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# Sensory Study of Knitted Fabrics that Have Gone Through Washing Cycles with Domestic Softener. Part II: Influence of Ageing During the Washing Cycle and the Use of Fabric Softener on Sensory Properties

## Abstract

*This study involved the sensory evaluation of knitted textiles which had gone through different domestic laundering treatments, with respect to whether the sensory attributes or a combination of the different sensory attributes measured can best predict the preference of consumers regarding comfort. We defined the parameter 'Degree of influence' for sensory attributes in order to check the level of the influence of ageing and the use of domestic fabric softener on each attribute. Principal component analysis (a statistical data analysis which includes appropriate criteria) was then performed in order to make a better interpretation of the sensory data by plotting a fabric map and sensory attribute map.*

**Key words:** washing, knitted fabrics, sensory testing, domestic softener.

## Introduction

In part one of this paper, the process of establishing a trained panel was defined and assessed by our defined criteria. On the basis of these criteria, our sensory data for this study was assumed to be acceptable for the second part. The different sensory evaluation procedures for fabric hand have already been reported and used for studying different types of textiles [1 - 3]. The sensory evaluation approach has also been used for developing intelligent systems for selecting customised garments and industrial products in an integrated supply chain [4 - 5].

This paper includes the following:

- An overview of different knitted fabrics (varying in fiber type, fiber fineness and structure) with respect to sensory attributes.
- The influence of the ageing process with and without fabric softener on sensory hand.

We used the most common approach of home laundering with and without softener in order to study the influence of ageing and softener on the handle of knitted textiles from their cradle to grave state (Life Cycle). The standard human evaluation method was adopted for various knitted textiles.

## Material and method

Different relevant market knitted fabrics were selected varying in knitted construc-

tion (Jersey, Rib and Interlock) and fibre type (micro or regular). One open-end Jersey Knitted fabric was also included to observe the effect of yarn construction on softener performance. Details of all the fabric samples is given part: 1 of this study [6].

## Principal component analysis

Principal component analysis (PCA) is a well known statistical method used to convert multi-dimensional data into those of lower dimensional in order to allow easier interpretation of them. Principal component analysis is a quantitatively rigorous method of achieving this simplification. The method generates a new set of variables, called *principal components*, each of which is a linear combination of the original variables. All the principal components are orthogonal to each other, hence there is no redundant information. The principal components as a whole form an orthogonal basis for the space of the data. The first principal component is a single axis in space. When you project each observation on that axis, the resulting values form a new variable, and the variance of this variable is the maximum among all possible choices of the first axis. The second principal component is another axis in space, perpendicular to the first. Projecting the observations on this axis generates another new variable. The full set of principal components is as large as the original set of variables.

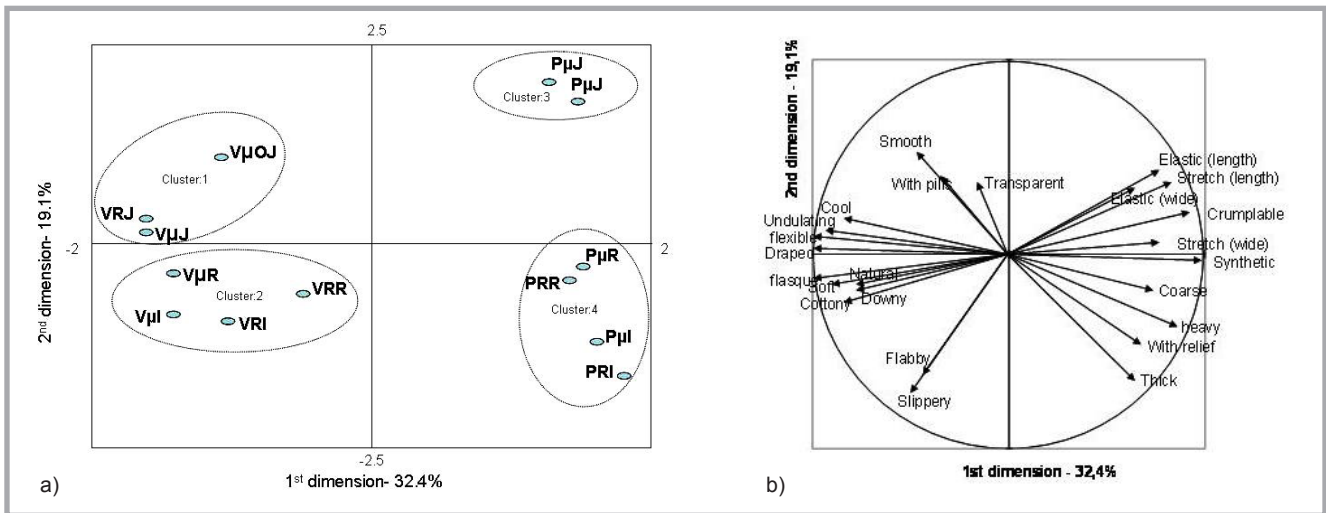


Figure 1.a & 1.b. First two dimensions of fabric and attribute maps of non-treated fabrics.

## Experiments and results

### An overview of different knitted fabrics with respect to sensory attributes

The first sensory evaluation session aimed to provide an overview of the fabrics and the way their attributes are perceived. The panellists were presented with 13 knitted fabrics and then asked to evaluate them by ranking them from 1 to 13 with respect to each attribute. For sensory evaluation of those 13 knitted samples, the pair comparison method was used, i.e. comparison of two samples with respect to a particular attribute. Then a new sample was ranked in relation to one of the samples that had already been compared. The panellists were asked to concentrate on the particular parameter being evaluated at a time. The procedure for the evaluation of each attribute is explained in detail.

