Quality and Aesthetic of Wool Fabrics through Sensory Evaluation

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Abstract

Value of fabric related to quality and aesthetic were investigated especially focusing on fabrics made from wool or from wool as the main material. Two sensory evaluations, comprising of a visual evaluation and visual with tactile (visual-tactile) evaluation were carried out in aspects of quality and aesthetic and also fabric hands using verbal expressions that people generally use. The visual and visual-tactile feelings of quality (high grade/low grade) and aesthetic (feels beautiful or fine/does not feel beautiful or fine) were found to be correlated well with the feelings of rough/smooth and coarse/fine; namely, the more smooth and fine the samples were, the more the subjects felt them as higher grade and more beautiful. On the other hand, quality and aesthetic feelings were independent from thin/thick, strong/week and heavy/light feelings of the samples. This study also suggested the important physical and surface properties for the quality and aesthetic feelings. The surface property, SMD, found to relate to the quality and aesthetic feelings of both visual and visual-tactile evaluations. Prediction models were also introduced. The quality and aesthetic feelings were described well with the models by taking into account not only the surface property, SMD, but also the properties such as shear properties for the visual evaluation and the shear property, the air resistance property and/or the bending property for the visual-tactile evaluation.

Key Words: Wool, Fabric hand, Value, Visual-tactile evaluation, Physical property

1. Introduction

Fabric hand has been studied for decades [1-7]. A great deal of research has been done by Kawabata, Niwa etc. [5-7]. However, their focus were directed to professionals’ senses in order to establish an index. For evaluating fabric, not only fabric hand but also value of fabric which is related to quality and aesthetic need to be considered. We believe that understanding the characteristics of the value and also describing the value using some machine measureable values such as physical and surface properties, will help to design more human oriented products.

This is a continuous study of our published paper “Fabric Hand, Quality, Aesthetic and Preference of Textiles through Sensory Evaluation [8]”. In the previous study, a wide range of fabrics (wool, cotton, hemp, polyester, etc.) were used as samples and a visual evaluation and visual-tactile evaluation were carried out by university students using word-pairs to measure the responses to the samples in aspects of the grade, beautifulness and preference as well as fabric hand. The result suggested that there were common evaluation standards for the grade and beautifulness; however there seemed to be a less common evaluation standard for preference. Therefore, in this study, we focused the quality and aesthetic value of fabric particularly on the grade and beautifulness. In this study, samples were confined only to fabrics made from wool, or from fabrics with wool as the main material, which are mostly suitable for jacket for males. It is because we normally compare fabrics for a particular purpose. For example choosing suite, coat or t-shirt etc., it is not usual to compare quite different materials such as silk-velvet and cotton-double gauze. As well as the previous work, series of sensory evaluations: visual evaluation and visual with tactile evaluation have been carried out by both professionals working in the textile industry and students. The results were analyzed in terms of subjects’ characteristics such as whether there is a common evaluation standard, and also relationships between the value and fabric hand. Moreover, physical and surface properties of the samples were measured and then the relationships between value of samples and physical and surface properties of the samples were investigated.

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2. Methods

2.1 Visual and visual-tactile evaluations

Two sensory evaluations: visual evaluation and visual with tactile evaluation (visual-tactile evaluation), were carried out. Fabric samples used in this study were wool or fabrics whose main material was wool. In order to avoid any influence of color, the color of the fabrics were all black. The fabrics were selected within the range of use as jacket for males except No.9 and No.11. The specification of the samples are given in Table 1.

As given in Table 2, the total of 19 word pairs were used for the evaluation. The 18 word-pairs excluding “Stretch - Unstretch (SU)” were used in the visual evaluation and the 17 word-pairs excluding “Glossy - Not-Glossy (GN)” and “Drapes or hangs beautifully - Does not drape or hang beautifully (VDN)” were used in the visual-tactile evaluation. As shown in Fig. 1, the seven-point semantic-differential (SD) scales [9] were used to score the samples. The evaluations were conducted under a normal office condition with fluorescent lamps. The samples were placed on grey paper on tables. The color of the grey paper in terms of CIELAB values was $L^* = 70.49$, $a^* = -3.65$, $b^* = -0.14$. The samples for the visual evaluation had a circle shape with a diameter of 30 cm and they were put on a three-dimensional base as shown in Fig. 2. For the visual-tactile evaluation, a 20×20 cm square shape of the samples was used.

