

Vicariously Touching Products through Observing Others' Hand Actions Increases Purchasing Intention, and the Effect of Visual Perspective in This Process: An fMRI Study

Yi Liu ^{1,*} Xuelian Zang,^{1,2} Lihan Chen,³ Leonardo Assumpção,² and Hong Li^{1,4,*}

¹College of Psychology and Sociology and Shenzhen Key Laboratory of Affective and Social Cognitive Science, Shenzhen University, Shenzhen, 518060, China

²General and Experimental Psychology, Ludwig Maximilian University, Munich, 80539, Germany

³School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, 100871, China

⁴Center for Intelligence Development and Protection, Shenzhen Institute of Neuroscience, Shenzhen, 518057, China



Abstract: The growth of online shopping increases consumers' dependence on vicarious sensory experiences, such as observing others touching products in commercials. However, empirical evidence on whether observing others' sensory experiences increases purchasing intention is still scarce. In the present study, participants observed others interacting with products in the first- or third-person perspective in video clips, and their neural responses were measured with functional magnetic resonance imaging (fMRI). We investigated (1) whether and how vicariously touching certain products affected purchasing intention, and the neural correlates of this process; and (2) how visual perspective interacts with vicarious tactility. Vicarious tactile experiences were manipulated by hand actions touching or not touching the products, while the visual perspective was manipulated by showing the hand actions either in first- or third-person perspective. During the fMRI scanning, participants watched the video clips and rated their purchasing intention for each product. The results showed that, observing others touching (vs. not touching) the products increased purchasing intention, with vicarious neural responses found in mirror neuron systems (MNS) and lateral occipital complex (LOC). Moreover, the stronger neural activities in MNS was associated with higher purchasing intention. The effects of visual perspectives were found in left superior parietal lobule (SPL), while the interaction of tactility and visual perspective was shown in precuneus and precuneus-LOC connectivity. The present study provides the first evidence that vicariously touching a given product increased purchasing intention and the neural activities in bilateral MNS, LOC, left SPL and precuneus are involved in this process. *Hum Brain Mapp* 39:332–343, 2018. © 2017 Wiley Periodicals, Inc.

Additional Supporting Information may be found in the online version of this article.

Contract grant sponsor: China Postdoctoral Science Foundation; Contract grant number: 2016M602502; Contract grant sponsor: Natural Science Foundation of Guangdong Province; Contract grant number: 2017A030310534; Contract grant sponsor: Shenzhen Peacock Plan; Contract grant number: KQTD2015033016104926.

*Correspondence to: Yi Liu, College of Psychology and Sociology, Shenzhen University, Shenzhen, China. E-mail: liuyi_psy@163.com

and Hong Li, College of Psychology and Sociology, Shenzhen University, Shenzhen, China. E-mail: lihongszu@szu.edu.cn

Received for publication 12 July 2017; Revised 21 September 2017; Accepted 3 October 2017.

DOI: 10.1002/hbm.23845

Published online 11 October 2017 in Wiley Online Library (wileyonlinelibrary.com).

Key words: vicarious experience; purchasing intention; mirror neuron system; visual perspective; fMRI

INTRODUCTION

“Sensory marketing” refers to a type of strategy used to promote products consumption by delivering product’s sensory information to potential consumers. The term emphasizes the importance of the role played by sensory experiences in consumer behavior [Krishna, 2012; Krishna and Schwarz, 2014]. In traditional shopping, firsthand sensory experience is important for product judgments. For example, consumers are more confident in their attitude towards a product when they can touch it, rather than otherwise [Peck and Childers, 2003]. However, not all types of shopping outlets enable their consumers to engage in direct sensory experiences, such as online stores. The continuous growth of online shopping requires retailers to generate new forms of virtual tactile inputs to improve consumer’s shopping experience and increase purchasing intention. This issue could be addressed by inducing vicarious tactile experiences, for example, by showing others’ experiences with the products of interest.

To date a few studies have attempted to deliver product’s sensory information, however by asking participants to deliberately imagine the sensations they could have from the products. For example, Escalas [2004] used advertisement texts to encourage a group of consumers to imagine themselves wearing the shoes described in the ad. The author found that the group showed a more favorable attitude to the ad, when compared to a control group of consumers that did not imagine the shoe experience. In a similar design, Yoon and Park [2012] showed participants a picture of a cup of coffee with first-person narratives describing the coffee smell. The authors explicitly asked participants to relate the stimuli to their own experiences. Participants reported the extent to which they imagined the self in the ad (i.e., self-referencing), and their attitude to the ad (i.e., likeability, favorability, and delightfulness). The results showed that the level of self-referencing predicted consumers’ attitude towards the coffee brand.

