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Lying and the Subsequent Desire for Toothpaste: Activity in the Somatosensory Cortex Predicts Embodiment of the Moral-Purity Metaphor

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It is well known from literature and religious ceremonies that there is a link between physical cleansing and moral transgressions. Only recently, psychological experiments explored this association and demonstrated that a threat to moral purity increases the demand of physical cleansing. Moreover, it has been shown that physical cleansing is actually efficacious to cope with threatened morality. This so-called Macbeth effect has been explained by an embodiment of the moral-purity metaphor. We tested this hypothesis by means of an functional magnetic resonsce imaging (fMRI) experiment. Participants were instructed to enact scenarios including either an immoral act (lying) or a moral deed (telling the truth). Subsequently, the participants were asked to rate the desirableness of various products. Results revealed that participants rated cleansing products (but not other goods) more desirable after performing an immoral than after a moral act. This Macbeth effect was accompanied by an active cortical network including sensorimotor brain areas during rating of cleansing products (but not while evaluating noncleansing goods). The results demonstrate neurobiological evidence for an embodiment of the moral-purity metaphor. Thus, abstract thoughts about morality can be grounded in sensory experiences.

Keywords: embodiment, fMRI, moral, premotor cortex, social, somatosensory cortex

Introduction

"Will all great Neptune's ocean wash this blood clean from my hand?" In an act full of misery and hopelessness, Lady Macbeth was trying to wash the blood of the murdered King Duncon from her hands. According to recent results in psychology, Lady Macbeth's efforts are reasonable. In a series of experiments, Zhong and Liljenquist (2006) demonstrated that physical and moral purity are psychologically interwoven. For example, they asked participants to hand-copy a short story written in first-person perspective. There were 2 versions of the story. One described a helping act (helping a co-worker), and the other an unethical deed (sabotaging a co-worker). Subsequently, the participants had to rate the desirability of various products. Results showed that copying the unethical story increased the desirability of cleansing products when compared with copying the ethical story, while the noncleansing products revealed no differences. Similar results have been reported by Schnall et al. (2008) and Lee and Schwarz (2010a, 2010b).

How can this psychological association between bodily and moral purity be explained? According to the theory of embodiment, abstract thoughts about morality are grounded in concrete experiences of physical cleanliness (Lakoff and Johnson 1999; Lee and Schwarz 2010a). The theory of embodied cognition claims that cognitive representations are structured by metaphorical mappings from sensory experience. According to this theory, knowledge is represented in modal systems derived from perception (Lakoff and Johnson 1999; Gallese and Lakoff 2005; Barsalou 2008), whereas in contrast more traditional views understand knowledge to be represented in abstract codes and distinct from the sensory modalities through which the knowledge was acquired (e.g., Fodor 1975). A number of behavioral studies support the theory of embodied cognition. In a series of experiments, Ackerman et al. (2010) demonstrated that basic tactile sensations have an impact on higher social cognitive processing in dimension- and metaphor-specific ways. For example, the abstract concept of importance seems to be grounded in bodily experiences of weight. Thus, holding a heavy clipboard-made job candidates appears more important (Jostmann et al. 2009; Ackerman et al. 2010). In another experiment, Ackerman et al. (2010) examined the concept of roughness, which is metaphorically associated with the concepts of difficulty and harshness. The authors revealed a link of this metaphor with sensory processing.

According to the theory of embodiment, mental processes involve simulations of body-related perceptions and actions. Thus, the retrieval of conceptual meaning involves a partial reenactment 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).

The current study aimed to test the theory of embodiment for the moral-purity metaphor. To test the hypothesis of a sensorimotor grounding, we employed an functional magnetic resonsce imaging (fMRI) approach. Participants were asked to read and enact scenarios. Then, the participants were told to perform an immoral act (conveying a malevolent message: lying) or a moral deed (conveying a benevolent message, control condition). Subsequently, participants were asked to rate different products according to their desirability. We hypothesized that cleansing (but not neutral) products were more attractive to people after they have behaved immorally (lying) than after they have behaved morally (telling the truth), thus replicating the Macbeth effect. We further hypothesized that this effect was accompanied by sensorimotor brain activations during the rating of cleansing products, thus providing evidence for the theory that sensorimotor grounding is intrinsic to abstract thoughts on morality (Gallese and Lakoff 2005).