To analyse data, a correspondence analysis was conducted. As for PCA (Principal components analysis), this statistical analysis aims to reduce multidimensional data sets to lower dimensions for analysis.

Figure 1.a is a two dimensional PCA map of the 13 knitted fabrics and Figure 1.b is of corresponding attributes.

#### 1st dimension

On the fabric map (1a), it appears that there is a strong opposition of viscose fabrics (on the left of the map) and polyester fabrics (on the right of the map) on the first dimension. This means that this is the main difference that the panellists perceived when they performed the

grouping tasks, representing 32.4% of the entire variability between the products described by the panellists. Looking at the terms map, it appears that the panellists had a strong tendency to group viscose fabrics together because of their “cottony”, “downy”, “draping”, “undulating”, “cooling” and “soft” characteristics. Some panellists mentioned that the viscose fabrics gave a feeling of being “natural” fabrics, as opposed to polyester fabrics, qualified as “synthetic” / “plastic”. The polyester fabrics were also put together according to the “synthetic” sensation they provide. They were also described as being creased.

#### 2nd dimension

The second dimension opposes fabrics that have different constructions. The main opposition was “Polyester Jersey” fabrics vs. “Polyester 1 × 1 Rib” and “Polyester Interlock”. The Jersey was perceived as elastic and stretching lengthwise, whereas the 1 × 1 Rib and Interlock were described as having relief, flabby, heavy and thick.

To a lesser extent, there was also an opposition between “Viscose Jersey” (perceived as smooth and undulating) and “Viscose 1 × 1 Rib” and “Viscose Interlock” (described as slippery).

Four clusters were computed using a hierarchical classification:

- Cluster 1: Viscose with a Jersey construction, i.e. fabrics VμJ, VRJ and VμOJ. They were often grouped together as they were all perceived as flexible, well-draped, undulating and smooth.

- Cluster 2: Viscose with a 1 × 1 Rib or Interlock construction, i.e. VμR, VμI, VRR and VμJRI. They were perceived as downy, cottony, soft, flexible, well-draped and providing a feeling of “natural” fabric.
- Cluster 3: Polyester with a Jersey construction, i.e. PμJ and PRJ (perceived as elastic and stretching lengthwise). Those two fabrics were perceived as creased, elastic and stretching lengthwise.
- Cluster 4: Polyester with a 1 × 1 Rib or Interlock construction, i.e. PμR, PμI, PRR and PRI, characterised by heaviness, thickness, and relief.

The material and construction were the two key-parameters for the sensory perception of our range of products. The nature of fibre (regular or micro) is not an important parameter compared to matter perception.

### Influence of the ageing process with and without fabric softener on sensory hand

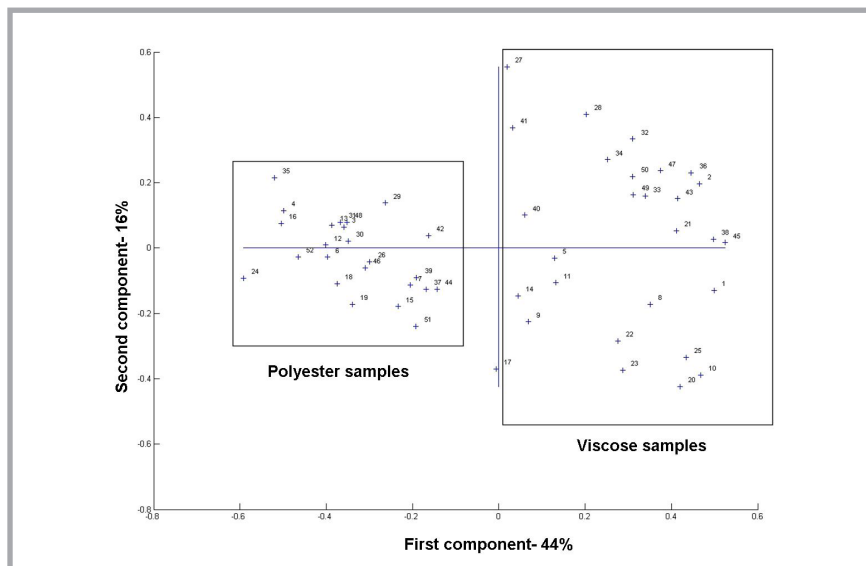
The important objective of this part of the work was to check the effect of repeated washing with and without softener on the sensory hand of the knitted textiles. All of the washing process variables were the same as in the previous study. We used a 3 kg load weight, and the composition was kept constant throughout the ageing process by introducing further knitted fabrics of the same composition when samples were removed for evaluation. The materials were subjected up to 40 cycles of loads. We used two washing machines of the same model and configuration, which were washed with deion-

**Table 1.** Lower and Upper boundaries of the sensory attributes.

Position	Wrinkle	Fluffy	Stretchable	Slippery	Light-Heavy	Flairy	Flexible
lower boundary	wrinkle free	fluffiest	most stretchable	most slippery	heavy	flairiest	most flexible
Upper boundary	with wrinkles	least fluffy	least stretchable	least slippery	light	least flairy	least flexible
Position	Cool	Drappable	Mellow	Pills	With Relief	Greasy	Synthetic
lower boundary	coolest	most drappable	most compressible	least pills	full relief	greasiest	cottony
Upper boundary	warmest	least drappable	least compressible	maximum pills	no relief	least greasy	synthetic feeling

**Table 2.** Sub matrices of sensory evaluation results.

S.N.	Fabric samples	Matrix size	Objective
1	All viscose samples	28 × 14	To check the influence of the ageing of 40 cycles on viscose knitted textiles
2	All polyester samples	24 × 14	To check the influence of the ageing of 40 cycles on polyester knitted textiles
3	All viscose samples went through 1 ageing cycle (with and without softener)	14 × 14	To check the influence of softener on viscose knitted textiles
4	All polyester samples went through 1 ageing cycle (with and without softener)	12 × 14	To check the influence of softener on polyester knitted textiles
5	All viscose samples went through 40 ageing cycles (with and without softener)	14 × 14	To check the influence of softener on viscose knitted textiles after 40 ageing cycles
6	All polyester samples went through 40 ageing cycles (with and without softener)	12 × 14	To check the influence of softener on polyester knitted textiles after 40 ageing cycles



**Figure 2.** Fabric mapping for all 52 knitted fabric samples.

ised water at 60 °C in order to remove remaining washing powder and softener from the machine.