The aforementioned studies reveal that sensory information through imagination influences consumers’ behavior. However, a few, but important points were overlooked by the methodological approaches employed in these studies. First, the method used to deliver the sensory messages, i.e., explicitly instructing consumers to imagine or recall their own sensory experiences, is rarely used, and somewhat impractical in real marketing. Second, the authors measured only consumers’ attitude to the ads or brand, but did not directly measure consumers’ purchasing intention. Last but not least, these studies did not demonstrate how the brain processes the imagined or recalled sensations. When it comes to product marketing, consumers are more commonly

exposed to methods, such as advertisements in which the sensory information of a given product is experienced by others (i.e., actors). For instance, showing a TV commercial, in which an actor touches a soft blanket will likely induce a potential consumer to vicariously experience the softness of the product. Such experience may thereafter have a direct influence on the consumers’ purchasing intention. However, whether this kind of vicarious sensory experiences can effectively increase purchasing intention has not yet been investigated. Moreover, the underlying neural substrates of this process are also unknown. These issues will be addressed in the present study. To induce vicarious sensory experiences, we asked participants to observe an actor’s hand interacting (touch vs. no-touch) with a series of products, and directly rate their purchasing intentions for these products. To demonstrate the neural substrates of vicarious sensory experiences, participants’ brain activities were recorded using functional magnetic resonance imaging (fMRI).

When observing object-directed/transitive hand actions, observers automatically simulate both the hand movements and the sensory consequences of the actions [Kilner et al., 2007; Schutz-Bosbach and Prinz, 2007; Wolpert et al., 1995]. In social neuroscience, vicarious neural responses to others’ hand movements were found in motor-related regions such as premotor cortex and parietal cortex. These brain regions were core sites of mirror neuron system (MNS), in which the brain regions were activated when individuals performed the actions themselves, as well as when observing others performing the same actions [Iacoboni and Dapretto, 2006; Iacoboni et al., 1999; Kilner et al., 2009; Molenberghs et al., 2012; Rizzolatti and Craighero, 2004]. When observing others being touched, vicarious neural responses to others’ tactile experiences were found in sensory-related regions such as the primary and secondary somatosensory regions [Ebisch et al., 2008; Keysers et al., 2004], which were also included in the MNS [Keysers and Gazzola, 2009]. In respect of purchasing behavior, the tactile experiences with the product are particularly important for inferring the product’s physical properties, such as the shape, weight, and temperature [Peck and Childers, 2003]. These tactile sensations can be vicariously experienced through the visualization of the hands moving and touching the products. Therefore, we are interested in the vicarious neural responses in both motor-related and sensory-related components in the MNS. The activation of these regions could be regarded as the neural representation of vicarious experiences of action and sensation.

Given the neural bases of the vicarious experiences to actions and tactile sensation aforementioned, the current study used fMRI to measure the vicarious neural responses of participants when they observed others’ hand

interactions with products. In doing so, we aimed to investigate whether and how observing others' hand actions (i.e., touch vs. no-touch) towards a product affect purchasing intention, and what the neural correlates underlying this process are. Regarding vicarious experience, it is known that it helps us understand others' physical sensations, action intention and emotional states during social interaction [Gallese et al., 2004; Iacoboni and Dapretto, 2006]. In the same vein, vicariously experiencing a product might be helpful to infer its sensory features, which may contribute to purchasing intention. Therefore, we hypothesize that vicariously touching a product through observing others' hand actions will increase purchasing intention. What is more, vicarious neural responses should be found in MNS (i.e., premotor cortex, somatosensory cortex) and correlated with the increased purchasing intention.

In addition, previous research demonstrated that vicarious motor and sensory experiences, and the corresponding neural responses are sensitive to visual perspectives (i.e., first-person perspective (1PP) or third-person perspective (3PP)). However, the neural representation of visual perspective and its effects on vicarious experiences in previous findings have been mixed. Jackson et al. [2006] showed that 1PP observation of non-object-directed/intransitive actions induced stronger neural activities in motor cortex than 3PP did, thus suggesting that 1PP facilitated vicarious motor representation in the brain. Similarly, observing painful stimulation on others' hand in 1PP also increased observer's somatosensory activation compared to the 3PP condition, suggesting that 1PP enhances vicarious neural representation of sensations [Canizales et al., 2013]. Schaefer et al. [2009] on the other hand, showed that both 1PP and 3PP observation activated somatosensory cortex during observation of touch, but that 1PP observation involved the anterior part of the primary sensory cortex, while 3PP involved the posterior part. In addition to the motor and somatosensory neural activities mentioned above, 1PP (vs. 3PP) action observation or imitation showed activation of cuneus, while 3PP (vs. 1PP) action imitation activated lingual gyrus, superior occipital gyrus and inferior frontal gyrus [Jackson et al., 2006]. In Ruby and Decety [2001], simulating actions in 1PP (vs. 3PP) activated the inferior parietal lobule and somatosensory cortex in the left hemisphere. While 3PP (vs. 1PP) action simulation activated the precuneus, posterior cingulate, right inferior parietal, and frontopolar cortex [Ruby and Decety, 2001]. In a behavioral study, Vandenbroucke et al. [2015] asked participants to observe the hand of an actor being stimulated with painful input in the 1PP or 3PP, while the participants themselves received a vibrotactile stimulation on their own hand in 75% of the trials. Participants' task was to report whether they felt the vibrotactile stimulation. False alarmed detection of the stimulation (i.e., reporting presence of vibration when it was actually absent) was regarded as vicarious tactile experiences. The results showed that 1PP (vs. 3PP)

increased the correct detection of the vibrotactile stimulation, while the vicarious experience was unaffected by visual perspective. Ultimately, the collection of mixed findings demonstrate that the role of visual perspective can vary depending on the nature of the vicarious experiences (actions, pain, touch, etc.), and a broad region of the brain is involved in perspective taking. Therefore, such variability raises the questions as to whether the visual perspective (during the observation of others' hand action towards a product) may interact with vicarious tactile experiences and benefit purchasing intention, and which brain regions are involved. To answer these questions, the hand actions presented in this study were viewed by participants either in 1PP or 3PP. In addition, after identification of the brain regions sensitive to the interaction between vicarious tactility and visual perspective, how these regions connected with other brain regions, and how the connectivity were modulated by vicarious tactility, visual perspective and the interaction of them were also explored.

