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# Research on evaluation method of fabric tactile sensibility

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## ABSTRACT

Tactile sensibility arising from the contact between fabrics and skin is the main factor affecting comfort of dressing. In this paper, the experimental paradigm of cognitive behaviors to study tactile sensibility cognition of the selected fabrics is introduced. The experimental program is written with E-Prime 2.0, while the expression of the experimental stimulus material is achieved with the self-made measurement device, which output the senses of urtication, roughness and smoothness. The results show that the evaluation values of those senses differs large, and can distinguish the intensity of tactile sensibility of four kinds of fabrics significantly. It is clear that there is no obvious difference among the evaluation values of tactile sensibility obtained with manual measurement and device for the expression of experimental stimulation materials, indicating a fact that it is scientific and effective to study the evaluation of fabric tactile sensibility with the self-made measurement device combined with the introduction of behavioral experimental paradigm.

## KEYWORDS

Tactile sensibility; Fabric; Evaluation method; Measurement device; Perception.

## INTRODUCTION

As customers' needs of sensible clothing have drastically increased, research for clothing design considering visual, auditory, and tactile sensibilities has been actively conducted. As for tactile sensibility, varieties of senses arise when skin contacts fabric. The sense of urtication arising from fabric has been proven as one of the most discomforting tactile sensibility[1]. The sense of roughness[2], refers to the sensibility of smoothness or roughness experienced when skin contacts fabric surface, which is a kind of physiological and psychic combined reaction arising from the stimulation formed by the surface topography and texture features of fabric.

Subjective evaluation is a common method to estimate urtication of fabrics[3]. However, this method needs to improve its efficiency in the administration of an experiment and the management of evaluation data. For example, the questionnaire method lacks efficiency in terms of time and staffing because the administrator must present specimens in person and handle evaluation data manually. Furthermore, the individual differences of subjects are easy to bring about instability to the eventual evaluation of urtication sense.

There are several objective evaluation ways, such as pallial marking method, voice frequency device measurement method, laser counting to highlight the quantity of hairiness, and low stress compression measurement method, etc[4]. The first three methods define the quantity and form of the surface hairiness through transition of physical indexes, while the latter one directly simulates the compression form when the fabric contacts skin to obtain relevant force value.

Ao Limin[3] has improved the low-stress compression measurement method, and developed a fabric single-side compression tester to measure mechanical properties of filament. According to the fiber needle bending model with one end fixed and the other end free, Qi Yuan[5] has studied the axial compression bending property of fabric hairiness. On this basis, Liu Yuqing[6] has adopted the multiple measurement ideology based on Euler compression bar model to design mechanical device and control software, which organically combined the force measurement and form evaluation to characterize the puncture property of filament.

Bergmami et al[7-9] have adopted ranking method to rank varieties of stimulation in terms of roughness sense. Cholewiak and Louw, et al[10, 11] have selected paired comparison method to analyze the threshold value and difference threshold value of roughness sensibility. Lederman et al[12-15] have adopted quantity estimation method to study the influence factor of roughness sense and its psychophysical measurement attributions.

At present, the research on roughness sense of fabrics mainly adopts objective evaluation method, i.e., measuring the basic mechanical and physical property parameters related to roughness sense of the fabrics with instrument, and measuring and representing the intensity of roughness sense with mathematical statistics method and specific indicators. The kinds of instrument adopted include KES-F system, YG821 surface friction tester, UST general tester, micro-friction sensor, etc[16-18]. Ren Jian[19] has designed a kind of new disk-method test system to optimize the test of surface roughness of fabrics.

Based on the analysis on the fabric tactile sensibility evaluation methods and devices, the experimental paradigm of cognitive behaviors is employed to study cognitive activities in tactile sensibility cognition of the tested fabrics. The experimental program is written with E-Prime 2.0, while the expression of experimental stimulus material is realized with the self-made measurement device, which output the senses of urtication, roughness and smoothness among the fabric tactile sensibility to test the feasibility of the proposed method.