After passing through so many washing cycles, the physical surface appearance and handle of the fabrics were expected to be different than that of fresh knitted fabric or fabric washed only once. Thus it was important to recheck the at-

tribute list for knitted samples that had undergone the ageing cycle. The panel members were provided with randomly selected knitted fabrics, including those that had gone through 40 washing cycles with and without softener. This time the terms generated were almost the same as before, but some attributes were removed and new attributes added:

- ‘Thickness’ and ‘Elastic’ were removed as, according to the panelists, these attributes cannot be differentiated from ‘Light’ and ‘Stretchable’, respectively.
- The panelists introduced three new attributes: ‘Wrinkle’, ‘Flairy’ and ‘Mellow’, which can be considered as synonyms of crease, undulating and flabby, respectively.
- Two new attributes were introduced: ‘Greasy’ and ‘Synthetic’, which were important in order to check the effect of fabric softener after a number of ageing cycles.

The panelists were provided with 52 knitted samples containing the 13 fabrics shown in **Table 1**, and the following conditions were designed to test the influence of ageing and the use of softener on sensory touch:

- Fabrics which have gone through 1 washing cycle without fabric softener.
- Fabrics which have gone through 1 washing cycle with fabric softener.
- Fabrics which have gone through 40 washing cycles without fabric softener.
- Fabrics which have gone through 40 washing cycles with fabric softener.

The panel members were 3 textile engineering students. They were asked to rank the 52 fabrics using the pair comparison method and then requested to wash their hands after assessing each attribute. As the number of samples was very large, the panelists were asked to evaluate a maximum of 3 attributes per session.

**Sensory data interpretation**

The average values of the ranking given by the 3 panelists were considered for the PCA analysis. **Figure 2** shows the fabric mapping of the 52 knitted fabrics, obtained from a matrix of 52 × 14 size (number of fabric samples x number of attributes). **Table 1** shows the lower and upper boundaries of the sensory attributes defined in Part I of the paper [6].

The main objective of the work was to check the influence of ageing and softener on the sensory properties of fabric, but in the fabric mapping of all the fabrics together, the influence of fibre type was so high that we were able to get two clear clusters of viscose and polyester samples. Hence, to check the results of the influence of other factors, the matrix has to be divided in sub matrices.

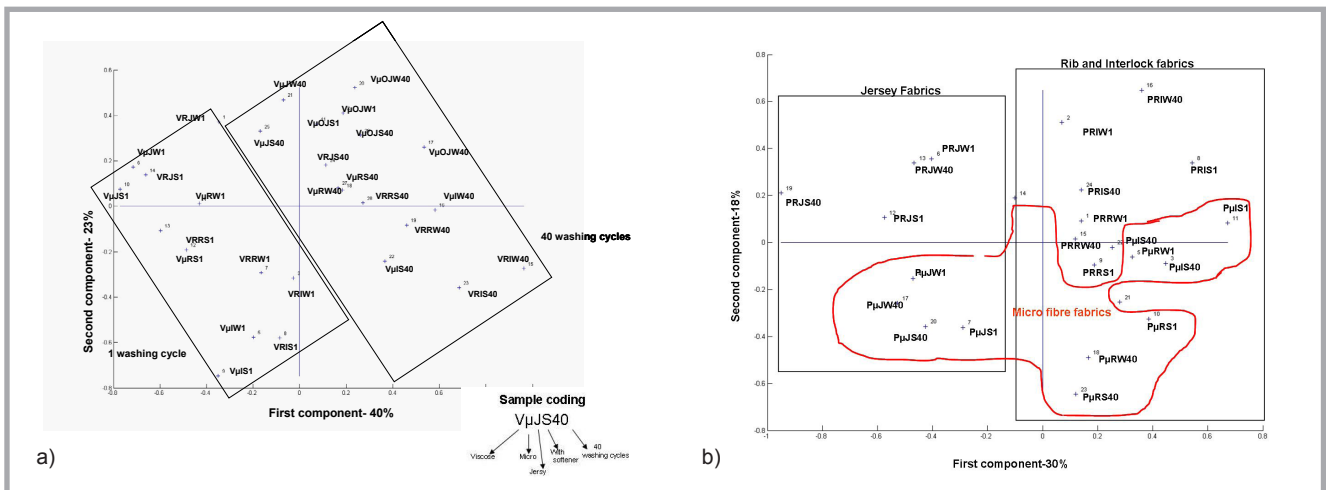


Figure 3. Fabric mapping for all viscose (a) and PET (b) fabric samples.

