



# Embodied empathy for tactile events: Interindividual differences and vicarious somatosensory responses during touch observation

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## ABSTRACT

A growing body of evidence suggests an involvement of the somatosensory cortices for social perception. For example, it has been shown that observing touch on other bodies (in the absence of any real touch on the own body) affects somatosensory brain areas. Thus, understanding others' sensory experiences seems to rely on vicarious activation of somatosensory cortices. Recent studies also demonstrated that observation of painful and nonpainful touch engages the observer's somatosensory cortex differentially. The somatosensory activation during observation of painful stimulation has been related to trait differences in empathy, thereby drawing the attention to inter-individual differences in vicarious somatosensory activation. The current study aims to test the hypothesis if vicarious somatosensory activation during observation of *nonpainful* touch is also linked to inter-individual differences in empathy. We employed a functional magnetic resonance imaging (fMRI) paradigm to present video clips showing simple non-painful touch with a paintbrush to a hand relative to a control condition including the same visual and motion parts. Results revealed vicarious somatosensory activation when seeing the hand being touched. This activation was associated with trait differences in interpersonal reactivity. Thus, we found that the somatosensory response in primary somatosensory cortex (SI) was associated with the empathy subscale perspective taking. This link demonstrates that vicarious somatosensory responses for simple touch are influenced by the observer's personality traits, therefore suggesting a role for personality traits in a putative mirror neuron system.

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## Introduction

The recent years have shown a growing interest in research on the neural mechanisms for perceiving and understanding social interactions. "Mirror neurons" were identified in the macaque brain using single-cell recordings, which are active not only when performing an action but also when observing another subject performing the same action (Rizzolatti et al., 2001). It has been speculated that a comparable system also exists in humans. This mirror neuron system may be important for the understanding and imitation of actions.

Recently, a mirror system for observed and experienced touch similar to the mirror neuron system for action observation has been suggested (Keysers et al., 2004). This may be crucial for the recognition and understanding of touch to form an internal representation of an event or a sensation. Using fMRI, Keysers et al. (2004) showed that observing someone else's legs being touched with a stick resulted in neural activity in the secondary somatosensory cortex (SII). Another fMRI study by Blakemore et al. (2005) revealed that observation of touch was associated with activity in SII and also in SI. Moreover, Blakemore et al. (2005) demonstrated that the mirror-like responses

in SI were somatotopically organized. The authors reported different regions of SI involved regarding the observation of someone being touched on the neck and on the face. Ebisch et al. (2008) used fMRI to examine the intentionality of the observed touch. They found a shared neural circuitry for touch in SII and a significant difference between the sights of an intentional touch compared to an accidental touch in left SI/BA2, which was correlated with the degree of intentionality of the seen touch. The authors concluded that this activity in SI may reflect a human tendency to resonate more with an intentional touch agent than with accidentally touched object. A study employing the method of electroencephalography (EEG) provided further insights. Bufalari et al. (2007) reported that somatosensory evoked potentials (SEPs) were modulated by the observation of a touched hand. They reported increased (and decreased, respectively) amplitudes of the P45 SEP component when observing a hand receiving nonpainful touch or painful stimulation (a needle penetrating a hand). Thus, the authors point to a different engagement of the somatosensory cortices depending if we observe painful or nonpainful touch experiences. Studies using magnetoencephalography (MEG) provide further support for mirror-like responses in the somatosensory cortices. Avikainen et al. (2002) showed modulated activation in SI and SII when observing hand actions (similar Hasson et al., 2004; Tecchio et al., 2002). Möttönen et al. (2005) demonstrated that viewing another person's articulatory gestures activates the left SI cortex in a somatotopic manner. Pihko et al. (2010)

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reported vicarious activation in SI when observing the experimenter touching her own hand. Furthermore, transcranial magnetic stimulation (TMS) was employed to show that the sensorimotor cortices are involved when observing touch. For example, Wood et al. (2010) report an involvement of SI during the observation of non-noxious tactile stimulation to the hand of a model.

