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Experimental Study of Clothing Tactile Comfort Based on Electro-neurophysiology

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Abstract

Electromyography (EMG) and electroencephalography (EEG) methods were used to evaluate the reaction of human skin to tactile stimuli evoked by textiles. The peak value of the EMG and energy percentage of the weave of the EEG when the subjects came into contact with 9 kinds of fabrics were selected for tests and next clothing was made on their basis. They were utilized as two important evaluating indexes. Statistical analysis was carried out to verify the correlation between the data obtained from objective measurements and the subjective measurements. The results showed that when the subjects came into contact with thicker, heavier and stiffer fabrics, the peak values of the myoelectric potential induced were higher. When clothing with a higher mass density was worn, energy percentages of the weave at both the left and right occipitalia were higher.

Key words: *tactile, clothing, electromyography, electroencephalography.*

Introduction

Nowadays there is a trend that modern consumers are fond of casual and comfortable clothing to pursue their dynamic lifestyle [1]. The comfort of clothing, including mental and physical comfort, has become a critical attribute to drive consumer purchasing [2]. Clothing that can produce comfortable handle and pleasant tactile perception is favoured by modern consumers [3]. The skin, which is the largest organ of the human body, has constant contact with the fabric [4], causing the prominence of interactions between the human skin and textiles [5]. It is therefore obvious that the hand of textiles is an important factor in the desire to purchase.

Over the years, the hand of clothing textiles has been evaluated by both objective and subjective methods. These two approaches are also called instrumental evaluation and sensory evaluation, respectively [6]. Instrumental evaluation, such as the KES system, can provide quantitative specifications of fabric handle as well as other physical properties [7]. Sensory evaluation is widely used for the tactile properties of textile products. This evaluation technique is based on the personal point of view and is affected by the evaluator's own experience and background [2]. Previous studies have been carried out to correlate fabric or clothing tactile properties obtained from sensory evaluation, with its physical properties obtained by instrumental evaluation [2, 8]. These studies have offered us much knowledge of the clothing hand of textiles.

In the 90's of the last century, researchers started to apply electro-neurophysiology to study the clothing hand of textiles. They employed medical instruments to study the physiological response and Kansei engineering (method aiming to deal with people's emotion analysis for elaborating new computer aided design) [9] when the subject touches a fabric or wears certain clothing. Electromyography (EMG) and electroencephalography (EEG) are involved in the two instrumental evaluation techniques. Electromyography is a medical technique that measures the electrical activity generated by a muscle fibre membrane [10]. The electromyogram recorded can indicate the muscular contraction intensity. Electroencephalography is another medical technique that reads scalp electrical activity generated by the brain's structure [11]. These two types of electrical activities can be picked up by metal electrodes or conductive media attached to the skin's or scalp's surface, respectively. From these electrical activities the tactile properties of clothing can be assessed.

Previous studies have employed these two approaches to evaluate textile products. Shizukai [12] utilised electromyography to assess a functional girdle that can assist walking. The peak value of the EMG integrated was utilised to calculate the muscle load imposed by the girdle. Naoyasu and Akihiro [13] measured myoelectricity activity using EMG to study the hand of textiles when the subjects touched different fabrics. Zimniewska *et al.* [14] employed the EMG method to determinate the influence of clothing made from natural and synthetic fibres on the activity of the forearm muscles. It was found that clothing made from synthetic fibres changed the pattern of the motor units' activity, whereas clothing made from natural fibres evoked no such effect. The technology of EMG has also been utilised in the field of protective clothing. Park *et al*. [15] utilised motion capture and EMG technologies to evaluate protective clothing which could create restriction of motion and ultimately compromise work efficiency, leading to muscular fatigue. In addition, Choi and Lee [16] evaluated the comfort of PET clothing treated by UV by means of measuring the subjects' physiological responses. In their study EEG was recorded to assess the tactile stimulation of the clothing. Yuki and Akiko [17] assessed the contact sensation using the material of pajama cloth. They measured the subjects' EEGs when they wore the pajama. The EEG measurement results showed a significantly high ratio of Alpha waves, which indicated that the subjects were in a state of relaxation. Hiroko *et al.* [18] used the emotion spectrum analysis method for evaluation of clothing handle. The subjects' EEGs were measured when they wore different blouses made of four kinds of fabrics. Herr *et al.* [19] proposed a novel objective analysis method to quantify Kansei outputs for clothing, in which they measured the brain waves by EEG when the subjects examined different clothes.

