Chapter 15
Exploring the Psychophysical Relationship Between Basic Fabric Construction Parameters and Typical Tactile Sensations

Ruitao Jiang, Jiyong Hu, Yuan Zhang and Xin Ding

Abstract The psychophysical relationship between fabric construction parameters and tactile sensations remains unknown, and it limits the development of textile products as well as their virtual rendering techniques. To uncover the underlying psychophysical relationship, this study designed a series of plain woven fabrics, and two basic construction parameters, i.e., weft yarn density and weft yarn diameter, gradually change. Meanwhile, the typical tactile sensations of these fabrics are evaluated by the magnitude estimation method and the paired comparison method. By applying the classical psychometric analysis to the sensation evaluation data, the discrimination threshold and the Weber fraction are calculated, respectively. From psychometric analysis, both perceived roughness and softness sensation decreased with an increase of weft density and weft yarn diameter. The Weber fraction for weft density is 0.16 in roughness and 0.21 in softness, for yarn diameter 0.3 in roughness and 0.26 in softness, respectively.

Keywords Yarn density · Yarn diameter · Roughness · Softness · Weber fraction

15.1 Introduction

The tactile quality of fabrics is a key parameter in successful textile marketing strategies. Meanwhile, with the development of the virtual rendering technology of fabric tactile textures, it needs to know the psychophysical characteristics of fabric tactile perception with respect to fabric properties, which is determined by the fiber and yarn properties, basic construction parameters, and finishing techniques. Several researchers have studied the effect of process parameters on the fabrics tactile quality. Winakor et al. [1] asserted that tactile feeling is affected by material type.

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Cotton, wool, acrylic, and polyester fabrics with the similar yarn linear densities and constructions were clearly differentiated on several sensory attributes. Other investigations have shown that the tactile quality of fabric is influenced by yarns properties, such as type [2, 3] (single or folded), production process (ring-traveler or open-end, combed or carded) [3, 4], count, and twist. Furthermore, it has been also observed that weave and knit construction [5] and fabric density [3, 6] affected the tactile feeling of fabrics. Some studies have investigated the influence of finishing treatments on tactile properties of fabrics. The effects of softening [7], bio-polishing [8], and calendaring [9] on the sensory properties of woven fabrics have been studied. However, the mechanism that the psychophysical characteristics of fabric tactile perception were affected by the basic fabric construction parameters is still unknown. Actually, fabric construction parameters such as weft density and weft yarn diameter determined the geometrical morphology and distribution characteristics of surface texture. This paper designed two sets of plain woven fabrics and two basic construction parameters, i.e., weft yarn density and weft yarn diameter to explore the psychophysical relationship between basic fabric construction parameters and typical tactile sensations by the methods of magnitude estimation and paired comparison.

15.2 Materials and Methods

15.2.1 Materials

In this study, the fabrics were industrially produced by means of LT102-type rapier loom. The following weaving parameters, i.e., material (100 % siro-spinning cotton), the weft density (16–24 weft yarns per cm) and the weft yarn diameter (210–305 μm), have varied as shown in Table 15.1. The stereoscopic microscope images of fabrics are shown in Fig. 15.1.

Table 15.1 Structural parameters of woven fabric

Group	Fabric number	Fabric weave	Weft density (weft yarn/cm)	Count (N_m)	Diameter (μm)
First	1	Plain	28 × 16	27 × 27	240
	2	Plain	28 × 18	27 × 27	240
	3	Plain	28 × 20	27 × 27	240
	4	Plain	28 × 22	27 × 27	240
	5	Plain	28 × 24	27 × 27	240
Second	6	Plain	28 × 24	27 × 17	305
	7	Plain	28 × 24	27 × 21	278
	8	Plain	28 × 24	27 × 24	258
	9	Plain	28 × 24	27 × 27	240
	10	Plain	28 × 24	27 × 36	210

