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Sensory and Physiological Issue

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1. Introduction

1.1 Economical, social, environmental, and industrial contexts

A significant added value of textiles is sensory in nature. During garment handling in a shop, the customer engages a selection process that involves touching and trying on clothing. A multifaceted multi-sensory, emotional and psychological experience occurs. A decision is made and motivations are based on anticipated reality of preference, personality, and emotion.

The Integration of sensory feeling in product development was not only focused in textile industry. The use of sensory analysis methods started in the sixties for food products and has been extended to many non-food products including personal care, pharmaceutical and paper products. New design processes integrating the designers' constraints and the consumers' expectations for better qualities perception have therefore been proposed in other industries. Sensory analysis methods have been widely used as market research tools in recent times and significant examples of application can be found in automotive industry. The latter has recently performed several attempts to understand and characterise the sensory preferences of end-users and to translate these features into technical specifications for new products development (Giboreau et al., 2001). However, this trend may be more prominent for textile industry as many factors can be given for conferring "character" to a material observed through handling. Micro fibres, silk-like and peach-like, cool or soft touches have been successfully developed in the past and new and exciting textile products. Hence, finishing treatments are still studied and launched on the market for that purpose. This phenomenon has been largely increased nowadays by the new textile industry developments in terms of globalization and new virtual-environment applications demand for variety and personalization. The main objective is to tailor products to the preferences of each consumer (Nakano, 1994), (Okamoto, 1991).

2. Scientific context – State of the art

Recently, industrialists have moved away from usability-based approaches and towards different ones to defining user requirements. This strategy provides a framework for

considering the sensory, hedonic and practical user's requirements within the product design or product evaluation process. Therefore, considering the benefits that a product should bring to its users, the next step is to determine the design characteristics through which the product can deliver these benefits. It can be considered to referring to *kansei engineering* which has been pioneered by Nagamachi (Nagamachi, 1995) in Japan since the 1970s. *Kansei* is a Japanese term for consumers' psychological impressions and feelings about a product. This approach encompasses physical, physiological, and psychological point of views.

2.1 Physical point of view

More than eighty years have passed since the earliest efforts of Peirce (Peirce, 1930) in the textile field to evaluate fabric hand thanks to physical measurement data. Several studies have then been undertaken to use instruments to measure fabric hand, notably Kawabata's method of the Japanese Hand Evaluation and Standardization Committee (HESC) in the 1970s (HSEC, 1980; Kawabata, 1988), and a number of mechanical devices, including KES (Kawabata Evaluation System), FAST (Fabric Assurance by Simple Testing), and UST (Universal Surface Tester), have been developed to objectively characterize fabric hand quality (Pan & Yen, 1992; Pac et al., 2001; Fontaine et al., 2005; Issa et al., 2008; Maâtoug et al., 2009). Along the instrumental tests, all fabrics are subjected to deformations similar to those applied by the hand experts, using the same modes and rates. These tools are usually fast, repeatable and well understood; however, they may not represent the textile good in use as the measured mechanical parameters cannot directly reflect human sensation in a precise way. Indeed, fabric perception, which can be defined as the human sensory response towards fabric, obviously involves not only physical and mechanical factors, but also physiological, perceptual and social factors.

2.2 Physiological point of view

Physiological approach is focused on the body - information derived from the sensory organs. This information covers tactile, visual and olfactory properties. Tactile pleasures concern holding and handling a textile product. This might be relevant in the context of garments shopping. Olfactory pleasures concern the smell of the new product: the smell inside a new car may be a factor that effects how pleasurable it is for the owner. Hedonic characteristics of fabrics and garments are therefore to be considered by textile manufacturers.

2.3 Psycho-physical point of view

The psycho-physical point of view relates to how the consumer mood is affected by interaction with a product. It might be expected, for example, that a new garment would provide a higher level of psychological pleasure than the old casual one. In the context of textile products it would relate to, for example, the aesthetics of a product and the values that a product embodies.

3. Methods to assess human perceptions: sensory analysis

In the 50s, sensory analysis emerged, first by the development of methods used by food industry and in 1974 in USA; a complete methodology for descriptive analysis was

proposed (Stone et al., 1974). The sensory analysis has shown a promising tool for taste and smell in food industry and has been applied with success in cosmetic industries such as Nestle, L'Oreal, Dior, (Young et al., 2005; Stone & Sidel, 2007). Textile materials have been a subject of interest concerning sensory analysis. The first attempt is reported by Binns (Binns, 1926). Since the early 80s, standard methods have been developed and published. They are customization of methods established in food science (Depled, 1998); Barthelemy et al., 1990; Meilgaard et al., 1991). A methodology for sensory analysis of tactile feeling of textile fabrics was developed in France and the results reported a creation of tactile sensory profile (Depled, 1998; Cardello et al., 2003; Philippe et al., 2003; Chollakup et al., 2004 a; 2004 b; Bensaid et al, 2006). Automotive industry has also applied sensory methods for their own products. Sensotact® reference frame is a commercial example of an attempt to formalize and calibrate descriptions of tactile perceptual dimensions. It was developed by French Renault Automotive Company (Sensotact, 2008). Italian Fiat Company (Bandini et al., 1997) has also shown some relevant sensory design engineering examples for their products.

3.1 Definition of sensory analysis

The basic assumption of sensory evaluation is the ability to perform objective measurements of sensations using a panel of people as an instrument. The sensory analysis is defined as « the examination of the organoleptical properties of a product using the human senses » (ISO 5492, 1992). Fortin and Durand (Fortin & Durand, 2004) give the following assertion « The sensory analysis can be defined as the study of the human response to a stimulus (...) The sensory analysis qualifies and quantifies the felt perceptions of persons called judges or panelists when they evaluate products or materials inducing our reactions senses. These methods could be applied to food, perfumes, cosmetics, textiles, automotives... Based on these definitions, it can be assumed that the sensory analysis of the products consists in the description or their evaluation through words called descriptors or attributes linked to each of our senses (sight, hearing, taste, smell, touch).

3.2 Measurement principle

The evaluation starts with the contact between the body and the environment and the interaction of the product with the judge. It is the "sensorial stimuli", which will be analyzed in different manners regarding the personal history of the "judge" and will be linked with the relationship existing between him or her and the evaluated object. The analysis of the "sensorial stimuli" is a unique function dedicated to the human being and no measurement device could reproduce it" (Fortin & Durand, 2004). In other words, the sensory analysis method uses the human senses as measurement device. In this way, it is essential to understand how the senses are working in general and the tactile sense in particular. Every sensory information is issued from a stimulus applied on the sensorial receptors by the environment. Generally, the stimulus feeling unrolls the following procedure (Rosenweig & al., 1998; Richard & Orsal, 2001).

Signal reception: every sensorial system is activated when a stimulus is generated by an external event applied on an organ. These sensory organs select stimuli, it is the filter phase.

Transduction: the human sensors convert the external event in electric signals understood by the nervous system. This step is followed by the transmission of this signal to the nervous centers.

Integration: The different information will be treated and computed by the central nervous system which will generate the response in relation to the solicitation.

The sensorial sensors are usually grouped in sensorial organs and are specialized in one particular sensorial solicitation.

A feeling is beginning when a stimulus activates a sensory organ. The sensory responses are generated after 0.1 to 0.2 second after the stimulation. First, the stimulus is coded in terms of quality and intensity. The response to a sensory stimulation could be physiological, behavioral, verbal, or psychological; taken into consideration that, at least, only the three first responses are observable (SSHA, 1998).

Generally, as a first step in fabric sensory analysis, monosense approach is preferred. Usually, tactile only or visual only examinations are performed by panelists: for tactile evaluation, tests are carried out in "blind" conditions in order to reduce biases that could be induced by seeing the fabric such as subjective preference of a special colour or material. However, human beings are equipped with multiple sensory channels through which they experience objects in the environment. There is obvious evidence that perception of information provided within one sensory modality can be greatly influenced by stimuli caused by another modality. It is true that consumer can see the fabric when touching it and tactile exploration of a textile surface is usually accompanied by visual sensory inputs and in a context of purchase. In such conditions, the consumer has the possibility to see the colour of the fabric and to know which kind of material it has been made from as well as its context of use. During tactile exploration, one can also sometimes hear the sounds made as the fingers explore the fabric. One can sometimes smell the odour of the fabrics. For all possible combination, the correlation between visual and tactile properties has mainly been studied (Lederman et al., 1981; Konyo et al., 2002, Cinel & al., 2002, Guest & Spence, 2003, Mucci et al., 2005, Bensaïd & al., 2008). In these studies, the superiority of vision in the multi-modal sensational perception has been somehow demonstrated (Konyo et al., 2002). This first modality corresponds to several marketing results showing that vision is the very first data required by consumers and that the risk of not feeling, and trying on clothing before purchase may be the greatest challenge for Internet clothing sales, and is an issue that must be addressed. Some companies are developing Virtual 3-D try-on technology that might reduce the risk of ill-fitting or inappropriately styled clothing for one's body type, by providing the consumer with a view of the garment on his/her body. Inappropriate tactile or sound or smell feelings would be more complex to address with such technologies. However, Lederman et al. (Lederman, 1981; Lederman & al., 1986) have shown that the extent to which the data from one modality is preferred over the other depends on the nature of the task to be performed. Consequently, some tasks appeared best suited to vision (e.g. determining the spatial density of texture elements), and some to touch evaluation (e.g. determining the roughness of fine textures).

