Rough primes and rough conversations: evidence for a modality-specific basis to mental metaphors

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How does our brain organize knowledge? Traditional theories assume that our knowledge is represented abstractly in an amodal conceptual network of formal logic symbols. The theory of embodied cognition challenges this view and argues that conceptual representations that constitute our knowledge are grounded in sensory and motor experiences. We tested this hypothesis by examining how the concept of social coordination is grounded metaphorically in the tactile sensation of roughness. Participants experienced rough or smooth touch before being asked to judge an ambiguous social interaction. Results revealed that rough touch made social interactions appear more difficult and adversarial, consistent with the rough metaphor. This impact of tactile cues on social impressions was accompanied by a network including primary and secondary somatosensory cortices, amygdala, hippocampus and inferior prefrontal cortex. Thus, the roughness of tactile stimulation affected metaphor-relevant (but not metaphor-irrelevant) behavioral and neural responses. Receiving touch from a rough object seems to trigger the application of associated ontological concepts (or scaffolds) even for unrelated people and situations (but not to unrelated or more general feelings). Since this priming was based on somatosensory brain areas, our results provide support for the theory that sensorimotor grounding is intrinsic to cognitive processes.

Keywords: somatosensory cortex; embodiment; touch; social; fMRI

INTRODUCTION

In the traditional understanding our knowledge is represented abstractly in a supramodal conceptual network of formal logic symbols. The theory of embodied cognition challenges this view and claims that cognitive representations are based in sensory and motor experiences, forming a ‘perceptual symbol system’ (Lakoff and Johnson, 1999; Gallese and Lakoff, 2005; Barsalou, 2008). Following this theory mental processes involve simulations of body-related perceptions and actions. Therefore, the theory argues that the retrieval of conceptual meaning involves a partial re-enactment of sensory and motor experiences. This may be explained by early experiences with the physical world, which structure our later understanding or representation of more abstract concepts (Williams et al., 2009; Ackerman et al., 2010; Meier et al., 2012). Others emphasize that we are ‘evolved from creatures whose neural resources were devoted primarily to perceptual and motor processing’ (Wilson, 2002).

Focusing in particular on the role of metaphors in human thought, numerous behavioral experiments provided support for this theory of embodied cognition (e.g. Zhong and Leonardelli, 2008; Ackerman et al., 2010; Lee and Schwarz, 2010a,b). For example, the abstract concept of importance has been shown to be grounded in bodily experiences of weight. Thus, holding a heavy clipboard made job candidates appear more important (Jostmann et al., 2009; Ackerman et al., 2010). Furthermore, it has been shown that basic tactile sensations have an impact on higher social cognitive processing in dimension- and metaphor-specific ways. For example, roughness is metaphorically associated with the concepts of difficulty and harshness (e.g. ‘having a hard day’). Ackerman et al. (2010) examined the link of this metaphor with sensory processing. Participants were instructed to complete a five-piece-puzzle, either in a version with pieces covered in rough sandpaper (rough condition) or a version with the pieces uncovered (smooth condition). Subsequently, they were asked to read a passage describing an ambiguously valenced social interaction and to answer questions regarding the nature of this interaction. Participants who completed the rough puzzle rated the interaction as less coordinated (more difficult and harsh) than participants who performed the same task but with smooth parts. Hence, the experience of rough objects made social interactions appear more difficult. As there was no effect for a set of questions asking for relationship familiarity, Ackerman et al. (2010) concluded that roughness specially changed evaluations of social coordination consistent with a ‘rough’ metaphor, but did not make the interaction seem more generally impersonal.

Recent advances in neuroimaging now allow testing the hypothesis that our thoughts and feelings are grounded in bodily interaction with the environment in a new way. This study aimed to test the theory of embodied cognition by examining brain responses of participants with functional magnetic resonance imaging (fMRI) in a paradigm on the touch-related metaphor of roughness. Roughness is metaphorically associated with the concepts of difficulty, adversary and harshness. Based on experiments by Ackerman et al. (2010), we hypothesized that tactile experiences with rough objects elicit a ‘haptics mindset’, which may trigger the application of associated concepts such as difficulty and adversary (in contrast to more general feelings) when assessing a social interaction, consistent with the ‘roughness metaphor’. An engagement of the somatosensory cortices in this process would provide support for the assumptions of the embodiment theory.