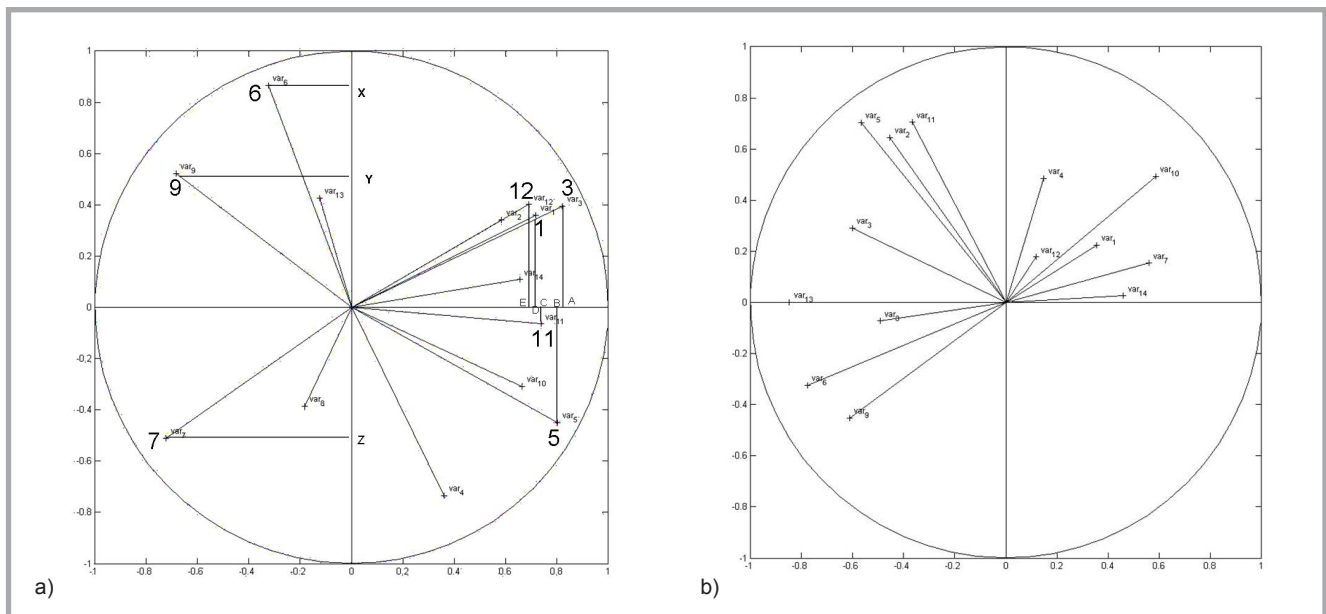


Figure 4. Attribute mapping for all viscose (a) and PET (b) fabric samples; 1 - Fluffy, 2 - Stretchable, 3 - Slippery, 4 - Cool, 5 - Drapable, 6 - Mellow, 7 - Synthetic, 8 - Wrinkle, 9 - Light-heavy, 10 - Flairy, 11 - Flexible, 12 - Pilling, 13 - With relief, 14 - Greasy.

**Degree of influence:** For each sub matrix, we also calculated the degree of the influence of key attributes i.e. the varia-

tion of the sensory score around the average score. A greater value of DOI for an attribute indicates a greater influence

on it by the parameter (constructional parameter, ageing, use of domestic softener), explained by the PCA map.

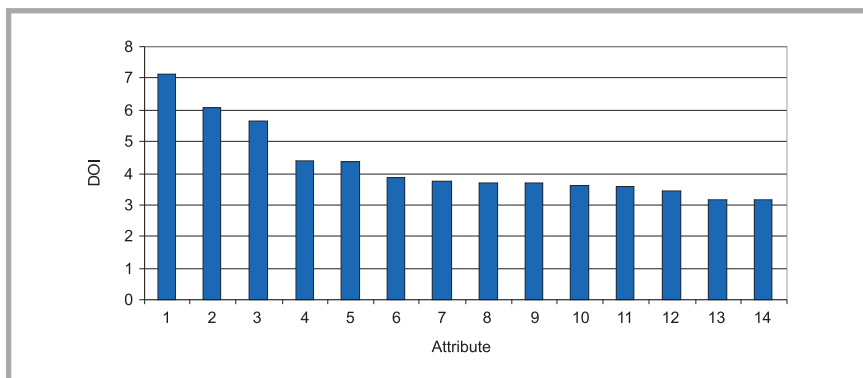


Figure 5. Degree of influence for all Viscose fabrics; 1 - Slippery, 2 - Pilling, 3 - Mellow, 4 - Stretchable, 5 - With relief, 6 - Light-heavy, 7 - Greasy, 8 - Fluffy Wrinkle, 9 - Cool, 10 - Drapable, 11 - Flairy, 12 - Flexible, 13 - wrinkle, 14 - Synthetic.

$$DOI = \sum_{i=1}^n (\mu - \mu_{av}) \quad (1)$$

where:

- $\mu$  - normalised score between 0 and 1
- $\mu_{av}$  - average score
- $n$  - number of samples.

**All Viscose samples**

On the fabric map (Figure 3.a), it appears that there is a strong opposition of the viscose fabrics that went through 1 washing cycle (on the left of the map) and those that underwent 40 cycles (on the right of the map) on the first dimension. This means that this is the main difference that the panellists perceived

