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Special issue: Research report

Distinct neural networks underlying empathy for pleasant and unpleasant touch

Claus Lamm [a,e,*,1], *Giorgia Silani* [b,c,e,1] *and Tania Singer* [d,e]

[a] *Social, Cognitive and Affective Neuroscience Unit, Department of Basic Psychological Research and Research Methods, Faculty of Psychology, University of Vienna, Austria*
[b] *Cognitive Neuroscience Sector, International School for Advanced Studies (SISSA-ISAS), Trieste, Italy*
[c] *Department of Applied Psychology: Health, Development, Enhancement and Intervention, Faculty of Psychology, University of Vienna, Austria*
[d] *Max Planck Institute for Human Cognitive and Brain Sciences, Department of Social Neuroscience, Leipzig, Germany*
[e] *Laboratory for Social and Neural Systems Research, Department of Economics, University of Zurich, Switzerland*

ARTICLE INFO

Article history:
Received 30 September 2014
Reviewed 23 December 2014
Revised 22 January 2015
Accepted 26 January 2015
Published online 10 February 2015

Keywords:
fMRI
Affective touch
Empathy
Orbito-frontal cortex
Anterior insula

ABSTRACT

In spite of considerable progress in the understanding of the neural mechanisms underlying the experience of empathy, the majority of previous investigations have focused on how we share negative affective states (and in particular pain) of others, whereas only few studies have targeted empathy for positive emotions. This bias has precluded addressing one of the central tenets of the shared representations account of empathy, which is that different networks should be engaged when empathizing with emotions that are represented on different neural levels. The aim of the present study was to overcome this limitation and to test whether empathy for pleasant and unpleasant affective touch is underpinned by different neural networks. To this end we used functional magnetic resonance imaging (fMRI), with two independent replication experiments ($N = 18$, $N = 32$), and a novel paradigm enabling the joint investigation of first-hand and vicarious responses to pleasant and unpleasant affect induced via visuo-tactile stimulation. This revealed that empathy is subserved by distinct neural networks, with those regions recruited in the first-hand experience of positive or negative affective states also being specifically recruited when empathizing with these respective states in others. More specifically, the first-hand and vicarious experience of pleasant touch commonly recruited medial orbitofrontal cortex (OFC), while unpleasant touch was associated with shared activation in the right fronto-insular cortex. The observation that specifically tailored subsystems of the human brain are engaged to share positive versus negative touch of others brings fresh evidence to one of the major goals of the social neuroscience of empathy: to identify which specific aspects of the affective states of others are shared, and what role this plays in enabling the understanding of the emotions of others.

* *Corresponding author*. Faculty of Psychology, University of Vienna, Liebiggasse 5, 1010 Vienna, Austria.
E-mail addresses: claus.lamm@univie.ac.at (C. Lamm), giorgia.silani@sissa.it (G. Silani), singer@cbs.mpg.de (T. Singer).
[1] These authors contributed equally to the paper.

http://dx.doi.org/10.1016/j.cortex.2015.01.021

1. Introduction

In the past few years, considerable progress has been made in understanding the neural mechanisms underlying the experience of empathy, i.e., the capacity to affectively share the emotions of another person (for review, see Bernhardt & Singer, 2012; Decety, 2011; Singer & Lamm, 2009). Recent image-based as well as coordinate-based meta-analyses of functional magnetic resonance imaging (fMRI) studies show that empathy consistently recruits the anterior medial cingulate cortex and the anterior insular cortex [aMCC and aIns, respectively, (Fan, Duncan, de Greck, & Northoff, 2011; Lamm, Decety, & Singer, 2011)]. For instance, aggregating the individual activation maps of 168 participants of nine different fMRI experiments on empathy, it has been demonstrated that observing others in pain consistently activates parts of the aMCC and of bilateral anterior dorsal insula, including adjacent inferior frontal cortex (Lamm et al., 2011). As these brain areas are also involved in the first-hand experience of pain, their activation has been interpreted as evidence for the "shared representations account" of understanding others. This account posits that one central mechanism enabling empathy is the recruitment of neural structures responses that are engaged during the first-hand experience of the emotions or sensations one is showing empathy for (for recent critical review, see Decety, 2010; Lamm & Majdandzic, 2014).