The touch feeling is known to be one of the most important senses. The skin which is the main organ of the tactile sensibility covers our body with an average surface of 1.7m² for an adult person. It is made of two layers: a top layer called epidermis which is renewed every 20 days and a bottom layer called dermis which contains nerves and blood vessels. The touch feeling groups three main modalities: mechanical sensibility, thermal sensitivity and pain.

The mechanical sensibility: also called touch sensibility corresponds to the response to pressure, touch and vibration solicitations. This sensibility depends on numerous

parameters such as shape, surface, duration and intensity of the stimulus. The mecano-receptors are the key elements of this sensibility.

Six kinds of receptors have been listed, the Merkel disks, the tactile disks, receptors of the hair follicles, the Meissner corpuscles, the Ruffini corpuscles and the Pacini corpuscles as shown in the figure 1.

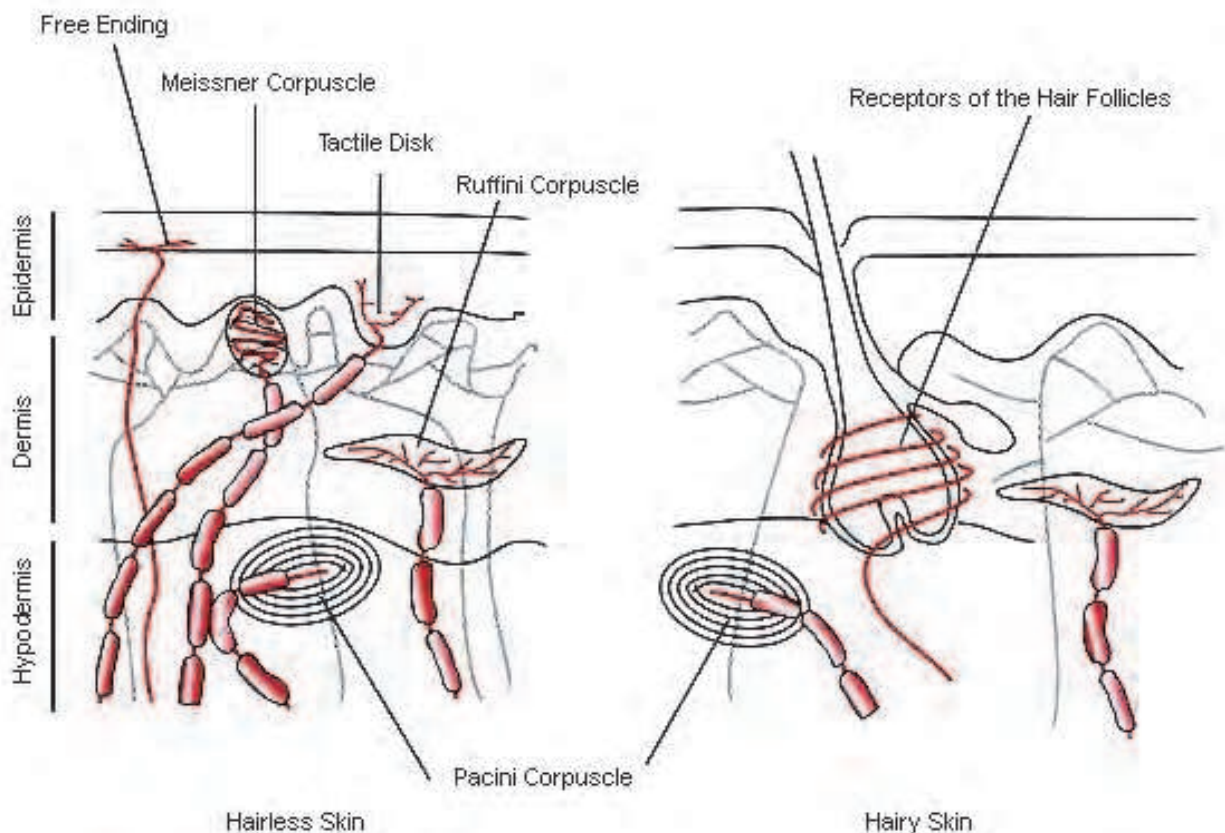


Fig. 1. Scheme of the skin and location of the touch sensors (Richard & Orsal, 2001)

The figure 2 displays the location (a), the size and the density (b) of the four kinds of receptors in the internal face of the hand (Richard & Orsal, 2001). Every cerebral region manages a precise skin part. This repartition has been presented in a caricature manner through the "homoculus" display (figure3) where every organ is represented with a surface in relation with its touch sensors density (Richard & Orsal, 2001). Nevertheless, the tactile sensibility is not fully linked with the density of the touch sensors but it is more driven by the number of connections in the sensitive cortex of the brain. On apes, some studies have shown that the sensitive surface could be increased or decreased thanks to training. Figure 4 represents a map of the spatial discrimination for the different organs. The more sensitive parts are the fingers tips and the tongue end.

Thermal sensitivity corresponds to two opposite sensibilities, the sensitivity to warm and the sensitivity to cold. These feelings are detected by some specific points which are sensitive to hot and warm and that are scattered all over the skin with a lower density than those dedicated to mechanical stresses. Moreover, the sensitive points to cold are more numerous than those sensitive to hot.