To sum up, the aims of the current study are to investigate (1) whether and how observing others' hand interactions with products affect purchasing intention, and its neural correlates; and (2) the effect of visual perspective in this process. We used video clips exhibiting products (common objects or food) with hand actions as stimuli. Vicarious tactility was manipulated using hand actions operating the products (referred to as touch), compared with hand actions around the products (referred to as no-touch). Visual perspective was manipulated by showing the hand actions in 1PP or 3PP. Participants watched the video clips and made judgments about their purchasing intention for each product. Using fMRI, vicarious neural activities were accessed and associated with self-reported purchasing intention. We hypothesize that vicarious tactile experiences (touch vs. no-touch) will increase purchasing intention. Moreover, we predict that this process will be associated with vicarious neural responses in MNS. Last but not least, we will shed light on the effect of visual perspectives (1PP and 3PP) on vicarious neural responses and purchasing intention.

METHOD

Participants

Twenty-five participants (age range = 19–28, $M = 22.60$, $SD = 2.84$ years, 13 females) were recruited as paid volunteers. All were right-handed and had normal or corrected-to-normal vision. Written informed consent was given prior to participation. This study was approved by the ethics committee of Peking University.

Stimuli and Procedure

Fifty-six products (28 types of food and 28 objects; see Supporting Information for itemized list) were used for purchasing intention rating. Each product was exhibited

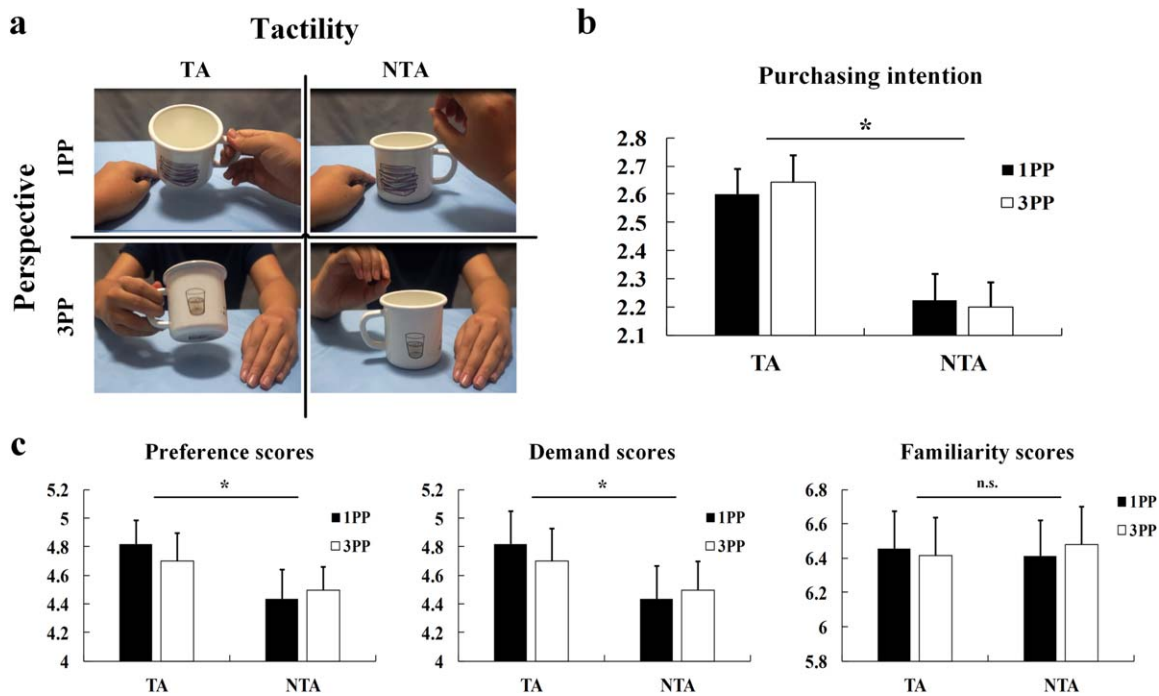


Figure 1.