Materials and Methods

Participants

Thirty-seven participants (18 females) with a mean age of 25 years (±3.66) 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 told that they would perform 2 separate experiments in the session: one including a cognitive neuroscience experiment and the other a marketing study. Participants were naive to the real aim of the study. After scanning, the participants were probed for suspicions concerning the experimental hypotheses.

The study used a two-factorial experimental design. The first factor was priming with either acting immorally (telling a lie) or morally (telling the truth). The second factor described the set of products the participants had to rate with respect to the desirability (cleansing vs. noncleansing products).

Participants were lying in the fMRI scanner and prompted with short scenarios they had to read. These scenarios were modeled after those used by Zhong and Liljenquist (2006) and Lee and Schwarz (2010a). For example, participants read the following scenario: "Imagine you are a law-firm associate competing for promotion with your colleague Sven. Today in the morning you found an important document on the floor by accident, which has obviously been lost by your colleague Sven. Returning this document to Sven would be very important for him, but might hurt your own career" (Lee and Schwarz 2010a). After 18 s, a new screen showed up, asking the participant to leave Sven a message. In the immoral condition (lying), the participant was prompted with the following screen: "Please leave a voice mail for Sven. Tell him who you are and that you *did not* find his document. Please speak now!" In the moral condition (telling the truth), the participant was prompted with this instruction: "Please leave a voice mail for Sven. Tell him who you are and that you *did* find the document. Please speak now!" The participants had 17 s for this task. Then, a new screen showed up asking the participants to rate the following products on a four-point scale (Likert-scale: 1 = completely undesirable and 4 = completely desirable). After 2.5 s, 2 pictures of different products were shown, each lasting for 4 s with an interstimulus interval of 9 s. Thus, participants were allowed to spend up to 13 s to evaluate the products (earlier responding did not automatically start the next trial). One of the pictures was taken out of a category of cleansing products, which consisted of toothpastes and mouthwash products. The other picture belonged to a category of noncleansing products, which included pictures displaying, for example, a tube with glue, a battery, or a tissue (Zhong and Liljenquist 2006; Lee and Schwarz 2010a). The category of noncleansing products was used in order to test if the Macbeth effect would extend to a theoretically unrelated measure.

Participants were required to respond with their right hand by using a key with 4 buttons (ranging from +2 to −2) to assess the products. Before the experiment they were explained that they could weight their responses from moderate (inner buttons) to extreme (outer buttons). The use of right and left buttons were randomized over the scenarios. Prior to the beginning of the experiment, we made the participants familiar with both tasks.

A total of 60 scenarios were shown to each participant. Each scenario was presented 2 times, followed by either the instruction to convey a malevolent or the instruction to give a benevolent message in the voice mail. The order of the scenarios as well as the order of presentation of the 2 product categories (first or second place after speaking task) was counterbalanced. Furthermore, the choice of products for each category was randomized (within and between subjects). Products were rated as equally attractive in a pre-study.

Participants were told that the voice messages inside the scanner were recorded for later analysis. In fact, we did not record these messages.

Visual images were back-projected to a screen at the end of the scanner bed close to the subject's feet. Subjects viewed the images through a mirror mounted on the birdcage of the receiving coil. Foam cushions were placed tightly around the side of the subject's head to minimize head motion.

The experiment consisted of 6 runs, each lasting for about 12 min. Each run included all conditions. Participants were allowed to take short breaks between the runs. Total participation time for each participant (including pre-measurements and preparation) was about 90 min.

fMRI Data Acquisition and Analysis

The functional imaging was conducted by using a 3-T scanner (Siemens MAGNETOM Trio, Germany) (gradient-echo T_2-weighted echo-planar images; time repetition (TR) = 2 s, time echo (TE) = 35 ms, flip angle = 80°, field of view = 224 mm). For each subject, data were acquired in 6 runs. In each session, 404 volumes were acquired. Functional volumes consisted of 32 slices. Each volume comprised 3.5 mm slices (no gap, in-plane voxel size 3.5 × 3.5 mm). For anatomical reference, a high-resolution T_1-weighted structural image was collected (magnetization prepared rapid gradient echo, TR = 1650 ms and TE = 5 ms).

fMRI data were preprocessed and analyzed using the Statistical Parametric Mapping Software (SPM8, Wellcome Department of Imaging Neuroscience, University College London, London, UK). For each subject, the fMRI scans were realigned to correct for interscan movement, using sinc interpolation and subsequently normalized into a standard anatomical space (MNI, Montreal Neurological Institute template), resulting in isotropic 3-mm voxels. Data were then smoothed with a Gaussian kernel of 6 mm full-width at half maximum.

