Abstract

Mechanism Study on Tactile Perception Evoked by Skin Friction
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The mechanism study on tactile perception evoked by skin friction is mainly the analysis of relationship between skin Physiology and object surface properties. It is the basis of research on human discriminative touch. It is significant to the fields of haptics, development of artificial skin, virtual reality, and medical science.

This article is divided into three parts of study; every part is independent of each other, bus going forward one by one. First, Study on nano tribological behavior of skin; Second, Study on pressure and vibration sense of tactile perception induced by friction; Third, Study on relationship between tactile perception and friction. The main experimental methods and conclusions are as follows:

First, animal skin and artificial skin were used to observe their nano tribology behavior.

Rat skin and pig skin are common animal models for studies, and were used as skin samples in this study. The nano- and macroscale friction and durability of damaged skin were measured and compared with virgin skin. The effect of skin cream on friction and durability of damaged and virgin skin samples is discussed. The effect of velocity, normal load, relative humidity and number of cycles were studied. The nanoscale studies were performed using atomic force microscope (AFM) and macroscale studies were performed using a pin-on-disk (POD) reciprocating tribometer. It is found that damaged skin has different mechanical properties, surface roughness, contact angle, friction and durability compared to that of virgin skin. But similar changes occur after skin cream treatment. Rat and pig skin shows similar trends in friction and durability.

A systematic study is carried out of the surface, nanomechanical and nanotribological properties of two synthetic skins with and without skin cream treatment using a scanning electron microscope (SEM), a nanoindenter and an AFM. The hardness, elastic modulus, surface roughness, contact angle, coefficient of friction, adhesive force and film thickness of the two synthetic skins are compared with that of virgin and damaged rat and pig skin. The data of the two synthetic skins are comparable to the rat and pig skin, which shows that the two synthetic skin are good simulations of animal skins for tribological study.

Second, mechanism of vibrotactile was discussed from mechanic perspective.

The coefficient of friction and vibration data was obtained from a biomimetic sensor during

it scanning fabric surfaces were dealt and compared with human sense. Human subjective sensing experiments were taken with twenty volunteers by classifying texture into ten grades according to three dimensions: Rough-Smooth, Coarse-Fine and Complex-Uniform. Vibrations and coefficient of friction (COF) between skin and fabric were measured using an artificial finger and a tribometer when finger scans across various fabrics. Five characteristic values were extracted based on features of fabric texture from the vibrating data: peak average (PA), peak ratio (PR), spectral centroid (SC), power (P), and Shannon entropy (SE). These features were evaluated by comparing with human sensing experiment. It is found that SC, P, SE and COF could characterize the perceived Rough-Smooth, Coarse-Fine, Complex-Uniform and comfort.

Third, discussion on event related potentials evoked by friction.

The test study was taken by using Neuroscan 64-channels event related potentials (ERPs) system. The latency and peak of P300 evoked by Oddball mode and its variation mode was observed and analyzed. Three paper samples with different coefficient of friction were used for experiments. The result shows that the latency and peak value is different with different coefficient of friction. It shows that ERPs Technique could be used to observe change of brain signals evoked by friction. Then, Oddball variation mode was carried out to evoke third positive peak (P3) of Event Related Potentials (ERPs). Three fabrics samples with different coefficient of friction were chosen. The result shows that the samples with larger coefficient of friction had smaller peak latency and peak amplitude of P3 than the samples with lower coefficient of friction. It indicated that the samples with larger coefficient of friction could be recognized quickly and easily.

This paper studied the mechanism of tactile perception evoked by skin friction based on many subjects, such as biotribology, nano mechanics, simulation experiments, psychological physics, cognitive science, et al. The results could provide theory and technique support for robot bionic skin, texture quantitative assessment, tactile feedback, touch bionics and so on.

Keywords: skin; tribology; tactile perception; vibrotactile; event-related potentials

Extended Abstract

The mechanism study on tactile perception evoked by skin friction is mainly the analysis of relationship between skin Physiology and object surface properties. It is the basis of research on human discriminative touch. It is significant to the fields of haptics, development of artificial skin, virtual reality, and medical science.

Tactile perception is a complex process highly dependent on the surface properties[1,2]. As finger scanning the surface of fabrics, deformations and vibrations, produced by friction force, stimulate the sensory receptors of skin. Action potential formed when sensory receptors response to stimulus. And then potential current carrying the surface information (relies on its direction, amplitude, lasting time, etc.) are transmitted to sensory cortex of brain along nerve fibers of different positions [3,4]. At last, tactile perception is formed in somatosensory cortex. Tactile sensation is not only related with deformations and vibrations of skin, but also with some other psychological factors, such as memory, personality, expectation and so on [6,7]. Tactile sensing is integrated perception formed by the response of the receptors induced by cutaneous mechanical stimulus [8]. Friction plays an important role in tactile perception, which is mediated by skin vibrations induced by tangential force between skin and surface.

