Colloids and Surfaces B: Biointerfaces xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Colloids and Surfaces B: Biointerfaces

journal homepage: www.elsevier.com/locate/colsurfb

Study of the tactile perception of bathroom tissues: Comparison between the sensory evaluation by a handfeel panel and a tribo-acoustic artificial finger

C. Thieulin[a,*], C. Pailler-Mattei[a,b,*], R. Vargiolu[a], S. Lancelot[b,c,d], H. Zahouani[a]

[a] *Laboratoire de Tribologie et Dynamique des Systèmes, UMR-CNRS 5513, Ecole Centrale de Lyon, 36 avenue Guy de Collongue, Ecully, France*
[b] *Université de Lyon, Faculté de Pharmacie-ISPB, laboratoire de biophysique, Lyon, France*
[c] *Université Claude Bernard Lyon 1, INSERM, CNRS, Lyon Neuroscience Research Center, Lyon, France*
[d] *Hospices Civils de Lyon, France*

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 3 October 2016
Accepted 3 November 2016
Available online xxx

Keywords:
Tactile perception
Artificial finger
Friction
Surface tissue
Acoustic vibrations

ABSTRACT

Tactile perception is one of the sensorial modes most stimulated by our daily environment. In particular, perceived softness is an important parameter for judging the sensory quality of surfaces and fabrics. Unfortunately, its assessment greatly depends on the tactile sense of each person, which in turn depends on many factors. Currently, the predominant method for evaluating the tactile perception of fabrics is the human handfeel panel. This qualitative approach does not permit the quantitative measure of touch feel perception.

In this study, we present a new artificial finger device to investigate the tactile sensing of ten bathroom tissues. It enables simultaneously measuring the friction and vibrations caused when sliding an artificial finger on the surface of the tissue.

The comparison between the results obtained with the artificial finger and the tactile perception evaluated using a handfeel panel showed that the artificial finger is able to separate the two parts of the tactile perception of bathroom tissues: softness and surface texture (velvetiness). The statistical analysis suggests that there is a good correlation between the vibrations measured with the artificial finger and the softness evaluated by the panel. It then shows that the friction measured by the artificial finger is related to the surface texture of a bathroom tissue. The ability of the artificial finger to mimic human touch is demonstrated. Finally, a Principal Component Analysis orders the signatures of the tactile perception of the bathroom tissues in four different groups.

1. Introduction

Tactile perception is one of the sensorial modes most stimulated by our daily environment due to the development of new products and new materials, such as smart clothes, cosmetics, automobile materials, information terminals, virtual reality systems, and robots. Consequently, information on the physical origin of tactile perception is very useful for designing many products and systems [1]. The human handfeel panel is the method most often used to evaluate and measure the tactile perception of different objects. This method consists in evaluating the tactile properties of samples by touching, rating and ranking them as a function of pre-defined criteria [2–4]. Some authors investigated the ability of humans to tactually discriminate the compliance of objects by indenting the surface with a human finger [5,6]. In particular, Bicchi et al. showed that it was possible to evaluate the compliance of a specimen with information on the contact area spread rate between the finger and the specimen as the contact force increases [6]. However, in general, the tactile perception of the object tested is estimated by rubbing a finger on the surface of the object. Sliding of the finger on the surface of the object causes vibrations which activate mechanoreceptors embedded in the skin. The mechanical signal generated by the friction between the finger and the surface material is then transformed into an electrical signal which is analyzed by the brain and translated into a tactile perception

* Corresponding authors at: Ecole Centrale de Lyon, Laboratoire de Tribologie et Dynamique des Systèmes-UMR CNRS 5513, 36 avenue Guy de Collongue, 69134 Ecully, France.
E-mail addresses: coralie.thieulin@doctorant.ec-lyon.fr (C. Thieulin), cyril.pailler-mattei@ec-lyon.fr (C. Pailler-Mattei).

http://dx.doi.org/10.1016/j.colsurfb.2016.11.006
0927-7765/© 2016 Published by Elsevier B.V.

Table 1
The thickness, basis weight, MD tensile strength and MD stretch values of the ten bathroom tissues samples. MD corresponds to the driving direction of the paper machine. All data are indicated as mean ± SD (SD: standard deviation).

Sample	A	B	C	D	E	F	G	H	I	J
Mean basis weight (g/m^2)	48.6 ± 2.4	61.4 ± 3.4	87.5 ± 1.4	54 ± 3.0	58.4 ± 2.4	57.1 ± 0.8	58.7 ± 1.4	51 ± 1.9	64.2 ± 3.7	68.3 ± 3.9
Mean thickness (mm)	0.40 ± 0.01	0.45 ± 0.05	0.77 ± 0.09	0.67 ± 0.04	0.55 ± 0.06	0.51 ± 0.02	0.60 ± 0.04	0.40 ± 0.04	0.54 ± 0.05	0.50 ± 0.06
Mean MD tensile strength (N/m)	460 ± 39	219 ± 15	484 ± 35	170 ± 19	127 ± 11	135 ± 12	438 ± 41	567 ± 33	501 ± 42	437 ± 16
Mean MD stretch (%)	11.3 ± 1.0	11.4 ± 0.2	17.9 ± 0.8	8.8 ± 0.2	21.5 ± 0.6	23.8 ± 2.4	10.6 ± 0.9	12.4 ± 0.6	16.1 ± 1.8	14.6 ± 0.3

feeling. Using a handfeel panel to evaluate the tactile perception of products is very time-consuming and expensive for industrial companies that need to evaluate the tactile perception of their products. Furthermore, these classical methods only provide subjective and qualitative evaluations of the tactile quality of products. The measurement of tactile perception with a human finger pad depends on the mechanical and physicochemical properties of skin finger testers, which in turn depend on ageing effect, gender and hydration level [7–9]. In recent years, the textile industry has played a pioneering role in tactile perception by trying to objectify tactile perception with physical and quantitative parameters.