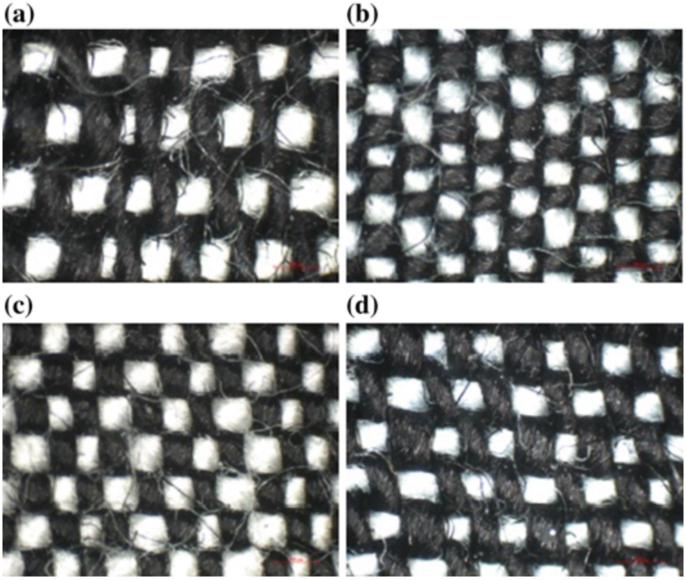

Fig. 15.1 The 20 times image of fabrics **a** is the first fabric, **b** is the fifth fabric, **c** is the sixth fabric, and **d** is the tenth fabric

15.2.2 Sensory Evaluation

Before instrumental and sensory evaluation, the samples were precut into 20 × 20 cm squares. The tests were performed in standard atmosphere (20 ± 2°C and 65 ± 5 % relative humidity). The fabrics were preconditioned for 24 h before evaluation.

To evaluate the typical tactile sensations of produced fabrics, the sensory evaluation method that refers to AATCC: Guidelines for the Subjective: Evaluation of Fabric Hand and GBT 19547-2004 Sensory Analysis Methodology Magnitude estimation has been used. The trained participants (6 men, 12 women, aged from 18 to 24) were recruited; most of them were textile background. The evaluation has been performed in blind condition and replicated thrice. Participants were asked to assess the roughness and softness by using both magnitude estimation method and paired comparison method. For magnitude estimation method, the roughness and softness of each fabric were scored on the basis of a reference fabric with defined score equal to 50. For paired comparison method, participants determined the rougher or softer fabric (left or right).

15.2.3 Research Method

This paper is based on the methods of magnitude estimation and paired comparison in sensory evaluation to explore the psychological physical properties of fabrics. A multivariate analysis of variance was computed in order to test the validity of experiment (significance level of 5 %). With the same weft density and weft yarn diameter, there were no significant difference on the roughness sensation (p=0.85, p=0.77) in these three repeatable experiments. The same results were obtained from three repeatable experiments of softness sensation (p=0.59, p=0.9); it can be concluded that the data of three repeatable experiments came from the same sample. At the same time, in order to avoid each assessor's score, coordinate system is different; the data of experiment were normalized. Meanwhile, we take Grubbs tests to reject the abnormal value in order to avoid assessors were affected by accidental factors in subjective experiment such as fatigue etc. The discrimination threshold of roughness and softness sensations that affected by weft density and weft yarn diameter, respectively, were calculated by constant stimulus method. So the Weber fraction is

$$\mathrm{K} = \frac{\sum_{i=1}^{5} \frac{\Delta\varphi}{\varphi}}{5}$$

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15.3 Results and Discussion

15.3.1 Weft Yarn Density Effect

The perceived roughness decreases with the increasing weft yarn density as shown in Fig. 15.2a. This result can be attributed to increased contact area and the number of yarn intersection point in per unit area. As the weft yarn density increases, more materials are filled in the gaps so we get more uniform stimuli when touching the fabric. According to Weber et al. [10], roughness sensation decreased with the figure getting uniform stimuli. Therefore, the perceived roughness decreases with the increasing weft density. The perceived hardness increases with the increasing weft yarn density as shown in Fig. 15.2b. Bergmann Tiest [11] found that softness is related to deformation. When the weft density is increased, the fabric samples are not easy with deformation and stress resistance increases so the hardness sensation increases.

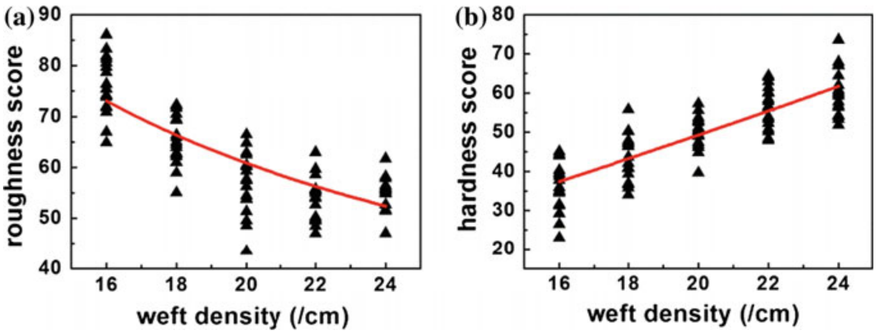

Fig. 15.2 Effect of weft density on sensory evaluation **a** weft density and roughness sensation **b** weft density and hardness sensation