The majority of previous social neuroscience studies of empathy have focused on how we share negative affective states of others, and in particular pain. Only a handful of investigations targeted empathy for positive emotions (e.g., Ebisch et al., 2011; Jabbi, Swart, & Keysers, 2007; Mobbs et al., 2009; Morelli, Rameson, & Lieberman, 2014). Hence, the consistent engagement of aMCC and AI in empathy studies might have been biased by this disproportionate focus on negative emotions and on empathy for pain. Furthermore, given the strong association between negative stimuli and high arousal, it might well be that activation of this network is limited to empathy for highly arousing responses – which would be in line with arguments associating these areas predominantly with high arousal, uncertainty and anxiety (e.g., Lamm & Singer, 2010; Paulus & Stein, 2006; Singer, Critchley, & Preuschoff, 2009) and the associated negative affect and withdrawal (e.g., Hayes & Northoff, 2011; Marcoux et al., 2013; see also Knutson, Katovich, & Suri, 2014; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012 for novel concepts of how emotions might be conceptualized and "detected" based on brain imaging).

This bias in empathy research therefore precludes addressing one of the central tenets of the shared representations account. If it is correct that the vicarious activation of the neural networks involved in the first-hand experience of a certain emotion *enables* an accurate empathic sharing of the other person's affect (see Lamm & Majdandzic, 2014 for more extensive discussion), then different networks should be engaged when empathizing with emotions that are represented on different neural levels.

The few former studies assessing empathy for positive affect are limited in several respects. For instance, some studies report activation only for the observation of positive events, but did not include or analyze vicarious responses to negative events (Hennenlotter et al., 2005; Mobbs et al., 2009). In other studies, which included emotions of both valences, analyses were limited to specific subregions of the brain such as the amygdala, fronto-insular cortex, or premotor areas, or predominantly analyzed correlations with trait empathy (Jabbi et al., 2007; van der Gaag, Minderaa, & Keysers, 2007). Other studies, which had included whole-brain analyses of both valences (e.g., Morelli et al., 2014; Perry, Hendler, & Shamay-Tsoory, 2012), were limited by tapping more into "cognitive" aspects of empathy, or by lacking a condition allowing within-subject comparisons of first-hand and vicariously experienced affect.

The aim of the present study was, therefore, to overcome the limitations of previous work and shed new light on the understanding of the brain mechanisms involved in empathy for both positive and negative emotions. In order to achieve these aims, we developed and implemented a novel paradigm enabling the investigation of first-hand and vicarious responses to pleasant and unpleasant affect via visuo-tactile stimulation. Importantly, this paradigm was novel compared to what has been proposed so far in various aspects. First, it was designed in a way that it allowed us to elicit pleasant and unpleasant affective responses of considerable magnitude directly and "online" in participants lying in the MRI scanner. Secondly, these first hand affective responses were compared in a within-subject analysis with empathy for affective responses that were also evoked directly and "online", using the exact same emotion elicitation procedure being applied to another participant. Note that this other participant was not an imaginary or fictitious other, but was present in the imaging lab and had been personally acquainted with the participant in the scanner at the outset of the experiment. The ecological validity of our paradigm was therefore particularly high, as it involved direct interaction of two participants witnessing other's emotions in the very moment they were happening. Finally, to test the robustness of our findings, we performed two consecutive and independent fMRI experiments with a total sample size of 50 participants.

In summary, this setup enabled the most straightforward test of shared activations during first-hand versus vicariously experienced emotions—as it allowed us to precisely determine for each participant which parts of the brain were activated during the first-hand experience of pleasant and unpleasant touch, and which of these areas were also activated when empathizing with the same types of affective touch.

In line with the predictions of the shared representations of empathy account, we expected to observe two distinct networks as a function of whether subjects were empathizing with unpleasant or pleasant affect elicited via visuo–tactile stimulation, respectively. Hence, empathy for unpleasant touch might distinctly engage areas such as the aIns and the aMCC, given the general role of these areas in coding for negative arousal, their role in empathy for negative emotions, as well as several reports showing the engagement in particular of aIns when witnessing social interactions entailing unpleasant touch (such as hitting a hand or stepping on someone's foot (Decety, Michalska, & Akitsuki, 2008; Grosbras & Paus, 2006)). In contrast, as pleasant touch has been