Statistical parametric maps were calculated using multiple regressions with the hemodynamic response function modeled in SPM8. Data analyses were performed at 2 levels. We examined data on the individual subject level by using a fixed-effects model. Then, the resulting parameter estimates for each regressor at each voxel were entered into a second-level analysis with the random-effects model. In order to examine responses in sensorimotor brain areas when participants performed the voice mail task, we computed statistical contrasts (*t*-tests) for the time window while telling a lie and while telling the truth (relative to rest). Furthermore, to investigate brain activations during the assessment process, we examined the time window during evaluation of the products. We calculated an analysis of variance (ANOVA) for repeated measurements with the factors previous ethical behavior (moral vs. immoral) and set of products (cleansing vs. noncleansing products). Statistical contrasts (post hoc *t* tests) were then performed to examine cortical activation associated with previous moral and immoral behavior and different sets of products. Furthermore, to explore if the Macbeth effect involves sensorimotor brain areas, we examined the effects masked with the results of the contrast speaking a lie on the voice mail relative to rest.

Behavioral responses (rating of the products) were used to test for possible correlations (Pearson) with the parameter estimates for voxels in the sensorimotor regions of interest (maximum peak in primary somatosensory cortex, SI). Additionally, we tested possible correlations of the behavioral responses with activations in premotor cortex (BA6), superior temporal gyrus, hippocampus, and amygdala.

The resulting images were thresholded at $P < 0.05$ family-wise error (FWE) corrected for multiple comparisons. Correction was achieved by imposing a threshold for the volume of clusters comprising contiguous voxels that passed a voxel-wised threshold of $P < 0.005$. Anatomical interpretation of the functional imaging results was performed by using the SPM anatomy toolbox (Eickhoff et al. 2005).

Results

Behavioral Results

Analysis of the behavioral results (ANOVA with factors ethics and product) revealed a significant interaction between ethics of behavior and subsequent ratings of the products (interaction of ethics with products, $F_{1,36} = 3.83$, $P = 0.05$). Post hoc *t*-tests showed that after telling a lie participants rated cleansing products significantly more desirable when compared with telling the truth (after unethical behavior: 2.56 ± 0.52, mean and standard deviation; after ethical behavior: 2.49 ± 0.56; $t_{(36)} = 2.15$, $P = 0.01$; Fig. 1). The noncleansing products did not show any differences with respect to previous ethical or unethical behavior ($t_{(36)} = -0.83$, $P =$ n.s).

Furthermore, post hoc *t*-tests also revealed that, after unethical behavior, cleansing products were more desired than noncleansing products ($t_{(36)} = 1.96$, $P = 0.02$). Thus, threatened moral integrity seems to result in increased preferences for cleansing products (similar to Zhong and Liljenquist 2006; Lee and Schwarz 2010a).

Analysis of the reaction times demonstrated again a significant interaction between ethics and product (ANOVA with factors ethics and product, interaction between ethics and product: $F_{1,36} = 8.02$, $P = 0.008$). Lying (immoral deeds) slowed the assessment of the toothpaste and mouthwash products, compared with telling the truth (moral acts) (cleansing products, unethical behavior: 1.91 ± 0.35 s; ethical behavior: 1.81 ± 0.31 s; $t_{(36)} = 3.12$, $P = 0.002$). For the noncleansing products, there were no differences ($t_{(36)} = -0.98$, P = n.s.). Furthermore, comparing the reaction times for desirability ratings for cleansing relative to noncleansing products (after unethical behavior) revealed slowed responses for cleansing products ($t_{(36)} = 2.83$, $P = 0.004$).

None of the participants reported any suspicions with respect to our experimental hypotheses when being asked after the end of the experiment.

fMRI Results: Brain Responses While Lying and Telling the Truth

Brain responses when leaving a lie on the voice mail relative to rest revealed activations in bilateral sensorimotor brain regions (SI, primary motor cortex [M1], bilateral premotor areas [BA6], left inferior frontal cortex [BA44], bilateral middle and superior temporal gyrus, bilateral amygdala, hippocampus, and occipital cortex; see Fig. 2, $P < 0.001$, FWE corrected).

