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Affective touch modulates the rubber hand illusion

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ABSTRACT

Introduction: Humans experience touch as pleasant when this occurs with a certain velocity (1–10cm/s). Affective, pleasant touch is thought to be mediated by a distinct neural pathway consisting of un-myelinated tactile afferents (C tactile fibers) that respond to stroking with a low velocity on the hairy skin. As pleasant touch provides additional information on bodily signals we hypothesized that, compared to regular touch, pleasant touch would have a stronger effect on body ownership as measured through induction of the rubber hand illusion (RHI).

Methods: Two experiments involving the RHI were conducted. In the first experiment, the effects of stroking velocity (3 cm/s and 30 cm/s) and stroking material (soft/rough) on the RHI were tested. In the second experiment, the effect of an additional stroking velocity (0.3 cm/s) and side of stimulation (hairy and glabrous) was examined.

Results: The first experiment showed that low velocity stroking in combination with a soft material was not only regarded as most pleasant but also resulted in an enhanced RHI on proprioceptive drift and temperature measurements. In the second experiment, we confirmed that stroking with a velocity of 3 cm/s resulted in a larger RHI in terms of proprioceptive drift. In addition, compared to regular touch, pleasant touch of the hairy skin resulted in a larger proprioceptive drift, while similar stroking on the glabrous side of the skin did not induce a stronger effect of RHI on proprioceptive drift.

Conclusion: Our data suggest that pleasant touch modulates the body representation which is consistently reflected in a larger proprioceptive drift. Our data also suggest that C tactile fibers are likely to be involved in the modulation of body ownership.

1. Introduction

The sense of touch plays an important role in interpersonal communication and can elicit a strong emotional experience; from a sensual caress to a pat on the hand signaling danger, or a stroke on the head to sooth a child. Touch that is regarded as pleasant facilitates bonding and interpersonal communication, one of foundations of emotions and motivation (Rolls, 2010). Pleasant touch also affects bodily functions such as blood pressure and heart rate (Grewen, Anderson, Girdler, & Light, 2003), hormone secretion (Ditzen et al., 2007) and improves visual-motor skills in low birth weight infants (Weiss, Wilson, & Morrison, 2004). Interestingly, pleasant touch has recently been shown to be processed by an anatomically and functionally distinct system, in parallel to the pathway for discriminative touch (Gordon et al., 2011; McGlone, Vallbo, Olausson, Loken, & Wessberg, 2007; Morrison, Loken, & Olausson, 2010; Olausson et al., 2008). Pleasant touch

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consists of a light, soft touch to hairy skin with a stroking velocity range of 1–10 cm/s. (Loken, Wessberg, Morrison, McGlone, & Olausson, 2009; McGlone et al., 2007; Morrison, Bjornsdotter, & Olausson, 2011). The neurological pathways through which pleasant touch is conveyed consists of slow-conducting, un-myelinated low-threshold mechano-receptive fibers (C tactile fibers) that project to the posterior insular cortex (Loken et al., 2009; Morrison et al., 2011; Olausson, Wessberg, Morrison, McGlone, & Vallbo, 2010; Olausson et al., 2002). The posterior insula is thought to be involved in the encoding of internal bodily signals to provide information about the current physiological state of the body that are linked to emotional processes (Craig, 2002; Farrell, Laird, & Egan, 2005). Several lines of research also implicate the posterior insula in the experience of body ownership (Baier & Karnath, 2008; Craig, 2002; Craig, 2009; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007; Tsakiris, 2010; Tsakiris, Tajadura-Jimenez, and Costantini, 2011). However, other evidence suggests that regions (strongly connected to the insula) such as the ventral premotor cortex and the intraparietal sulcus (Berti et al., 2005; Ehrsson, Holmes, & Passingham, 2005; Ehrsson, Spence, & Passingham, 2004; Ehrsson, Wiech, Weiskopf, Dolan, & Passingham, 2007; Guterstam, Gentile, & Ehrsson, 2013; Makin, Holmes, & Ehrsson, 2008) are involved in the integration of visual, tactile and proprioceptive information, which is thought to be the foundation for creating a sense of ownership over a limb (Ehrsson et al., 2004; Graziano, 1999; Lloyd, Shore, Spence, & Calvert, 2003).

