</tr>
<tr>
<td>Bouncy</td>
<td>Fingertips</td>
<td>Small/pressure/no movement</td>
</tr>
<tr>
<td>Elastic</td>
<td>Hands</td>
<td>Large/movement</td>
</tr>
<tr>
<td>Mobile</td>
<td>Finger</td>
<td>Small/pressure/movement</td>
</tr>
<tr>
<td>Compact</td>
<td>Fingertips</td>
<td>Small/pressure/movement</td>
</tr>
</tbody>
</table>
The test is a comparative sensory profile: the 14 fabrics are given at the same time to the assessor. For each descriptor, the subject touches the corresponding references and the sample to evaluate in order to give score of perceived intensity (between the two references). The other samples can also be touched for relative perception.

For each attribute the 14 scales appear on the screen. The scaling procedure consists of an unstructured horizontal scale (12.5 cm long), anchored at the ends with the shortest (for perceived intensity). The scale is automatically converted into figures between 0 and 10.

Each sample is provided in a large envelop coded with a three digit number where the subject introduces his/her hand.

A William Latin square design is used to determine the order of evaluation for each assessor. Three sessions are conducted on separate days (with different presentation orders) to have the complete data set. The FIZZ software (version 1.2, Biosystèmes, Couternon, F.) is used to provide the design and acquire scores via a computer network.

**Data analysis**

*Univariate analysis.* Each sensory attribute is analyzed by a three-way mixed model analysis of variance (Product, Subject and Session) with all two-way interactions. Subjects are treated as a random effect. Differences are considered significant at $P < 0.05$. Significant differences between products are evaluated by a Duncan multiple comparison test.

The analyses are carried out with the FIZZ Software (version 1.2, Biosystèmes, Couternon, F.).

*Multivariate analysis.* Multivariate mapping is used to describe the relationship between tactile properties and to identify differences between fabrics. A Principal Component Analysis is performed on the correlation matrix of the samples means with the SPAD Software (version 4.0, Cisia-Ceresta, Paris, F.). Data is standardized to allow the attributes to contribute in the analysis in the same way.

### 3. Results

#### 3.1. Part I. Tactile categorization by naive subjects

The complete set of data (12 naive subjects×two replicates) is used to analyze the tactile similarities/dissimilarities of the 23 tested fabrics.

**Stress and RSQ**

Fig. 1 presents the variations of the stress and the RSQ according to the number of dimensions in the model, increased step by step from 2 to 5 by the experimenter.

The representation quality can be considered as poor for a stress value above 0.2 and becomes good when the stress value is below 0.05. Fig. 1 reveals that a four-dimensional solution seems to be a good consensus since the stress is 7% and RSQ is close to 1 (0.97).

**Fabrics positioning**

The first graph (dimensions one and two) mainly separates flat fabrics (A) from velvet-like fabrics (B). Actually, these two types of fabrics correspond to two car categories. Group (A) mainly gathers woven and warp knitted fabrics whereas group (B) mainly refers to velvet technologies. In the latter group, a sub-group of velvets with a superimposed 3D pattern is identified on the second dimension (B*: OPA, BOL, MOA).

The second graph (dimensions three and four) separates two sub-groups of more typical fabrics: RAC and FRA (C) exhibit a specific touch (large relief) because of their technological parameters and ALC and FLO (D), obtained with non-classical textile processes, are also perceived as different.

**Selection of typical fabrics**

From the above qualitative description of the MDS mapping, the product space is split into three main groups: (A) fabrics with a flat aspect, (B+B*) velvet-like fabrics, (C+D) typical touch fabrics.

Using the MDS coordinates, the cluster analysis identifies nine classes of fabrics (see Fig. 3) which subdivides this overall grouping (see Fig. 4). Thus, these nine classes correspond to a detailed tactile perceptive space of tested fabrics and allow the identification of typical touches.