In a recent review Keysers et al. (2010) tried to integrate these findings in a coherent model. According to this theory the somatosensory subregions in SI have different contributions for social perception. The authors argue that BA2 has direct, reciprocal connections with regions in the intraparietal sulcus and the inferior parietal lobe, which combine visual, auditory, and somatosensory information. In contrast, BA3 has access to such information only indirectly through BA2 and SII, making it likely that this area only processes signals that originate in our own body. Based on these anatomical considerations and a review of previous studies the authors suggest that a putative mirror system affects only later stages of cortical somatosensory processing (BA1, BA2, SII), whereas the earliest stages (BA3) remain 'private' (Bastiaansen et al., 2009; Keysers et al., 2010). The authors suggest that mirror-like responses in somatosensory cortices (in particular BA2) may provide a somatic dimension to our perception of other people's experiences.

Several studies suggest that this role for somatosensation in social perception may also be prone to interindividual differences when observing somatic pain of others. Osborn and Derbyshire (2010) report that when observing clips or pictures of injuries about one-third of participants experience feeling pain on the corresponding part of their own body, while the remaining two-thirds report negative feelings without a sense of somatic pain. In a subsequent fMRI study vicarious activity in SI and SII associated with the images of injuries was seen only in those participants who experienced localized vicarious pain. Moreover, it has been demonstrated that vicarious activation in the sensorimotor cortices whilst witnessing painful stimulation was associated with measures of empathy. For example, Avenanti et al. (2009) reported that somatomotor responses to others' pain were influenced by the observers' empathy traits.

Whereas these studies suggest a close relationship between empathy and activation in SI when seeing others being painfully stimulated, the current study aimed to test the hypothesis if even the observation of nonpainful touch is linked to empathic abilities of the participants. Since earlier studies provided evidence that empathy in complex social situations is associated with activation in SI (Hooker et al., 2010; Ruby and Decety, 2004), we hypothesized an empathic matching system for observations of nonpainful sensory experiences. In order to test our hypothesis we employed an fMRI paradigm to present video clips depicting a hand that received non-painful touch with a paintbrush. A control condition included the same picture and motion parts, but without showing the hand being touched. The experiment is based on previous paradigms on observation of touch (Keysers et al., 2004; Schaefer et al., 2009). We expected an involvement of somatosensory cortices when participants observe touch, thus confirming earlier results. According to Bastiaansen et al. (2009) and Keysers et al. (2010) we hypothesized in particular an involvement of BA2 when seeing the hand being touched. We further assumed that this somatosensory activation in BA2 is linked with inter-individual differences in empathy.

## Materials and methods

### Participants

Twenty-two subjects (eleven females) with a mean age of 26 years (range 23–39) participated in the study. The participants gave informed consent to the study, which adhered to the Declaration of Helsinki and was approved by the local human subjects' committee. All subjects were right-handed as assessed by the Edinburgh Handedness Inventory

(Oldfield, 1971). Two subjects were discarded prior further data analyses due to technical problems during data recording.

### Procedure

The stimuli we used were video clips depicting a right hand (in an egocentric viewpoint) and a paintbrush. Each video clip lasted for 18 s and was followed by a resting period of 15 s ( $\pm 3$  s). In this resting period subjects were instructed to focus on a fixation cross. For the touch observation condition, the video clips showed the hand being touched on the index finger repeatedly by this paintbrush. For the control condition the paintbrush did not touch the hand. Here the paintbrush made identical motions as in the touch observation condition except that the brush stroked on the side of the index finger (Fig. 1). In all conditions, a right hand was stimulated. The same visual stimuli and motion frequency (1/s) were applied in all video clips. The motion of the paintbrush was vertical in about 90% of all trials and horizontal in about 10%. Subjects were required to press a key to report the number of vertical strokes at the end of each video clip. The key was custom-made and had two buttons. This task was designed to ensure that subjects paid attention to the videos (similar to Blakemore et al., 2005; Schaefer et al., 2009). Performance of the task did not affect data analysis. Hence, data analysis included all trials of the participants, regardless if their responses were correct or incorrect.

Furthermore, we also applied a real touch condition; in which a paintbrush repeatedly touched the right hand during the fMRI scan. The manner and frequency of brushing were identical to that shown in the touch observation videos. In the real touch condition no visual display was presented. This condition was implemented in order to localize the somatosensory cortices for each participant.