![Fig. 1 The scoring system for the evaluations.](image1)

![Fig. 2 The samples at the experimental settings: the visual evaluation (left) and the visual-tactile evaluation (right).](image2)
were placed on the table as shown in Fig. 2.

Subjects started from the visual evaluation then carried out the visual-tactile evaluation. In the beginning of the visual evaluation, subjects were asked to look through the samples in order to become familiar with the range of the sample variations. Each subject was then asked to score the 20 samples against one of the 18 word-pairs and repeat 18 times to score the samples using all the 18 word-pairs. Each subject evaluated the word-pairs in a random order so as to prevent any systematic and experimenter bias. In the visual evaluation, subjects assessed the samples visually without touching, but in the visual-tactile evaluation, subjects were asked to feel the samples by touching without closing their eyes. To restrict the way to handle the samples, the instruction was given with the picture as shown in Fig. 3; subjects were asked to take a sample between their thumb and index finger, then feel a sample by sliding the fingers vertically and horizontally, and also by stretching it sideways. In the visual-tactile evaluation, each subject first assessed one sample against all the 17 word-pairs, then moved on to the second sample and so on. Each subject assessed the samples in a random order.

Subjects participated in this study were university students and professionals working in the textile industry. A total of 84 subjects: 62 students and 22 professionals, took part in the visual evaluation. For the visual-tactile evaluation, a total of 83 subjects: 61 students and 22 professionals, participated.

2.2 Physical and surface properties

As listed in Table 3, physical and surface properties: air-resistance, warm-cool feeling (q-max), tensile, bending, shear, compress and surface properties, were measured using a KES-F system (KATO TECH CO., LTD, Japan) using a standard KES condition [7] and at a room temperature of 20±2°C with a humidity of 60±5%. Moisture regain was also measured using an FD-720 (Kett Electric Laboratory). The sample sizes used for these measurements were 20×20cm except for q-max which had measurements with 10×10cm samples.

3. Results and discussion

3.1 The value in relations to the fabric hands

At first, the characteristics of the subjects were analyzed by applying the hierarchical cluster analysis with squared Euclidean distance and the Ward’s method to all the scores obtained from the visual evaluation and the visual-tactile evaluation respectively. Most of the professionals fell into the same group when the result of the visual evaluation was clustered into three groups: Group 1 consisted of 43 students and 2 professionals, group 2 consisted of 15 students and 20 professionals and group 3 consisted of 4 students. Similarly, the professionals were mostly clustered into the same group when the visual-tactile evaluation result was clustered into 5 groups: group 1 consisted of 19 professional and 34 students, group 2 consisted of 1 professional and 20 students, group 3 consisted of 7 students, group 4 consisted of 1 professional and group 5 consisted of 1 student. Overall, the professionals appeared to have a common evaluation standard for these samples. This may be due to their experiences working in this field or simply greater experience of wearing suits.

The principal component analysis (PCA) was then applied to each group to describe the relationships between the evaluated word-pairs. Only the major groups were focused; group 1 (Visual Evaluation Group 1: VE-G1) and 2 (VE-G2) from the visual evaluation result and group 1 (Visual-Tactile Evaluation Group 1: VTE-G1), 2 (VTE-G2) and 3 (VTE-G3) from the visual-tactile evaluation result, because the other groups consisted of only a few subjects. The first two PCA components were considered in this study since the total variances were high enough (around 70%) to describe the results [10]. The first component (PC1) and the second component (PC2) described 42% and 34% of variance in the VE-G1 data, similarly PC1 (38%) and PC2 (28%) for VE-G2, PC1 (40%) and PC2 (30%) for VTE-G1, PC1 (43%) and PC2 (26%) for VTE-G2, and PC1 (42%) and PC2 (28%) for VTE-G3. The loading plots of each group were given in Figs. 4 and 5 for the visual and
the visual-tactile evaluation, respectively.