Many works in the literature have attempted to gain insight on and quantify tactile perception using different materials, such as cosmetic products, surfaces used for braille reading and textured polymers and skin surfaces [11–15]. However, most of studies on tactile perception have been performed for feeling woven fabric tissues. In general, tactile fabric feeling is quantified by measuring the friction coefficient between the fabrics and the finger [16–18]. It has been demonstrated that friction properties are correlated to the slipperiness and smoothness properties of textiles [16]. However, the relationship between fabric tactile perception and tribological behavior seems to be highly influenced by experimental conditions, such as contact pressure and friction speed. Some studies have included in their analysis the effect of vibrations induced by friction to improve understanding of tactile perception [19]. The vibrational analysis of tactile perception is often carried out by using a specific probe or artificial finger [20]. As for the tribological analysis, vibration measurements can also be disturbed by experimental and environmental conditions.

In this study, we focused on the softness feeling of nonwovens, more especially bathroom tissues. Softness is one of the most important parameters for judging the sensory quality of bathroom tissues. Bathroom tissues have received less attention in the literature than woven fabrics. Unlike woven fabrics, nonwoven fabrics have no internal structure and are composed of separate cellulose fibers. In the first part, the softness feeling of ten bathroom tissues is estimated by a handfeel panel as a function of the intrinsic characteristics of the papers. As mentioned previously, analysis of the handfeel panel is qualitative and subjective, which is why a specific artificial finger has been developed to quantitatively investigate the softness feeling of the tissue. The artificial finger allows simultaneously measuring quantitative parameters such as the friction coefficient between the artificial finger and the fabrics and the acoustic vibratory level generated by sliding the finger on the bathroom tissue. In the second part, the softness of the bathroom tissues is studied with the original artificial finger device. The effects of the intrinsic tissue characteristics on the friction coefficient and the acoustic vibratory level are observed. The results from the artificial finger are then compared to the subjective evaluation from the handfeel panel. The ability of the artificial finger to mimic the human touch of bathroom tissues is studied. To this end, a tribo-haptic system using the human finger was used to measure the friction coefficient and the acoustic vibratory level between the human finger and the same bathroom tissues. Finally, a principal component analysis was performed to highlight the signature of the tactile perception of the bathroom tissues.

2. Materials and methods

2.1. Bathroom tissues

Ten commercial bathroom tissues were used in this study. All the papers used resulted from conventional drying technology. We distinguished conventional drying technology that uses mechanical pressing to dewater paper sheets from the Through Air Drying (TAD) method that uses heat. Arbitrary names for the bathroom tissues were assigned to the ten samples (from A to J). The tissues samples were chosen in order to cover a wide range of softness feelings. The samples had different thicknesses, basis weights and intrinsic characteristics, such as machine direction (MD), tensile strength (maximum stress to break a strip of paper sheet) and MD stretch (ratio of the elongation of a strip of paper sheet over its initial length, at the moment when the maximum tensile force is reached) (Table 1). MD corresponds to the driving direction of the paper machine. Only the MD characteristic of the paper sheet was used in the study because it corresponds to the direction of touch. In this study, all the physical parameters were measured according to ISO standard methods for the paper industry (for tensile strength and stretch: EN 12625-4, for basis weight: EN 12625-6, and for the thickness: EN 12625-3).

Before performing the measurements, the tissue samples were stored for 24 h in a room at a temperature of 23 °C and a relative humidity (RH) of around 50%. For the measurements, the tissues were cut into pieces of 7 × 10 cm^2 with the 10 cm side parallel to the machine direction.

2.2. Handfeel panel

A trained sensory handfeel panel of thirty representative persons, including 13 women and 17 men aged between 25 and 55 years old, took part in the study. These healthy volunteers were right-handed and were asked to evaluate the tactile properties of the tissues based on two descriptive criteria: softness and surface texture. These criteria correspond to sensory perception when touching the samples.

In this study, the experimental method used by the handfeel panel to evaluate softness perception and surface texture consisted in gripping the tissue sample with both hands and rubbing it with both thumbs at the same time. Rubbing between both thumbs and the sample paper was in the machine direction (MD). All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the ethical standards of the 1964 Declaration of Helsinki. All participants gave their written informed consent to the psychophysical protocol.

Softness was defined on four levels of a haptic scale according to the softness of the reference papers. These levels were quantified by scores: 0, 1, 2, 2.5 from the least soft to the softest. The four reference papers were commercial bathroom tissues with different surface textures and different physical properties.

Please cite this article in press as: C. Thieulin, et al., Study of the tactile perception of bathroom tissues: Comparison between the sensory evaluation by a handfeel panel and a tribo-acoustic artificial finger, Colloids Surf. B: Biointerfaces (2016), http://dx.doi.org/10.1016/j.colsurfb.2016.11.006