## EXPERIMENTAL

### Subjects

64 young female undergraduates with relevant specialized knowledge are selected randomly as subjects, aged from 20 to 23 years. The reason to choose female college students is that the study of Gamsworthy[20] shows that females are more sensitive than males. All the subjects are normal in vision or normal after correction, and are right hander. All the subjects are separately measured, and have not done any similar experiment.

Gamsworthy[20] adopted forearm measurement method to conduct subjective evaluation on fabric tactile sensibility, and found that the skin on the forearms have excellent sensibility for external stimulation. Then, Naylor[21] adopted the method to conduct experiments on urtication sense, and further proved the feasibility and scientificity of arm evaluation method. Therefore, this experiment adopts forearm as measurement location.

### Experimental program

The self-made device comprises the base (1), main control system (2), and three-freedom-degree driving installation (3) fixed on the base, the measurement installation (4) set on the driving installation, whose location can be adjusted in X, Y and Z coordinate space. Through the driving of the installation, the displacement with different speeds or forces can be realized, as shown in Figure 1.

When using the device, open power switch of the main control system, and press start button on the main control system, so as to transmit the order to the stepper motor (33) through the stepper motor driver (34), and regulate the mechanical movement of the screw rod (32) at the three directions of X, Y, Z, and conduct the zero correction of the measuring wheel (41).

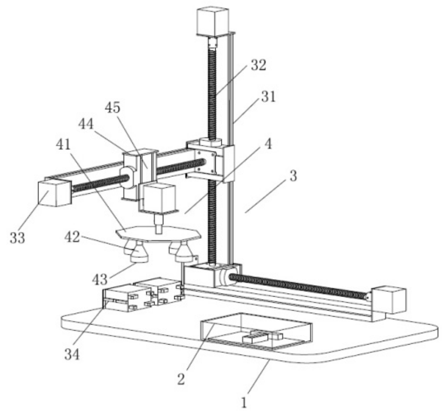


**Figure 1 : Self-made measurement device**

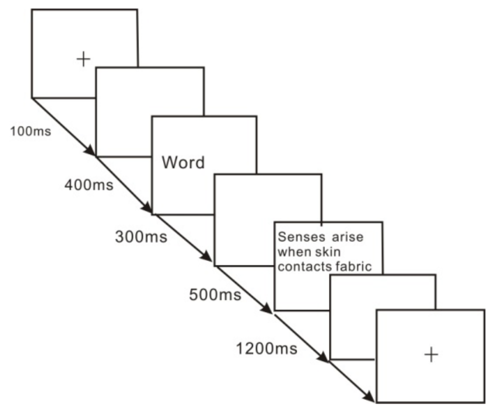


**Figure 2: A schematic illustration of the trial**

In the behavioral experiment mode, the expression program of the experimental paradigm, the expression of experimental stimulation materials, the random display of evaluation indexes, and the storage program of evaluation results has been designed firstly. The experiment program is shown in Figure 2. The experiment is conducted on computer, and its program is written with E-Prime2.0.

After the evaluation indexes show, the measuring head (42) loading fabric starts to contact the skin. When the contact is detected by the pressure sensor (43), the sensor will send the information to the main control system, which will send the order to control the stepper motor to run, and the fabric will start to have movement relative to the skin; when the proximity sensor (44) detects the specified route mark, it will give an information feedback to the main control system, which will send an order to stop the measuring wheel. During this process, the subjects feel tactile sensibility with the fabric, and makes quantization judgment. The continuous evaluation results are saved in the storage system.

After completion of one measurement, press the button on the main control system, then the measuring wheel will automatically rotate for 1/4 circle, and the measuring wheel will move to the initial position, i.e., zero position, where the next fabric will contact the skin.

The reaction data will be generated by the subjects through pressing buttons. If the subject feels that the fabric tactile sensibility and the meaning of sensory word is same and the sense is quite strong, press button "/"; if the subject feels the sense is common, press button "X"; if the subject feels that fabric contiguous sense and the meaning of sensory word is different, press button "Z".

During the experiment, subjects could be given time to rest and everyone participated once in the same experiment to prevent memory mechanism disturbing subjects' cognitive processes.