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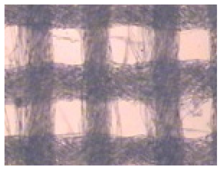
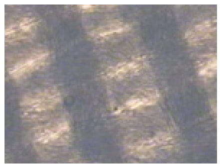
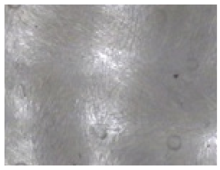
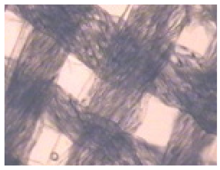
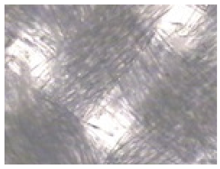
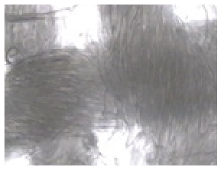
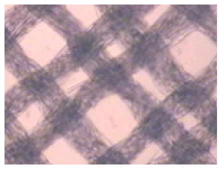
In this study we present a systematic approach to evaluate the hand of clothing textiles. 9 kinds of fabrics were selected and were made into clothes. These fabrics were first tested for mechanical properties. EMG and EEG methods were then used to evaluate the hand of the textiles of the fabrics and clothing. Sensory evaluation by the Semantic Differential (SD) method was also used to evaluate the subjective tactile perception. Statistical analysis was carried out to correlate objective data with subjective data. The study was intended to explore the various factors affecting the clothing hand of textiles and validate the evaluation method based on electro-neurophysiology.

Materials and method

Materials

The clothing hand of textiles is closely related to fibre type, texture and density [4]. In this study 9 kinds of fabrics of the same white colour with different constructions were selected as test samples. ***Table 1*** shows a description of their characteristics.

Table 1. *Description of fabric samples tested.*

Fabric sample no.	Fabric construction	Component	Density	Weight per unit, g/m2	Fabric morphology by microscope (40 times amplification)
1#	Plain cloth, plain weave	100% cotton	353 × 348	54.5	
2#	Poplin, plain weave		566 × 270	120.3	
3#	Twill weave		512 × 274	236.3	
4#	Plain weave	100% Ramie	262 × 240	92.7	
5#		100% flax	242 × 190	161.0	
6#			158 × 132	264.0	
7#	Chiffon, Plain weave	100% silk	500 × 460	33.2	
8#	Twill weave		668 × 344	62.1	
9#	Satin weave		998 × 360	138.5	

The fabrics' shearing, bending , surface and compression performance was tested by a KES-FB instrument, which was manufactured by the Japanese company of KATO TEKKO. Their draping performance was tested by a fabric draping testing instrument (XDP-1, Lipu Applied Science and Technology Research Institute, Shanghai, China).

EMG test

Seven female college students (Year: 22 ± 3 years; height: 162 ± 3 cm; weight: 50 ± 3 kg) were recruited as subjects. They were all healthy and willing to participate in the test. Heavy exercise was restrained for at least one hour before the test. They were briefed about the content of the experiment and potential risks. Their consent to participate in the test was obtained. The entire study was approved by the Research Committee of the Fashion Institute of Donghua University. Each subject came to the lab at the same time of the day to perform the test.

Before the test, the subject sat quietly at a table for half an hour to control muscle fatigue-relaxation impact on muscle efficiency. A previous study showed that the finger tips had the highest tactile distinguishing ability, hence were chosen for the tactile test [20]. The fabric samples tested were pulled towards the subject's finger tips to touch it at a speed of one touch per two seconds. When the stimulation is constant, the perception intensity will diminish. Therefore after some times of contact with the fabric samples, the test was stopped to let the subject have a short break and then contact with the finger tips was further induced. During the stimulation process, the subject's hands were quietly rested on the table to make sure that the myoelectricity recorded was

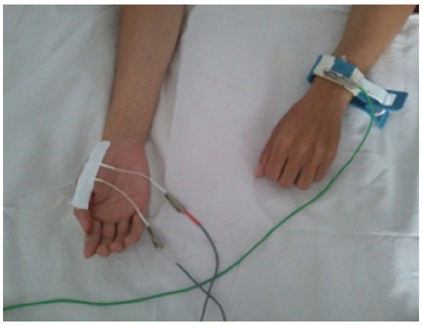


Figure 1. *EMG test.*

evoked by the fabrics and not by the fingers' muscle activity.

The recording electrode (NDI-200P, Haishen Electronic Instrument Manufacturing for Medical Treatment, Shanghai, China) was attached to the short abductor muscle of the hand. The reference electrode was attached near the recording electrode - from 3 to 5 cm.

The earth electrode was placed on the wrist of the left hand (***Figure 1***).

EEG test

The fabric samples in table 1 were made into male shirts. In total there were 9 shirt items, each shirt made by one of the fabrics. All the 9 shirts had the same sizes. The bust girth of the shirt was 92 cm, worn with a pair of casual trousers.