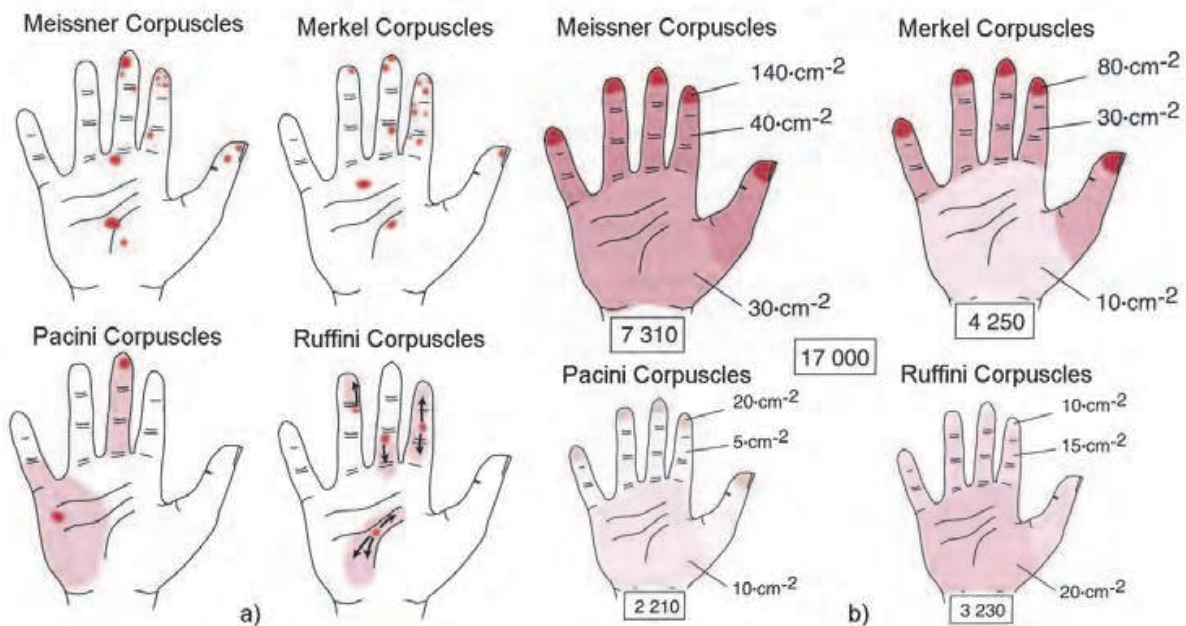


Fig. 2. Touch Sensors location a) and density b) in the inside hand

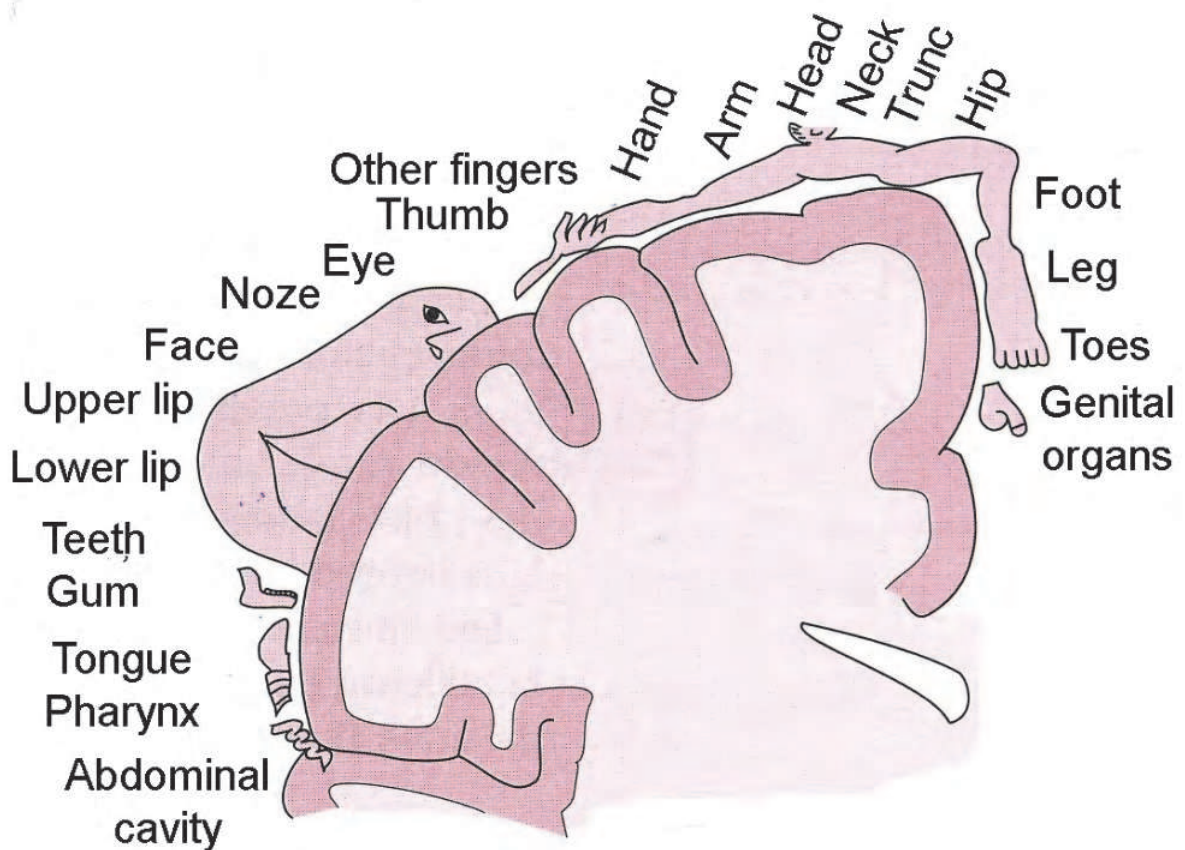


Fig. 3. Homoculus caricature display

Pain is a feeling generated by a high level stimulation called “novice” because it induces injuries in the organism. Different kinds of pain can be detailed: superficial pain which is

coming from the skin, deep pain coming from the bones, from the muscles, from the joints or the tendons. The receptors involved in this feeling are called “nociceptors”.

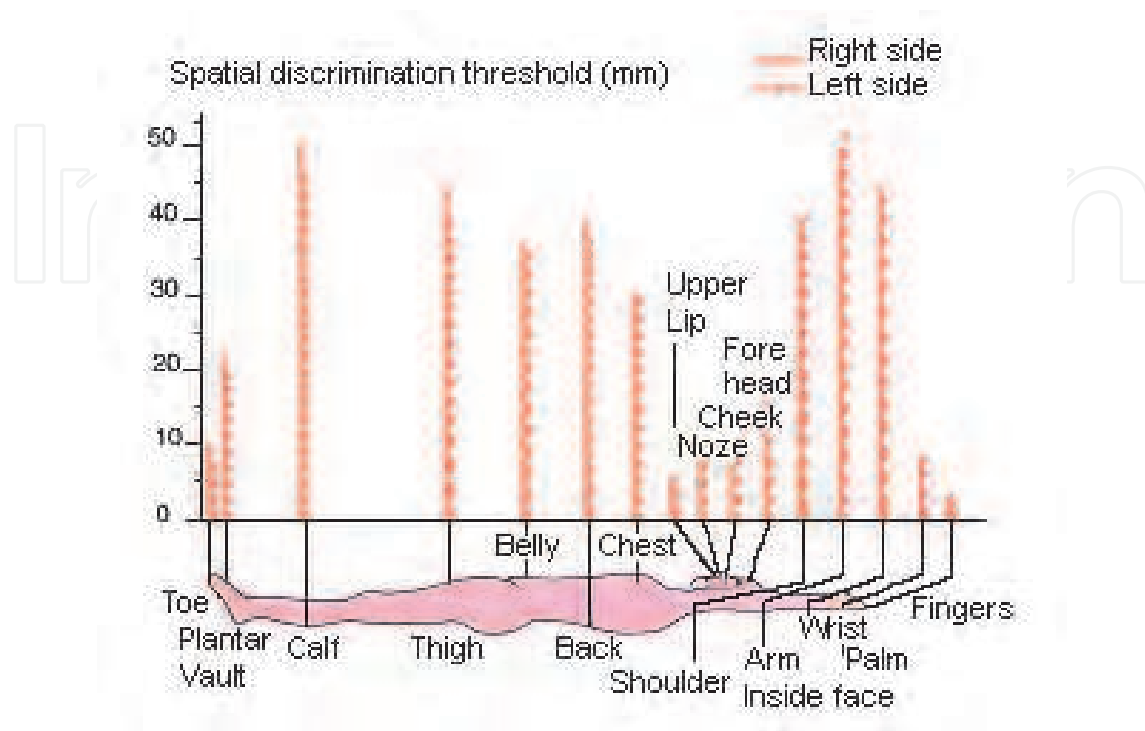


Fig. 4. Spatial discrimination threshold of human organs

3.3 Sensory analysis: Methodology

In regard to the final goal of the evaluation, comparison, quality measurement, new product characterization, etc, different kinds of tests issued of the sensory analyze set could be performed (AFNOR V09-001, 1983; AFNOR XP V 09-501, 1999; ISO 6658, 1985). One of the most frequently used, the descriptive test allows characterizing, comparing and quantifying differences between tested products. The method requires a group of trained judges (panelists), who are intensively trained to qualify and quantify their feeling and hedonic judgment in an objective way. The product characteristics are dissected through their expertise. The panelists first agree on specific and objective sensory vocabulary (ISO 11035, 1995) to describe the feeling of a product range (Nogueira & al., 2009).

Continuous training enables them to sharpen their perceptions and to perceive differences of intensity between products for every criterion. Training the panels also leads to homogeneity and reproducibility in the ratings (ISO 8586, 1993). Finally, a final grading enables to build out product sensory *identity maps* or *profiles*, or *fingerprints*. The obtained results are rich and powerful as they allow identifying all of a product's perception characteristics along with measures of the importance of those characteristics.

Figure 5 represents a sensory map of raw cotton woven fabrics before (non-treated) and after various commercial post-treatments (m, sd, sp, k) evaluated by 11 trained panelists. The tests were replicated twice and the order of presentation of the samples was randomized for each assessor. The displayed differences on figure 5, even the smallest one, are significant in regards to statistical analysis.

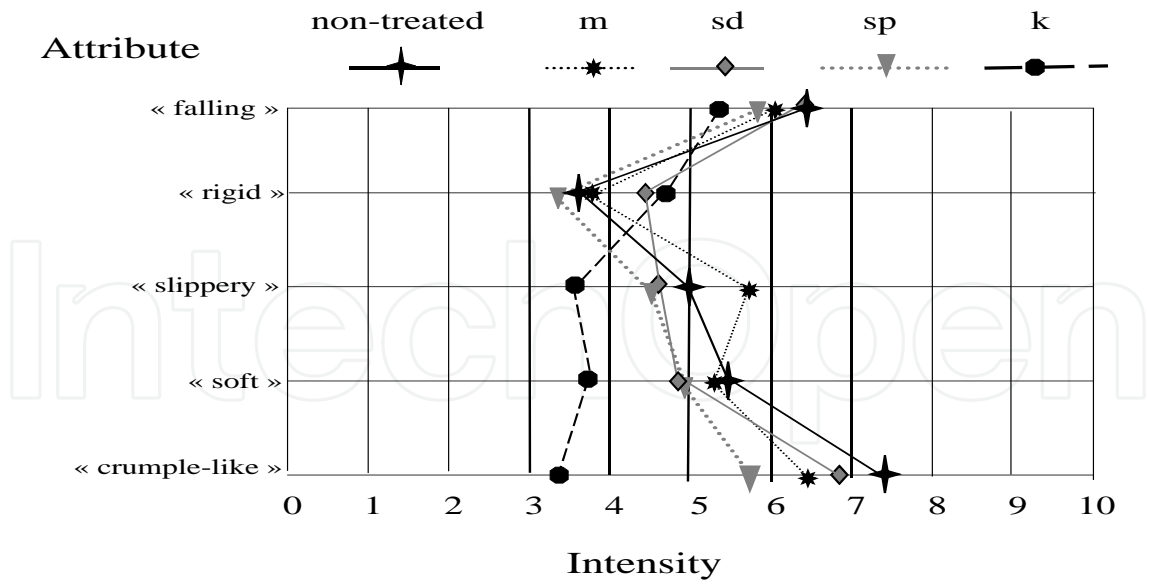


Fig. 5. Example of tactile sensory profiles of textile woven fabrics

However, the panelists are not representative of the end-users and therefore are not asked to perform the hedonic studies. The complete sensory methodology process involves another group of persons: the final consumers. This group is not trained, the persons being merely questioned on their preferences (like-dislike). Both approaches lead to *preference mapping* (Schlich, 1995) that allows specifying preferred sensory characteristics of products for given groups of end-users. Figure 6 represents the main methods in sensory analysis.