(a) Example of one of the products shown in the touch (TA) vs. no-touch actions (NTA) in either 1PP or 3PP, which resulted in 4 conditions (TA-1PP, NTA-1PP, TA-3PP, NTA-3PP). Each product was randomly assigned to only one of the conditions for each subject. (b) behavioral results for purchasing intention in different conditions. (c) behavioral results for subjective rating

on preferences, demands and familiarity to the products in different conditions. Error bars represent standard error of the mean. TA: touch action; NTA: no-touch action; 1PP: first-person perspective; 3PP: third-person perspective; * $P < 0.05$. [Color figure can be viewed at wileyonlinelibrary.com]

with hand movements in a 3 seconds (s) video clip. A 2×2 factorial design with Tactility (touch action (TA) vs. no-touch action (NTA)) and Perspective (1PP vs. 3PP) was adopted in the current experiment. Tactility was manipulated by showing the stimulus hands touching or not touching the products, whereas perspective was manipulated by showing the actions in 1PP or 3PP (see Fig. 1a for an illustration). The 56 products were randomly assigned to 4 conditions (TA-1PP, NTA-1PP, TA-3PP, NTA-3PP) for each subject. Each product was shown only once to each subject, resulting in 14 trials in each condition. The results of the 2 (TA vs. NTA) \times 2 (1PP vs. 3PP) ANOVA on the market price of the products confirmed that the price of the products in 4 conditions were matched ($p_s > 0.4$).

hand (i.e., left-middle, left-index, right-index, right-middle). Participants had to press a button to make a judgment as to what extent they would like to buy the presented product (i.e., 1: not at all, 4: very much). After the button press, the corresponding choice number on the screen changed into green. Thereafter, a central fixation cross was presented for nine seconds, followed by the next trial.

The fMRI experimental procedure was designed in a slow event-related manner in 2 functional scans. For each trial, a 3s video clip ($4.2^\circ \times 2.7^\circ$) was presented on a black background at the center of the screen with the name of the product above the video to help participants recognize the product. In the sequence a 4-point Likert scale in white letters was presented for 3s. The four numbers (i.e., 1,2,3,4) on the screen corresponded to the four buttons present in two response boxes (2 buttons per response box). The four buttons were held by participants with two fingers of each

After the fMRI scanning, pictures of each product (without hand actions) were shown to the participants at the center of the screen. Participants were asked to rate their preference, demand and familiarity to each product using 8-point scales (1: not at all, 8: very much). Three of the eight buttons (1–8) were pressed successively as the rating scores of preference, demand and familiarity respectively.

fMRI Data Acquisition and Analysis

Brain images were acquired using a 3.0T GE Signa MR750 scanner (GE Healthcare; Waukesha, WI) with a standard head coil. Functional images were acquired by using T2-weighted, gradient-echo, echo-planar imaging (EPI) sequences sensitive to BOLD contrast ($64 \times 64 \times 32$ matrix with $3.75 \times 3.75 \times 5 \text{ mm}^3$ spatial resolution, repetition time = 2,000 ms, echo time = 30 ms, flip

angle = 90°, field of view = 24 × 24 cm). A high-resolution T1-weighted structural image (512 × 512 × 180 matrix with a spatial resolution of 0.47 × 0.47 × 1.0 mm³, repetition time = 8.204 ms, echo time = 3.22 ms, flip angle = 12°) was acquired before the functional scans.

Functional images were preprocessed using SPM12 (the Wellcome Trust Centre for Neuroimaging, London, UK). The functional data were first time corrected to compensate for delays associated with acquisition time differences between slices. Functional images were realigned to the first scan to correct for head movement between scans; six movement parameters (translation; x, y, z and rotation; pitch, roll, yaw) were extracted for further analysis in the statistical model. The anatomical image was co-registered with the mean realigned functional image and further normalized to the standard Montreal Neurological Institute (MNI) template. The functional images were resampled to 3 × 3 × 3 mm³ voxels, normalized to the MNI space using the parameters of anatomical normalization and then spatially smoothed using an isotropic of 8 mm full-width half-maximum (FWHM) Gaussian kernel.

Fixed effect analyses were first conducted by applying a general linear model (GLM) to the fMRI data. All four conditions (TA-1PP, NTA-1PP, TA-3PP, NTA-3PP) were included in the model with reaction time in each trial as a regressor of no interest (for a similar method see also Knutson et al. [2007]). The design matrix also included the realignment parameters to account for any residual movement-related effect. A box-car function was used to convolve with the canonical hemodynamic response in each condition. Whole-brain random effect analyses were then conducted on the contrast images of TA vs. NTA (collapsing 1PP and 3PP) to access the vicarious tactile neural responses regardless of visual perspective. The contrast values of TA vs. NTA were extracted (using MarsBaR: <http://marsbar.sourceforge.net>) for the brain regions that showed significant main effect of Tactility. The contrast values were correlated with the differential purchasing intention (TA vs. NTA) to link the brain activity with subjective purchasing intention. Apart from the between-subject correlations, we also extracted beta values for each trial to check whether the trial-wise brain activity in these brain regions was correlated with the purchasing intention for each product. After Fisher's *r* to *z* transformation, the correlation coefficients of brain activity and purchasing intention within each subject were subjected to one-sample *t*-tests to test whether the within-subject correlations were significantly different from zero in the group level.

To explore the effect of visual perspective while observing others' hand actions towards a product, similar analyses were conducted on the contrast images of 1PP vs. 3PP (collapsing TA and NTA) and on the contrast images of interaction between Tactility and Perspective (vector: TA-1PP: 1, TA-3PP: -1, NTA-1PP: -1, NTA-3PP: 1) to access the brain regions showing significant main effect of Perspective and its interaction with Tactility.