Figure 1. Participants' mean evaluation (+standard errors) of cleansing products after unethical (lying) or ethical acts (telling the truth). Cleansing products were evaluated significantly higher when participants performed an unethical deed before.

Contrasting brain responses for lying relative to telling the truth revealed activations in prefrontal and frontal brain areas.

fMRI Results: Brain Responses While Assessing Products

To test our hypothesis that the Macbeth effect is grounded in sensorimotor activations, we used the results of the contrast lying relative to rest as a mask for data analysis of the subsequent rating task. Analysis of brain activations while rating the products revealed engagement of sensorimotor brain regions (SI and BA6), middle/superior temporal gyrus, hippocampus, and amygdala (ANOVA interaction between factors ethics and set of products, unmasked analysis revealed additional activation in superior parietal lobe/precuneus).

Post hoc *t*-tests showed that brain responses while participants rated cleansing products after having behaved immorally compared with previous moral acts involved left sensorimotor activation (SI and BA6), activation of middle/superior temporal gyrus, amygdala, and hippocampus (at $P <$ 0.05, FWE corrected; Table 1 and Fig. 3). The unmasked contrast revealed additional activation in the right prefrontal gyrus and precuneus (MNI coordinates: 26, 54, −2, $z = 4.74$; −6, −80, 48, $z = 4.93$; FWE corrected). The analogue contrast when rating noncleansing products failed to reveal significant activations (immoral vs. moral, at $P < 0.05$, FWE corrected, both for masked and unmasked results; even at $P < 0.01$ uncorrected no activation in the sensorimotor cortex).

The reverse contrast for cleansing products (ethical relative to unethical behavior) revealed no significant activations (at $P < 0.05$, FWE corrected, masked and unmasked; even at $P < 0.01$ uncorrected no activation in the sensorimotor cortex). The analogue contrast (ethical relative to unethical behavior) for noncleansing products also failed to reveal significant activations in the sensorimotor cortex (at $P < 0.05$, FWE corrected, masked and unmasked; even at $P < 0.01$ uncorrected no activation in the sensorimotor cortex). Hence, the results demonstrate that immoral behavior resulted in left sensorimotor activation only when participants rated cleansing products, not when being asked to judge noncleansing goods.

We then calculated the correlation between the strength of the Macbeth effect (preference ratings for cleansing products after lying minus rating for those products after telling the truth) with signal changes in sensorimotor peak areas for the contrast preference ratings of cleansing products after unethical relative to ethical deeds. Figure 3 displays a significant correlation of the behavioral responses with signal change in SI ($r = 0.50$, $P < 0.01$, Pearson, two-sided). Brain activation in premotor cortex (BA6) failed to reach the level of significance. There were no other significant correlations. Furthermore,

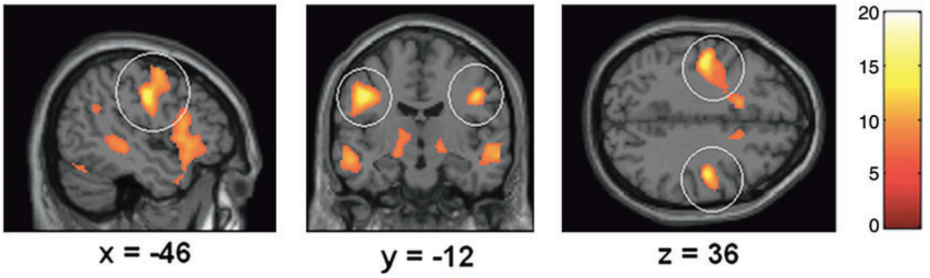

Figure 2. Statistical maps showing brain activation while participants were leaving a lie on a voice mail (relative to rest, FWE corrected). Areas of significant fMRI signal change are shown as color overlays on the T1-MNI reference brain. Circles mark sensorimotor activation.

Table 1
Results of random-effects analysis for brain responses when rating different set of products

Contrast	Brain region	Peak MNI location (*x*, *y*, *z*)	Peak *z*-value	Number of voxels
Evaluation of cleansing products				
After lying > after telling the truth	L SI	−44, −16, 28	4.30	510
	Premotor cortex (BA6)	−44, −8, 56	3.90	
	(R SI)	44, −14, 32	3.34	12
	L sup. temporal gyrus	−54, −18, −2	4.60	265
	L hippocampus/amygdala	−14, −20, −12	3.48	91
	(R hippocampus)	22, −24, −8	2.94	16
	Occipital cortex/cerebellum	8, −84, 2	5.35	
After telling the truth > after lying	–	–	–	–
Evaluation of noncleansing products				
After lying > after telling the truth	–	–	–	–
After telling the truth > after lying	Occipital cortex	−10, −92, 4	5.09	

Note: Displayed are activations surviving cluster-level correction ($P < 0.05$, FWE corrected, threshold of $P < 0.005$ used to define the clusters, masked with speaking task results; L: left hemisphere; R: right hemisphere; in brackets: uncorrected results).