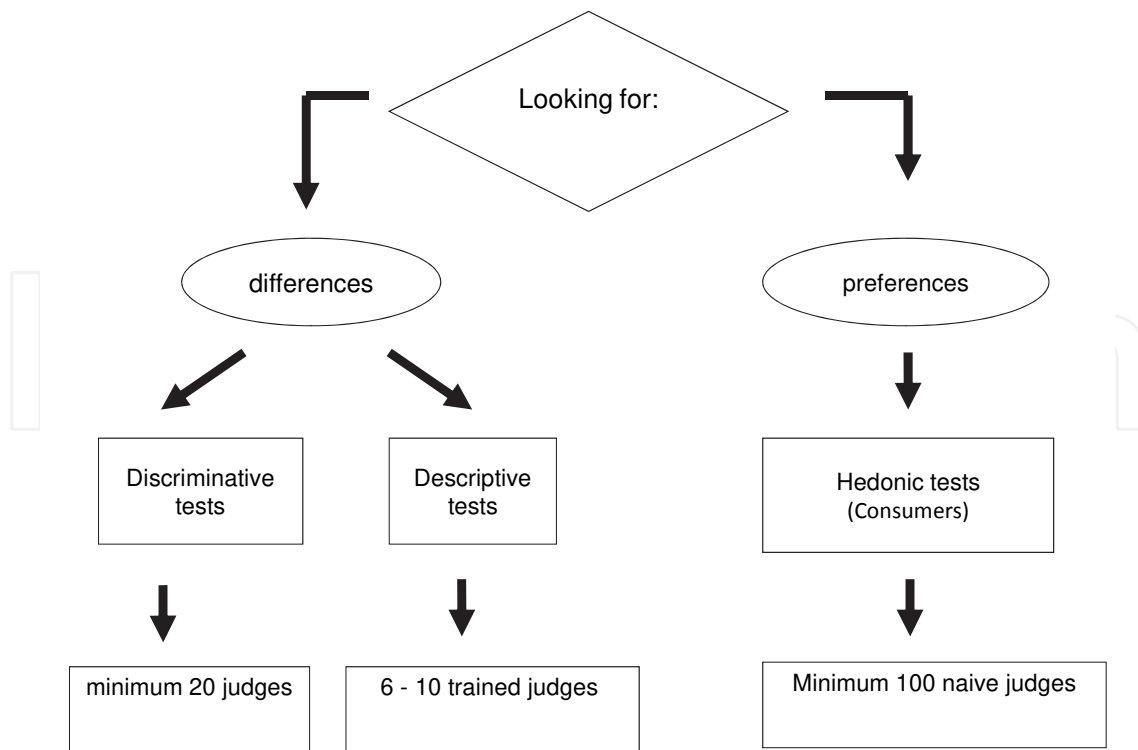


Fig. 6. Methods of sensory analysis

Sensory analysis is using “human beings” as a tool but it is employing objective methods to collect their subjective sensory responses. One disadvantage of the sensory methodology is the time consuming due to the panel recruitment, training and the validations of each step of the methods using the appropriate statistical tools.

4. Innovating method and numerical tool to simulate complex systems

Several attempts have been made to model the relationship between tactile sensory attributes of fabrics and their production parameters, or their instrumental measurements. Hence, statistics and multivariate analysis (Bishop, 1996) and methods based on intelligent techniques (neural networks, fuzzy logic...) have been used (Vassiliadis et al., 2010). The intelligent techniques have proven a very efficient tool for the fast and precise solution. Therefore, they have found increasing applications in the textile field such as properties prediction and process optimization.

4.1 Artificial Neural Network

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that tries to simulate the structure and functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. Neural networks are non-linear statistical data modelling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data.

There are many different ANN structures and learning algorithms available in the literature (Haykin, 2000). Among these algorithms, multilayer perceptron (MLP) has been successfully applied. A typical multi-layer neural network with a single hidden layer is shown in Fig.7. Each neuron receives a signal from the neurons of the previous layer and these signals are multiplied by separate synaptic weights. The weighted inputs are then summed up and passed through a transfer function, which converts the output to a fixed range of values. The output of the transfer function is then transmitted to the neurons of next layer. This process is continued and finally the output is produced at the output node. Predicted output is then compared with the desired output and an error signal is generated.

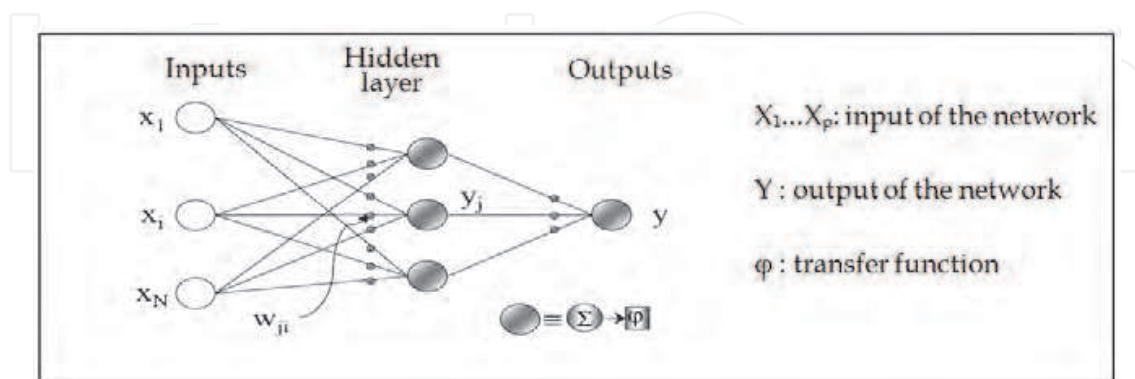


Fig. 7. A multilayer artificial neural network

The error signal is then minimised in iterative steps by adjusting the synaptic weights using a suitable training algorithm (figure 7). Among the various kinds of algorithms for training neural network, the back-propagation algorithm developed by Rumelhart et al. (1986) is the

most widely used. Network weights are adapted iteratively until some appropriate stopping criteria are met and the best weight vector that corresponds to the best generalization is achieved.

4.2 Fuzzy inference system

The foundation of fuzzy logic, which is an extension of crisp logic, was first proposed by Zadeh (Zadeh, 1965). The theoretical aspects of fuzzy logic and fuzzy arithmetic have been explained in many standard textbooks (Zimmerman, 1996). In crisp logic, such as binary logic, variables are true or false, black or white, 1 or 0. In fuzzy logic, a fuzzy set contains elements with only partial membership ranging from 0 to 1 to define uncertainty of classes that do not have clearly defined boundaries. For each input and output variable of a fuzzy inference system (FIS), the fuzzy sets are created by dividing the universe of discourse into a number of sub-regions, named in linguistic terms (high, medium, low etc.). If X is the universe of discourse and its elements are denoted by x , then a fuzzy set A in X is defined as a set of ordered pairs as $A = \{x, \mu_A(x) \mid x \in X\}$ where $\mu_A(x)$ is the membership function of x in A .

Once the fuzzy sets are chosen, a membership function for each set is created. A membership function is a typical curve that converts the input from 0 to 1, indicating the belongingness of the input to a fuzzy set. This step is known as "fuzzification". Membership function can have various forms, such as triangle, trapezoid, sigmoid and Gaussian.

The linguistic terms are then used to establish fuzzy rules. Fuzzy rules provide quantitative reasoning that relates input fuzzy sets with output fuzzy sets. A fuzzy rule base consists of a number of fuzzy if-then rules. For example, in the case of two inputs and single output fuzzy system, it could be expressed as follows:

$$\text{If } x \text{ is } A_i \text{ and } y \text{ is } B_i \text{ then } z \text{ is } C_i \quad (1)$$

where x , y and z are variables representing two inputs and one output; A_i , B_i and C_i , the linguistic values of x , y and z respectively.

The rule base contains linguistic rules that are provided by experts. It is also possible to extract rules from numerical data. Once the rules have been established, the FIS can be viewed as a system that maps an input vector to an output vector.

The output of each rule is also a fuzzy set. Output fuzzy sets are then aggregated into a single fuzzy set. This step is known as "aggregation". Finally, the resulting set is resolved to a single output number by "defuzzification". These main steps involved in modeling a fuzzy system are shown in Fig.8.