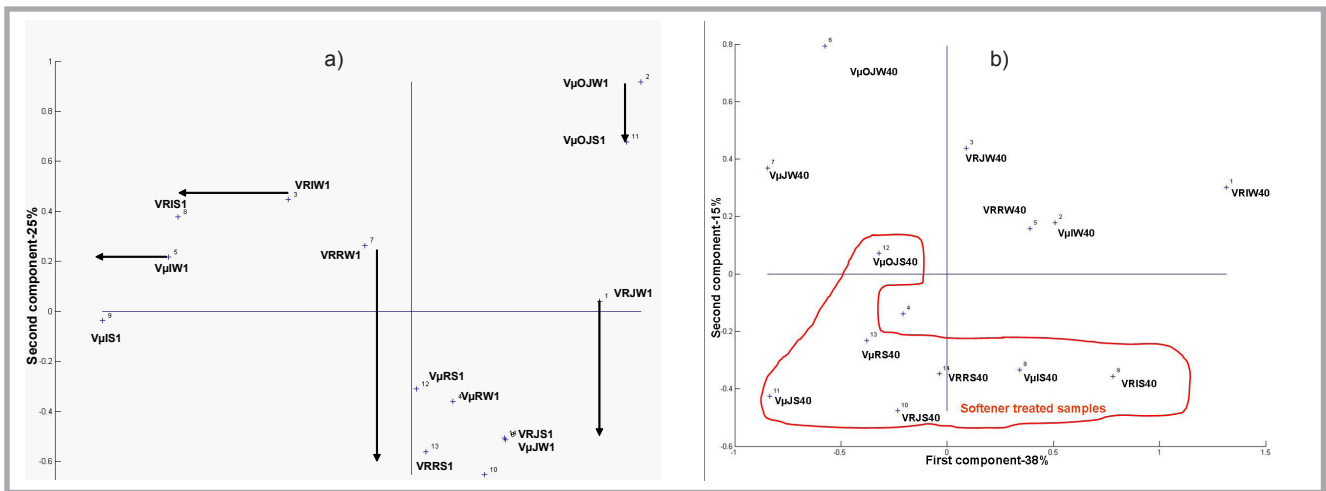


Figure 6. Fabric mapping for viscose fabric samples after 1 (a) and 40 (b) washing cycle.

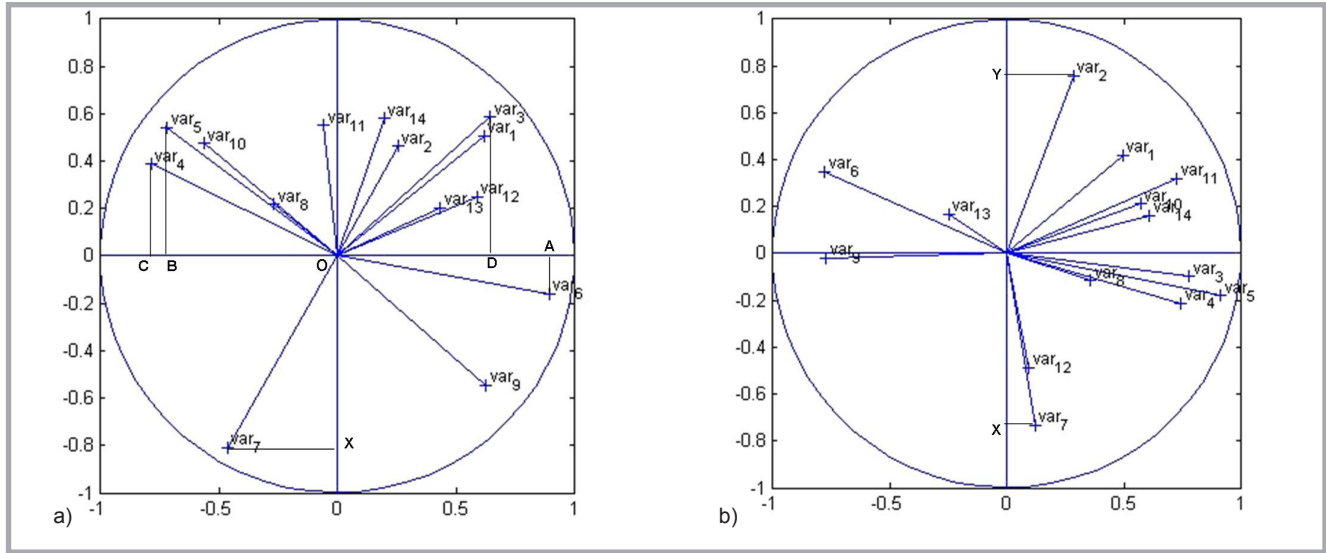


Figure 7. Fabric mapping for viscose fabric samples after 1 (a) and 40 (b) washing cycle; 1 - Fluffy, 2 - Stretchable, 3 - Slippery, 4 - Cool, 5 - Drapable, 6 - Mellow, 7 - Synthetic, 8 - Wrinkle, 9 - Light-heavy, 10 - Flairy, 11 - Flexible, 12 - Pilling, 13 - With relief, 14 - Greasy.

when they performed the grouping tasks. It represents 40% of the entire variability between the products described by the panellists, implying that the influence of ageing can be mainly explained by the 1<sup>st</sup> component, while the second principal component separates the clusters because of the knitted construction.

Looking at the terms map (Figure 4.a), the projection of the following attributes: drapable, slippery, flexible, fluffy and pilling (OA, OB, OC, OD, OE) is the maximum for the first principle component, which means that these attributes are the most relevant with respect to this component. It appears that the panellists had a strong tendency to group viscose fabrics which had gone through 40 washing cycles according to their drape, slippery, flexible, fluffy and pilling characteristics; or we can conclude that these

are the sensory attributes which are influenced by repeated washing. On the fabric map (Figure 3.a), there is an opposition of single Jersey and double Jersey (Rib and Interlock) fabrics on the second component of the map. Attributes - mellow, light-heavy and synthetic have a maximum projection (OX, OY and OZ) on the second principal component.

For Light- heavy with respect to the first component, the left hand side favours a high value (Upper boundary in Table 1) of this attribute, meaning that samples on the left side (Fabrics that went through 1 ageing cycle) of the fabric map are lighter than those on the right side (samples that went through 40 ageing cycles).