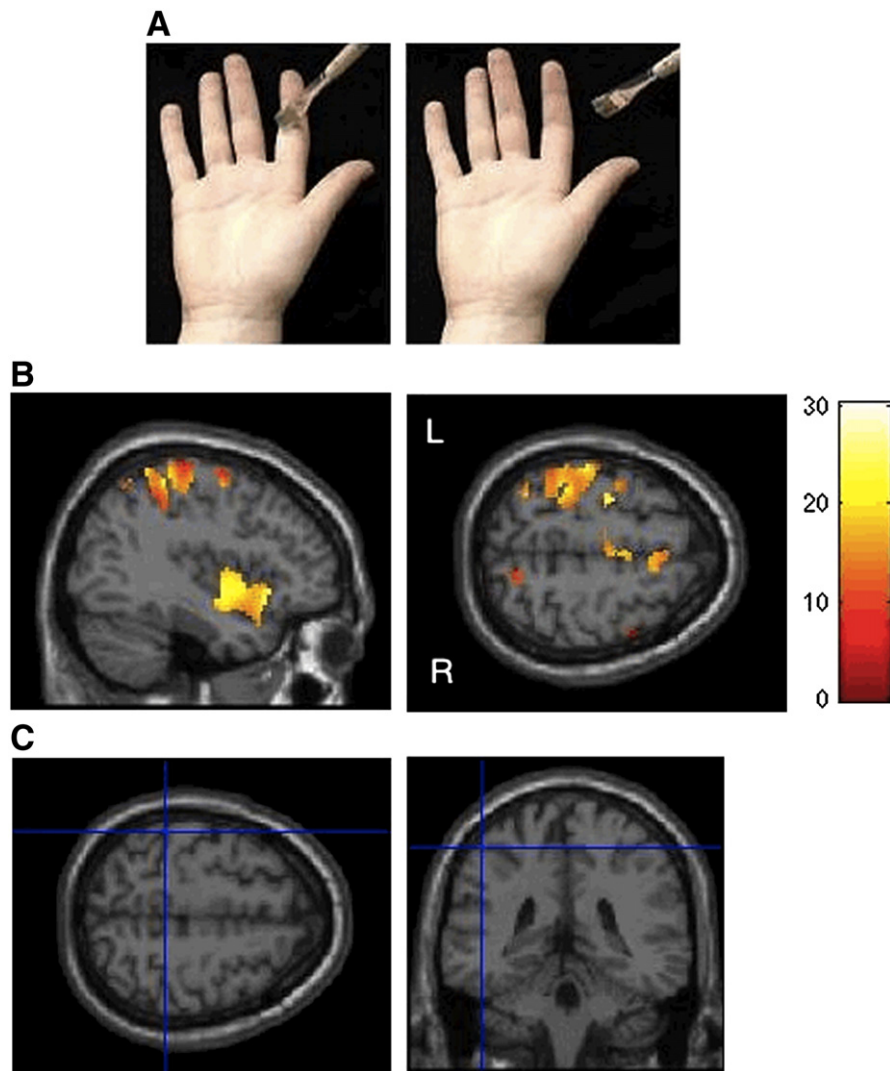
Visual images were back-projected to a screen at the end of the scanner bed close to the subject's feet (projector: JVC DLA G150CL). Subjects viewed the images through a mirror mounted on the bird-cage of the receiving coil.

The experiment consisted of three runs. Each run included all conditions. The order of presentation was pseudorandomized. The experiment lasted for about 45 min.

After the fMRI experiment subjects were asked to complete a German version of the Interpersonal Reactivity Index (IRI, Davis, 1983), which has been previously used in fMRI studies to examine empathy-related brain activations (e.g., Avenanti et al., 2009; Betti et al., 2009; Singer et al., 2004). The IRI is a 28-item self-report survey that consists of four subscales: Perspective Taking (PT), Fantasy (F), Empathic Concern (EC), and Personal Distress (PD). PT measures the tendency to cognitively imagine a situation from the other person's point of view. The F subscale describes the tendency to project oneself into the place of fictional characters in books and movies. EC reflects a person's tendency to have feelings of sympathy and concern for others. The PD subscale assesses the extent to which someone feels negative emotions, particularly in stressful situations. Cognitive empathy consists of the subscales PT and F. Affective empathy consists of EC and PD. While PD taps self-oriented aspects of interpersonal reactivity, higher scores on PT, F, and EC are associated with other-oriented interpersonal activity (Davis, 1983).