Following the identification of the brain regions sensitive to the interaction between tactility and visual perspective, we were also interested in how these regions connected with the brain regions sensitive to tactility and visual perspective respectively. Thus, we conducted generalized psychophysiological interaction analyses (gPPI) [McLaren et al., 2012] to find the brain regions that are functionally connected with the seed regions and modulated by tactility, visual perspective or their interaction. Seed regions are defined as spheres with 5-mm-radius, centered at coordinates of the peak voxels in the brain regions that showed significant Tactility × Perspective interaction across all participants. The time series of each seed region was extracted. The psychophysiological interaction regressors were calculated as the product of brain activity and a vector coding for each condition. The psychophysiological interaction regressors reflected the interaction between each psychological condition (TA-1PP, NTA-1PP, TA-3PP, NTA-3PP) and the activation of the seed regions. The functional connectivity images modulated by Tactility, Perspective, or Tactility × Perspective were subsequently subjected to one-sample *t*-tests to find the brain regions functionally connected with the seed regions. Finally, the beta values of the functional connectivity in different conditions were extracted and correlated with purchasing intention.

Brain activations in the whole brain analyses were defined using a threshold of $P < 0.05$ under false discovery rate (FDR) correction with single voxel threshold of $P < 0.001$.

RESULT

Behavioral Results

We calculated the self-reported purchasing intention in TA-1PP, NTA-1PP, TA-3PP and NTA-3PP conditions respectively. A 2 × 2 repeated measures analysis of variance (ANOVA) was conducted on the purchasing intention with Tactility (TA vs. NTA) and Perspective (1PP vs. 3PP) as within-subject variables. The results showed a significant main effect of Tactility ($F(1,24) = 17.389, P < .001, \eta^2 = .420$) with stronger purchasing intention for the products exhibited in the touch compared to no-touch condition (Fig. 1b). Consistent with our hypothesis, the vicarious tactility increased purchasing intention. However, neither the main effect of Perspective ($F(1, 24) = .030, P = .864, \eta^2 = .001$) nor the Tactility × Perspective interaction ($F(1, 24) = .422, P = .522, \eta^2 = .017$) were significant. A similar 2 × 2 ANOVA was conducted on the reaction times, however, neither the main effects nor the interaction were significant ($ps > .1$).

The post-scanning rating scores of preferences, demands and familiarity to the products were also subjected to 2 × 2 ANOVAs. Results showed that, for preferences and demands, the main effect of Tactility were significant (preferences: $F(1,24) = 7.777, P = .010, \eta^2 = .245$; demands: $F(1,24) = 8.341, P = .008, \eta^2 = .258$) with higher scores for TA products than NTA products (preferences: $P = .010$; demands: $P = .008$). Neither the main effect of Perspective

TABLE I. Brain activity and functional connectivity in different contrasts

Region	MNI Coordinates			Cluster Size	Peak Z
	X	y	z		
Brain activity					
TA vs. NTA					
Left SI/SII	-57	-25	32	1038	4.87
Left PMv	-60	5	32	311	4.76
Right SI/SII	63	-16	26	1202	5.65
Right PMv	57	8	32	a	5.72
Left LOC	-45	-70	-7	154	4.79
Right LOC	42	-64	-4	335	4.82
1PP vs. 3PP					
Left SPL	-24	-49	71	330	4.05
Left middle occipital gyrus (EBA)	-45	-70	5	110	4.58
Left superior occipital gyrus	-18	-85	20	101	4.19
Left precentral gyrus (M1)	-33	-10	56	75	4.07
Tactility × Perspective interaction					
Precuneus	-9	-61	47	341	4.03
Right inferior frontal gyrus	45	20	32	291	4.37
Supplementary motor area	3	26	47	112	3.65
Left medial frontal gyrus	-36	41	8	83	4.16
Functional connectivity with precuneus					
Tactile × Perspective interaction					
Left LOC	-48	-73	-10	85	3.69
Right LOC	54	-67	-13	76	3.50

a: the same cluster with right SI/SII. TA: touch action; NTA: no-touch action; 1PP: first-person perspective; 3PP: third-person perspective; PMv: ventral premotor cortex; SPL: superior parietal lobule; SI: primary somatosensory cortex; SII: secondary somatosensory cortex; EBA: extrastriate body area; M1: primary motor cortex; LOC: lateral occipital complex.

nor the Tactility × Perspective interaction were significant ($F_s < 1$, $p_s > .3$). For the familiarity rating scores, neither the main effects nor the interaction were significant ($F_s < 1$, $p_s > .4$) (Fig. 1c). These results suggest that vicarious tactile sensation not only increased purchasing intention, but also increased the subjective preferences and demands of the products. Moreover, we found the increased preference scores (TA vs. NTA) were correlated with the increased purchasing intention (TA vs. NTA) ($r(25) = .465$, $P = .019$), while the similar correlations were not found for demand or familiarity scores (demands: $r(25) = .315$, $P = .126$; familiarity: $r(25) = -.017$, $P = .935$).