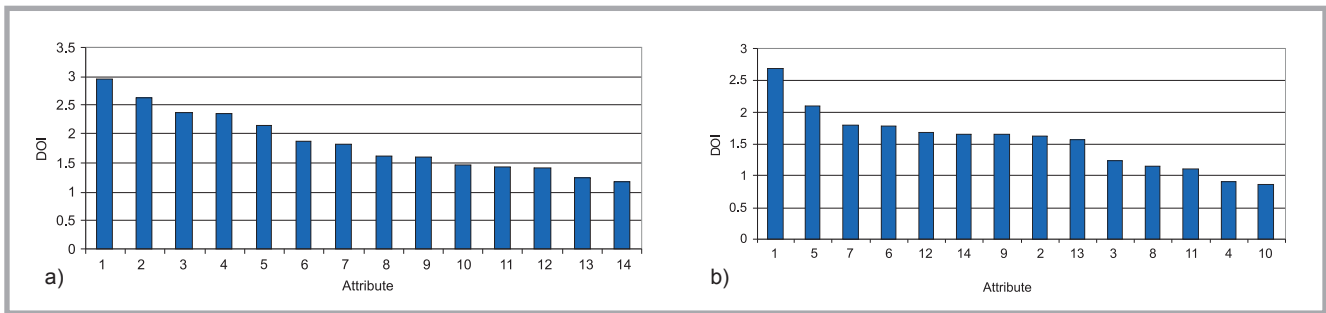
On the other hand, if we consider the second component for this attribute, the upper half of the fabric map favours the

upper boundary of the attribute, implying that fabrics on the upper half of the fabric map (Single jersey fabrics) are light and those on lower side of the fabric map - heavy.

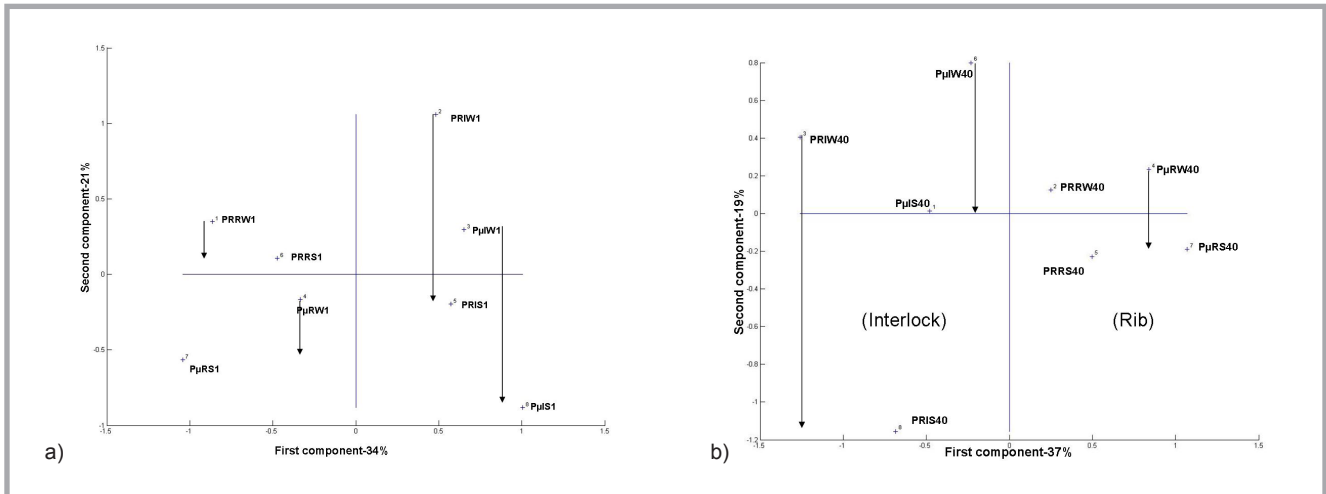
The degree of Influence for all Viscose fabrics was calculated using equation (1). Figure 5 shows that 'Slippery' and 'Pilling' have a maximum DOI, which implies that the major influence of ageing is on 'Slippery' and 'Pilling', while 'Fluffy', 'Drapable' and 'flexible' were affected to a lesser degree.

All PET Samples

Figure 3.b is the fabric map for all Polyester samples. It appears that there is a strong opposition of single Jersey and double Jersey (Rib and Interlock) on the first dimension. It can be observed in Figure 4.b the panellists found that single



**Figure 8.** Degree of Influence for viscose fabrics after 1 (a) and 40 (b) washing cycle; 1 - Mellow, 2 - With relief, 3 - Greasy, 4 - Slippery, 5 - Stretchable, 6 - Cool, 7 - Light-heavy, 8 - Fluffy, 9 - Flairy, 10 - Synthetic, 11 - Pilling, 12 - Flexible, 13 - Drapable, 14 - Wrinkle.



**Figure 9.** Fabric mapping for PET fabric samples after 1 (a) and 40 (b) washing cycle.

Jersey fabrics can be represented by their light feel, mellowness and relief characteristics, while double Jersey fabrics are flairy, greasy, and give a more synthetic feel on touch. The first component represents 30% of the entire variability among the products described by the panellists. The second component, which represents 18% of data variability, distributes the fabrics on the map according to fibre type i.e. micro or regular. It seems that the effect of ageing on polyester is not as much as on Viscose because of its highly crystalline region, hydrophobicity and mechanical toughness.

**Viscose samples after 1 ageing cycle**

**Figure 6.a** is the fabric map for viscose fabrics subjected to one washing cycle. There was not a clear cluster of softener treated and non-treated fabric, but it can be observed that there is a significant change in the sensory properties of all Interlocks, single Jersey regular fibre and Rib regular fabric

In **Figure 7.a**, Mellow, 'Drapable', 'Cool', and 'Slippery' have the maximum projection (OA,OB,OC,OD) on the first principal component, implying that

Interlock viscose fabric has better handle in respect of these attributes when treated with fabric softener.

Cool/Drape: - These attributes increase to the left, meaning that the use of fabric softener for interlock fabrics favours the upper boundary (least drape and warmest) of these attributes; however, at the same time, it can be observed that these changes are small (especially for Viscose-micro fibre).