### fMRI data acquisition and analysis

We used a 1.5 T scanner (General Electrics Signa LX, Fairfield, Connecticut, USA) to conduct functional imaging (gradient echo T2-weighted echo-planar images; TR = 2 s, TE = 35 ms, flip angle = 80°, FOV = 20 mm). Data were acquired in three functional imaging sessions. In each session, 392 volumes were acquired including 4 'dummy' volumes, which are acquired at the start of each session and subsequently discarded to allow for T1 equilibration effects. Functional volumes consisted of 23 slices. Each volume comprised 5 mm slices



**Fig. 1.** A: Stimuli used in the study. The left picture shows a hand being touched with a paintbrush (touch observation condition), the right picture includes the same motion and picture elements, but here the paintbrush does not hit the depicted hand (control condition). B: Statistical map showing common brain activation (random-effects analysis,  $p < 0.05$ , FWE corrected) for the observation of touch (touch observation > control condition, masked by real touch > rest). Areas of significant fMRI signal change are shown as color overlays on the T1-MNI reference brain (sagittal picture displays the left hemisphere). See text and Table 1 for details. C: Crosslines mark the position of the peak voxel of the maximum activation in SI for the contrast touch observation relative to control condition (masked by real touch > rest). Parameter estimates of this peak voxel were used for correlational analysis with empathy measures.

(1 mm gap, in plane voxel size  $3.125 \times 3.125$  mm). Functional slices were acquired interleaved in ascending order. For anatomical reference a high-resolution T1-weighted structural image was collected (3D-SPGR, TR = 24 ms, TE = 8 ms).

fMRI data was preprocessed and analyzed using the Statistical Parametric Mapping Software (SPM5, Wellcome Department of Imaging Neuroscience, University College London, London, UK). For each subject the fMRI scans were realigned to correct for inter-scan movement, using sinc interpolation and subsequently normalized into a standard anatomical space (MNI, Montreal Neurological Institute template), resulting in isotropic 3 mm voxels. The scans were then smoothed with a Gaussian kernel of 6 mm full-width half maximum.

Statistical parametric maps were calculated using multiple regression with the hemodynamic response function modeled in SPM. First, we examined data on the individual subject level by using a fixed effects model (the three runs were concatenated for each subject). Second, the resulting parameter estimates for each regressor at each voxel were then entered into a second-level analysis with the random effects model. Statistical contrasts (t tests) were performed to examine cortical activation associated with real tactile touch (i.e., real touch – resting baseline), and observing touch vs. control condition. To investigate

common activations during real tactile stimulation and observation of touch, the resulting images for the contrast touch observation relative to control were inclusively masked (at  $p < 0.05$ ) with the contrast real touch relative to rest.

We report regions that survived correction for multiple comparisons over the whole brain (at  $p < 0.05$ , family-wise (FWE) correction). Anatomical interpretation of the functional imaging results was performed by using the SPM Anatomy toolbox (Eickhoff et al., 2005).

Scores of the empathy traits (EC, PD, PT, and F) were tested for possible correlations (Pearson) with the parameter estimates for voxels in the somatosensory region of interest (maximum peak in SI for contrast touch observation relative to control condition, masked with real touch relative to rest).

## Results

### Behavioral results

Analysis of the IRI questionnaire revealed participants' mean score on the PD subscale ( $\pm$  standard deviations) of  $9 (\pm 3)$ , on the EC subscale of  $15 (\pm 2)$ , on the F subscale of  $14 (\pm 3)$ , and on the PT subscale

of 15 ( $\pm 3$ ). One subject was excluded prior further data analysis since she answered all questions (with one exception) with the highest score.

The subscale EC correlated significantly with F ( $r = 0.59$ ,  $p < 0.05$ ). There were no further significant correlations between the subscales.

The overall accuracy of the task performance during fMRI scanning across conditions was 81% (standard deviation  $\pm 16\%$ ). There were no significant differences in subjects' performance (i.e., accuracy of stroke count) over the experimental conditions (touch observation, control condition). Furthermore, accuracy of the behavioral responses did not correlate with the subscores of the IRI questionnaire.

### fMRI results

Analysis of the fMRI data showed that direct tactile stimulation of the participant's right hand relative to rest (real touch condition) engaged contralateral SI, bilateral parietal operculum (SII/parietal ventral area), the precentral gyrus (BA4 and BA6), the insula, the lateral temporo-occipital cortex, the superior parietal/intraparietal cortex, and the thalamus ( $p < 0.05$ , FWE corrected).