MATERIALS AND METHODS

Participants

Twenty participants (10 females) with a mean age of 26 years (range 23–39) took part in the study. All participants were right-handed native German volunteers with no neurological or psychiatric history. The participants gave informed consent to the study, which adhered to the Declaration of Helsinki and was approved by the local human subjects’ committee.

Procedure

Participants were explained that the study would involve two separate experiments: an experiment to examine neural correlates of different
touch and an experiment to investigate neural correlates of social judgments.

We used a two-factorial experimental design. The first factor described the tactile priming, which was either rough by applying touch with sandpaper, smooth by using a smooth paintbrush, or was omitted (no stimulation). The second factor was the set of questions. One set of questions addressed the social coordination quality, the other set of question was asking for relationship familiarity.

While lying in the scanner the participants received passive tactile stimulation (rough, smooth or no touch) for 10 s. After 5 s participants were prompted with a screen describing an ambiguous valenced social interaction. The presentation of the scenario lasted for 19 s, while the first 5 s overlapped with the tactile stimulation. These social interactions were oriented to the experiments of Ackerman et al. (2010) and included both positive (e.g. kidding around) and negative components (e.g. sharp words), making the whole scenario ambiguous in its meaning (analog to Kay et al., 2004). For example, participants read the following scenario: ‘’Hello, have you seen the pictures of our last Christmas party? What is your girlfriend thinking of this? Well, she doesn’t have to know everything!<< >>Ooops, what am I doing there?<< >>Well, you seem to have fun!<< >>That’s what it looks like, he he. Hey, don’t show this to someone else!<< >>Don’t worry, I won’t tell her.<< >>Has someone taken these pictures with some intentions behind? What’s all this crap?? >>Calm down, look, I just deleted them!<<‘’.

After a break of 4 s we asked the participants about the nature of this interaction. One set of questions addressed the social coordination quality (was the interaction adversarial or friendly, competitive or cooperative, a discussion or an argument), for example: ‘’What do you think, was this interaction adversarial or friendly? Friendly: right buttons. Adversarial: left buttons’. The other set of question was asking for relationship familiarity (closeness of relationship, business or casual interaction style, relationship of the agents). The latter set was applied to test if the priming effect would extend to a theoretically unrelated measure. Participants used a key with four buttons (Likert-scale ranging from +2 to −2) to assess the scenarios. Before the experiment they were explained that they could weight their responses from moderate (inner buttons) to extreme (outer buttons). Use of right and left buttons were randomized over the scenarios. They were allowed to spend up to 17 s to respond (earlier responding did not automatically start the next trial). To collect comparable parts of the decision process for each participant, we decided to measure brain activity in a time window around the button press. Thus, condition-related activity was measured using an individual ‘floating’ time window of eight MR images; repetition time (TR) = 2 s, echo time (TE) = 35 ms, flip angle = 80°, field-of-view (FOV) = 20 mm). For each subject, data were acquired in three scan runs. Functional volumes consisted of 23 slices. Each volume comprised 5 mm slices (1 mm gap, in plane voxel size 3.125 × 3.125 mm). For anatomical reference, a high-resolution T1-weighted structural image was collected (3D-SPGR, TR = 24 ms, TE = 8 ms).

FMRI data acquisition and analysis

Functional scans were acquired by using a 1.5 T scanner [General Electrics Signa LX, USA; gradient echo T2-weighted echo-planar images; repetition time (TR) = 2 s, echo time (TE) = 35 ms, flip angle = 80°, field-of-view (FOV) = 20 mm]. For each subject, data were acquired in three scan runs. Functional volumes consisted of 23 slices. Each volume comprised 5 mm slices (1 mm gap, in plane voxel size 3.125 × 3.125 mm). For anatomical reference, a high-resolution T1-weighted structural image was collected (3D-SPGR, TR = 24 ms, TE = 8 ms).