Slippery/ Mellow:- when the direction of these vectors is towards the right, the use of fabric softener shifts interlock fabrics towards the left, indicating that the use of fabric softener favours the lower boundary of the attribute; hence, fabric softener makes interlock fabrics more compressible and more slippery.

As Interlock has a dense structure of higher area density, it was found to be mellow and drapable.

The change in the position of Jersey regular fabric and Rib regular fabric on the fabric map can be explained by the second principal component. 'Synthetic' has a maximum projection (OX) on the sec-

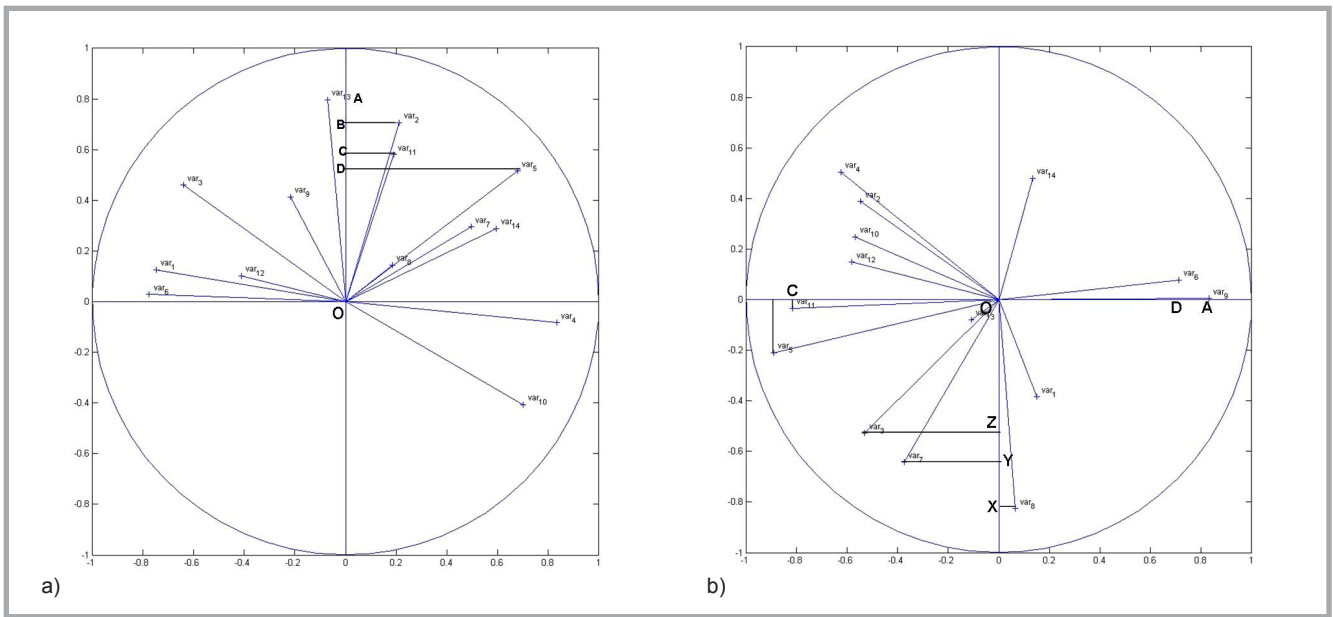
ond component, implying that the panellist could experience a more synthetic feel with softener treated fabric.

**Figure 8.a** shows the order of the influence of attributes affected by fabric softener is Mellow > Slippery > Cool > Synthetic > Drapable, implying that for Jersey and Rib fabrics, softener affects their cottony feel, but not at a low DOI, while in the case of Interlock fabrics, the Mellow

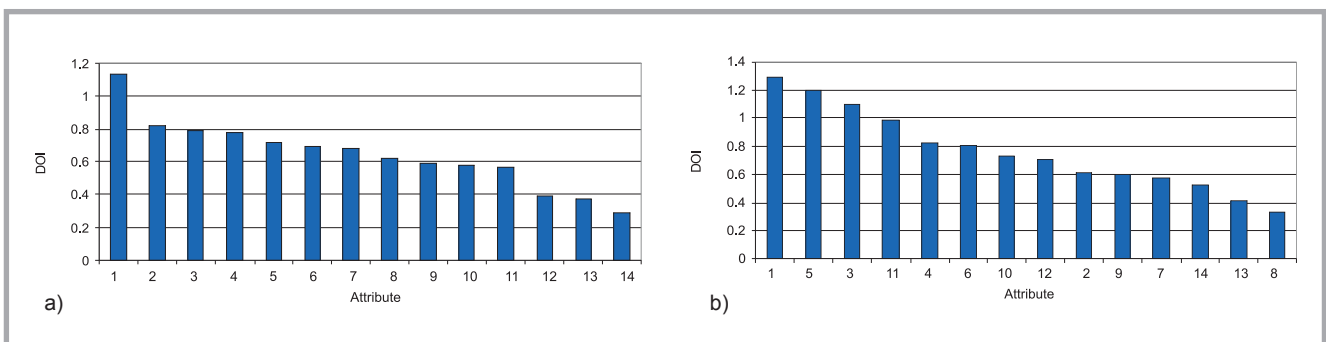
(Compressibility) of the fabric is enhanced with use of fabric softener.