fMRI Results

Whole-brain analysis on TA vs. NTA contrast revealed that, increased neural activities were found in MNS, i.e., bilateral primary and secondary somatosensory cortex (SI/SII) (left: $x/y/z = -57/-25/32$, $z = 4.87$, $k = 1,038$; right: $x/y/z = 63/-16/26$, $z = 5.65$, $k = 1,202$), and ventral premotor gyrus (PMv) (left: $x/y/z = -60/5/32$, $z = 4.76$, $k = 311$; right: $x/y/z = 57/8/32$, $z = 5.72$, $k = 1,202$). Similar neural responses were also found in lateral occipital complex (LOC, left: $x/y/z = -45/-70/-7$, $z = 4.79$, $k = 154$; right: $x/y/z = 42/-64/-4$, $z = 4.82$, $k = 335$) (Table I, Fig. 2a). Moreover, the activation of right PMv in TA vs. NTA was positively correlated with the differential purchasing intention

(TA minus NTA) ($r(25) = .496$, $P = .012$, Fig. 2b). Apart from the between-subject correlation, we were also interested in whether these vicarious activities in single trial were correlated with the purchasing intention for each product within-subject. Thus, for each subject, we extracted beta values for each product in bilateral MNS and LOC and correlated those with purchasing intention. After Fisher-z transformation, one-sample t -tests revealed significant (above zero) within-subject correlation coefficients in bilateral SI/SII (left: $t(24) = 2.536$, $P = .018$; right: $t(24) = 2.220$, $P = .036$) as well as in right PMv ($t(24) = 2.134$, $P = .043$), but not in left PMv ($t(24) = .907$, $P = .373$) or LOC (left: $t(24) = 1.638$, $P = .115$; right: $t(24) = 1.247$, $P = .224$). These results suggest that vicarious tactile experiences increased purchasing intention through the vicarious responses in bilateral MNS, which is consistent with our hypothesis.

To the effect of visual perspectives, similar whole-brain analysis on 1PP vs. 3PP was conducted first to test whether perspective taking would induce specific brain activity independent of tactility. The results showed that, compared with 3PP, stronger activation to 1PP was found in left superior parietal lobule (SPL, $x/y/z = -24/-49/71$, $z = 4.05$, $k = 330$), left extrastriate body area (EBA, $x/y/z = -45/-70/5$, $z = 4.58$, $k = 110$), left superior occipital gyrus (SOG, $x/y/z = -18/-85/20$, $z = 4.19$, $k = 101$) and left precentral gyrus (M1, $x/y/z = -33/-10/56$, $z = 4.07$,

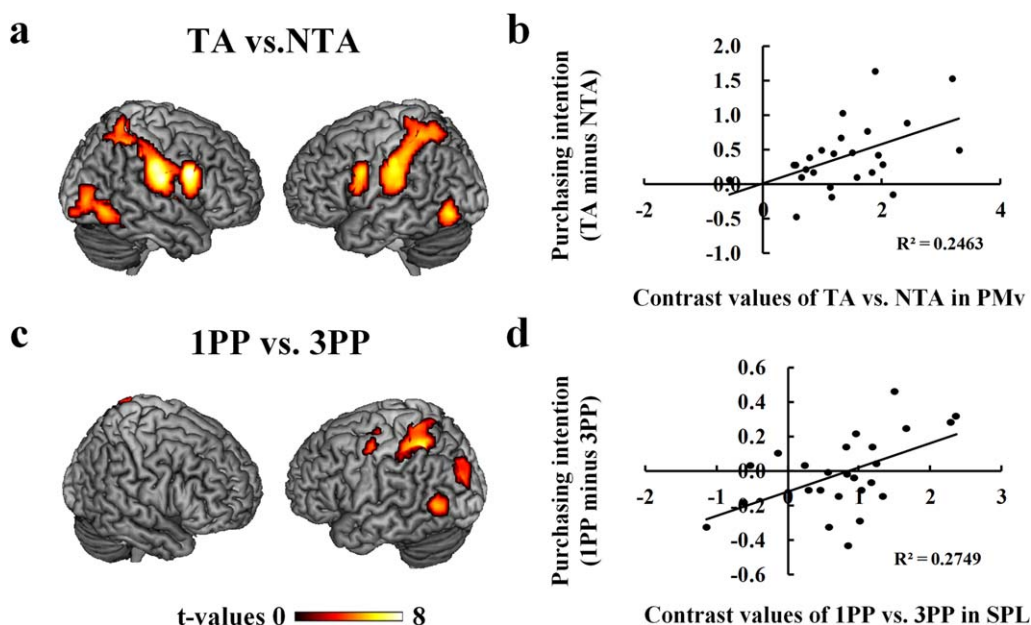


Figure 2.