Fig. 8. General depiction of fuzzy system

4.3 Modeling the relationship related to sensory evaluation

4.3.1 Modeling the relationship between sensory properties and production parameters

In order to face the competitive environment, textile companies are interested in designing and producing new industrial products adapted to the specific needs of consumers with a

minimal number of experiments. In fact, specific fabrics tactile properties desired by consumers can be reached by adjusting the process parameters.

Several investigators have used statistics and multivariate analysis, such as multiple factor analysis MFA and principal component analysis PCA for studying the influence of finishing treatments on low stress mechanical properties and sensory attributes (El-Ghezal Jeguirim et al. 2010 a; 2010b; 2011). Although classical computing techniques are relatively efficient to interpret and analyze the relationship between sensory properties and production parameters, some limitation related to the non-linear relations in sensory domain has been reported (Zeng et al., 2008).

New methods based on intelligent techniques (fuzzy logic, neural networks...) are used to treat a great number of textile applications (Dubois & Prade, 1997; Kwak et al., 2000; Jain et al., 2004; Wong et al., 2006; Ertugrul & Ucar, 2000; Vassiliadis et al., 2010). Zeng et al. have used the fuzzy logic technique for modeling the relationship between the production parameters and the physical features of fabrics (Zeng et al., 2004). The instrumental features have been measured on Kawabata Evaluation System. In order to reduce the inputs number, a small number of relevant physical features have been selected using human knowledge on fabric production and fabrics properties. In the modeling procedure, the fuzzy rules have been extracted from measured numerical data. These extracted rules have been validated and adjusted by human knowledge on production processes. In this way, the two information sources (human knowledge and measured data) are both taken into account in the fuzzy rules of this model.

El-Ghezal Jeguirim et al. (El-Ghezal Jeguirim et al., 2009) have developed neural network and fuzzy logic based models to predict the sensory attributes, evaluated by a trained panel, of knitted fabrics from the structure and process parameters. In their further work, the intelligent techniques have been used for modeling the relationship between the instrumental properties measured by Kawabata Evaluation System and the finishing parameters of knitted fabrics (El-Ghezal Jeguirim et al., 2011). The prediction performance of these models was considerably lower than the mean variations of experimental values. These results showed the intelligent techniques ability to model the relationship between manufacturing parameters and instrumental or sensory tactile properties. The fuzzy or neural models provide contribution in industrial products engineering, with minimal number of experiments and short cycles of product design. The prediction performances of neural and fuzzy models were also similar. However, the 'black box' problem associated with neural networks can hinder the widespread adoption of this method. In fact, the fuzzy techniques have two advantages over the neural ones. In fuzzy models, the linguistic rules can be interpreted and the linguistic sensory attributes can be integrated. Thus, it is possible to observe how the fuzzy model performs its computations.

Moreover, better results can be obtained when these techniques are used in combination. In fact, hybrid models based on neuro-fuzzy methodologies combine the self learning ability of neural networks and the human-like reasoning style of fuzzy systems. Hence, neuro-fuzzy models can provide enormous scopes to link sensory attributes or mechanical properties with processes parameters of fabrics.

4.3.2 Modeling the relationship between sensory properties and instrumental measurements

The sensory evaluation method has been adapted to textile products to characterize consumer preference for textile products. However, sensory evaluation is time-consuming

and expensive. Therefore, reliable and practical instrumental methods are needed to accurately predict sensory tactile attributes, at least in the product development and quality control stages. Several instrumental methods (Kawabata, 1975; 1980; Kawabata et al., 1982; Tester and De Boos, 1990; Pan & al., 1993, Pan & Yen., 1992) have been developed for measuring the tactile feeling of fabrics according to their physical mechanical, thermal and surface properties. Hence, modeling the relationship between instrumental measurements and sensory attributes becomes a key problem in tactile quality assessment.

Wide ranges of statistical or multivariate analysis have been proposed for characterizing this relationship and selecting the relevant instrumental and sensory properties. In particular, Weber-Fechner's law (Matsuo et al., 1971; Bishop, 1996; Rombaldoni et al., 2010), Stevens's power law (Bishop, 1996; Elder et al., 1984; Rombaldoni et al., 2010), and PCA (Mackay et al., 1999; El-Ghezal Jeguirim et al., 2010 b) have been usually applied.

Matsuo et al. (Matsuo et al., 1971) used the Weber-Fechner's law to translate instrumental measurements of a wide of fabric mechanical properties into corresponding hand parameters. Although the method has the virtue of independence of fabric type, further work would be needed to check the validity of the Weber-Fechner's law for modeling the complex sensory-instrumental relationship.

Elder et al. (Elder et al., 1984) used Stevens's power law to examine the relationships between subjectively measured softness and a compression and also between subjective stiffness and a flexural rigidity. Excellent correlation was found, correlation coefficients for the Stevens's law being about 0.97. On the evidence of the results of Elder et al., Stevens's law appears to be an excellent model. Although the relationship breaks down in some cases, this fact is probably because the subjective evaluation attribute cannot be adequately represented by a single instrumental parameter. This problem may be overcome by relating each sensory score to the sum of the different contributions made by a number of instrumentally measured properties that are relevant to well-defined fabric types or end uses. Rombaldoni et al. (Rombaldoni et al., 2010) investigated the possibility of predicting the human psychophysical perception of crispness and coolness hand of men's suit woven fabrics made from animal fibers (wool, mohair, cashmere and alpaca) from measurable low-stress mechanical and thermal parameters. In particular, the parameters chosen were weight per unit area, thickness at 9.81 kPa, surface thickness, bending rigidity, extensibility at 98.1 N/m, shear rigidity, formability and thermal absorptivity. The sensory-instrumental relationship was explored using the Stevens's power law. The correlation results were also compared by the predictive power of other mathematical models: a linear function and the Weber-Fechner law. The obtained results showed that the Weber-Fechner-law-based model was the best to predict the sensory hand value.

Mackay et al. (Mackay et al., 1999) used Principal Component Analysis (PCA) to study relationships between sensory and instrumental measurements of the effect of washing processes on 1x1 rib knitwear fabrics. El-Ghezal Jeguirim et al. (El-Ghezal Jeguirim et al., 2010 b) investigated the relationship between instrumental data and sensory attributes, assessed by a trained panel by using PCA. The obtained results have shown that the compression resilience, the geometrical and frictional roughness are significantly correlated with the following sensory parameters thick, heavy, soft, elastic and crumple-like attributes. The intelligent techniques, including fuzzy logic and neural networks are also used for modeling the relationship between instrumental measurements and sensory properties. Hui et al. have developed a neural network to predict the consumers sensory data from fabric properties (Hui et al., 2004). The predicted results are highly correlated to the targets in the

fabrics made by five materials: cotton, wool, polyester, nylon, and acetate. In the validation, the results show that the proposed network also predicts the hand of linen and silk. Another work for predicting fabric hand from physical measures has been done by combining fuzzy logic and neural networks (Park et al., 2000). The obtained results revealed that the neural networks and fuzzy logic provide an alternative approach for predicting sensory properties from instrumental measurements of fabrics.

5. Applications study cases for cotton/woolen woven fabrics with difference pattern

The main applications of sensory analysis in textile industry are focused on the analysis of the factors affecting fabric hand. Many studies have been conducted to identify the effect of construction factors, such as pattern, yarn properties, fabric materials, or finishing treatments on the fabric tactile quality by using the sensory analysis (Bensaid & al., 2006; El-Ghezal Jeguirim et al., 2010 a; 2010 b).

In order to provide reliable descriptions and evaluation of fabric hand, rigorous procedures have to be implemented i.e. exploratory procedures, samples presentation and data analysis. In this section, a detailed description of the followed procedure is presented before the discussion of some studies' results.

Description of the followed experimental protocol

Sensory analysis method has been developed in the group since 1999. It requires a group of trained persons. In these cases, the sensory panel comprises nine adults between 20 and 50 years old. These persons, called assessors, have been trained according to a previously established methodology (Nicod, 1990; NF-ISO, 1993). The tests are conducted in an environmentally controlled room (20°C and 65% Relative Humidity) (NF EN 20139, 1992). The assessors evaluate the products twice, in particular conditions, in order to avoid some bias due to other senses. The presentation of the fabrics is randomised and the evaluation is done without seeing the fabric using specially designed booth.

Sensory rating is done using a set of 15 individual sensory attributes (Table 1) to build profile consisting of the descriptive, quantitative and objective analysis of the fabric. These attributes have been consensually selected by the assessors and have been used for different types of fabrics (NF-ISO 5492, 1992; NF-ISO 11035, 1995). Quotation is performed on a non-structured scale 0-10.

Before every new product category evaluation, the assessors are retrained for ten sessions. This step allows them to become familiar with the procedure of evaluation and to remember the right meaning and extremes of each attribute.

The pertinence of the attribute is checked later using statistical tools.

In this chapter the effect on the fabric hand of cotton fabrics of three series of parameters will be presented: effect of the weaving patterns, effect of the yarn count, and effect of finishing treatments.