FMRI data were 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 [Montreal Neurological Institute (MNI) 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 regressions with the hemodynamic response function modeled in SPM5. Data analyses were performed at two levels. We examined data on the individual subject level by using a fixed effects model (all three runs concatenated for each subject). Then, the resulting parameter estimates for each regressor at each voxel were entered into a second-level analysis with the random effects model. To examine brain responses when participants received touch we computed statistical contrasts (t-tests) for rough stimulation (sandpaper) relative to rest, smooth stimulation (paintbrush) relative to rest and both rough and smooth stimulation relative to rest. To reveal brain responses during the judgment process we calculated an ANOVA for repeated measurements with the factors priming (rough, smooth, none) and set of questions (social coordination, relationship familiarity). Subsequently, statistical contrasts (t-tests) were performed to examine cortical activation associated with priming conditions for the different set of questions. Finally, to further investigate if regions that are specific to preprocessing tactile sensations survive the priming effect, we examined priming effects on the judgments masked with the results of the contrast receiving rough and smooth touch relative to rest.

Scores of participants’ judgments were tested for possible correlations (Pearson) with the parameter estimates for voxels in the somatosensory region of interest [maximum peak in left somatosensory
cortex (SI)). In addition, we tested possible correlations with participants’ judgments for secondary SI (SII), inferior frontal gyrus (IFG), inferior parietal cortex (IPC), hippocampus and amygdala.

We report regions that survived correction for multiple comparisons over the whole brain [at \( P < 0.05 \), family wise (FDR) correction]. To describe the anatomical regions, we used the SPM anatomy toolbox (Eickhoff et al., 2005).

RESULTS

Behavioral results

None of the participants reported any suspicions with respect to our experimental hypotheses.

Behavioral results revealed a significant interaction between way of tactile priming and the set of questions [ANOVA interaction with factors condition and set of questions, \( F(2,38) = 3.77, P < 0.05 \). Post hoc \( t \)-tests demonstrated effects for tactile priming of the social coordination set. Rough priming revealed significant lower scores on the social coordination scale compared with smooth priming [rough priming of social coordination judgment, mean and s.d.: 2.61 ± 0.39; smooth priming: 2.71 ± 0.39; \( t(19) = 2.41, P < 0.05 \), two-sided, Bonferroni corrected for multiple tests] or with no priming [no priming: 2.74 ± 0.39; \( t(19) = -2.35, P < 0.05 \); no effect for smooth priming relative to none priming \( t(19) = -0.49, P = \text{n.s.} \)] (Figure 1). Since there were no effects for tactile priming of the relationship familiarity set we concluded that tactile priming with rough objects specifically made social interactions appear less coordinated (more harsh, difficult and adversarial), but did not make the scenario seem more generally impersonal (similar to Ackerman et al., 2010).

Analysis of the reaction times revealed no significant effects (social coordination: rough priming: 5.55 ± 1.37 s, smooth: 5.37 ± 1.31 s, none: 5.96 ± 1.73 s; familiarity relationship: rough: 5.42 ± 0.97 s, smooth: 5.46 ± 1.16 s, none: 5.52 ± 1.06 s; ANOVA with factors condition and set of questions: no significant main effects or interactions).

FMRI results: Brain responses while participants received touch

Brain responses during passive touch applied by both a smooth paintbrush and rough sandpaper revealed activation in left primary SI and left SII (rough + smooth touch relative to rest; Figure 2). The contrasts rough touch relative to rest as well as smooth touch relative to rest revealed comparable activation in left SI and left SII. The statistical contrast for rough relative to smooth touch and smooth relative to rough touch failed to reveal any significant activation (at \( P < 0.05 \), FDR corrected). Thus, brain responses to rough and smooth touch showed no significant differences in brain activations.

FMRI results: Brain responses while participants judged the social interactions

Brain responses during judging interactions revealed involvement of somatosensory brain areas (SI, SII), IFG, hippocampus, amygdala, premotor cortex and IPC (ANOVA interaction with factors condition and set of questions). Post hoc \( t \)-tests with respect to social coordination

![Fig. 2](https://academic.oup.com/scan/article-abstract/9/11/1653/1681524)
assessments for rough relative to no priming demonstrated involvement of SI, SII, IFG, hippocampus, amygdala, premotor cortex and IPC (rough > no priming, for SCI, FDR corrected; Figure 3 and Table 1). Comparison of rough relative to smooth priming showed engagement of SI, premotor cortex, IFG, hippocampus and amygdala (rough > smooth priming, for SCI, FDR corrected). Smooth relative to rough or relative to no priming failed to reveal significant activations (for SCI; at $P<0.05$, FDR corrected; Table 1). Post hoc t-tests with respect to RFI questions (control condition) failed to show significant activations (rough > smooth priming, rough > no priming, smooth > rough priming, smooth > no priming, for RFI; at $P<0.05$, FDR corrected).