## RESULTS AND DISCUSSION

### Device measurement of fabric tactile sensibility

In order to verify the feasibility of fabric tactile sensibility testing method proposed in the paper, the experiment selected 4 types of fabrics with relatively significant differences: (1) chemical fabric with woolen weave; (2) polyester/rayon blended fabric with pointed twill weave; (3) polyester fabric with plain weave; (4) cotton & linen blended fabric with plain derivative weave.

In order to conduct a quantitative evaluation on tactile senses, three-point system is adopted to assign each evaluation index. If the subject feels that the fabric tactile sensibility and the meaning of sensory word is same and the sense is quite strong, the evaluation value will be 2 points; if the sense is quite common, the evaluation value will be 1 point; if the subject feels that the fabric contiguous sense is different from the meaning of sensory word, the evaluation value will be 0 point.

Variance analysis on evaluation values of the senses of urtication, roughness and smoothness of 4 kinds of fabric is carried out by using SPSS 20, and the analyzed results are shown in TABLE 1.

**TABLE 1 : Variance analysis result**

| Sensory word | F | P-value |
|---|---|---|
| Urtication | 25.484 | 0.000 |
| Roughness | 21.040 | 0.000 |
| Smoothness | 19.958 | 0.000 |

TABLE 1 shows that, when expression of the stimulation material adopts installation, the significance level of the senses of urtication, roughness and smoothness will be: $P=0.000 <0.05$. So the tactile sensibility among 4 kinds of fabrics has significant differences with each other. In order to study the differences of the 4 fabrics in terms of those senses, SPSS 20 is employed to accomplish multiple comparisons analysis, and the results are shown in TABLE 2.

**TABLE 2 : Multiple comparisons analysis of tactile sensibility**

| Fabric | Fabric | Urtication Sig. | Roughness Sig. | Smoothness Sig. |
|---|---|---|---|---|
| 1 | 2 | 0.004★ | 0.053 | 0.565 |
| | 3 | 0.000★ | 0.000★ | 0.000★ |
| | 4 | 0.117 | 0.733 | 0.954 |
| 2 | 1 | 0.004★ | 0.053 | 0.565 |
| | 3 | 0.000★ | 0.000★ | 0.000★ |
| | 4 | 0.601 | 0.413 | 0.864 |
| 3 | 1 | 0.000★ | 0.000★ | 0.000★ |
| | 2 | 0.000★ | 0.000★ | 0.000★ |
| | 4 | 0.000★ | 0.000★ | 0.000★ |
| 4 | 1 | 0.117 | 0.733 | 0.954 |
| | 2 | 0.601 | 0.413 | 0.864 |
| | 3 | 0.000★ | 0.000★ | 0.000★ |

**★ The mean difference is significant at the 0.05 level**

As shown in TABLE 2, from the perspective of the significance level of 0.05, fabric 1 and fabric 2 has obvious differences in terms of urtication sense; fabric 1 and fabric 3 has distinct differences in this sense; and fabric 2 and fabric 3 also has obvious differences in sensibility of urtication; and it is clear that fabric 4 and fabric 3 has apparent differences.

The differences between fabric 1 and fabric 2 are caused by the differences of fiber composition and weave. The surface of fabric 1 has relatively tough hairiness with quite dense distribution, which is extremely easy to incur the reaction of receptors of skin and thus form the sense of urtication. Fabric 2 is constituted with polyester/rayon. The polyester fiber surface is relatively smooth, while the rayon (regenerated cellulose fiber) has skin core layer structure, and there are longitudinal grooves with smooth surface. Therefore, the intensity of itch sense of fabric 1 is stronger than that of fabric 2. Because the weave structure of fabric 2 is weaved with in pointed twill pattern, and there are extruding fibers on the surface of the fabric; fabric 3 is weaved with polyester in plain weave, so the senses of urtication between fabric 2 and fabric 3 has great differences. Fabric 4 includes linen fiber with extruding hairiness on the surface, so its sense of urtication is greater than that of fabric 3.

TABLE 2 shows that fabric 1 and fabric 3 has obvious differences in terms of roughness sense. And there are significant differences between fabric 2 and fabric 3 in roughness sense. As for roughness sensibility, the analyzed result also indicates that fabric 4 and fabric 3 has apparent differences.