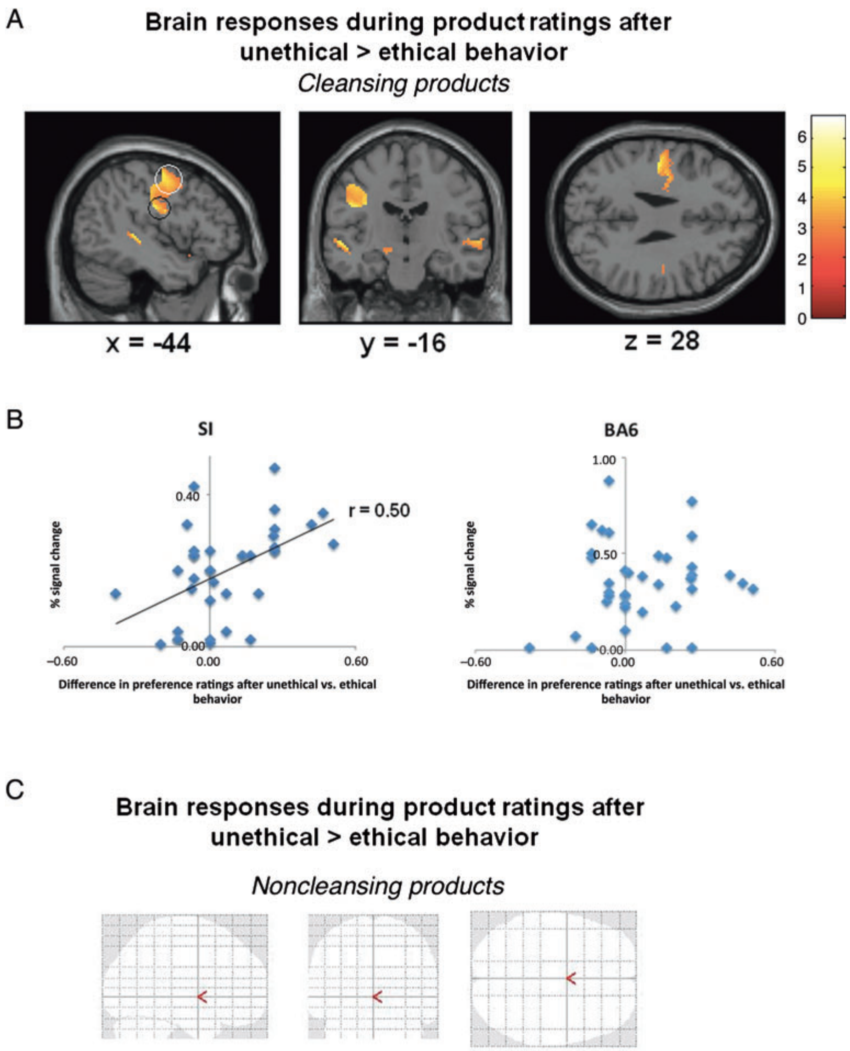

Figure 3. Statistical maps showing brain activation while participants assessed different sets of products. (*A*) Brain responses revealed activation in sensorimotor brain areas (black circle: SI and white circle: BA6) when participants were lying before (relative to telling the truth in the previous task). (*B*) Activity in the left SI could significantly predict the increased desirability of cleansing products after unethical deeds. Activity in BA6 failed to show a significant correlation. There were no other significant correlations. (*C*) Brain responses after unethical deeds were not altered when participants had to evaluate noncleansing products.

there were no significant correlations of reaction times with regions of interest.