Six male volunteers (Year: 20 ± 2 years; height: 170 ± 3 cm) were selected as subjects, all healthy. They were addressed briefly about the content and procedure of the test. Likewise they were not allowed to take any heavy exercise before the test and each came to the lab at the same time of the day. The experiment was conducted in a quiet lab at a room temperature of 20 ± 1 °C and humidity of 60 ± 5%. The subject wore the shirt and casual trousers and rested quietly on a chair with their eyes closed to avoid any internal or external disturbance. The electrodes (ZN7A00, Sichuan Intelligent Electronics Manufacturing, China) were placed on the scalp at positions according to the International 10-20 System [21] (***Figure 2***).

Tactile perception will decrease or disappear after the body comes into contact with the clothing for some time. Therefore only the first three minutes when the shirts were put on were recorded for electroencephalography. A previous study showed that a state of *intention*, *joy* is characterised by an increase in the α weave, whereas *anxiety*, *uncomfort* are observed with a decrease in the α weave [22]. Hence α weave activity can be used to evaluate whether the wearer is in comfort or not [23]. In this study the energy percentage of the α weave at the occipitalia was chosen to evaluate clothing tactile perception. Since the left part of the brain specialises in positive emotion, such as joy, and the right part in negative emotion, such as depression [21], in both the left and right brain α weaves were applied as evaluating indexes.

Subjective evaluation for tactile sensations

All the fabric samples and shirts were also evaluated by subjective ratings for tactile sensations. The fabric samples were rated for their tactile sensations of coolness, adherence sensation, prick sensation, surface roughness sensation and stiffness sensation. All the shirts were rated for their tactile sensations of coolness, adherence sensation, prick sensation, weight sensation, tightness sensation and total comfort sensation. A rating scale was used in which 1 = very weak, 2 = weak, 3 = slightly weak, 4 = normal, 5 = slightly strong, 6 = strong and 7 = very strong.

Results and discussion

Peak values of the EMG

In the study of Shizukai [12] the peak value of EMG was utilised as an index for evaluation of muscular contraction. In this study the same method was used. The higher the peak value is, the stronger the muscular contraction is. Peak values of the EMG when the subject came into contact with the fabric samples are shown in ***Figure 3***. As seen in the figure, when fabric samples 3# and 6# touched the finger tips the highest peak values of

Figure 2. *EEG test.*

myoelectric potential were triggered. In contrast fabric samples 7# and 1# evoked the lowest peak values of myoelectric potential. This might be due to the different texture and construction of the fabric samples. Fabric samples 3# and 6# had the biggest weight per unit area and they were thicker, whereas 7# and 1# had the smallest weight per unit area. This indicated that thicker and heavier fabrics could trigger stronger muscular contraction.

Relationship of the myoelectric potential with the fabric sample's objective and subjective properties

Table 2 shows the correlation analysis of the myoelectric potential in relation to the fabric samples' physical properties. As shown in the table, the fabric bending rigidity, thickness and weight per unit area had a significant correlation with the myoelectric potential, which was in line with the above implication that thicker and heavier fabrics could stimulate more intense muscular contraction.

Table 3 shows the correlation analysis of the myoelectric potential in relation to subjective tactile sensations. From the table it can be seen that the surface roughness and stiffness sensations had a significant relation with the myoelectric potential, indicating that the higher the myoelectric potential the rougher and stiffer the fabric was felt.

Table 2. *Correlation analysis of the myoelectric potential in relation to fabric samples' physical properties; * shows significant at P < 0.001 level.*

	Bending rigidity	Average friction coefficient	Compression resilience ratio	Shear stiffness	Thickness	Weight per unit area	Static drape coefficient
Pearson correlation coefficient	0.892**	0.303	-0.647	0.659	0.942**	0.947**	0.499
P value	0.001	0.428	0.060	0.054	0.000	0.000	0.172

Energy percentage of α weave of the EEG

The energy percentage of the α weave of the EEG when the 9 shirts were worn is shown in ***Table 4***. It can be seen that the various shirts caused different energy percentages of the α weave.

Energy percentage of α weave of the EEG in relation to the clothing's objective and subjective properties

Since the full range of tactile responses to the clothing includes the pressure sensation [24], the pressure imposed by the various shirts on the skin was measured as well. The correlation analysis between the energy percentage of the α weave of the EEG with the clothing pressure is shown in ***Table 5***. From the table it can be seen that the energy percentage of the α weave at the left occipitalia had a positive correlation with the upper body clothing pressure.

The correlation analysis between the energy percentage of α weave of the EEG and the clothing subjective sensations is described in ***Table 6***. As shown in the table, the energy percentage of α weave at the left occipitalia had a significant correlation with the clothing adherence sensation and the clothing weight sensation. The energy percentage of α weave at the right occipitalia had a significant correlation with the clothing weight sensation. They had no significant correlation with the other subjective sensation indexes. The reason might be that people were always in a clothed state so that the stimulation induced by the different clothing was not strong.