To investigate vicarious activation of somatosensory cortices we examined common activations for observed and real touch (touch observation > control, masked with real touch > rest). Significant overlap was found in the left postcentral gyrus (SI), bilateral SII, left premotor cortex, and insula (at  $p < 0.05$ , FWE corrected, see Fig. 1 and Table 1). More in detail, the cluster in SI contained 1626 voxels and included 49% of BA2, 25% of BA1, and 20% of BA3b (all left side, see Table 1). According to Taylor et al. (2009) the significant overlap of the insula is located in mid insula.

For correlation analyses we used the parameter estimates for the maximum activation (peak voxel) of the cluster in left SI (MNI coordinates:  $-48 -38 55$ ). The localization probability of this maximum was 80% in BA2. Fig. 2 depicts scatterplots of all empathy subscales with parameter estimates in SI. We observed a significant positive correlation between the touch observation effects in SI with the participants' score on the PT subscale ( $r = 0.62$ , at  $p < 0.05$ ). Thus, the more strongly individuals scored on PT, the more the putative mirror neurons in SI were engaged. No other empathy subscale showed significant correlations with the BOLD response in SI (EC:  $r = -0.24$ ;  $p = \text{n.s.}$ ; PD:  $r = -0.19$ ,  $p = \text{n.s.}$ ; F:  $r = 0.11$ ,  $p = \text{n.s.}$ ).

Furthermore, we tested if activations in left insula, left premotor cortex, bilateral SII, and bilateral parietal lobe (BA7A) were correlated with IRI subscores. Data analysis was analogue to the correlation analysis of SI activity. Results revealed no significant correlations. In addition, we calculated correlations between task performance and vicarious somatosensory activation in SI. Data analysis was analogue to the correlation analysis of empathy measures. Results revealed no significant correlations.

### Discussion

It seems reasonable to assume that we perceive the social world differentially according to our personality traits. Aim of the present study was to test the hypothesis that the mirror neuron system for seen nonpainful touch, which is supposed to play a key role for basic social perceptions, is influenced by inter-individual differences in empathy. Our results confirm this hypothesis by showing that vicarious (or mirror-like) activation in SI is associated with the empathic subscale PT. Thus, a mirror mechanism in our somatosensory cortex responds differentially to seen simple touch depending on our personality.

The vicarious activity in SI merely by viewing touch in the absence of any direct stimulation confirmed earlier studies on a mirror system for observed touch (Blakemore et al., 2005; Bufalari et al., 2007; Ebisch et al., 2008; Gazzola and Keysers, 2008; Keysers et al., 2004; Pihko et al., 2010; Schaefer et al., 2009; Wood et al., 2010). It has been suggested that vicarious activation in SI may be linked to the mirror neuron theory (Bastiaansen et al., 2009; Keysers et al., 2010). In accordance with this theory we also report activation in insula, bilateral SII, premotor areas (BA44, BA6), superior temporal gyrus and superior parietal lobe (BA7A) (similar to Blakemore et al., 2005; Ebisch et al., 2011; Keysers et al., 2004; Morrison et al., 2011).

Furthermore, it has been discussed that a putative mirror system affects only later stages of cortical somatosensory processing (BA1, BA2, SII), whereas the earliest stages (BA3) remain "private" (Keysers et al., 2010). The current study provides support for this hypothesis. Mirror-like responses in SI in our study involved mainly BA2. Thus, our results encourage the view of a functional dissociation in SI, pointing to a role for BA3 in processing signals that originate in our own body and a role for BA2 (and probably BA1) in providing a somatic dimension to our perception of other people's experiences.

The present study extends previous work by showing that this putative mirror neuron system for seen nonpainful touch is affected by personality traits. Recent studies already reported embodied empathy in SI for observation of painful touch (e.g., Avenanti et al., 2009), but the present study is the first one demonstrating that even vicarious somatosensory activation for observed nonpainful touch is associated with empathy. The results suggest that "mirror neurons" in SI (BA2) in general (and not only when witnessing painful stimulations) are prone to personality traits. This is reasonable since the mirror neuron system is discussed to be crucial for social learning and behaving appropriately in a social world (Dapretto et al., 2006), abilities that are interrelated with personality dimensions.