(a) Brain regions activated during the observation of touch (TA) vs. no-touch actions (NTA). (b) Cross-subject correlation between contrast values of TA vs. NTA in PMv and the differential purchasing intention (TA vs. NTA). (c) Brain regions activated during observations in 1PP vs. 3PP. (d) Cross-subject correlation between contrast values of 1PP vs. 3PP in SPL and

the differential purchasing intention (TA vs. NTA). TA: touch action; NTA: no-touch action; 1PP: first-person perspective; 3PP: third-person perspective; PMv: ventral premotor cortex; SPL: superior parietal lobule * $P < 0.05$. [Color figure can be viewed at wileyonlinelibrary.com]

$k = 75$) (Table I, Fig. 2c). These left hemispheric activations in 1PP vs. 3PP were similar to previous findings [Ruby and Decety, 2001]. Although purchasing intention in 1PP and 3PP was not significantly different from one another, the contrast values of 1PP vs. 3PP in left SPL were positively correlated with the differential purchasing intention (1PP-3PP) ($r(25) = .524$, $P = .007$, Fig. 2d). The within-subject correlations between beta values in each trial and purchasing intention for each product were also significantly above zero in left SPL ($t(24) = 3.939$, $P = .001$) and M1 ($t(24) = 5.844$, $P < .001$) but not in left EBA ($t(24) = .633$, $P = .533$) or left SOG ($t(24) = .162$, $P = .873$). These results suggest that, although the 1PP did not increase purchasing intention significantly, stronger activation of the left SPL during 1PP observation (vs. 3PP) was correlated with stronger purchasing intention.

In addition, the effect of visual perspective was also modulated by tactility and resulted in significant Tactile \times Perspective interaction in precuneus ($x/y/z = -9/-61/47$, $z = 4.03$, $k = 341$) and other brain regions (Table I, Fig. 3a). Beta values in different conditions were extracted and showed that, in the TA condition, the activation of the precuneus was stronger in 3PP than in 1PP ($t(24) = 3.547$, $P = .002$), while the pattern was reversed in NTA condition ($t(24) = -2.375$, $P = .026$) (Fig. 3a). These results suggest that tactility modulated the effect of visual perspective.

Using the precuneus as a seed region, gPPI analyses showed that, the functional connectivity between precuneus and bilateral LOC (left: $x/y/z = -48/-73/-10$, $z = 3.69$, $k = 85$; right: $x/y/z = 54/-67/-13$, $z = 3.50$, $k = 76$) was also sensitive to Tactile \times Perspective interaction. The precuneus-LOC connectivity increased in 1PP compared with 3PP when observing touch actions, while a decreased connectivity in 1PP compared with 3PP was observed when tactile information was limited by no-touch actions (Fig. 3b). We calculated the differential purchasing intention (i.e., $(TA_{1PP} - NTA_{1PP}) - (TA_{3PP} - NTA_{3PP})$), and correlated it with brain activities that showed significant Tactility \times Perspective interaction. However, no significant correlations were found ($ps > 0.1$). Of note, the precuneus-LOC functional connectivity was positively correlated with purchasing intention for products in the TA condition, after collapsing 1PP and 3PP conditions (left: $r(25) = .424$, $P = .035$; right: $r(25) = .494$, $P = .012$), while the correlations were negative in NTA condition (left: $r(25) = -.498$, $P = .011$; right: $r(25) = -.493$, $P = .012$). To compare the correlation coefficients in TA and NTA conditions, bootstrap re-sampling approach [Lunneborg, 1985] was used to estimate the 95% confidence interval (CI) of each correlation coefficient (based on 1,000 bootstrap samples). The significant difference of the correlations between TA and NTA conditions was supported by the lack of overlapping