Conclusions

This study was based on electro-neurophysiology and researched clothing tactile sensations. EMG and EEG tests were conducted when the subjects came into contact with various fabric and clothing samples. The main conclusions can be summarized as follows:

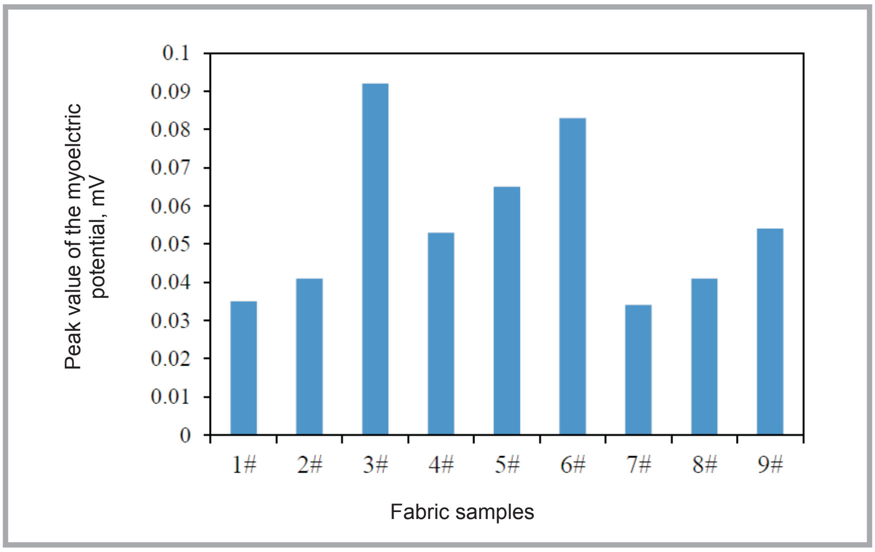


Figure 3. *Peak values of myoelectric potential in different fabric conditions.*

Table 3. *Correlation analysis of the myoelectric potential in relation to subjective tactile sensations; * shows significant at $p < 0.05$ level, ** shows significant at $P < 0.001$ level.*

	Tactile sensation of coolness	Adherence sensation	Prick sensation	Surface roughness sensation	Stiffness sensation
Pearson correlation coefficient	-0.101	-0.661	0.593	0.749*	0.890**
P value	0.796	0.052	0.092	0.020	0.001

Table 4. *Energy percentages of the weave of the EEG in different clothing conditions.*

Fabric sample no.	Clothing no.	Energy percentage of α weave at the left occipitalia, %	Energy percentage of α weave at the right occipitalia, %
1#	F-1	85.15	79.40
2#	F-2	85.65	85.33
3#	F-3	85.75	85.53
4#	F-4	84.40	83.07
5#	F-5	85.75	88.60
6#	F-6	83.40	81.13
7#	F-7	83.20	81.27
8#	F-8	82.90	83.40
9#	F-9	85.25	88.40

Table 5. *Correlation analysis of the energy percentage of the α weave of the EEG with the clothing pressure; * shows significant at $p<0.05$ level.*

		Average clothing pressure
Energy percentage of α weave at the left occipitalia	Pearson correlation coefficient	0.782*
	P value	0.022
Energy percentage of α weave at the right occipitalia	Pearson correlation coefficient	0.461
	P value	0.250

Table 6. *Correlation analysis of the energy percentage of α weave of the EEG with the clothing subjective sensations; * shows significant at $p < 0.05$ level.*

		Tactile sensation of coolness	Adherence sensation	Trick sensation	Weight sensation	Tightness sensation	Total comfort sensation
The energy percentage of α weave at the left occipitalia	Pearson correlation coefficient	-0.093	-0.773*	0.526	0.757*	-0.338	-0.477
	P value	0.827	0.025	0.181	0.030	0.412	0.232
The energy percentage of α weave at the right occipitalia	Pearson correlation coefficient	0.605	-0.203	0.343	0.813*	-0.110	-0.168
	P value	0.112	0.629	0.405	0.014	0.796	0.690

- When the subjects came into contact with the various fabric samples, the peak values of the myoelectric potential were different. When they came into contact with thicker, heavier and stiffer fabrics, the peak values of the myoelectric potential induced were higher. The higher the peak values of the myoelectric potential the stiffer and rougher the fabrics were perceived.
- When heavier clothing was worn, energy percentages of the α weave at both the left and right occipitalia were higher. When the clothing surface was smooth and the clothing pressure relatively high, the energy percentage of the α weave at the left occipitalia was also high.

Acknowledgements

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