**Viscose samples after 40 ageing cycles**

**Figure 6.b** is the fabric mapping for viscose textiles subjected to 40 ageing cycles. The second component of the map clearly separates softener treated and non-treated fabrics due to their stretchable and synthetic attributes, implying that fabric softener changes the synthetic feel and stretchable behaviour of viscose fabrics when subjected to several washing cycles with softener. The reason behind the change in the stretchable behaviour and synthetic feel of softener treated fabrics is the boundary lubrication of the



**Figure 10.** Attribute mapping for PET fabric samples after 1 (a) and 40 (b) washing cycle; 1 - Fluffy, 2 - Stretchable, 3 - Slippery, 4 - Cool, 5 - Drapable, 6 - Mellow, 7 - Synthetic, 8 - Wrinkle, 9 - Light-heavy, 10 - Flairy, 11 - Flexible, 12 - Pilling, 13 - With relief, 14 - Greasy.



**Figure 11.** Degree of Influence for PET fabrics after 1 (a) and 40 (b) washing cycle; 1 - Stretchable, 2 - Wrinkle, 3 - Flexible, 4 - Greasy, 5 - Mellow, 6 - Drapable, 7 - With relief, 8 - Flairy, 9 - Pilling, 10 - Cool, 11 - Light-heavy, 12 - Fluffy, 13 - Synthetic, 14 - Slippery.

fibres and yarn, which enhances mobility by reducing inter fibre friction.

The change in Stretchability and synthetic feel can be explained by **Figure 7.b**.

**Stretchable:** - Here the direction of the vector of the stretchable attribute is up, while the softener treated fabrics are on the lower side of the fabric map, implying that softener treatment favours the lower boundary of this attribute i.e. most stretchable. Hence softener makes fabrics more stretchable.

**Synthetic:**- The direction of this vector is down, and softener treated fabrics are also on the lower side of the fabric map, indicating that softener favours the upper boundary of this attribute i.e. fabrics with a more synthetic feel.

**Figure 8.b** shows that use of softener for 40 washing cycles affects the stretchabil-

ity of viscose fabrics with a higher degree of influence, while the affect of a cottony feel exists but with a lower degree of influence.

#### **PET samples after 1 ageing cycle**

**Figure 9.a** is a fabric mapping of PET fabrics subjected to 1 washing cycle. Because of the curling behaviour of single Jersey fabrics, sensory evaluation could not be performed accurately, especially for attributes like ‘Drape’, ‘Flairy’, and ‘Wrinkle’. The behaviour of single Jersey fabrics is quite different from other fabrics (**Figure 3.b**). Hence they were not included in the mapping of polyester fabrics in order to check the effect of softener.

The second component of fabric map (**Figure 9.a**) explains the influence of softener on PET fabric subjected to 1 washing cycle. **Figure 10.a** explains that the change in position when the fabric is

washed with softener is due to the following attributes: ‘With relief’, ‘Stretchable’, ‘Flexible’ and ‘Drape’.

It can be observed that the fabric conditioner treated samples are shifting towards the lower part of the fabric map, while the vectors of ‘Relief’, ‘Stretchable’, ‘Flexible’ and ‘Drape’ are on the upper side of the attribute map, indicating that softener treatment favours the lower boundary of attributes i.e. more relief, more stretchable, more flexible and more drapable.

On the basis of DOI (**Figure 11.a**), it can be said that ‘Stretchable’ and ‘Flexible’ are the most influential attributes for PET fabric after 1 washing cycle.

#### **PET having samples gone through 40 ageing cycles**

**Figure 9.b** is a fabric mapping of PET fabrics subjected to 40 washing cycles.

**Table 3.** Summary of the effect of ageing and softener on the knitted textiles; + indicates that treatment favours the upper boundary of the sensory attribute, - indicates that treatment favours the lower boundary of the sensory attribute.

S. N.	Factor	Fibre type	Attributes influenced
1	Ageing	Viscose	Drape(+), Slippery(+), Flexible(+), Fluffy(+), Pilling(+)
2		PET	Almost no Effect
3	Softener	Viscose (One ageing cycle)	Mellow(-), Drape(+), Cool (+), Slippery(-), Synthetic(+)
4		Viscose (Forty ageing cycles)	Synthetic (+) and Stretchable(-)
5		PET (One ageing cycle)	With Relief(-), Stretchable(-), Flexible(-), Drape(-)
6		PET (Forty ageing cycles)	Wrinkle(+), Synthetic(+), Slippery(+)

The panellists perceived a difference due to the structure i.e. Rib and Interlock.

It can be observed by **Figure 10.b** that the first component of the map distributes Rib and Interlock fabrics on the basis of the following attributes: 'Light-heavy', 'Mellow', 'Drapable' and 'Flexible'.

Interlock fabrics are on left hand side of the fabric map, implying here that these fabrics favour the upper boundary of 'Drapable' and 'Flexible', and the lower boundary of 'Mellow' and 'Light-heavy' i.e. less drapable, least flexible, most compressible and the heaviest.

The second component represents the influence of softener on fabrics. The position of Rib and Interlock polyester fabrics treated with softener changes on the fabric map because of sensory attributes 'Wrinkle', 'Synthetic' and 'Slippery'.

The position of softener treated fabrics and the direction of the attribute vectors are on the lower side of the fabric and attribute map, respectively. Hence softener treatment favours the upper boundary of the following attributes: more wrinkles, more synthetic feel and more slippery.

**Figure 11.b** indicates that the use of fabric softener on PET fabrics for 40 ageing cycles influences 'Wrinkle', 'Synthetic feel' and 'Slippery feel' but not with a high degree of influence.

## Conclusion

The type of fibre and construction of knitted fabrics play an important role in the sensory evaluation of knitted fabrics. It seems difficult to perceive the difference in the sensory feel of micro fibre and regular fibre. The influence of ageing on sensory feel is significant only for viscose fabrics: PET fabrics do not change with ageing cycles. The use of softener

significantly changes the sensory feel of different attributes for both Viscose and Polyester knitted fabrics.

The Influence of ageing and use of fabric softener is summarised in the **Table 3**.

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