NEURONAL REPRESENTATION OF FABRIC TEXTURE FOR THERMAL MICROENVIRONMENT

by

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Short paper
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Fabric, our second skin with moisture and thermal capacity for skin temperature regulation, can arouse feelings of pleasant and discomfort. To examine the neurocognitive ability and emotion of fabric tactile perception under different local temperatures, we used functional magnetic resonance imaging with the same denim fabric stimuli and forearm contact area, and found a functional dissociation: the affective regions was more involved during warm condition, the discriminative regions were more involved during neutral condition and the basis regions were significance during cool condition. The higher local skin temperature environment can result in the improvement of sensitivity and discriminability by dorsal pathway (spatial) and ventral pathway (frequency) for fabric perception. Our results help to explain how the brain uses internal models to interpret external fabric tactile stimuli with micro environmental changing.

Key words: *fabric texture, thermal microenvironment, neuroimaging, tactile cognition network*

Introduction

Textile fibers are the materials in contact with human skin for 24 hours per day. The thermal microenvironments have big impact on the skin [1]. The buckling and surface friction properties of hairiness fiber are the basic factors for tactile perception [2].The shape and mechanical properties of hairiness fibers on surface directly affect the contact force [3], however, the brain function of tactile perception for the soft fibrous surface is unclear, especially with local skin temperature changing. Expert scoring method is one of the means of traditional textile industry for tactile perception [4], but not for perception mechanism. The neuroimaging (fMRI) is a non-invasive research technique [5], which provides new methods and ideas for fabric tactile perception research. We compared the activated regional differences of brain by different local skin temperature regulation, to investigate the structures and co-ordination mechanisms of our brain for fabric tactile.

Subjects and methods

General information: testing from Nov. 2011-May 2012, 18 healthy subjects for scanning, including nine men and nine women, aged 23 to 33 years, median age of 26.5 years,

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right-handed, no brain diseases and history of severe skin diseases, no taking drugs 3 days before the experiment. Studies have got the Ruijin Hospital Ethics Committee approval.

GE 3.0T Signa HDxt MRI System is a standard head coil. Forearm skin irritation textile is denim (right-hand twill cotton, warp 58, wefts, 58, fabric g380 g/m^2). The denim fabric fixed on the semi-automatic tactile devices. The device can control skin contact area and contact pressure and frequency of reciprocating for stimulation.

There are three different local temperature adjustment methods. First, low temperature regulation (ice): using single layer 0 °C ice packs changed the local temperature on the forearm skin of subjects, after 3 minutes removed the ice packs, wiped away the residues cold water from the surface of the forearm skin by dry towel. Second, normal temperature regulation (at room temperature): the volunteers are were required stay in 20 °C standard laboratory temperature for 9 minutes. Third, high temperature conditioning (hot towels): use the 55 °C hot towel on the forearm skin, contact with towel for 6 minutes, remove the hot towel, and wipe away residue hot water.

Results and conclusions

Major activated region by fabric tactile stimulation under three local temperature conditions are shown in fig. 1. First, using ice bag condition for 3 minutes, the average local temperature of contact region on forearm is 23 °C. The activated brain regions included the parietal operculum (OP/S2), the declive (Dec) part of the cerebellum and the cuneus (Cun) part of the occipital cortex. Second, under standard room temperature 20 °C for 9 minutes, the average local temperature of contact region on forearm is 29 °C. The brain regions for tactile included the parietal operculum (OP/S2), the cuneus part of the occipital cortex, the declive (Dec) part of the cerebellum, the superior temporal gyrus (STG, BA22), the Brodmann area 2 (BA2), the premotor cortex (PMC, BA6), the primary somatosensory cortex (S1), the inferior parietal lobule (IPL) and the posterior parietal cortex (PPC). Third, with hot towel 55 °C for 6 minutes, the average local temperature of contact region on forearm is 32 °C. The brain regions included the Parietal Operculum (S2) the declive (Dec) part of the cerebellum, the lingual gyrus (Lin) part of the occipital cortex, the middle occipital gyrus (MOG), the culmen

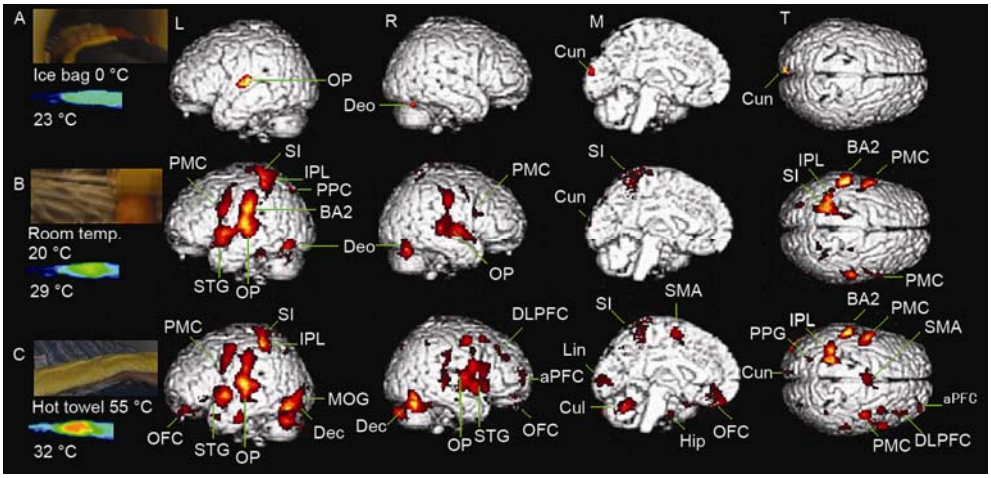

Figure 1. The brain activation maps for textile tactile under different local skin temperature
(for color image see journal web site)