Fabric 1 is of woolen weave with extruding hairiness on the surface, whose surficial roughness is stronger than that of fabric 3 with smooth surface. The pointed twill weave of fabric 2 increases the roughness degree on the surface; fabric 4 includes linen fibers, whose surface is of cross knots, and the initial modulus is high but the elastic recovery ratio is extremely low. Therefore, fabrics 2 and fabric 4 has relatively remarkable differences in terms of roughness degree.

The results of TABLE 2 also show that fabric 1 and fabric 3 has obvious differences in terms of smoothness sense. It is obvious that not only fabric 2 and fabric 3, but also fabric 4 and fabric 3 have apparent differences in smoothness sense.

The major reason for the obvious differences between fabric 3 and other three types of fabrics in terms of smoothness sense is that fabric 3 is weaved with polyester filament yarn, and has extremely smooth surface; while the other three types of fabrics have extruding hairiness, cross knots or salient points on the surfaces, so the surfaces are uneven.

**Feasibility test**

It is a common method for the expression of stimulus materials in the contiguous evaluation to let operators hold the fabrics in hands and contact the fabrics with skin. The experiment has employed the method to accomplish the evaluation of the senses of urtication, roughness and smoothness of 4 kinds of fabrics. Meanwhile, variance analysis is carried out by using SPSS 20, whose results are shown in TABLE 3.

**TABLE 3 : Variance analysis result by manual measurement**

| Sensory word | F | P-value |
|---|---|---|
| Urtication | 8.585 | 0.000 |
| Roughness | 26.133 | 0.000 |
| Smoothness | 18.883 | 0.000 |

TABLE 3 shows that when the expression of experimental stimulus materials is achieved by hand, the significance level of the sensibility of urtication, roughness and smoothness will be: P=0.000<0.05. Therefore, the tactile senses among 4 fabrics also have obvious differences with each other.

**Comparative analysis**

The mean values of tactile senses of urtication, roughness and smoothness after contacting the fabrics with skin are shown in Figure 3, 4 and 5.

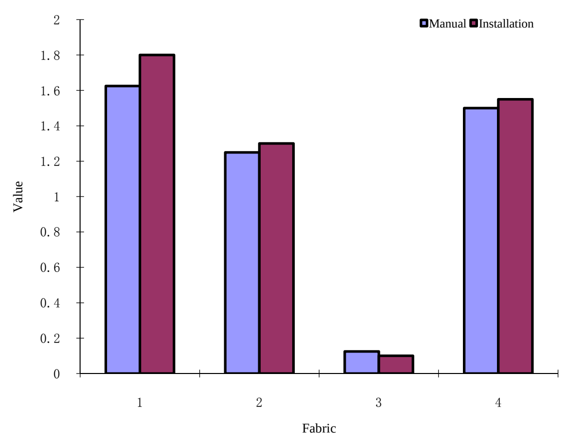


**Figure 3 : Evaluation value on urtication**

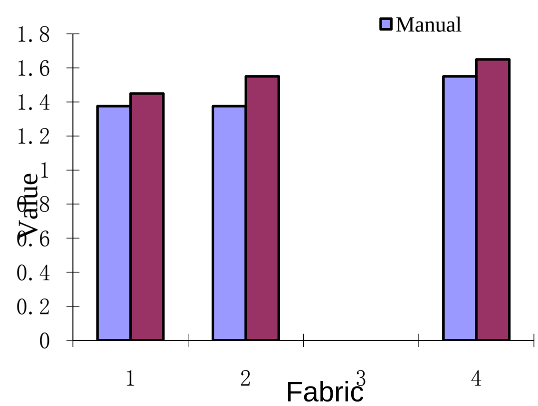


**Figure 4 : Evaluation value on roughness**

The results of Figure 3 show that, when the expression of experimental stimulus materials is performed by hand or by device, the difference on evaluation values in terms of urtication sense will be quite small, and can well distinguish the intensity of urtication sense of those fabrics.

The results also indicate that the evaluation values of urtication sense obtained from measurement by device is slightly higher than that measured by hand. The device has set with pressure sensor (thin film pressure sensor) on the lower surface of the measuring head, which has quite high sensitivity, and can well control contiguous pressure.

