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Research paper

A positive touch: C-tactile afferent targeted skin stimulation carries an appetitive motivational value

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A B S T R A C T

The rewarding sensation of touch in affiliative interactions is hypothesised to be underpinned by an unmyelinated system of nerve fibres called C-tactile afferents (CTs). CTs are velocity tuned, responding optimally to slow, gentle touch, typical of a caress. Here we used evaluative conditioning to examine whether CT activation carries a positive affective value. A set of neutral faces were paired with robotically delivered touch to the forearm. With half the faces touch was delivered at a CT optimal velocity of 3 cm/s (CT touch) and with the other half at a faster, non-CT optimal velocity of 30 cm/s (Control touch). Heart-rate and skin conductance responses (SCRs) were recorded throughout. Whilst rated equally approachable pre-conditioning, post-conditioning faces paired with CT touch were judged significantly more approachable than those paired with Control touch. CT touch also elicited significantly greater heart-rate deceleration and lower amplitude SCRs than Control touch. The results indicate CT touch carries a positive affective value, which can be acquired by socially relevant stimuli it is associated with.

1. Introduction

Motivated reactions to emotionally salient stimuli can be broadly grouped into two categories, aversive and appetitive. While aversive reactions are observed in response to environmental stimuli or contexts that threaten survival, ultimately leading to withdrawal or escape, the appetitive motivational system is activated by stimuli which promote survival, signalling for example, food, sex or social interaction (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Lang & Bradley, 2010). In a range of social species, across the life span, affiliative behaviours are associated with activation of the brain's reward systems and in sensory terms, touch is a key component of the rewarding value of such interactions (Dunbar, 2010; Loseth, Ellingsen, & Leknes, 2014; Walker & McGlone, 2013 for reviews).

C-Tactile afferents (CTs) are a class of unmyelinated low threshold mechanoafferent found in the hairy skin of mammals (see McGlone, Wessberg, & Olausson, 2014 for recent overview). The specific response properties of these cutaneous afferents have been characterised using the electrophysiological technique microneurography. CTs respond optimally to a skin temperature stimulus moving across their receptive field at between 1 and 10 cm/s (Ackerley et al., 2014; Löken, Wessberg, Morrison, McGlone, & Olausson, 2009; Vallbo, Olausson, & Wessberg, 1999). This velocity tuning distinguishes them from larger diameter myelinated mechanoafferents, which respond linearly to stimuli of increasing velocity. In contrast, CTs show an inverted U shaped response function, responding less strongly to speeds that are either slower or faster than their preferred stimulus (Löken et al., 2009; Vallbo et al., 1999). Intriguingly, CT firing frequency is positively correlated with people's perceptions of stroking touch pleasantness. That is, the stimuli which CTs respond most strongly to are also those which are rated as subjectively most pleasant (Essick, James, & McGlone, 1999; Essick et al., 2010; Löken et al., 2009). While CTs are found as frequently as other C-fibres coding pain and itch in the hairy skin of the body, in humans they have never been found in the glabrous skin of the palms of the hands or soles of the feet (McGlone, Wessberg, & Olausson, 2014; Olausson, Wessberg, Morrison, McGlone, & Vallbo, 2010).

The social touch hypothesis proposes that CTs' response characteristics and central projections make them ideally suited to signal the positive affective value of socially relevant tactile interactions (Morrison, Löken, & Olausson, 2010; Olausson et al., 2010). Direct evidence that CT activating touch is rewarding comes from rodent studies where stroking the back of rats, at a CT optimal velocity, has been reported to induce dopamine release within the Nucleus Accumbens (Maruyama, Shimoju, Ohkubo, Maruyama, & Kurosawa,

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2012). Additionally, selective pharmacogenetic activation of C-low threshold mechanoreceptors (CLTMs – the animal homologue of CTs), which respond to massage like stroking, promotes the formation of conditioned place preference (Vrontou, Wong, Rau, Koerber, & Anderson, 2013). In humans, psychophysical and fMRI investigations reliably show that CT optimal stimulation is preferred over slower and faster velocity stimulation (Essick et al., 1999; Löken et al., 2009; Perini, Morrison, & Olausson, 2015) and leads to activation in reward related neural regions, such as the orbitofrontal cortex (Gordon et al., 2013; Mcglone et al., 2012; Trotter et al., 2016). Recently, using facial EMG, we reported that CT optimal velocity touch on the forearm, but not the glabrous skin of the palm, elicited a significantly greater activation of the zygomaticus major (smile) muscle than did faster, non-CT optimal stroking (Pawling, Cannon, McGlone, & Walker, 2017). Given enhanced activity over this muscle is associated with processing pleasant stimuli (Bradley et al., 2001; Cacioppo & Tassinary, 1992; Larsen, Norris, & Cacioppo, 2003), this finding provides further evidence of the positive affective value of CT activation in humans.