5.1 Effect of the weaving patterns on the fabric hand of cotton fabrics

Materials

In order to study the effect of weaving pattern, nine fabrics have been selected. The samples have been woven with nine classical weft effect patterns on a Jacquard loom. The patterns include a plain weave, 3-twill weave, 4-twill weave (Z direction), waved twill weave

| Bipolar attributes | Surface attributes | Handle attributes |
|--|--|--|
| cold-warm thin-thick light-heavy supple-rigid | pilous soft granulous sticky grooved greasy slippery | falling responsive crumple-like elastic |

Table 1. List of the 15 attributes used for the sensory evaluation

(horizontal effect), 4-satin weave, 5-satin weave, 6-satin weave, 12-satin weave and crêpe weave; the yarns are 100% cotton, 14 Tex for the warp and 25 Tex for the weft. In order to highlight the influence of the pattern on the tactile feeling, we tested fabrics having close characteristics. Hence, the saturation index in weft direction was kept equal to 52%. This index is defined as following:

$$I_r = \frac{100 \times D \text{ (yarn count within the fabric)}}{D_{\max} \text{ (maximum yarn count)}} \quad (2)$$

Microphotographs of the fabrics weaved in different patterns are presented in Figure 9. Their characteristics are presented in Table 2.

| Pattern | Weft count (tex) | Warp count (tex) | Area density g/m ² | Saturation index (%) |
|-------------|------------------|------------------|-------------------------------|----------------------|
| Plain | 25 | 14 | 124.8 | 52 |
| 3-Twill | 25 | 14 | 140.0 | 52 |
| 4-Twill | 25 | 14 | 140.8 | 52 |
| 4-Satin | 25 | 14 | 141.8 | 52 |
| 5-Satin | 25 | 14 | 141.6 | 52 |
| 6-Satin | 25 | 14 | 147.0 | 52 |
| 12-Satin | 25 | 14 | 147.2 | 52 |
| Waved twill | 25 | 14 | 150.2 | 52 |
| Crêpe | 25 | 14 | 135.6 | 52 |

Table 2. Characteristics of the tested fabrics

Results and discussion

Statistical methods of data analysis have been applied. The ANOVA 2-way test (5%), applied on product across assessor variables, outlined that only 4 attributes are not affected by the fabric pattern (*warm*, *sticky*, *greasy* and *elastic*), the other 11 attributes are significantly affected (Table 3). Four attributes are considered as non pertinent for this study: *cold-warm*, *sticky*, *greasy* and *elastic*. The three first are material dependant and the same weft and warp material (100% cotton) was adopted whatever the pattern is. The last one, *elastic*, could be dependant of the pattern, but in woven fabrics case, the elastic behavior is relatively low in comparison to the knitted fabrics. Hence, the marks given by the panellists are around 0 with a non significant difference between the different samples.

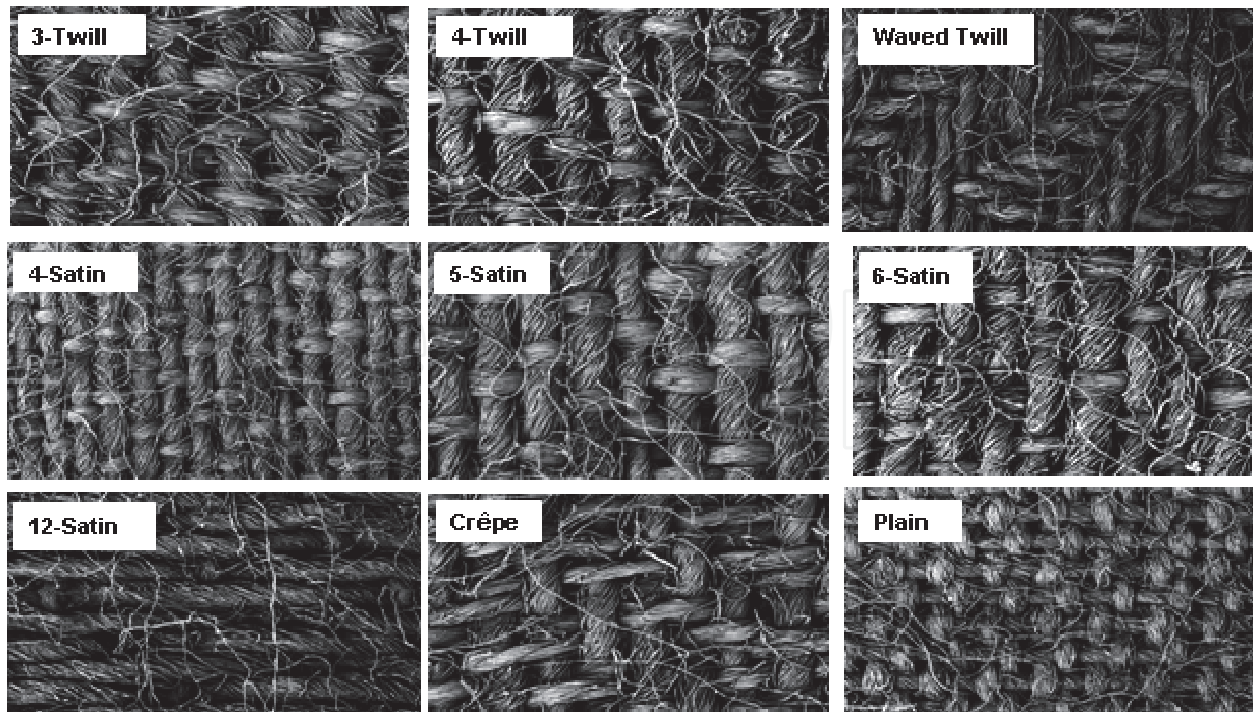


Fig. 9. Microphotographs of the nine different patterns

| Attribute | Product | Assessor | PdxAs |
|--------------|---------|----------|-------|
| Warm | NS | × | NS |
| Falling | × | × | NS |
| Thick | × | × | NS |
| Heavy | × | × | NS |
| Rigid | × | × | NS |
| Sticky | NS | × | NS |
| Slippery | × | × | NS |
| Soft | × | × | × |
| Granuluous | × | × | × |
| Greasy | NS | × | NS |
| Pilous | × | × | × |
| Grooved | × | × | × |
| Elastic | NS | × | NS |
| Responsive | × | × | NS |
| Crumple-like | × | × | × |

Table 2. ANOVA 2-way test (5%) for all the attributes and all the fabrics

According to the column PdxAs, it appears that *soft*, *granuluous*, *pilous*, *grooved* and *crumple like* have been marked in a different manner depending of the judges.

The sensory profile is the simplest way to visualize the results. Each horizontal line represents the scale of one attribute, on which the mean score is plotted. All marks related to the same product are joined by a line. Figure 10 shows the profiles of the nine weaving patterns.

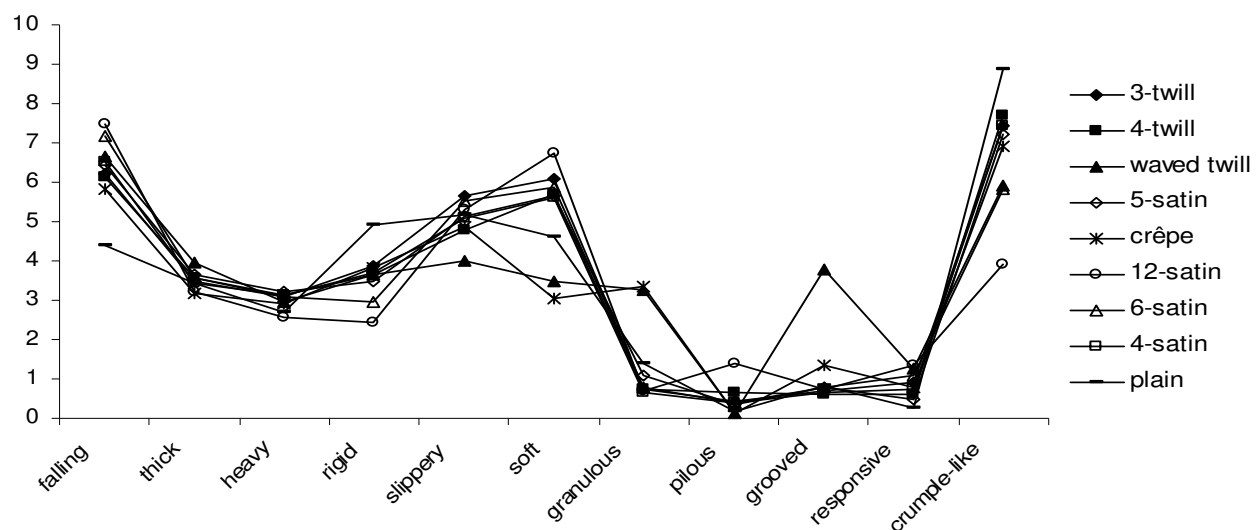


Fig. 10. The sensory profiles of the nine fabrics for the relevant attributes

According to this figure, it can be observed that the waved twill, the crêpe, the plain, and the 12-satin weaves have distinguished profiles.