part of the cerebellum, the anterior insula (AI), the superior temporal gyrus (STG), the anterior prefrontal cortex (aPFC), the dorsolateral prefrontal cortex (DLPFC), the posterior parietal cortex (PPC), the posterior cingulated cortex (PCC), the orbitofrontal cortex, the Brodmann area 2 (BA2), the inferior parietal lobule (IPL), the premotor cortex (PMC), the supplementary motor area (SMA), and the primary somatosensory cortex (S1).

Our results provide new sights into the functional organization of the fabric tactile perception system. Neurocognitive model of fabric tactile perception have shown the connections and the pathways of activated regions to different aspects of fabric perception. The basis region areas for tactile are highlighted with ellipses of blue tints (fig. 2), including thalamus, declive, cuneus, and OP/insula. The discriminative region areas are pointed with ellipses of green tints (fig. 2), including PMC, STG, BA2, S1, IPL, and PPC. The affective region areas are colored with ellipses of red tints, including SMA, DLPFC, aPFC, AI, OFC, and hippocampus. The dorsal (where) pathway [6] may contribute to fabric spatial cognition (supple/stiff) through PMC, S1, IPL, and PPC processing. The ventral (what) pathway may contribute to fabric frequency cognition (soft/harsh) through AI, STG, and OFC processing. The brain is more complex than what we imaging for the tactile perception under temperature condition [7]. The present results shown a functional dissociation, the affective regions was more involved during warm condition, while the discriminative regions were more involved during cool condition.

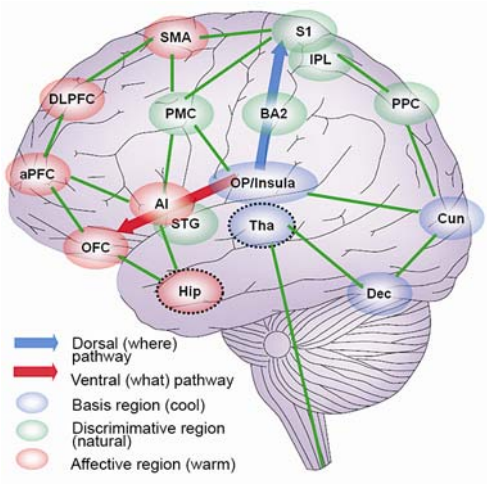

Figure 2. The brain connection for fabric tactile under different local skin temperature
(for color image see journal web site)

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Acronyms

AI – anterior insula
aPFC – anterior prefrontal cortex
BA2 – Brodmann area 2
Cun – cuneus
Dec – declive
DLPFC– dorsolateral prefrontal cortex
IPL – inferior parietal lobule
Lin – lingual gyrus
MOG – middle occipital gyrus
OP/S2 – parietal operculum
PCC – posterior cingulated cortex
PMC – premotor cortex
PPC – posterior parietal cortex
S1 – primary somatosensory cortex
SMA – supplementary motor area
STG – superior temporal gyrus

Reference

[1] He, J.-H., *et al.*, Can Polar Bear Hairs Absorb Environmental Energy? *Thermal Science, 15* (2011), 3, pp. 911-913
[2] Liu, Y. Q., *et al.*, Soft Contact of Fibrous Surfaces, *International Journal of Nonlinear Sciences and Numerical Simulation, 11* (2010), 1, pp. 71-79
[3] Yu, W. D., Liu, Y. Q., Softness Evaluation of Keratin Fibers Based on Single – Fiber Bending Test, *Journal of Applied Polymer Science, 101* (2006), 1, pp. 701-707
[4] Lu, J., *et al.*, A Linguistic Multi-Criteria Group Decision Support System for Fabric Hand Evaluation, *Fuzzy Optimization and Decision Making, 8* (2009), 4, pp. 395-413
[5] Heeger, D. J., Ress, D., What Does fMRI Tell us about Neuronal Activity? *Nature Reviews Neuroscience, 3* (2002), 2, pp. 142-151
[6] Griffiths, J. D., *et al.*, Functional Organization of the Neural Language System: Dorsal and Ventral Pathways are Critical for Syntax, *Cerebral Cortex, 23* (2013), 1, pp. 139-147
[7] Silvanto, J., Pascual-Leone, A., Why the Assessment of Causality in Brain–Behavior Relations Requires Brain Stimulation, *Journal of Cognitive Neuroscience, 24* (2012), 4, pp. 775-777

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