In common with all the groups, the PC1 values of the grade and beautifulness, which were the subjects’ response to the word-pair “High-grade – Low-grade (VHL: refer to the symbol in Table 2)” and “Feels beautiful/fine – Does not feel beautiful/fine (VBN)”, respectively, and the responses of “Rough – Smooth (RS)” and “Coarse – Fine (CF)” were large in magnitude in either positive or negative direction as it can be seen in Figs. 4 and 5. Namely they were strongly correlated with PC1. This suggests that these responses vary together. Consequently, fabric hands RS and CF are the important factors for both visual and visual-tactile feelings regarding the grade and beautifulness: VHL and VBN, which were associated with the value of the samples. Also, the more smooth and fine the samples were, the more the subjects felt them as higher grade and more beautiful. The responses of “Thin – Thick (TT)”, “Heavy – Light (HL)” and “Strong – Weak (SW)” were strongly correlated with PC2 and not with PC1. Therefore, TT, SW and HL were independent from value such as VHL and VBN. These characteristics were consistent with the previous study [8] that wide range of the materials were used as samples.

Different from the visual evaluation, “Hard – Soft (HS)” showed the close correlation with VHL and VBN in the visual-tactile evaluation. This attribute perhaps could be judged better by tactilely rather than visual. Thus, there were differences between the visual and the visual-tactile results. In this study, the factors which divided the cluster groups were “Cool – Warm (CW)”, “Natural – Artificial (NA)” or “Short furs – Shaggy (SS)” rather than the values. For example the visual evaluation showed CW and SS of VE-G2 were related to neither PC1 nor PC2, while VE-G1 were related both PC1 and PC2, although the CW and SS were located close together in both groups. It can be assumed that both groups associated short furs samples with cool. Comparing between VTE-G1, VTE-G2 and VTE-G3, the locations of NA in VTE-G3 were different from others. VTE-G3 associated natural materials Heavy and Strong.

3.2 The samples in relation to the value

The cluster analysis in the previous section showed the similarity among the groups in terms of the relationships between the values and the fabric hands. In order to see the value of the samples, the
VHL and VBN scores of each sample were plotted against the groups in Figs. 6 and 7. From the comparison of VE-G1 and VE-G2 in Fig. 6, it was found that the response to the samples of these two groups were similar regarding VHL and VBN. The correlation coefficients $R$ were 0.76 for VHL and 0.74 for VBN. This indicates that the subjects shared common evaluation standards even for the grade and beautifulness of the samples, which are thought to be very subjective. The samples selected comparatively as higher grade were No.4, 5, 11, 12 and 15. They mostly gave the impressions of smooth and fine seen from the responses of RS and

![Fig. 6 Comparison of the samples' scores between VE-G1 and VE-G2 (visual evaluation): VHL (left) and VBN (right).](image)

![Fig. 7 Comparison of the samples’ scores between VTE-G1, VTE-G2 and VTE-G3 (visual-tactile evaluation): VHL (top) and VBN (bottom).](image)
CF as shown in Fig. 8 which shows the subjects’ average scores of the samples for each group of VE-G1 and VE-G2 as well as VTE-G1 and VTE-G2. On the other hands, No.1 and 17 were selected as low grade and these samples, especially No.1, gave the impressions of rough and coarse (Fig. 8). Similarly, No.4, 5, 11, 12, 13 and 15 were selected as beautiful/fine and No.1, 10 and 17 as not beautiful/fine samples. No.4 and 5 are in fact expensive materials to manufacture. No.12 is a material often used for tuxedos. In this experiment, the subjects were not told the prices nor use of the samples. These results also suggest there is something in common even for the value of fabric.

