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Pleasant human touch is represented in pregenual anterior cingulate cortex

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ABSTRACT

Touch massage (TM) is a form of pleasant touch stimulation used as treatment in clinical settings and found to improve well-being and decrease anxiety, stress, and pain. Emotional responses reported during and after TM have been studied, but the underlying mechanisms are still largely unexplored. In this study, we used functional magnetic resonance (fMRI) to test the hypothesis that the combination of human touch (i.e. skin-to-skin contact) with movement is eliciting a specific response in brain areas coding for pleasant sensations. The design included four different touch conditions; *human touch* with or without movement and *rubber glove* with or without movement. Force (2.5 N) and velocity (1.5 cm/s) were held constant across conditions. The pleasantness of the four different touch stimulations was rated on a visual analog scale (VAS-scale) and human touch was rated as most pleasant, particularly in combination with movement. The fMRI results revealed that TM stimulation most strongly activated the pregenual anterior cingulate cortex (pgACC). These results are consistent with findings showing pgACC activation during various rewarding pleasant stimulations. This area is also known to be activated by both opioid analgesia and placebo. Together with these prior results, our finding furthers the understanding of the basis for positive TM treatment effects.

Introduction

Human touch, i.e. skin-to-skin contact between individuals, is a special form of tactile sensation that typically is perceived as pleasurable and has important social and affective values (Gallace and Spence, 2010; Guest et al., 2009; Morrison et al., 2009). Human touch can also be used in a more systematic form, such as touch massage (also called tactile, gentle or soft massage). This kind of massage is characterized by long, stroking movements over the skin and does not involve the muscles like classic or Swedish massage. Touch massage is sometimes used in clinical settings and has been found to decrease pain, anxiety and stress in the receiver (Andersson et al., 2009; Billhult and Maatta, 2009; Henricson et al., 2009; Suzuki et al., 2010). Although the emotional responses to this treatment are quite well known, the underlying mechanisms are still unexplored. To our knowledge no study has evaluated brain activity during touch massage (TM) stimulation.

There is limited evidence on the representation of pleasant *human* touch (i.e. skin-to-skin contact) in the brain, but a few studies have focused on pleasant touch stimulation. Nerve fibers classified as C-tactile (CT) afferents have been found in human hairy skin (Johansson et al., 1988). These fibers respond to light forces (0.8 N) and slow stroking movements. Activation of CT-fibers is perceived as pleasurable and engages the insular cortex (Loken et al., 2009; Olausson et al., 2002), a brain area involved in emotional processing (Craig, 2009). However, CT-afferents and related insular activation cannot fully explain the emotional response of touch because pleasurable sensations have also been reported when stimulating glabrous skin which lacks CT-afferents (Francis et al., 1999; Kramer et al., 2007). In addition to insula activation, other brain regions have also been found to be activated during pleasant touch stimulation. Francis et al. (1999) demonstrated that discriminative touch and affective touch activated different brain areas. Discriminative and neutral touch more strongly activated somatosensory cortex whereas emotional (pleasant) touch produced stronger activation in OFC (Francis et al., 1999). The affective value of touch also seems to influence brain regions differently. Painful and pleasant touch has been shown to affect different parts of the OFC (Rolls et al., 2003a). Furthermore, painful touch stimulation activated dorsal anterior cingulate cortex (dACC) whereas pleasant touch activated a more rostral part of the ACC (pgACC) (Rolls et al., 2003a). A role of the pgACC area in pleasant touch is consistent with findings showing that this region is involved in the processing of other forms of pleasant sensory stimuli such as warm temperature, flavor, and oral texture (Grabenhorst et al., 2010a; Guest et al., 2007; Rolls, 2008; 2010).

The pressure applied in TM is lighter than the pressure used in classic massage/Swedish massage but higher than what is typical for

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stroking movement with a brush (Lindgren et al., 2010). Knowledge about the representation of pleasant touch in the brain generally originates from pleasant touch stimulation using soft materials (e.g. brushes or soft texture), stimulating the skin with light forces (0.8 N) and slow stroking movements (Francis et al., 1999; Olausson et al., 2002; Rolls et al., 2003a). Although the velocity (1–5 cm/s) is similar in TM stimulations, the *human* factor (skin-to-skin contact) and the force of 2.5 N differ from other touch stimulations (Lindgren et al., 2010). Here we therefore assumed that *human* touch with movement (force 2.5 N and velocity 1–5 cm/s) would differ with respect to subjective ratings and neural activity relative to movement with a rubber glove and stationary conditions. Specifically, the purpose of the present study was to examine how the brain responds to pleasant *human* touch with the same force and velocity as used in TM. In order to evaluate the combination of human and moving touch stimulation we used a factorial design and four different forearm touch conditions; light human touch with or without stroking movement, and light touch with a rubber glove with or without stroking movement with forces and velocity held constant. To control for force (2.5 N) and velocity (1–5 cm/s) a custom-made device with a dummy arm was used during touch stimulations (Fig. 1). The pleasantness of the conditions was rated on a visual analog scale (VAS), and regional brain activity induced by the various conditions was measured using fMRI BOLD imaging. Based on previous studies (Francis et al., 1999; Olausson et al., 2002; Rolls et al., 2003a) we hypothesized that human touch with light pressure and long stroking movement would be rated as pleasant and engage the insula, OFC, and/or ACC.

Materials and methods

Participants

Eighteen healthy individuals (eight females, ten males) between 18 and 45 years (mean age = 30.2 years old, SD = 8.2 years) were recruited to the study and provided written informed consent in accordance with the Regional Ethical Review Board in Umeå (Dnr 07–183M). Inclusion criteria included no psychiatric or neurological disorder and no medical conditions that interfered with the study objectives. Sixteen of the subjects rated the perceived pleasantness of the four touch stimulations, whereas two served as pilot subjects and only took part in the fMRI part of the study and were omitted from the final analyses reported here.

Stimulation procedures

After providing consent, the participant rated pleasantness following the four different touch stimulations (human hand with or without movement and rubber glove with or without movement) on a VAS-scale (−5.0 = very unpleasant; 0 = neutral; +5.0 = very pleasant). All touch conditions included neutral oil. In the scanner, the participants' left forearm was placed on a vacuum pillow on their abdomen. A table was fixed above the participants to carry a touch device (Fig. 1). The participants were instructed to close their eyes and not fall asleep. The four touch stimulations were applied according to instructions from the device for 20 s on- and 20 s off-periods (block design), and every condition was repeated six times for approximately 960 s in total. The device indicated the correct pressure and velocity, and when to start and stop the different touch stimulations. During movement stimulations, both human hand and rubber glove, four strikes (2.5 N and 1–5 cm/s velocity) on the participants forearm were carried out for 20 s. In the stationary stimulations, the human hand and the rubber glove were placed on the participants forearm with the same pressure (2.5 N) for 20 s. The four conditions were balanced with respect to occurrence; i.e. each condition was repeated 6 times for each subject, and each condition was equally preceded by the other three conditions. Further, different sequences were presented to the individual subject to get an even better balance of prehistory.

Touch measurement

All stimulations during fMRI relied on mirror movements (lateral to medial) of the palm of the experimenter's hands, with or without rubber-glove. The training phase was done outside the scanner. The experimenter was trained using a device with two half-cylindrical

Fig. 1. Touch conditions. A touch device in the scanner room indicated the different touch conditions, the correct force (2.5 N) and the correct velocity (1–5 cm/s). The force of the mirror movement applied on the dummy arm was measured by force transducers and sampled in a computer.