Next, we tested brain activations when rating cleansing relative to noncleansing products (after unethical behavior). The results showed left sensorimotor activation during rating of cleansing products relative to noncleansing products (FWE corrected at $P < 0.05$; Table 2 and Fig. 4; unmasked results revealed additional activation in precuneus for cleansing

Table 2
Comparison of brain responses after ethical and unethical behavior

Contrast Number of voxels	Brain region	Peak MNI location (*x*, *y*, *z*)	Peak	*z*-value
After lying				
Cleansing products > noncleansing products	L SI	−28, −10, 28	4.21	683
		−52, −12, 28	2.72	
	Premotor cortex (BA6)	−52, −10, 54	3.86	
	(R sup. temporal gyrus)	56, −18, −2	3.91	602
	(L sup. temporal gyrus)	−52, −18, −4	4.28	204
	(L hippocampus)	−30, −28, −6	2.89	10
	(R hippocampus)	22, −24, −8	2.87	9
	(L amygdala)	−16, −8, −10	3.04	8
	Occipital cortex/cerebellum	−10, −88, −2	6.60	
Noncleansing products > cleansing products	–	–	–	–
After telling the truth				
Cleansing products > noncleansing products	–	–	–	–
Noncleansing products > cleansing products	–	–	–	–

Note: Displayed are activations surviving cluster-level correction ($P < 0.05$, FWE corrected, threshold of $P < 0.005$ used to define the clusters, masked with speaking task results; L: left hemisphere; R: right hemisphere; in brackets: uncorrected results).

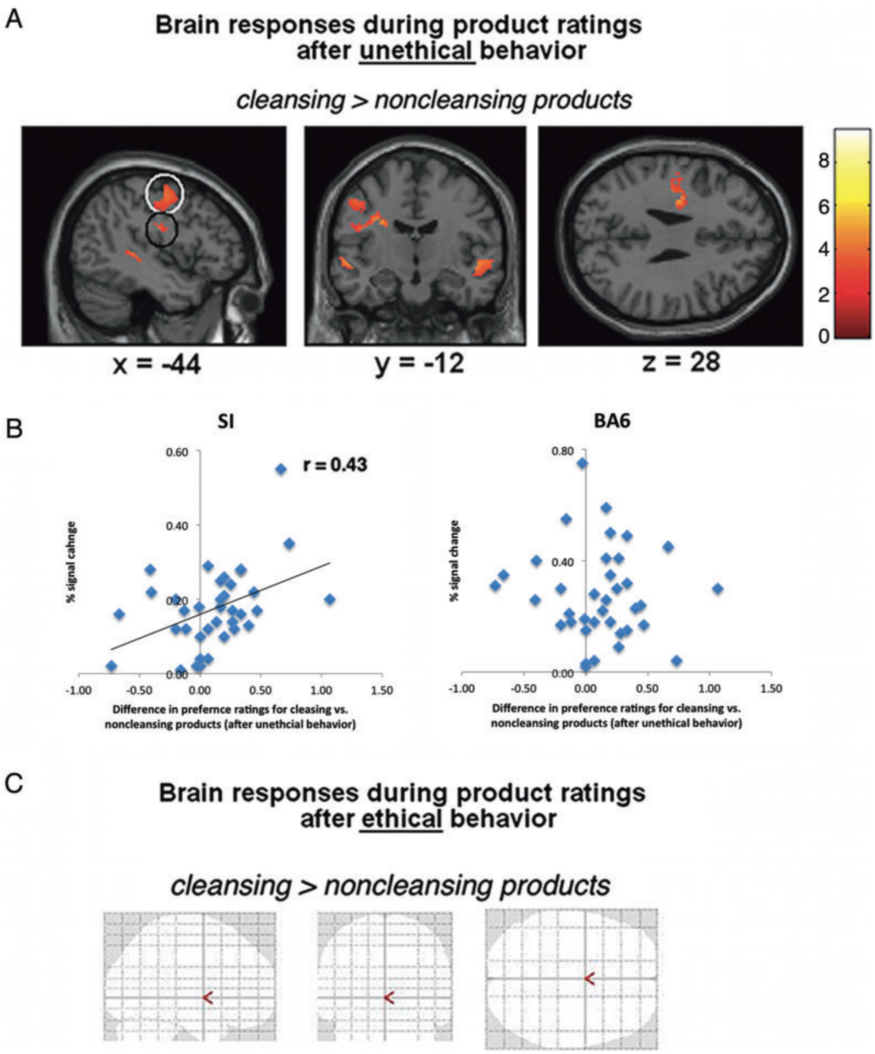

Figure 4. Statistical maps showing brain responses after unethical and ethical behavior. (*A*) Brain responses after unethical behavior revealed activation in sensorimotor brain areas (black circle: SI and white circle: BA6) for cleansing relative to noncleansing products. (*B*) Activity in the left SI could significantly predict the increased desirability of cleansing relative to noncleansing products after unethical deeds. There were no other significant correlations. (*C*) Brain responses for product ratings after ethical deeds were not different with respect to cleansing versus noncleansing products.