Under the action of external force, the surficial hairiness of fabric 1 has relatively strong stimulation on the skin; fabric 2 is of pointed twill weave, and the surficial salient points have greater stimulation on the skin under the action of external force; fabric 4 includes linen fibers in, so it gives stronger stimulation on the skin, and is easy to reach the threshold value of the receptor. Therefore, when the above fabrics presented the stimulation conditions via the instrument, the degree of the urtication sense felt by the subject is increased.

It is clear that fabrics 1, 2 and 4 obtain higher evaluation value in terms of roughness sense via the device than that obtained manually. Under the action of external force, the extruding hairiness, cross knots and salient points of those fabric surfaces will give stronger stimulation on the skin receptor, so the subject will feel the fabrics uneven and with great surficial roughness.

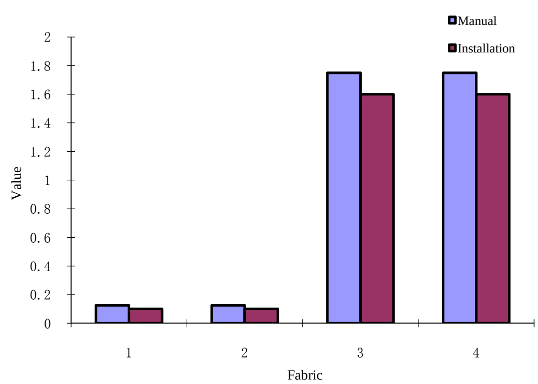


**Figure 5 : Evaluation value on smoothness**

Figure 5 shows that when the expression of experimental stimulus material adopts manual measurement or device, the difference on evaluation values in terms of smoothness sense will be quite small, and can well distinguish the intensity of smoothness sense of those fabrics. When device measurement is employed, evaluation values of both urtication sense and roughness sense will be slightly higher than that measured by hand, so the evaluation value of smoothness sense measured with installation will be slightly lower. The results of Figure 5 indicate the consistency between theoretically predicted results and actually evaluated results.

In order to further test the feasibility of adopting device evaluation for expression of experimental stimulus materials, the results of T test of the two evaluation values are shown in TABLE 4.

**TABLE 4 : T test on installation and manual measurement**

| Sensory word | Fabric | T-value (2-tialed) | Sensory word | Fabric | T-value (2-tialed) | Sensory word | Fabric | T-value (2-tialed) |
|---|---|---|---|---|---|---|---|---|
| Urtication | 1# | 0.352 | Roughness | 1# | 0.729 | Smoothness | 1# | 0.654 |
| | 2# | 0.620 | | 2# | 0.659 | | 2# | 0.352 |
| | 3# | 0.870 | | 3# | 0.263 | | 3# | 0.473 |
| | 4# | 0.610 | | 4# | 0.346 | | 4# | 0.654 |

As shown in TABLE 4, it is clear that the values of sig. (2-tialed) are higher than 0.05, i.e., $P>0.05$; it means that the tactile evaluation values obtained from both experimental methods has no significant differences. Therefore, it is scientific and reasonable to adopt the device method for the expression of experimental stimulation materials. That is to say, the fabric tactile sensibility measurement method proposed in the paper is feasible.

## CONCLUSIONS

In summary, the experimental paradigm of cognitive behavior is introduced to study the cognitive activities of the subjects in tactile sensibility cognition of four types of fabrics. The expression of experimental stimulation materials is mainly achieved with the self-made fabric tactile sensibility measurement device. When the expression of experimental stimulus material adopts manual measurement or device, the difference on evaluation values in terms of urtication, roughness and smoothness sense will be quite small, and can well distinguish the intensity of those senses.

The evaluation values in terms of fabric tactile sensibility obtained with manual measurement and device for the expression of experimental stimulation materials has no obvious differences. The results indicate that it is scientific and effective to study evaluation on tactile sensibility of fabrics with the self-made measurement device combined with introduction of behavioral experimental paradigm.

Moreover, reaction time that subjects respond to make a decision in evaluating tactile sensibility and the tactile sense evaluation of fabrics with relatively small differences will be measured in further research and the results will provide theoretical and cognitive basis for evaluation in fabric design.

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