Physiological Principle of Tactile Discriminability of Fabric Softness by Touching Method

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Abstract: Fabric Softness is one of main factors in guiding consumers' purchasing decisions, and many instrumental testing techniques quantifying this attribute have been proposed to substitute for its sensory evaluation. However, the performance is poor. By establishing a biomechanical model equivalent to the manner in which human fingertips sense the mechanical resistance against lateral compression of fabric, this study theoretically discusses the mechanical sensitivity of human sensing organs and the perceptual sensitivity of human sensory system. The results show that the mechanical sensitivity depends on the ratio of the mechanical resistance against compression of fabric to that of fingerpad, and the perceptual sensitivity on both the mechanical sensitivity and the capacity of human tactile system. Furthermore, the scatter among individual tactile evaluation on softness is attributed to the limitation of human tactile system processing stimulus information, and the assigned magnitude principally obeys a certain probability distribution, not a single averaging value statistically. In this sense, the deformability of soft tissues leads to an intrinsic difference of tactile evaluation from instrumental testing, although fabric compression property is detected on the same mechanical principle. The present conclusions will correct our misunderstandings in the effect-cause relationship between sensory attributes and instrumental testing.

Keywords: mechanical resistance, softness, sensitivity, fabric, fingertip, tactile

1. Introduction

Fabric softness sensation is the frequently desired feeling by consumers [1] and considered to be one of the primary perceptual attributes [2,3]. Softness of objects is characterized as hardness, namely the resistance to penetrate of materials by mechanical engineers, or as the perceived softness by sensory experts, namely the perceived ability to resistance against lateral compression of objects [4]. To quantitatively predict human sensory impression on fabric softness, all kinds of instrumental testing methods have been established to substitute for subjective evaluation on fabric softness. However, the performance is poor [4]. The failure is attributed to the lack understanding of human tactile system in respect to identification and discrimination in fabric softness. This alone necessities a deep investigation and understanding of the differences between sensory evaluation and an instrumental test under the same testing conditions. The present interests are in physiological mechanism on tactile discriminability of fabric softness, and the attempt is to discover the intrinsic capacity of human tactile organs in detecting softness property.

2. Equivalent Mechanical Models

2.1 Physiological Principles

According to the exploratory procedures extracting object properties[5-7], softness sensation of fabric as a typical compliant thin-shell material, is mainly perceived through the forces that the fingers exert, either by compressing or squeezing fabric surfaces. From the deformation modes of fabric, they can be totally classified into: compression deformation when

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fabric is compressed between two fingers, or fingers and experimental platform[5,8], as schematized in Figure 1; bending deformation when human fingers squeeze and fold fabric[5]. In the present study, the compression deformation of fabric surfaces as an example is considered. When human fingerpad presses toward fabric surfaces, generally, the perceived tactile impression on compressibility is due to a multi-modality combination in the secondary cognition of human central nervous systems, involving heat, chemical acoustic and mechanical stimuli, et al. Although it has been recognized that human fingers have different sensitivities to rich tactile properties of textiles including softness [4,5], there have no ideas of what affect human evaluation on fabric softness by touch means. And also, it is difficult to qualify and evaluate their magnitude in terms of simple physical and mathematical models.

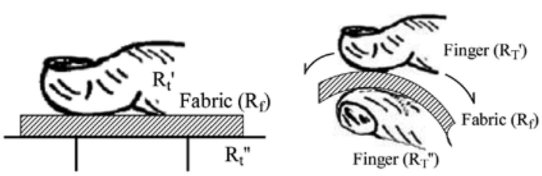

Figure 1 Schematic view of in-series array of fabric-finger(s) mechanical system

The case, however, where pure mechanical properties are concerned, will be feasible to evaluate in the principle of mechanical deformations. The tactile perception of physical attributes by human is probably based on the information generated during mechanical deformations of the in-series fabric-finger(s) arrays in contact [6,9]. The term "pure mechanical properties" in this context means those objective properties that can be evaluated, at least theoretically, by the instrumental testing. In this sense, the differences of the sensory thresholds in respect of subjected force to different sensory organs and their sensitivity can be explained partially by the same mechanical principles that apply to man-made instruments.

Therefore, we can develop a lumped-parameter mechanical model to represent the force-deformation curves of the in-series fabric-finger(s) arrays, and discuss the sensory responses to mechanical stimulus in combine with the recognized psychophysical law. By this study, attempts are to demonstrate the role of fabric's resistance against compression in determining the mechanical sensitivity of human sensing organs and perceptual sensitivity of human sensory system, and uncover the intrinsic differences between touch evaluation and instrumental testing.

2.2 Lumped-parameter Biomechancial Model

Two points must be noted before the model is developed. Firstly, it is necessary that soft tissues within fingerpad over contact area are not subject to concentrated stress. In terms of the gentle fibres protruding from fabric surfaces, they are easily broken down, so that a common substantial amount of soft tissues involve in contact with sufficient fabric surfaces. Therefore, the situation of concentrated stress can be avoided. That's to say, it is justified to treat the integrated mechanical signal as the representative stress/strains sensed by cutaneous mechanoreceptors within soft tissues [2,6] in the context of this discussion. And then, from Figure 1, the mechanical sensing system of fingerpad and fabric in contact can be equivalent to the in-series array of fingers and fabrics in Figure 2, mechanically. Secondly, it is assumed that the stimulus information received by cutaneous mechanoreceptors can be characterized in the form of mechanical resistance against compression, and it means the stimulus intensity to receptors. Note, the mechanical resistance only represents the overall resistance of a whole system against deformation among all levels of loading, not the familiar Young's modulus applicable in the case of small elastic strain.

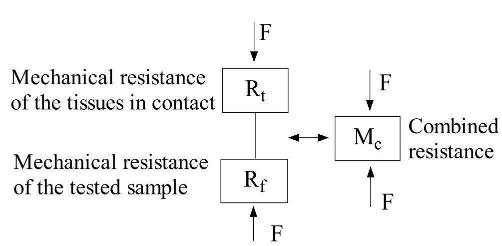

Figure 2 Equivalent mechanical sensing system

Base on the definition of mechanical resistance, the mechanical resistance of the system is expressed by the displacement (δ) at any give net force (F)

$$R_i = F/\delta_i, i = t, f \,. \tag{1}$$