A comparison between rough priming for SCI relative to rough priming for RFI was accompanied by activations of SI, premotor cortex, IPC and IFG (FDR corrected; Table 2). For smooth priming, the analog contrast revealed no significant voxels. Hence, the demonstrated metaphor-specific impact of rough priming on social judgment seems to rely on a network of brain regions including sensorimotor brain regions, IFG, IPC, hippocampus and amygdala.

To better understand if regions that are specific to process tactile sensations subserve the tactile priming effect, we masked our analysis with the results of the contrast tactile stimulation (rough + smooth touch) relative to rest (at $P<0.05$, FDR corrected). Figure 4 shows for SCI judgments that rough relative to none or relative to smooth priming engaged brain areas that were also involved during receiving the tactile primes (SI and SII). In contrast, Table 3 depicts that control comparisons (smooth relative to rough priming, smooth relative to no priming) failed to reveal any significant activation in SI or SII. Furthermore, Tables 3 and 4 and Figure 5 show that this results accounts only for the SCI judgments, RFI judgments (control condition) did not show any somatosensory activations.

Brain responses in SI for the contrast rough relative to no priming were significantly linked with the bias to assess the interaction less coordinated ($r=0.69$, $P<0.005$, Pearson, two-sided; Figure 4; correlation between signal change in SI and decreased SCI assessments).

Brain responses in SI for the contrast rough relative to smooth priming revealed a similar significant correlation with the behavioral bias to perceive the scenarios less coordinated and more harsh and adversarial ($r=0.61$, $P<0.005$; Figure 4; correlation between signal change in SI and decreased SCI assessments). Correlations for SII activity failed to show significant relationships with SCI judgments. Furthermore, activation in IFG, IPC, hippocampus and amygdala showed no significant correlations with SCI assessments.

**DISCUSSION**

This study examined brain responses of participants when being asked to judge ambiguous interactions. Tactile priming with a rough stimulus (compared with smooth or no priming) resulted in a assessing the interaction as more harsh, difficult and adversarial, but did not make the scenario seem more generally impersonal. This bias is in accordance with a rough metaphor of social coordination and was accompanied by an active network of brain responses including sensorimotor brain areas, hippocampus, amygdala, IPC and IFG.

The behavioral responses are in line with the results of Ackerman et al. (2010). Experiencing rough objects made social interactions appear more difficult. Whereas Ackerman et al. (2010) report these

| Contrast | Brain region | Peak MNI location ($x, y, z$) | Peak $z$-value | Number of voxels |
|----------|--------------|-------------------------------|----------------|------------------|
| Rough priming > smooth priming | L SI/premotor cortex (BA6) | $-14$ $-44$ $70$ | 3.88 | 658 |
| Rough priming > no priming | L IFG (BA44) | $-58$ $10$ $8$ | 3.32 | 175 |
| Rough priming | L IPC | $-54$ $-38$ $23$ | 3.79 | 187 |
| Rough priming | R IPC | $62$ $-42$ $23$ | 3.56 | 180 |
| Smooth priming > no priming | L SI | $-28$ $42$ $58$ | 3.88 | 373 |
| Smooth priming | L IFG (BA45) | $54$ $28$ $2$ | 4.07 | 122 |
| Smooth priming | L hippocampus/amygdala | $-16$ $0$ $10$ | 3.56 | 70 |
| Smooth priming | smooth > no priming | R IFG (BA45) | $52$ $28$ $-4$ | 3.32 | 76 |
| Smooth priming | smooth > no priming | L IFG (BA45) | $44$ $30$ $-6$ | 3.53 | 75 |
| Smooth priming | smooth > no priming | L hippocampus/amygdala | $-18$ $-8$ $-14$ | 3.80 | 318 |
| Smooth priming | smooth > no priming | R hippocampus/amygdala | $40$ $-6$ $-20$ | 3.56 | 168 |
| Smooth priming | smooth > no priming | R IPC | $66$ $-36$ $20$ | 4.19 | 120 |