The Friedman test (5%) ranges the products into groups. The obtained results show that the nine fabrics are close, and they belong to the same group for *cold-warm*, *light-heavy*, *sticky*, *slippery*, *greasy*, and *elastic* attributes, since the differences between fabrics are not significant. However, the fabrics are divided into several groups for *falling*, *thin-thick*, *supple-rigid*, *soft*, *granulous*, *pilous*, *grooved*, *responsive* and *crumple-like* attributes.

The Principle Component Analysis (PCA) is one of the most frequently used methods for the analysis of data collected from sensory tests. It is applied on the mean score of the panel across replication to analyze the pertinence of the attributes and to obtain graphical displays of the multivariate data simplifying subsequent analysis and highlighting similarities and differences between the woven fabrics. Sensory attributes were abstracted into two sensory independent factors, which explain respectively 46% and 28% of the total variance. These groups are carried to the map of products, in order to see the different correlations between fabrics and attributes. The results are presented in Figure 11.

In this figure, it can be observed that:

- the plain weave is the most *rigid* and *crumple-like* and the least *falling* and *responsive*.
- the waved twill is the most *granulous* and *grooved* and the least *soft* and *slippery*.
- the 12-satin is the most *pilous*, *responsive*, *falling*, *soft*, and *slippery*.
- the crêpe has a *rigid feeling*; it is also less *pilous*, *soft*, and *responsive* than most of the other fabrics.

Conclusion

Based on the obtained results, and as predicted, it is seen that the pattern strongly influences tactile feeling. Several attributes have been affected: *soft*, *slippery*, *grooved*, *granulous*, *pilous*, *rigid*, and *falling*. These results are in accordance with textile professionals' expectations.

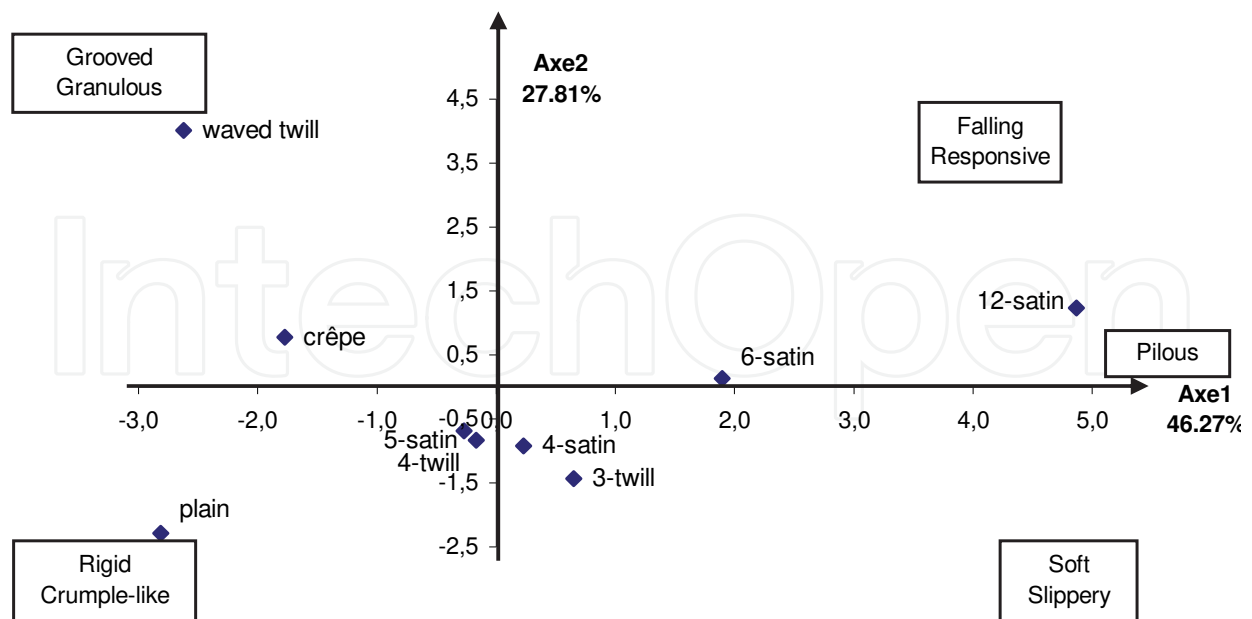


Fig. 11. Principle Component Analysis, map of products

Plain weave, waved twill, crêpe and 12-satin have very distinguished tactile profiles as compared to the other fabrics.

Knowing the correlations that may exist between fabric pattern and tactile properties, manufacturers would be able to design specific touch by the weaving process instead of using finishing treatments. This may be interesting in order to develop an environmental friendly process and avoid the use of chemical products.

5.2 Effect of the yarn count on the fabric hand of cotton woven fabrics

All woven fabrics are made by yarns. It is therefore interesting to study the effect of yarn properties on fabric hand. In this paragraph, on yarn property, the yarn count is studied. The impact of this factor on fabric sensory properties is underlined.

Materials

The study is carried out on 4 fabrics having different weft counts: 25 Tex, 50 Tex, 71 Tex and 100 Tex. The other parameters are unchanged: 100% cotton, Warp count (14 Tex) and Index of saturation (52%).

The experiment is applied on nine different patterns. Only the results of the plain weave are presented in this paragraph.

Results and discussion

The ANOVA 2-way test (5%) revealed that 9 attributes are significantly affected. These attributes are: *thin-thick*, *light-heavy*, *supple-rigid*, *soft*, *granulous*, *grooved*, *falling*, *responsive* and *elastic*.

The sensory profiles are presented in Figure 12. It can be noticed that some attributes are positively correlated to the yarn count. These attributes are: *thin-thick*, *light-heavy*, *supple-rigid*, *granulous* and *responsive*.

On the map of products obtained by the Principle Component Analysis (Figure 13), it can be noticed that fabrics are ranked on one principle axe (79.53%). On the left side of the axe, there are fabrics with high yarn counts and they are correlated to *thick*, *heavy*, *rigid*,

granulous, grooved, elastic and *responsive* attributes. The right side contains fabrics with low yarn counts which are positively correlated to *falling, thin, light, supple* and *soft* attributes. Those results are proven for the all other patterns: twills, satins and crêpe.

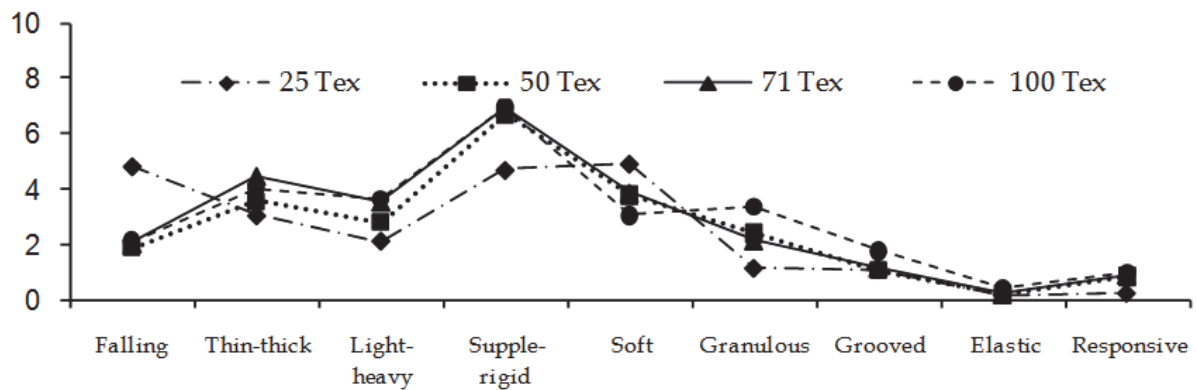


Fig. 12. Sensory profiles of plain weave fabrics with different yarn counts

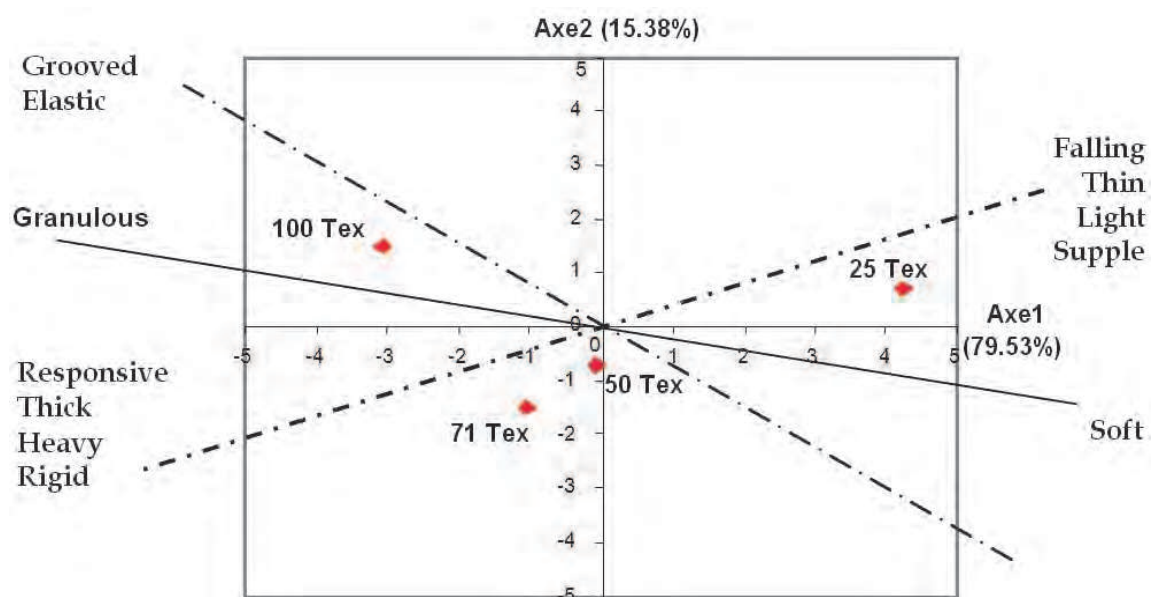


Fig. 13. Map of products, yarn count effect

Conclusion

The study of the influence of yarn count on the touch quality of fabrics has been proven as very important and has shown very interesting results. Surface properties as well as full hand properties are strongly affected by the yarn count. The more the yarn count is important, the more the fabric is *granulous, grooved, thick, heavy, rigid* and *responsive*.