A widely used paradigm to investigate body ownership is the rubber hand illusion (RHI) (Botvinick & Cohen, 1998). In this illusion, a visible rubber hand and the covered hand of the participant are stroked congruently and synchronously (Botvinick & Cohen, 1998), after which participants experience the touch applied to the rubber hand as if it was applied to the own hand, suggesting that the rubber hand has now been incorporated in the representation of their own body. A crucial component of the RHI is that manipulations of multisensory input (vision, touch, proprioception) cause profound changes in higher-order body representations (Holmes, Calvert, & Spence, 2007; Tsakiris & Haggard, 2005). Recent studies suggest a link between the RHI and emotion. A higher ability to recognize emotional states predicts the magnitude of the RHI (Germine, Benson, Cohen, & Hooker, 2013) and threatening a rubber hand causes an anxiety response (Ehrsson et al., 2007). These findings suggest a connection between emotional states and the RHI. However, the influence of affective tactile input on the rubber hand illusion has received limited attention. This is unexpected, since pleasant touch adds information to bodily signals and it might therefore be used form a representation of the body. A study of Schutz-Bosbach, Tausche, and Weiss (2009) examined the effect of pleasantness of stroking material on the RHI, but not stroking velocity, and did not find differences. A recent study of Crucianelli, Metcalf, Fotopoulou, & Jenkinson (2013) found an effect of stroking velocity on the subjective experience of the RHI. Unfortunately, this study failed to explicate which aspect of the stimulation resulted in an enhanced RHI, since factors such as site of stimulation and the duration of visuotactile congruent information was not taken into account. In the current study, the effects of pleasant touch on the body representation as quantified through the RHI were examined. In the first experiment, the effects of pleasant vis-à-vis regular touch were explored. The tactile input was manipulated by changing the stroking velocity as well as the stroking material. In a second experiment, the effects of stroking velocity and potential involvement of C tactile fibers were further scrutinized by comparing pleasant touch to stimulation with an additional velocity and at a part of the arm not containing c tactile fibers (i.e., glabrous skin). Due to additional involvement of C tactile fibers in pleasant touch, we anticipated that pleasant touch would have a stronger effect on the RHI than touch that does not activate C tactile fibers.

2. Experiment 1

2.1. Methods

2.1.1. Subjects

Twenty-one healthy volunteers participated in the study (10 male), age range 17–33 years. For all outcome measures, one participant was excluded (>3SD above the mean). The subjects received financial compensation for their participation. Handedness was assessed using the 'Van Strien Dutch Handedness Questionnaire' (Van Strien, 1992). The sample consisted of 14 right-handed, 5 left-handed, and 2 ambidextrous participants. The experiment was performed in accordance with the declaration of Helsinki, and the protocol was deemed to be without psychological or medical risks, and complied with good ethical standards by the ethical advisory committee of the Faculty of Social and Behavioral Sciences at Utrecht University.

2.1.2. Material

2.1.2.1. Stroking. Stimulation was delivered with two different stroking materials, one optimal for pleasant touch (Clinique goat's hair foundation brush, width 2.6 × 2 cm, pressure approximately 11.5 Pa) and one not specifically aimed to induce a pleasant experience (plastic rough texture, mesh 7, width 2.6 × 0.5 cm/s, pressure approximately 8.3 Pa).

The RHI was induced using two different stroking velocities, about 3.0 cm/s optimal for pleasant touch and about 30 cm/s suboptimal for pleasant touch. The length of the strokes was 15 cm with an irregular interval varying from 2 to 3 s. For the 3 cm/s condition, 12 strokes were applied each trial, whereas 30 strokes were applied for the 30 cm/s condition. The length of the strokes was measured by a ruler that was attached to the inner wall of the wooden framework (not visible for the participant). The number of strokes was counted and randomly checked by a second experimenter. In total the duration of material-skin contact was 60 s for the low velocity stroking an 15 s for the high velocity stroking. This procedure was practiced and video-recorded in advance to verify stroking velocity.

2.1.2.2. Set-up. The experimental set-up of inducing the RHI was adopted from the study by Kammers, de