products). The reverse contrast yielded no significant activations (at $P < 0.05$, FWE corrected, masked and unmasked; even at $P < 0.01$ uncorrected no activation in the sensorimotor cortex). Comparing brain responses when rating both kinds of products after "ethical" behavior failed to show any significant activations (at $P < 0.05$, FWE corrected, masked and unmasked; even at $P < 0.01$ uncorrected no activation in the sensorimotor cortex).

Computing a correlation between the strength of the Macbeth effect with signal changes for the contrast preference ratings for cleansing products relative to noncleansing products (after unethical behavior) revealed a significant correlation in SI ($r = 0.43$, $P < 0.01$, Pearson, two-sided, Fig. 4). Brain activation in BA6 and other areas showed no significant correlations. Also, there were no correlations of reaction times with signal changes.

Discussion

The current study aimed to test the hypothesis that the Macbeth effect is grounded in sensory cognitions, suggesting that the moral-purity metaphor that is described in the Macbeth effect can be explained by an embodiment of the abstract concept of moral. Participants were asked to enact short scenarios in which they were either asked to lie (unethical behavior) or to tell the truth (ethical behavior). Subsequently, we asked the participants to rate different set of products with respect to their desirability. The desirability ratings were significantly higher when participants were lying before, but only for cleansing products, not for noncleansing products. Therefore, the behavioral results replicated the Macbeth effect. fMRI results demonstrated that this effect was associated with sensorimotor activations in SI and premotor cortex (BA6). We found positive significant correlations between the strength of the Macbeth effect and signal changes in SI. Based on these results, we argue that the moral-purity metaphor is based on sensorimotor brain activations, suggesting that sensorimotor grounding is intrinsic to cognitive processes including even abstract thoughts on morality.

Numerous behavioral studies have demonstrated that there is a link between threatened morality and physical cleansing. Zhong and Liljenquist (2006) showed that copying an unethical story increased the desirability of cleansing products when compared with copying an unethical story. Schnall et al. (2008) reported that cleaning products soften one's judgment of others' misdeeds. Furthermore, Lee and Schwarz (2010a) showed that the moral-purity metaphor is specific to the motor modality involved in moral transgression. Another study by the same authors demonstrated that hand washing also seems to reduce postdecisional dissonance (Lee and Schwarz 2010b). But why do we feel better when washing our hands after having behaved unethically? In the moral-purity metaphor, physical and moral cleanliness are linked. According to the theory of embodied cognition, it can be hypothesized that abstract thoughts about morality are grounded in concrete experiences of physical cleanliness (Lakoff and Johnson 1999; Lee and Schwarz 2010a). Thus, the alleviation people feel when trying to wash away their sins may be grounded in activations in modality specific brain areas (Lee and Schwarz 2010a).

An increasing body of evidence supports the theory of embodied cognition (e.g., Zhong and Leonardelli 2008). More recently, the theory of embodied cognition received also supports from studies using neuroimaging approaches. For example, Williams and Bargh (2008) demonstrated that experiencing physical warmth, for example, 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, and demonstrated that insular regions sensitive to physical warm perceptions are also engaged during manipulations of trust in the context of decision-making. An earlier study explored embodiment for pain and reported overlapping activation in anterior cingulate cortex for processing physical and psychological pain (Eisenberger et al. 2003). Lacey et al. (2012) showed texture-selective somatosensory cortex activation when processing sentences containing textural metaphors compared with literal sentences. The authors concluded that the comprehension of metaphors is perceptually grounded. This is supported by our previous study, which examined the metaphor roughness and reported that rough tactile priming made social interactions appear more difficult and adversarial (consistent with the rough metaphor; Schaefer et al. 2013). This effect was accompanied with a cortical network including the somatosensory cortices, thus providing further evidence for the theory that sensorimotor grounding is intrinsic to cognitive processes.