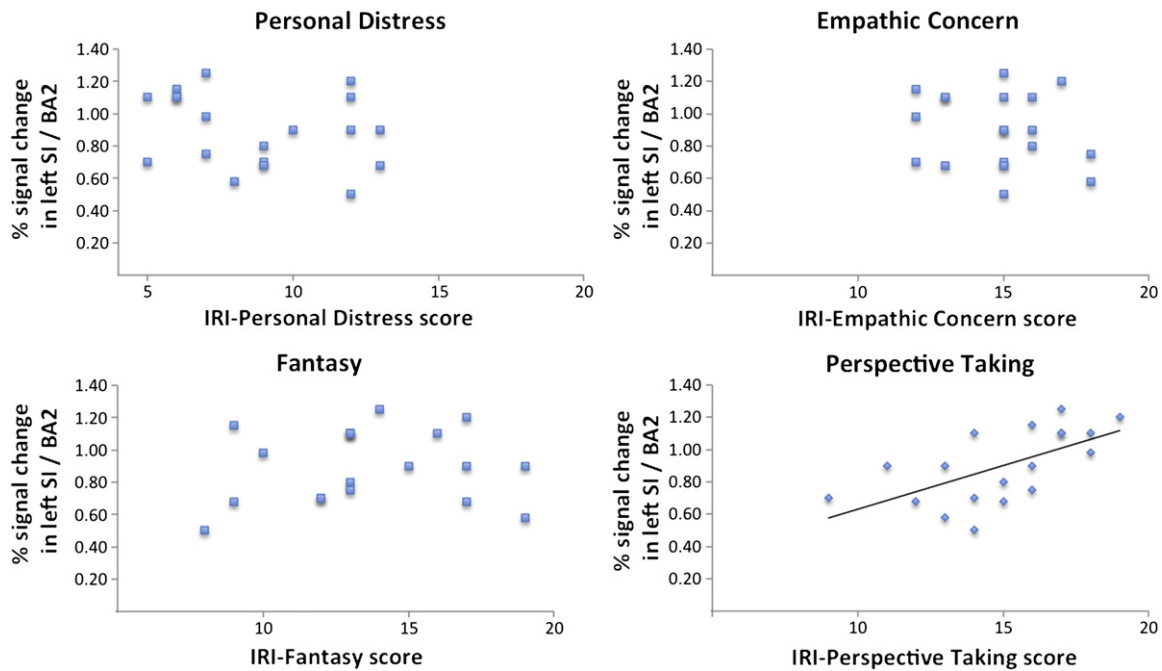
The results are in line with a recent study on empathy and the auditory mirror system (Gazzola, et al., 2006). Gazzola et al. (2006) reported that a group of more empathic subjects compared with a group with lower empathy scores activated the auditory mirror system more strongly. Interestingly, they also report brain activations in SI and

**Table 1**

Results of random effects analysis (at  $p < 0.05$ , FWE corrected, L = left hemisphere, R = right hemisphere, masked with real touch > baseline).

	Contrast	Brain region	Peak MNI location (x, y, z)	Peak t-value
Touch observation	Touch observation > control	L SI	$-38 -38 50$	19.67
		L premotor cortex/BA44	$-54 4 15$	15.90
		L premotor cortex (BA6)	$-28 -14 65$	22.77
		L precentral gyrus (BA6)	$-54 4 38$	12.33
		R SMA (BA6)	$6 14 60$	18.96
		L SMA (BA6)	$-4 4 46$	30.22
		L insula	$-42 0 -4$	27.28
		R SII/sup. temp. gyrus	$58 -32 22$	15.86
		L SII	$-56 -22 14$	15.18
		R sup. parietal lobe (BA7A)	$22 -60 64$	16.06
		L sup. parietal lobe (BA7A)	$-32 -60 60$	5.59
		L sup. temp. gyrus	$-60 -44 20$	13.85
		cerebellum	$-8 -44 -31$	23.41
	Control > touch observation	–	–	–





**Fig. 2.** Correlation scatterplots for empathy subscales PT, F, EC, and PD with participants' mean activations in left SI/BA2 (parameter estimates). PT showed a significant positive correlation ( $r = 0.62$ , at  $p < 0.05$ ), whereas EC, PD, and F revealed no significant results (EC:  $r = -0.24$ ;  $p = \text{n.s.}$ ; PD:  $r = -0.19$ ,  $p = \text{n.s.}$ ; F:  $r = 0.11$ ,  $p = \text{n.s.}$ ).

SII to be correlated with empathy. Based on these results the authors concluded that the mirror system for actions may be linked with empathy. Our results provide further support for this hypothesis by demonstrating that a putative mirror system for observed non-painful touch is similarly affected by empathy.