$P<0.05$, FDR corrected. L, left hemisphere; R, right hemisphere.

| Contrast | Brain region | Peak MNI location ($x, y, z$) | Peak $z$-value | Number of voxels |
|----------|--------------|-------------------------------|----------------|------------------|
| Rough priming SCI > rough priming RFI | L SI/premotor cortex (BA6) | $-14$ $-44$ $70$ | 3.88 | 658 |
| Rough priming SCI > smooth priming RFI | R IFG (BA45) | $54$ $24$ $0$ | 3.56 | 248 |
| Rough priming SCI | L IFG (BA44) | $-58$ $10$ $8$ | 3.32 | 175 |
| Rough priming SCI | L IPC | $-54$ $-38$ $23$ | 3.79 | 187 |
| Rough priming SCI | R IPC | $62$ $-42$ $23$ | 3.56 | 180 |

$P<0.05$, FDR corrected.

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**Fig. 3** Statistical maps showing brain activation while participants assessed ambiguous social scenarios with respect to social coordination (SCI). Areas of significant fMRI signal change are shown as color overlays on the T1-MNI reference brain. (A) Judging the SCI when primed with rough relative to no touch demonstrated activation in SI (and hippocampus) and IFG. (B) Judging the SCI when primed with rough relative to smooth touch revealed similar areas in SI and IFG.
results as the outcome of a social psychology experiment, we here demonstrate that this effect can also be operationalized for the purpose of an fMRI study, which usually requires many repetitions and includes less participants.

We hypothesized that the effect originally reported by Ackerman et al. (2010) involves in particular the somatosensory regions, which would provide neurophysiological evidence for the embodiment theory. Our results confirm this hypothesis. Rough tactile priming (relative to smooth or no priming) was associated with activation in somatosensory brain areas, accompanied with an involvement of hippocampus, amygdala, IPC and IFG. Moreover, somatosensory activation correlated highly positive with the degree participants judged the interaction as being harsh, difficult and adversarial. This network was involved when being asked to judge the interactions with respect to its social coordination, but not when participants were instructed to relate the familiarity of the agents. Hence, it was closely associated with the roughness metaphor.

The role for somatosensory brain regions in this metaphor-specific tactile priming of social judgments strongly supports the embodiment theory, which postulates that the retrieval of conceptual meanings (metaphorical knowledge) includes a re-enactment of corresponding sensory experiences. But how may this re-enactment work? It has been demonstrated that cells in the SI may act as a transient storage site for tactile (Harris et al., 2002) and even for visual and acoustic information (Zhou and Fuster, 1996, 2000). Anatomic studies in monkeys revealed that the somatosensory cortices are linked with prefrontal cortices via the medial temporal lobe for long-term encoding (Burton and Sinclair, 2000). The IFG has been related to the evaluation of semantic information (e.g. Heim et al., 2009) and to the storage of rules learned in a social context (Monfardini et al., 2008). In addition, numerous studies relate the IFG with tactile memory (e.g. Romo et al., 1999; Kelly et al., 2007; Aukstulewicz et al., 2012). Together with somatosensory brain areas the IFG seems to code the knowledge (the metaphor) that roughness is associated with the concepts of difficulty and harshness. SI and IFG may be linked via memory structures in the medial temporal lobe (hippocampus, amygdala), which have been suggested to bind distributed activated sites in the neocortex that

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**Table 3** Results of random effects analysis, masked with brain responses during real touch

| Contrast                          | Brain region | Peak MNI location (x, y, z) | Peak z-value | Number of voxels |
|----------------------------------|--------------|----------------------------|--------------|------------------|
| SCI Rough priming > smooth priming | L SI         | −30 −40 58                | 3.78         | 738              |
| SCI Rough priming > smooth priming | L SII        | −62 −18 22               | 2.46         | 22               |
| SCI Rough priming > no priming   | −32 −32 62   |                           | 4.10         | 1196             |
| SCI Rough priming > no priming   | −60 −18 22   |                           | 3.05         | 418              |