The visual-tactile results are also compared in Fig.7. The high correlation was obtained between VTE-G1 and VTE-G2: the $R$ values for VHL was 0.88 and for VBN was 0.93. However, the VHL between VTE-G2 and VTE-G3 had a low correlation ($R = 0.60$). One of the reasons for this differences is due to the sample No.12. VTE-G2 selected No.12 as a highest grade sample whereas VTE-G3 selected it as rather lower grade. No.12 is a quite hard and glossy tuxedo material, so it is different from standard suit materials. The unusual characteristics influenced and divided the subjects’ responses. Because the number of the subject belong to VTE-G3 was only 7, VTE-G3 can be considered as minority. VTE-G1 and VTE-G2 were well correlated and the large number of the subjects belonged to either VTE-G1 or VTE-G2. Therefore, these two group represents the majority opinion. From the results of these two major groups, the samples gave the impression of higher grade and beautiful/fine were No.4, 5, 12, 15 and No.4, 5, 11, 15 respectively. They also gave the impression of smooth and fine (Fig. 8). The low grade and not beautiful/fine samples were No.1, 3 and 17 and also these gave the impressions of rough and coarse (Fig. 8). For fabric, tactile feeling is considered to be important. Since these sample choices were very similar to the results of the visual
evaluation, only the visual evaluation may be able to understand tactile feeling at some level.

3.3 The value relation to the physical and surface properties

The relationships between the values (VHL and VBN) and the physical and surface properties (Table 3) were investigated. Since VE-G1 and VE-G2 in the visual evaluation were correlated well, the average scores of all the subjects’ responses in the two groups were used as the representative scores of VHL and VBN. Similarly, the average scores of VTE-G1 and VTE-G2 were used as representative scores for the visual-tactile evaluation.

Various physical and surface properties were measured to characterize the samples. Some of the properties were characterized in the weft and warp directions, respectively. An average of the weft and warp directions is often used to describe the characteristics and also derive mathematical models; however some of the samples in this experiment showed the different characteristics between weft and warp directions. Therefore, the individual directions of properties were considered to see factors which contribute to VHL and VBN. In this study, a stepwise linear regression method was used to find the important properties to describe the value. This is a method of regressing multiple variables while simultaneously removing the weakest correlated variable. The model coefficient and summary were given in Table 4. All variables added were statistically significant to the prediction, $p<0.05$. Generally, as more variables are added, the mathematical prediction model used to describe the target performs better, in this case, the targets were the responses of VHL and VBN. However, it may over-fit a data set described by the model. Therefore, only the models with a few variables were considered. In fact, $R$ values of models with three
Variables were already over 0.90 and fit the subjects’ responses well as shown in Fig. 9. For instance, a model with three variables (Table 4) for the subjects’ response of VHL of the visual evaluation can be described in the equation (1):

\[
VHL_i \text{(prediction)} = 0.150 \cdot SMD_i + 1.354 \cdot 2HG_i - 0.220 \cdot 2HG5_i - 1.246
\]

where \(i\) indicates a sample, SMD, 2HG and 2HG5 are the surface and physical properties.

Consequently, these results indicated that even the value such as VHL and VBN can be described with simple models of the physical and surface properties. As it can be seen from the coefficients in Table 4, SMD was found to be one of the most important properties. The SMD values (weft) of the samples were from 0.67 (the sample No.12) to 8.00 (No.1) with an average of 3.39. The SMD values of the samples No. 4, 5 and 15 which the samples gave the impression of higher grade and beautiful/fine in both evaluations were 1.54, 0.91 and 0.82, respectively. The SMD values of the samples No.1 and 17, selected as low grade and not beautiful/fine, were 8.00 and 7.61 respectively. In the previous section, it was showed that the subjects’ responses of VHL and VBN were both related with RS and CF. Then, the RS and CF responses also showed good correlations with SMD as summarized in Table 5. Only the SMD could derive relatively good models; however, in the case of the visual results, by considering the shear property (2HG and 2HG5), the models were improved (\(R^2 > 0.9\)). For the visual-tactile results, the shear property (2HG) and the air resistance property (R) or the bending