This article is divided into three parts of study; every part is independent of each other, bus going forward one by one. First, Study on tribological behavior of skin; Second, Study on pressure and vibration sense of tactile perception induced by friction; Third, Study on relationship between tactile perception and friction. The main experimental methods and conclusions are as follows:

First, animal skin and artificial skin were used to observe their nanotribology behavior.

It's hard to get human skin directly. Rat skin and pig skin are common animal models for studies, and were used as skin samples in this study. The nano- and macroscale friction and durability of damaged skin were measured and compared with virgin skin. The effect of skin cream on friction and durability of damaged and virgin skin samples is discussed. The effect of velocity, normal load, relative humidity and number of cycles were studied. The nanoscale studies were performed using atomic force microscope (AFM) and macroscale studies were performed using a pin-on-disk (POD) reciprocating tribometer. It is found that damaged skin has different mechanical properties, surface roughness, contact angle, friction and durability compared to that of virgin skin. But similar changes occur after skin cream treatment. Rat and pig skin shows similar trends in friction and durability.

Artificial skin is largely used in clinic as replace of broken skin, so it's important to study its

tactile sense. A systematic study is carried out of the surface, nanomechanical and nanotribological properties of two synthetic skins with and without skin cream treatment using a scanning electron microscope (SEM), a nanoindenter and an AFM. The hardness, elastic modulus, surface roughness, contact angle, coefficient of friction, adhesive force and film thickness of the two synthetic skins are compared with that of virgin and damaged rat and pig skin. The data of the two synthetic skins are comparable to the rat and pig skin, which shows that the two synthetic skin are good simulations of animal skins for tribological study.

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The coefficient of friction and vibration data was obtained from a biomimetic sensor during it scanning fabric surfaces were dealt and compared with human sense. Human subjective sensing experiments were taken with twenty volunteers by classifying texture into ten grades according to three dimensions: Rough-Smooth, Coarse-Fine and Complex-Uniform. Vibrations and coefficient of friction (COF) between skin and fabric were measured using an artificial finger and a tribometer when finger scans across various fabrics. Five characteristic values were extracted based on features of fabric texture from the vibrating data: peak average (PA), peak ratio (PR), spectral centroid (SC), power (P), and Shannon entropy (SE). These features were evaluated by comparing with human sensing experiment. It is found that SC, P, SE and COF could characterize the perceived Rough-Smooth, Coarse-Fine, Complex-Uniform and comfort.

Third, discussion on event related potentials evoked by friction.

During the tactile perception, the brain electrical of human will changes due to the change of the vibration, friction, and surface properties between the perceived surface and human skin. The first discussion on event related potentials evoked by friction were taken by using Neuroscan 64-channels event related potentials (ERPs) system. The latency and peak of P300 evoked by Oddball mode and its variation mode was observed and analyzed. Three paper samples with different coefficient of friction were used for experiments. The result shows that the latency and peak value is different with different coefficient of friction. It shows that ERPs Technique could be used to observe change of brain signals evoked by friction.

To establish the relationship between tactile perception and friction, Neuroscan 64-channels ERPs system and a three-axis force sensor was used to get electroencephalograph (EEG) and friction signal separately. Oddball variation mode was carried out to evoke third positive peak (P3) of Event Related Potentials (ERPs). 20 volunteers were selected. Three fabrics samples with different coefficient of friction were chosen. The experiment was divided into three groups to

compare every two of three fabric samples. The coefficient of friction was calculated from the data of three-axis force sensor when the fingers slide across the surface of fabrics. For all experiments groups, lines had the largest coefficient of friction and silk the smallest. The result shows that the samples with larger coefficient of friction had smaller peak latency and peak amplitude of P3 than the samples with lower coefficient of friction. It indicated that the samples with larger coefficient of friction could be recognized quickly and easily.

This paper studied the mechanism of tactile perception evoked by skin friction based on many subjects, such as biotribology, nano mechanics, simulation experiments, psychological physics, cognitive science, et al. The results could provide theory and technique support for robot bionic skin, texture quantitative assessment, tactile feedback, touch bionics and so on.

Keywords: skin; tribology; tactile perception; vibrotactile; event-related potentials

The full dissertation is available at this link,

https://nlbb.engineering.osu.edu/sites/nlbb.osu.edu/files/uploads/mechanism_study_on_tactile_perception_evoked_by_skin_friction_si_chen_2016_0.pdf