A group of nine fabrics (one from each class) can be selected to represent the tactile space according to the classification by naive consumers without loosing too much initial information.
3.1.4. Conclusions of Part I

The 23 selected fabrics illustrating the existing car seats from the market are perceived by naive consumers as a four dimension space. The two first dimensions split the products space by the opposition between flat aspect fabrics and velvet-like fabrics. The third and fourth dimensions separate fabrics obtained by typical processes or with a large relief structure.

The cluster analysis identifies nine classes of typical touches. One exemplar fabric is selected to represent each tactile class. Within two classes, two samples are selected to offer a relative inter-class versus intra-class contrast.

Fig. 2. Product mapping of the MDS model. (a) Dimensions 1 and 2; (b) dimensions 3 and 4.
comparison in the following tasks conducted with the experts.

3.2. Part II. Interview and observation of specialists

Both terms and gestures used by the textile experts are analyzed from the 16 filmed interviews. Experts describe typical fabrics as well as pairs of close samples in terms of touch. A total of 16 fabrics is examined.

3.2.1. Gestures

The visioning of the films reveals important differences from one expert to another, in terms of the gestures themselves as well as of their amplitude. Attention is given to similar approaches rather than to individual specificity. The following procedures are observed for several experts (illustrated in Fig. 5):

1. Use of the palm, flat on the fabric surface, mainly related to the description of overall quality, such as comfort, softness, richness.
2. Use of the fingertips, with small or large movements, mainly to evaluate more detailed properties, such as rough, relief, slippery. Movements are either circular or linear.
3. Use of the fingertips with a local pressure, to evaluate softness, thickness.
4. Use of the all hand for grasping the fabric, to evaluate stiffness or softness.

Many other gestures are observed, using the back of the hand, using both hands to stretch the material, using only one finger.

3.2.2. Words

The textile specialists generated 146 words. Some are mentioned more frequently than others: sticky, warm, comfortable, compact, hollow, dense, soft, elastic, thick, smooth, slippery, flat, rough, relief, rich, rugged, dry, flexible, structured, synthetic. The word ‘soft’ is very often used by specialists and represents 11% of all the citations. However, when asking more information on its meaning, no consensual definition is obtained. The high frequency of citation can be explained by the fact that this word may be used as a descriptive term as well as an hedonic term.

All the terms are indexed in a contingency matrix (textiles as rows and words as columns). Terms mentioned only once or twice over all specialists and all products are removed from the table. Thus, 64 terms are used for the Correspondence Analysis. A Cluster analysis is then performed on the term coordinates. Ten classes of words seem to be a good compromise to synthesize the information of all the generated terms (see Fig. 6). The first factorial map of the Correspondence Analysis explains only 30% of the inertia. It is presented in Fig. 7. Fig. 7a indicates the average of each class of terms, one or two representative term(s) of each class being indicated on the graph.

3.2.3. Fabrics positioning

The simultaneous study of Figs. 7a and b allows to determine the geometric relationships between fabrics and words (Higgs, 1990). The map clearly shows the products that are very specific and different from the others: ALC, FLO, MOA/BOL, FRA/RAC. They are respectively characterized by the classes of words ‘skin’, ‘short-pile/cardboard’, ‘creased’ and ‘stretching/relief’. Less typical fabrics correspond to exemplars of flat aspect fabrics, being flat/rough and the velvet-like ones, being warm/velvet.

3.2.4. Conclusions of Part II

The analysis of words and gestures used by the textile experts gives information on the most cited properties and procedures of evaluation: they are proposed as a starting point of the sensory panel discussions of part III.
The first factorial map separates flat aspect fabrics from velvet-like ones and from typical fabrics. These groups of touches are comparable to the ones obtained with the naive consumers even if only a sub-group of samples was tested with the experts.

3.3. Part III. Sensory profiling of velvet-like fabrics

The complete data set (14 products×10 subjects×3 replicates) is used for the sensory description of the velvet-like fabrics.

Fig. 5. Photographs illustrating the most common gestures used by textile professionals when describing tactile properties of fabrics.

a. use of fingertips with no pressure  b. use of fingertips with pressure  
c. use of the palm with no pressure  d. use of all hand with manipulation

Fig. 6. Histogram of the level index of the cluster analysis conducted on the coordinates of the words on the correspondence analysis dimensions.
3.3.1. Univariate analysis

The F-ratios calculated through the three-way ANOVAs are given in Table 3.