The present study aimed to test if the moral-purity metaphor can be explained by the theory of embodied cognitions. Do even abstract moral cognitions ground in sensory experiences? To answer this question, we employed fMRI to examine neural activations during the Macbeth effect. We manipulated the ethical factor by either lying or telling the truth in an enacted scenario. Subsequently, we asked participants to evaluate several products. Behavioral results demonstrated that we could successfully replicate the results by Zhong and Liljenquist (2006). Thus, cleansing products were evaluated more positively after unethical acts, but we did not see any differences for noncleansing products. Hence, we demonstrate for the first time that the moral-purity metaphor also works in an intrasubject design with a number of replicated scenarios.

fMRI results demonstrated that this Macbeth effect was accompanied by an activation of sensorimotor brain regions very similar to the activation during performing the unethical deed (along with the hippocampus and amygdala, brain regions known to be involved in memory processing, Squire et al. 1993). These sensorimotor brain areas were engaged during the evaluation of cleansing products, but not while assessing noncleansing goods. Furthermore, sensorimotor activation was found after unethical behavior, but not after ethical behavior. This interaction strongly supports the theory of embodied cognition. Thus, even abstract thoughts on moral concepts seem to be grounded on sensory experiences.

Our results show that the moral-purity metaphor is in particular associated with activity in SI. The more SI was activated, the higher the participant showed the Macbeth effect. This result of an involvement of somatosensory cortices is in line with previous studies examining the neural underpinnings of embodied metaphors (Gallese 2005; Gallese and Lakoff 2005). For example, Lacey et al. (2012) examined textural metaphors and found activation of texture-selective somatosensory cortex in the parietal operculum. Our previous study investigated how basic tactile sensations had an impact on higher social cognitive processing in metaphor-specific ways. Results showed that the neural correlates of this bias involve in particular the somatosensory cortex (Schaefer et al. 2013). Saxbe et al. (2013) examined language use during the feeling of social emotions and found in particular somatosensory activity linked with complex social emotional processing. Kang et al. (2011) examined effects of physical temperature on trust behavior and found activation in bilateral anterior insula, central operculum, and SI associated with the embodied metaphor of warmth.

Beyond studies on embodiment, numerous studies have already demonstrated that somatosensory cortices can be linked with social perceptions, for example, with empathy. For example, Ruby and Decety (2004) reported that empathy in complex social events is associated with activation in SI. 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. Mirror-like activations in somatosensory cortices when observing others being touched suggest a mechanism that may provide a somatic dimension to our perception of other people's experiences (Keysers et al. 2010). Moreover, these mirror-like activations in SI have been shown to be linked with empathic abilities of the observer (e.g., Bufalari et al. 2007; Schaefer et al. 2012). A recent study provides further support for a role of somatosensory cortices in social perception by demonstrating long-term effects of reading a novel on connectivity in the brain. Berns et al. (2013) measured changes in resting-state connectivity over several days. Each evening before participants had to read a novel. Results revealed long-term changes in connectivity that persisted for several days after reading, in particular, in bilateral somatosensory cortex. Thus, the somatosensory cortex seems to play an important role for memory processing of empathic feelings (see also Zhou and Fuster 1996, 2000; Harris et al. 2002). Therefore, in contrast to traditional views, the somatosensory cortices seem to be involved in social perceptions, including complex empathic processes and even abstract moral cognitions.

The current study confirms and also extends previous imaging results on embodied cognitions (e.g., Eisenberger et al. 2003; Kang et al. 2011; Lacey et al. 2012; Schaefer et al. 2013). Whereas previous studies validated the theory of embodied cognition for pain, trust, and texture, the present study is the first one demonstrating that even much more abstract metaphors such as the moral-purity metaphor are grounded in sensorimotor perceptions and experiences. In addition, whereas previous studies actually applied real priming stimuli, the present study asked the participants only to imagine to behave in an immoral way. Based on our results, we conclude that conceptual metaphors can be so strong that even the mere imagination of immoral behavior makes people feel literally dirty, associated with sensorimotor perceptions. The results may be important for institutions in which decisions based on moral assessments have to be made (e.g., organizations of the justice system). In addition, the relationship of moral behavior with sensorimotor perceptions may also provide valuable contributions for theoretical concepts of moral philosophy.

Taken together, the present study demonstrated neural correlates for the moral-purity metaphor in somatosensory cortices. The results provide support for the theory that cognition depends on perceptual simulations (Barsalou 2008) and may further help to understand how abstract knowledge is represented in the brain.

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Notes

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