This may help to control and evaluate fabric tactile properties by modifying the yarn characteristics and parameters.

5.3 Effect of finishing treatment on the fabric hand of cotton woven fabrics

In order to confer a variety of looks and effects on fabrics, there are many new finishing products and treatments proposed by chemical suppliers. This investigation was aimed by

the fact that differences between fabric treatments technologies could be distinguished more evidently than it was done before thanks to sensory evaluation methods.

Testing methods and materials

The tests are carried out on 100% cotton plain weave fabric, 24 yarns/cm weft and warp, 160 g/m², scoured and bleached. Two finishing products were studied: the crease-resistant finishing Knittex "K" and the softener macro silicone Ultratex® "UI".

Knittex® FEL: a nonionic crosslinking resin based on a modified dimethyloldihydroxyethylene, allows bringing properties of anti-crease and anti-shrink to the fabric.

Ultratex® UM: cationic emulsion of functional polydimethylsiloxane, allows bringing a very soft touch to the fabric.

The products were processed using semi-industrial range and with varied concentrations of the two products (Table 4). Fabrics were tested and evaluated under controlled environmental conditions following the previously described procedure.

| Product | Product code | Concentration (g/l) |
|--------------------|--------------|---------------------|
| Non treated fabric | 0 | 0 |
| Knittex® FEL "K" | 21 | 20 |
| | 22 | 50 |
| | 4 | 80 |
| Ultratex® UM "UI" | 23 | 5 |
| | 24 | 20 |
| | 17 | 40 |

Table 4. Different finishing treatments

Results and discussion

Seven attributes are significantly affected by the treatments. Table 5 shows the mean scores for the tested fabrics and the 7 pertinent attributes. For the silicone finishing, the *slippery* and *greasy* attributes change clearly with the concentration of the product. This result was expected as UI treatment was known to soften the fabric and with the increase of concentration fabric becomes more *greasy* and *slippery*. It is also worth noting that the panel greatly perceived the modifications obtained by this treatment for the different concentrations.

For the resin treatment it is expected to have more *responsive* and less *crumple-like* fabrics. This is confirmed by the obtained results, since fabrics treated with a high concentration of resin finishing were significantly more *nervous* and less *crumple-like* than the non-treated fabric.

These results show that both treatments changed the hand-feel of the fabric in the expected direction and that the panel clearly perceived the modifications. Figure 14 shows the variation of sensory attributes according to the concentration of the finishing product.

The analysis of the results shows that the sensory evaluation ranges the treated fabrics as follows:

- for the resin finishing we have in terms of *responsiveness* $4 < 22 < 21 < 0$, and for the *crumple-like* attribute $0 < 21 < 22 < 4$;

- for the silicone treatment *greasy* and *slippery* attributes are ranged: $0 < 23 < 24 < 17$.

Conclusion

The effects of finishing products' concentrations were found in accordance with the manufacturers' technical specifications and with the finishing industrialists' expectations. The evaluation of this effect was carried out by the sensory evaluation. The panel was able to detect the modifications and to evaluate them in the right sense.

| | Non treated | K | | | UI | | |
|---------------|-------------|------|------|------|------|------|------|
| Fabric code | 0 | 21 | 22 | 4 | 23 | 24 | 17 |
| Concentration | 0 | 20 | 50 | 80 | 5 | 20 | 40 |
| Falling | 7.31 | 6.71 | 6.29 | 6.49 | 7.34 | 7.37 | 7.26 |
| Rigid | 3.09 | 3.90 | 4.01 | 4.38 | 3.18 | 2.78 | 2.99 |
| Slippery | 5.01 | 4.48 | 4.16 | 4.84 | 5.73 | 6.77 | 7.67 |
| Soft | 5.73 | 4.48 | 3.62 | 3.84 | 5.28 | 5.83 | 6.65 |
| Greasy | 2.14 | 1.81 | 1.55 | 1.70 | 2.98 | 4.77 | 5.52 |
| Responsive | 1.29 | 1.35 | 1.79 | 2.26 | 2.00 | 2.77 | 2.84 |
| Crumple-like | 7.60 | 6.98 | 6.06 | 4.47 | 7.32 | 7.67 | 7.40 |

Table 5. Mean values for the attributes according to the finishing treatments

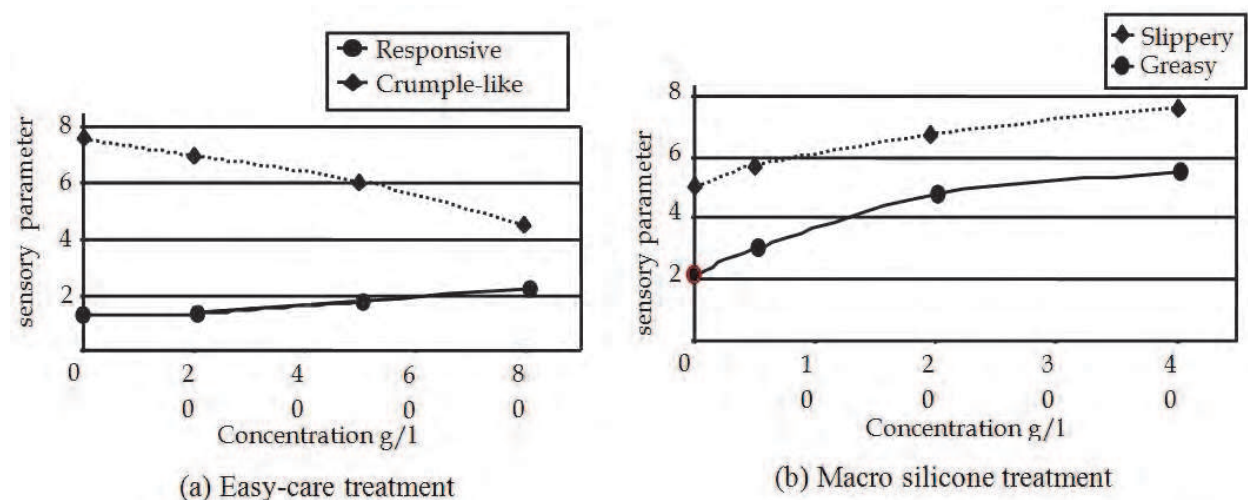


Fig. 14. Variation of the effected attributes according to the concentration of the finishing product

6. Conclusion

Sensory analysis has become a powerful tool for helping textile industries in product design and marketing tasks. In fact, haptic perceptions, including both cutaneous and kinesthetic perceptions, guide consumers' choice for clothes as well as textile manufacturers for

development of new products. Our studies on woven fabric have shown that modification of structure parameters or finishing treatments have a significant effect on sensory feeling. The trained panelists have detected those modifications. Sensory analysis methods provide quantification of tactile feeling. Moreover, sensory analysis approach allows understanding some complex sensation such as softness, comfort and well-being. It can therefore be concluded that sensory analysis has a solid future into the next century. In the meantime, development of dedicated devices for modeling of human perception and use of intelligent techniques which can be used in a complementary way for that purpose can be helpful and a promising approach.

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The importance of woven fabrics increases constantly. Starting from traditional uses mainly in clothing applications, woven fabrics today are key materials for structural, electronic, telecommunications, medical, aerospace and other technical application fields. The new application fields of the woven fabrics is directly reflected in the contents of the book. A selected collection of papers in the technological state-of-the-art builds the book "Advances in Modern Woven Fabrics Technology". It is written by internationally recognized specialists and pioneers of the particular fields. The chapters embrace technological areas with major importance, while maintaining a high scientific level. This interdisciplinary book will be useful for the textile family member as well as for the experts of the related engineering fields. The open access character of the book will allow a worldwide and direct access to its contents, supporting the members of the academic and industrial community.

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