While PT and F code cognitive dimensions of empathy, EC and PD represent affective components. Previous studies on empathy when witnessing pain also report correlations with affective IRI subscores EC. In particular, EC has been related to insular activation while participants were aware of other people's pain (Singer et al., 2004, 2006).

Previous studies demonstrated vicarious responses in the insula when observing affective or social touch (Ebisch et al., 2011; Morrison et al., 2011). Our results similarly report insular activation even when observing simple nonpainful touch. However, we did not find significant correlations of insular activity with the IRI subscores. Furthermore, brain responses in SI (BA2) correlated with PT, but not with other measures of the IRI (EC, PD, and F). This is in line with the results of Gazzola et al. (2006), which also report significant correlations for mirror activations only with PT. Thus, our results as well as the study of Gazzola et al. (2006) support the hypothesis that different aspects of empathy could depend on different neural substrates (Gallese et al., 2004). Witnessing pain or observing non-painful touch (or hearing not pain related sounds of actions) may activate different aspects of empathy and thus different neural substrates. Hence, affective empathy (EC, PD) might be elicited when seeing others in pain and may be linked to activation in insula and sensorimotor areas (Avenanti et al., 2009; Betti et al., 2009; Cheng et al., 2008; Singer et al., 2004, 2006), whereas cognitive empathy (PT) might be involved when watching others being nonpainfully touched, associated with activation of SI (but not insula).

While Gazzola et al. (2006) report correlations of mirror activity with empathy for SI and also for premotor areas, the current study failed to report correlations with premotor regions. However, in the study of Gazzola et al. (2006) participants were asked to listen to sounds of actions, whereas our paradigm was simply showing touch events with only a very minor link to motor activity (instruction to count the strokes of the paintbrush). This may have focused empathic activity on somatosensory brain regions.

The current study reports that empathy is linked to vicarious activity in somatosensory cortex. What are the mechanisms through which higher PT scores lead to differences in this vicarious somatosensory activity? Similar to Gazzola et al. (2006) we speculate that changes in efficacy of the connections in the mirror network may account for this link. However, based on the present data we cannot provide more detailed information about these putative changes. Furthermore, empathic subjects may express stronger attention to other human sensations, thus influencing sensory processing via top-down processes (Gazzola et al., 2006). Previous studies report local changes due to top-down feedback in the visual cortex of monkey (Driver and Spence, 2000). Rockland and Ojima (2003) highlighted the role of top-down projections from multimodal to unimodal areas by showing direct anatomical connections from both auditory and parietal association cortices to area V1 and V2, suggesting bimodal interactions. Employing fMRI, Staines et al. (2002) showed top-down modulations for bilateral somatosensory cortices. The authors showed facilitation of the contralateral SI and a concomitant suppression of the ipsilateral SI as a result of a task-relevant somatosensory stimulation. Staines et al. (2002) suggested that the prefrontal cortex may mediate the specific modulation of early cortical reception areas by facilitating the sensitivity of neuronal networks as well as by inhibiting responses to task-irrelevant stimuli. We speculate that a similar process may also account for the association of vicarious brain activity in SI with empathy.

However, alternative explanations for our results should also be taken into account. One could object that the task in our paradigm (counting the strokes) may have caused the brain activations we report or affected the correlation with the empathy scores. For example, more empathic participants may have focused more strongly on the task. Nevertheless, since we did not find any significant correlations of task performance with empathy subscales and no significant effects for task performance on experimental and control conditions, we think that it is unlikely that the effects in mirror-like responses or the correlations of those effects with IRI subscores are simply reflecting attention to the task.

Whereas empathy for painful touch seen on other bodies is evident, empathy for nonpainful touch may seem difficult to understand. However, previous studies already demonstrated a role for SI and

empathy beyond the observation of painful stimulation. For example, Ruby and Decety (2004) reported that empathy in complex social events is associated with activation in SI. Similar Hooker et al. (2010) presented social scenes in an fMRI experiment and showed a correlation of somatosensory areas on the left postcentral gyrus with empathy. Moreover, early studies pointed to a relationship between personality traits and somatosensory processing (Shagass and Schwartz, 1965). Our study demonstrated that empathy interacts with vicarious activation in SI for seen nonpainful touch, thus expanding the role of the somatosensory cortices for empathy (Preston and de Waal, 2002).

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