3.3.1.1. Repeatability. All attributes show no significant session effect neither product×session interaction effect. Three attributes show a slight subject×session interaction effect. From a global point of view, the panel is then considered as repeatable.

3.3.1.2. Consensus intra-panel. Almost all attributes show a significant subject effect and a significant product×subject (P×S) interaction effect. Subject effect is expected: no specific work on the exact positioning of intensities on the scale is included in the training, the subject calibrates himself/herself with the scale. These differences in the use of the scale is fullyacceptable as affecting all products in a similar way. The P×S effect is less acceptable as it denotes a disagreement between some of the assessors. However, a more detailed analysis of the results mainly shows scaling disagreements (proportions) rather than ranking disagreements.

3.3.1.3. Product discrimination. All attributes show a significant product effect with large F-ratios (P < 0.001).

Depending on the attributes, the Duncan test separates between two to four groups of different fabrics (one group is defined here with no overlapping of classes). Fig. 8 gives the examples of ‘relief frequency’, ‘rough 1’ and ‘compact’. These graphs show the wide use of the scale and the clear separation of samples by the sensory profiling analysis.

3.3.2. Multivariate analysis

The principal component analysis is conducted on the mean data to describe the overall positioning of the fabrics in relation to the sensory attributes.

Three components have a greater than 1 Eigen value and explain 80% of the total inertia (see Fig. 9).

The correlation circles (Fig. 10) show that ‘relief frequency’ and ‘deep’ essentially describe the first axis and

Some improvement can probably be brought on intrapanel agreement but the overall product discrimination is large enough to interpret the results with confidence.

![Fig. 7. Product mapping of the correspondence analysis of dimensions 1 and 2. (a) Terms; (b) products.](image)

Table 3

Results of the three-way ANOVA for each sensory attribute (F ratio)

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Product</th>
<th>Subject</th>
<th>Session</th>
<th>Product×subject</th>
<th>Product×session</th>
<th>Subject×session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td>34.83***</td>
<td>4.86***</td>
<td>0.44</td>
<td>1.82***</td>
<td>0.56</td>
<td>1.20</td>
</tr>
<tr>
<td>Deep</td>
<td>50.10***</td>
<td>33.62***</td>
<td>0.57</td>
<td>2.85***</td>
<td>0.92</td>
<td>3.20***</td>
</tr>
<tr>
<td>Relief frequency</td>
<td>38.74***</td>
<td>27.26***</td>
<td>0.58</td>
<td>3.79***</td>
<td>1.03</td>
<td>2.82***</td>
</tr>
<tr>
<td>Rough 1</td>
<td>45.69***</td>
<td>7.69***</td>
<td>0.18</td>
<td>2.71***</td>
<td>0.94</td>
<td>1.82*</td>
</tr>
<tr>
<td>Rough 2</td>
<td>21.69***</td>
<td>10.87***</td>
<td>0.19</td>
<td>1.98***</td>
<td>1.11</td>
<td>1.59</td>
</tr>
<tr>
<td>Bouncy</td>
<td>17.94***</td>
<td>4.47***</td>
<td>1.26</td>
<td>1.44**</td>
<td>0.63</td>
<td>1.27</td>
</tr>
<tr>
<td>Elastic</td>
<td>295.48***</td>
<td>2.61**</td>
<td>2.15</td>
<td>1.25</td>
<td>0.98</td>
<td>0.95</td>
</tr>
<tr>
<td>Mobile</td>
<td>18.12***</td>
<td>9.92***</td>
<td>1.67</td>
<td>1.67***</td>
<td>1.07</td>
<td>1.03</td>
</tr>
<tr>
<td>Compact</td>
<td>14.52***</td>
<td>5.83***</td>
<td>1.99</td>
<td>1.65***</td>
<td>0.92</td>
<td>1.10</td>
</tr>
</tbody>
</table>

*P < 0.05.
**P < 0.01.
***P < 0.001.
that the anti-correlated ‘compact’ versus ‘bouncy’ and ‘mobile’ describe the second axis. The third axis is explained by rough and rigid.