In the present study, we set out to further test the social touch hypothesis by determining whether touch, which optimally activates CTs, carries a positive affective value that can be acquired by previously neutral stimuli it becomes associated with. Evaluative conditioning refers to a change in the value of a neutral stimulus as a result of its repeated co-occurrence with a valenced stimulus (De Houwer, Thomas, & Baeyens, 2001; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). Previous evaluative conditioning studies have reported reductions in explicit affective ratings and speeding of reaction times to neutral faces following repeated pairing with an unpleasant electrocutaneous stimulus (Andreatta & Pauli, 2015; Bradley, 2009; Petrovic, Kalisch, Singer, & Dolan, 2008). Here we paired the presentation of faces participants had previously rated as moderately approachable with touch delivered by a robotic tactile stimulator that was either CT optimal in terms of velocity (3 cm/s – CT touch) or Non-CT optimal (30 cm/s – Control Touch). Our primary hypothesis was that, if CT touch carries a positive affective value, post conditioning we would see a significant increase in the explicit approachability ratings of CT-touch paired faces compared to those paired with Control touch. Secondly, given that positive emotional stimuli have been shown, like aversive stimuli, to capture attention, we included a dot probe task as an additional, implicit measure of conditioning (Pool, Brosch, Delplanque, & Sander, 2016). Our hypothesis was that reaction times to faces paired with CT touch, having acquired a positive affective value, would elicit significantly faster reaction times than those paired with Control touch.

Several previous studies have reported that social touch leads to a general increase in parasympathetic nervous system activity (Ditzen et al., 2007; Grewen, Girdler, Amico, & Light, 2005; Light, Grewen, & Amico, 2005). More specifically, CT optimal velocity touch has been reported to decrease the heart rate of both adults and infants to a significantly greater degree than faster or slower velocity stroking (Fairhurst, Löken, & Grossmann, 2014; Pawling et al., 2017). Additionally, in both healthy controls and two rare neuronopathy patients who have lost all large myelinated afferents, CT targeted brush stokes have been shown to elicit a sympathetic response (Olausson et al., 2008). Physiologically, exposure to emotionally salient stimuli, either appetitive or aversive, initially leads to co-activation of the parasympathetic and sympathetic branches of the autonomic nervous system (Bradley et al., 2001; Lang & Bradley, 2010). Functionally, these reflex reactions capture attention, prioritising perceptual processing and prepare the body for action (approach or avoidance) (Bradley, Keil, & Lang, 2012; Löw et al., 2008). Thus, during conditioning we collected both heart rate and skin conductance responses (SCR), measures of parasympathetic and sympathetic nervous system activity respectively and traditional indices of orienting (Bradley, 2009; Bradley et al., 2012; Löw et al., 2008). We hypothesised that if, as the social touch hypothesis suggests, CTs form the first stage of encoding socially relevant and rewarding tactile information, CT targeted touch will elicit reflexive autonomic orienting responses, indicated by a decrease in heart rate and increase in SCR in comparison to Control touch.

2. Methods

2.1. Participants

Thirty-four participants (mean age 24 years ± 3.4, 15 female) with no history of psychiatric illness or cardiac abnormalities and normal or corrected to normal vision, took part in exchange for shopping vouchers. Positive And Negative Affect Scale (PANAS; Watson et al., 1988) scores revealed that participants were more positive than negative in their mood state on beginning the study (mean positive mood = 33.56, SD = 5.61; mean negative mood = 14.25, SD 4.39, scale ranges 10–50). The study was approved by the LJMU Research Ethics Committee.

2.2. Materials

2.2.1. Face stimuli

Twenty-four emotionally neutral female faces (Kramer & Ward, 2010) were used. The photographs, originally taken against a white background, were cropped with an oval frame that showed just the head and upper shoulders. For all photographs, hair was tied back where necessary, so the full face including the forehead was visible. The resulting images were 800 × 1132 pixels in size, and onscreen the faces appeared at a size of approximately 10 × 14.5 cm.

2.2.2. Rotary tactile stimulator

Touch was delivered to the volar surface of the left forearm using a rotary tactile stimulator (RTS – Dancer Design). The RTS can deliver touch, using a rotating probe ‘arm’, with precise force & velocity (Essick et al., 1999; Löken et al., 2009). Touch was delivered at a force of 0.3 N using a probe with a stroking surface measuring approximately 10 × 2 cm, coated in a soft, smooth, synthetic fabric. The RTS interfaced with the PC delivering the conditioning task via parallel port triggers. The two conditions of touch were: CT touch (3 cm/s × 2 strokes) and Control touch (30 cm/s × 3 strokes). In both conditions, the RTS stroked backwards and forwards, starting proximally, over an aperture of 8.1 cm. In the CT touch condition, stimulating at 3 cm/s resulted in approximately 5700 ms of contact time between the RTS probe and the participant’s skin. In the Control touch condition at 30 cm/s, contact time was approximately 1500 ms.

2.3. Procedure

After briefing and consent, participants completed the tasks as follows (see Fig. 1): Firstly, seated at a desk, they completed the first iteration of the Ratings Task. After this they were moved to a reclining chair and fitted with the electrodes for the physiological measures, before completing a short questionnaire on their current mood (PANAS; Watson, Clark, & Tellegen, 1988), after which the experimenter calibrated the RTS. The participants then completed the Conditioning Task. Next, the experimenter removed the electrodes and the participant returned to the desk, where they completed the Dot Probe task, and finally the second iteration of the Ratings Task, before being debriefed.

2.3.1. Ratings task

The ratings task was presented using PsychoPy (Pierce, 2009). First, participants passively viewed all 24 faces, presented in a random order, to reduce the chances that order effects might influence their later judgements. Each face was presented centrally for 1000 ms, preceded by a 500 ms fixation, and followed by a 500 ms blank screen (see Fig. 1, row 1). The participants then viewed an identical presentation of all 24 faces, once more in random order, but this time they were asked after