*P < 0.05, FDR corrected.*

**Table 4** Results of random effects analysis for social coordination judgments relative to familiarity relationship judgments, masked with brain responses during real touch

| Contrast                          | Brain region | Peak MNI location (x, y, z) | Peak z-value | Number of voxels |
|----------------------------------|--------------|----------------------------|--------------|------------------|
| Rough priming SCI > rough priming RFI | L SI         | −36 −64 64               | 3.65         | 641              |
| Rough priming RFI > rough priming SCI | L SII        | −50 −30 16               | 3.15         | 161              |

*P < 0.05, FDR corrected.*

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Fig. 4 Statistical maps showing brain activation in SI and SII while assessing ambiguous social scenarios for the contrast rough relative to no priming (A) and rough relative to smooth priming (B), masked with brain responses when receiving real touch. (A) Activity in left SI could significantly predict reduced social coordination scores. SII failed to show significant activation. (B) Activity in left SI again predicted the reduced social coordination assessments. SII displayed no significant relationships.
late our environment (Gallace and Spence, 2010). Given that touch always 2-folded: we use it to acquire information, but also to manipu-
sely linked to tactile experiences? From infancy, touch on our hands is
metaphorical knowledge (Williams et al., 2010). Thus, activating similar touch experiences may result in an activation of the metaphor-specific bias. Since our results demonstrated that this embodied knowledge seems to be represented even in primary cortex areas, incidental and unconscious manipulations via tactile experiences appear to be very easy.

Recent studies similarly examining embodied metaphors support our results. Williams and Bargh (2008) demonstrated that experiencing physical warmth, e.g. holding a cup of hot (vs iced) coffee make it likely to judge a person as having a ‘warm’ personality. Kang et al. (2011) employed fMRI to examine the neural underpinnings of this link between physical and social warmth. They demonstrated that in-
sular regions sensitive to physical warm perceptions are also engaged during manipulations of trust in the context of a decision-making game. Thus, physical temperature influenced human decision making associated with an engagement of the insula. Similarly, Eisenberger et al. (2003) reported overlapping activation in anterior cingulate cortex for processing physical and psychological pain.

Both the Kang et al. (2011) as well as our own study demonstrate that embodied metaphor effects are grounded in neurophysiological processes. Whereas Kang et al. (2011) report a functional overlap in the processing of information related to physical and psychological warmth in the left insula, our study shows that the roughness meta-
por links physical touch and psychological impressions of a rough conversation in SI. In the traditional view, the map in SI represents physical touch on the body surface. Recent studies in the last two decades challenge this view and suggest a more complex role for SI. For example, an increasing body of evidence demonstrates vicarious activation in SI when witnessing pain or simple touch on other’s bodies in the absence of any real touch (e.g. Keysers et al., 2004; Bufalari et al., 2007; Ebisch et al., 2008). Based on these results, a role for somatosensation in social perception has been suggested, which might point to simulation processes in the observer’s SI (Gallese, 2003, 2005; Keysers et al., 2010). Recent work also link mirror-like responses in SI with interindividuale differences in empathy (Gazzola and Keysers, 2008; Schaefer et al., 2012). The results of this study extend the research on mirror-like responses in SI, suggesting that activation in primary somatosensory areas may include higher-
order cognitions including psychological concepts such as the rough-
ness metaphor.

Our results provide evidence for tactile priming with rough touch, but fail to demonstrate analog effects for smooth touch. Several rea-
sons might explain this lack of effect. First, the smooth tactile primes we used in the current experiment might not have affected the rough-
ness–smoothness metaphor. Although we used a particular smooth paintbrush another tactile stimulation (e.g. satin) might have been more successful. Second, there may not be a smoothness counterpart of the roughness metaphor. While our study as well as the experiment by Ackerman et al. (2010) provided behavioral evidence for a priming effect of rough tactile experiences on subsequent evaluations of social coordination, no experiment has shown that this effect also works for smooth tactile experiences (Ackerman et al. worked with pieces of a puzzle covered with rough sandpaper relative to pieces uncovered, but there was not a particular smooth condition). Further studies are needed to better understand which haptic experiences influence social impressions.