The factorial mappings (Fig. 10) give the relative positions of the samples. Three fabrics, BOL, MOA, OPA are differentiated from the others on the first axis because of their ‘relief’. They are the most typical among the studied sub-group of velvet-like fabrics, as noticed with the naive consumers and experts results (B’ group). The sensory profile also allows to describe the differences that exist between these three samples: on the third axis, one can see that those fabrics have different ‘rough’ touches. BOL is the least rough and OPA the roughest.

The other fabrics are also described in details. For instance, SPA and POR are bouncy and not compact. On the second axis, VOL and CAN (warp knitted fabrics with a brush knit finish) are perceived as very compact and not bouncy as the circular velvet POL. On the third axis we notice that POL has a touch more rough. So, VOL and CAN present an interesting smoothness although they are not obtained with the velvet technology.

3.3.3. Conclusions of Part III

The developed methodology shows good panel performances and large product discrimination. It gives a detailed description of the studied velvet-like fabrics.

These results validate the sensory descriptive tool for further R&D studies.

4. Discussion

The reported works showed the interest of tactile categorization by naive subjects to have an overview of the perceptual space of the tested samples. It allowed to select, in terms of touch properties, typical samples for more focused exercises and to split the global product space in more coherent groups of products for detailed sensory description.

Then, results showed the benefits of analyzing words and gestures of specialists. It allowed to clearly improve the textile competence of the panel leader. By knowing the most important classes of terms and gestures, it also brought specialized information which allowed to drive the training tasks in optimized directions.

Finally, the developed sensory method applied to an homogeneous sub-set of velvet-type fabrics gave good results in terms of panel performance and product discrimination.

Categorization task is valuable for consumer approach as it is an easy exercise and it focuses on perception only. Interviewing experts also brings important information as this allows us to be in phase with the specialists’ know-how. Thus, the proposed complementary approach combining different tasks and

![Fig. 8. Mean results (10 subjects x 3 replicates) for the attributes: Relief frequency; Rough 1; compact.](image)

![Fig. 9. Principal component analysis: histogram of the Eigen value.](image)
different levels of expertise can be considered as a powerful methodology to successfully set-up accurate sensory profiling methods. This could be applied when starting the study of new product domains as well as other sensory dimensions.

In a long-term perspective, these works raise directions for future research topics:

The level of expertise. The comparison of perceptual spaces showed consistency between naive and expert subjects, even with different tasks and sample numbers. The velvet-like fabrics were opposed to flat aspect fabrics and typical touch fabrics were separated in both cases. However, these similar results can only be considered from a macroscopic standpoint. Exactly similar experiments would be necessary to better know the border between naive and expert sensitivity. In addition, one should notice that experts specificity is to bring semantic descriptive information, which is not feasible with naive consumers.

The type of task. Categorization task allows us to focus on the sensory perception itself without asking a large cognitive effort. It was used in the present work to help the selection of typical fabrics by naive subjects. Other objectives could be pursued with such a simple exercise. For instance, it could be included in sensory training as preliminary steps or in more basic studies on object perception, to discriminate between sensory and functionality or to study the link between perception and preference. On the other hand, non-verbal information was studied in our works. Its use to better integrate the expert know-how is still of interest and other applications can be planned. Such as the validation of sensory training procedures or the analysis of spontaneous consumer behavior while using the object of interest. Although interpretation is not easy and time consuming, new means are available to decompose images in terms of duration and frequencies of gestures, allowing statistical analysis.

In a short-term perspective, application studies will be conducted to link the descriptive results to car customers perception, for instance with a preference mapping approach.

Fig. 10. Principal component analysis: attribute correlation and product mapping. (a) Dimensions 1 and 2; 9b) dimensions 1–3.
Acknowledgements

The authors wish to acknowledge C. Egoroff for her collaboration in the sensory profiling phase and V. Deiss and L. Ganet for their participation, respectively, in the observation and the interview of experts.

References