15.3.2 Weft Yarn Diameter Effect

The roughness sensation is illustrated in Fig. 15.3a, which decreases with the increasing weft yarn diameter. This result can be attributed to increased contact area and intersection area. Thicker yarn provides increased contact area between sliding surfaces in comparison with finer yarn under the condition that yarn densities of fabrics are same in a unit area. Fabrics constructed with thicker yarns yield more uniform surface than finer yarns since intersection points of yarns causing the distance between two adjacent yarns are smaller. Hardness sensation measurement results of weft yarn fineness, presented in Fig. 15.3b, show parallel behavior in the matter mentioned above of weft yarn density. Fabrics constructed with finer yarns yield smoother surface than thicker yarns. Hu et al. [12] asserted that softness was depended on the relative elastic modulus of fabrics to finger pad. With the increased weft yarn diameter , stress resistance of fabric samples becomes bigger so the perceived hardness increased.

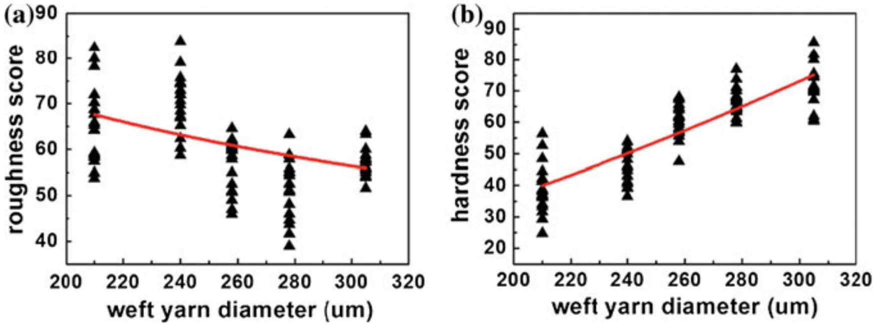

Fig. 15.3 Effect of weft yarn diameter on sensory evaluation **a** weft yarn diameter and roughness sensation **b** weft yarn diameter and hardness sensation

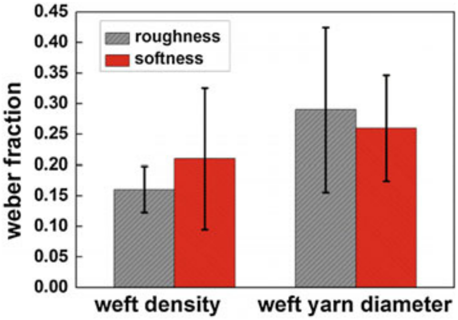

Fig. 15.4 The Weber fractions of different structure parameters

15.3.3 *Weber Fraction*

We can calculate the mean of Weber fraction by 75 % difference threshold. All other construction variables (warp yarn density and warp yarn diameter, pattern) are kept constant, only weft yarn density and yarn diameter varied, the Weber fraction for weft yarn density is 0.16 in roughness and 0.21 in softness, for yarn diameter 0.3 in roughness and 0.26 in softness, respectively.

The Weber fractions of typical tactile sensations are shown in Fig. 15.4. For weft yarn density, the Weber fraction of roughness sensation is less than that of softness which means people can easily sense the difference of roughness when we add a slightly smaller amount at the same weft density condition. When weft yarn diameter varies, Weber fraction of roughness sensation is larger than that of softness sensation and the Weber fractions of roughness and softness sensations are both larger than the Weber fractions of weft density which indicates the variation of weft yarn density can easily cause the discrimination of roughness sensation and softness sensation.

15.4 Conclusions

In this article, the psychophysical relationship between basic fabric construction parameters and typical tactile sensations was discussed by the sensory analysis method. The obtained results show that the varied weft yarn density and weft yarn diameter have a significant effect on the tactile sensory, the perceptions of roughness and softness decrease with an increase of weft yarn density and yarn diameter. Furthermore, the Weber fraction for weft density is 0.16 in roughness and 0.21 in softness, for yarn diameter 0.3 in roughness and 0.26 in softness, respectively. Obviously, weft yarn density and yarn diameter as two major construction parameters are able to tell the tendency of fabrics' roughness and softness in sensory evaluation. Textile industries could develop products in a method of adjusting process parameters with the guidance of Weber fraction.

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