This study examined brain responses in a time window around a judgment decision. Thus, we did not trace the whole complex deci-
making process which may start much earlier. Based on this limi-
tation, it remains unclear if the SI is directly involved in the process of assessing a social interaction, or whether a tactile stimulus can some-
how evoke a haptic mindset, triggered by a tactile sensation. However, fMRI has a limited temporal resolution, making it difficult to separate different processing stages of decisions (Hauk and Tschentscher, 2013).
Future research is needed to disentangle which aspect in the complex decision-making process are affected by touch sensations.

Several previous studies reported different activation in somatosensory cortices and other brain regions when comparing gentle or smooth with rough or unpleasant touch (e.g. Francis et al., 1999). However, comparing brain responses while experiencing rough relative to smooth touch in our study yielded no significant activation. We speculate that in this study these differences were too small to reach the level of significance.

In sum, our findings demonstrate that basic tactile sensations have an impact on higher social cognitive processing in metaphor-specific ways and that the neural underpinnings of this bias involve SI, IFG and memory-related structures. Thus, physical environment cues may influence people’s judgments and decisions. The results show how an evolutionary physical concept such as touch is functionally related on a neural level to a metaphorically linked psychological concept (Williams and Bargh, 2008; Anderson, 2010; Kang et al., 2011).

REFERENCES

Ackermann, J.M., Novera, C.C., Bargh, J.A. (2010). Incidental haptic sensations influence social judgements and decisions. Science, 328, 1712–3.

Anderson, M. (2010). Neutral reuse: a fundamental organizational principle of the brain. Behavioral and Brain Sciences, 33, 245–66.

Axsäter, R., Spitzer, B., Goltz, D., Blankenburg, F. (2012). Impairing somatosensory working memory using rTMS. European Journal of Neuroscience, 34, 839–44.

Barsalou, L.W. (2008). Grounded cognition. Annual Review Psychology, 59, 617–45.

Bifulco, A., Apile, A., Avenanti, A., De Ruosi, F., Aglioti, S.M. (2007). Empathy for pain and touch in the human somatosensory cortex. Cerebral Cortex, 17, 553–61.

Burton, H., Sinclair, R.J. (2000). Attending to and remembering tactile stimuli: a review of brain imaging data and single-neuron responses. Journal of Clinical Neurophysiology, 17, 575–91.

Ebisu, S.I., Perruci, M.G., Ferretti, A., Del Gratta, C., Romani, G.L., Gallese, V. (2008). The sense of touch: embodied simulation in a visuotactile mirroring mechanism for observed animate or inanimate touch. Journal of Cognitive Neuroscience, 20, 1–13.

Eickhoff, S.B., Stephan, K.E., Mohlhöfer, H., et al. (2005). A new SPM toolbox for combining probabilistic cytoarchitectonic maps and functional imaging data. Neuroimage, 25, 1325–35.

Eisenberger, N.I., Lieberman, M.D., Williams, K.D. (2003). Does rejection hurt? An FMRI study of social exclusion. Science, 302, 290–2.

Francis, S., Rolls, E.T., Bowtell, R., et al. (1999). The representation of pleasant touch in the brain and its relationship with taste and olfactory areas. Neuroreport, 10, 453–9.

Gallese, A., Spence, C. (2010). The science of interpersonal touch: an overview. Neurosci Biobehavioral Reviews, 34, 246–59.

Gallese, V. (2003). A neuroscientific grasp of concepts: from control to representation. Philosophical Transactions of the Royal Society B: Biological Sciences, 358, 1231–40.

Gallese, V. (2005). Embodied simulation: from neurons to phenomenal experience. Phenomenology and the Cognitive Sciences, 4, 23–48.

Gallese, V., Lakoff, G. (2005). The Brain’s concepts: the role of the Sensory-motor system in conceptual knowledge. Cognitive Neuroscience, 22, 455–79.

Gazzola, V., Keysers, C. (2008). The observation and execution of actions share motor and somatosensory voxels in all tested subjects: single-subject analyses of unsmoothed data. Cerebral Cortex, 19, 1239–55.

Greene, J.D., Sommerville, R.B., Nystrom, L.E., Darley, J.M., Cohen, J.D. (2001). An fMRI investigation of emotional engagement in moral judgment. Science, 293, 2105–8.

Harrenski, C.L., Antonenko, O., Shaner, M.S., Kiehl, K.A. (2010). A functional imaging investigation of moral deliberation and moral intuition. Neuroimage, 49, 2707–16.