| Model | Variable | Unstandardized Coefficients | Standardized Coefficients | Sig. | R | R² | Adj.R² |
|-------|----------|-----------------------------|---------------------------|------|----|----|------|
| Visual Evaluation VHL | 1 Constant SMD (weft) | -1.233 | 0.169 | 0.764 | -0.57 | 0.54 | ** |
| | 2 Constant SMD (weft) | -1.246 | 0.150 | 1.354 | 2.20 | 2.49 | ** |
| Visual Evaluation VBN | 1 Constant SMD (weft) | -1.550 | 0.178 | 1.232 | 0.63 | 0.36 | ** |
| Visual-tactile Evaluation VHL | 1 Constant SMD (weft) | -0.90 | 0.16 | 0.11 | -0.29 | 0.71 | ** |
| | 2 Constant SMD (weft) | -0.99 | 0.18 | 0.13 | -0.32 | 0.82 | ** |
| Visual-tactile Evaluation VBN | 1 Constant SMD (weft) | -1.48 | 0.22 | 0.65 | 0.39 | 0.63 | ** |
| | 2 Constant SMD (weft) | -1.69 | 0.21 | 0.59 | 0.35 | 0.85 | ** |
| | | | | | | | ** |

Table 5 The correlation coefficients \(R\) between SMD and fabric hands RS and CF.

| VE-G1 | VE-G2 |
|-------|-------|
| RS     | CF    | RS    | CF    |
| Visual Evaluation | -0.65 | -0.69 | 0.81 | 0.80 |
| Visual-tactile Evaluation | -0.72 | -0.70 | 0.81 | 0.83 |
property (B) were found to be important too. 2HG was selected for both evaluations. The difference is that, the models for the visual results used the 2HG measured in weft direction, whereas the models for the visual-tactile results used the 2HG measured in warp direction. Most of the samples had similar 2HG values between the weft and warp directions. A remarkable difference was only found from the sample No.8 which was a warp stretch fabric. Therefore this stretch characteristic was described in the data measured in the warp direction and not in the weft direction, and was reflected only to the subjects’ tactile response of this sample. B is also only selected in the model for the visual-tactile evaluation. There was no strong correlation between B and the response “Hard – Soft (HS)”; however it can be considered that B described the tactile response rather than the visual response.

4. Conclusions

In the previous study, the value and fabric hand of various materials were evaluated visually and visual with tactility. Similar, visual and visual-tactile evaluations were carried out in this study, but when comparing with the previous study, the samples were confined only to fabrics made from wool, or from a fabric with wool as the main material, which were mostly suitable for jacket for males. Although there were differences among the samples, similar characteristics had been found in this and previous studies. Consistent in all the visual and visual-tactile evaluations, the feelings described with the value related terms, “High-grade – Low-grade” and “Feels beautiful/fine – Does not feel beautiful/ fine”, found to correlate well with the fabric hands, “Rough – Smooth” and “Coarse – Fine”. Also, “Thin – Thick” and “Strong – Weak” were independent from these value related terms. Therefore, no matter whether the fabrics are thin or thick, or strong or weak, people highly value fabrics if they are smoother and/or fine. The results also indicate that most of the subjects shared the common evaluation standards even for the grade and beautifulness of the samples. Also, this study suggested the important physical and surface properties for the grade and beautifulness. SMD found to commonly important to describe the responses of the grade and beautifulness of both visual and visual-tactile evaluations, and then the correlation coefficients R were improved (R>0.9) by considering the shear property (2HG and 2HG5) for the visual evaluation, and the shear property (2HG) and the air resistance property (R) or the bending property (B) for the visual-tactile evaluation.

This and previous experiments cover a limited range of fabric samples and also sense of value. Therefore, it is necessary to continue the study with more variations. By accumulating the data,
the relationships between the values and fabric hands and also physical and surface properties reveal a better understanding of the value of a fabric. A greater knowledge of the values may help to contribute to the better design of more human oriented products.

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