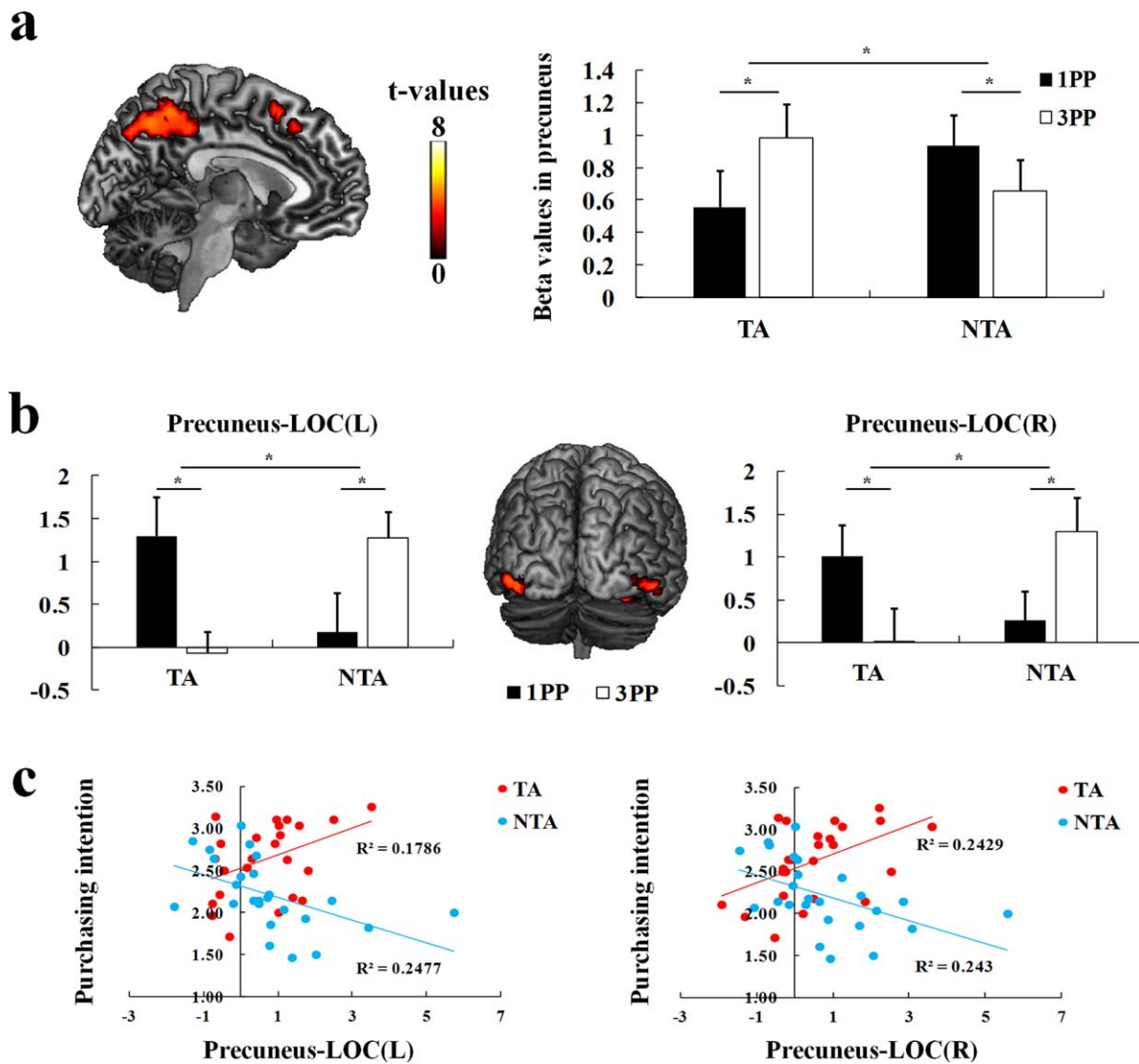


Figure 3.

(a) Brain regions showing significant tactile x perspective interaction and the beta values of different conditions in precuneus. (b) Brain regions functionally connected with precuneus and modulated by tactile x perspective interaction. Beta values of the precuneus-LOC functional connectivity in different conditions are also shown. (c) Cross-subject correlations between

95% CI of the correlation coefficients in the respective conditions (TA: left: 95% CI = [.007 .722]; right: 95% CI = [.127 .769]; NTA: left: 95% CI = [-.759 -.311]; right: 95% CI = [-.723 -.301]) (Fig. 3c). Similarly, the functional connectivity and purchasing intention correlations were calculated for 1PP and 3PP conditions respectively collapsing TA and NTA conditions. However, no significant correlation was found in 1PP or 3PP condition ($ps > 0.1$). Taken together, the effects of visual perspective on precuneus activity, precuneus-LOC connectivity and its association

precuneus-LOC functional connectivity and purchasing intention in TA and NTA conditions. TA: touch action; NTA: no-touch action; 1PP: first-person perspective; 3PP: third-person perspective; LOC: lateral occipital complex. $*p < 0.05$. [Color figure can be viewed at wileyonlinelibrary.com]

with purchasing intention were dependent on tactile accessibility. Similar gPPI analyses using other brain regions (i.e., brain regions showed significant Tactility x Perspective interaction) as seed regions did not show any functional connectivity with other brain regions that was significantly modulated by psychophysical interaction.

We also analyzed the data separately for food and objects. The results (both behavior and fMRI results) were quite similar for these two types of products. Therefore, we did not report the results of food and objects separately.

DISCUSSION

The current study investigated whether and how vicariously interacting with products through observing others' hand actions affect purchasing intention, and the effect of visual perspectives in this process. Participants observed others' hand actions towards a number of products, and rated their own purchasing intention during fMRI scanning. Behaviorally, the present study provided the first empirical evidence that, observing others touching a product significantly increased purchasing intention, as well as the subjective preference and demand of the product. At the neural level, the vicarious neural responses were found in bilateral PMv, SI/SII, and LOC. Moreover, the neural activities in PMv and SI/SII were associated with increased purchasing intention. Compared to 3PP, watching others' actions in 1PP activated SPL, EBA and M1 in left hemisphere. Although visual perspectives did not significantly increase purchasing intention, the neural activity in left SPL was associated with purchasing intention. In addition, tactility of the actions also modulated the effect of visual perspective. This modulation was manifested in precuneus activity and its functional connectivity with bilateral LOC. The increased precuneus-LOC functional connectivity was associated with increased purchasing intention when observing others' direct contact with the products, while the association was reversed when no tactile information was observed in others' actions.

Previous studies demonstrated that the PMv was the typical region showing vicarious neural activity for hand actions/motion [Iacoboni and Dapretto, 2006; Iacoboni et al., 1999; Molenberghs et al., 2012; Morin and Grezes, 2008], while the somatosensory regions such as SI and SII showed vicarious neural activity for tactile sensations [Ebisch et al., 2008; Gazzola and Keysers, 2009]. Our results showed that, observing actions of the "touch" condition (vs. no-touch) activated both PMv and SI/SII, suggesting that vicariously experiencing a product involved sensory-related activity for tactile sensations as well as motor-related activity for hand movements in bilateral MNS. These results are consistent with previous findings that the premotor and parietal network were preferentially active during object-directed actions, rather than during non-object-directed actions [Agnew et al., 2012]. Moreover, vicarious neural responses were positively correlated with self-reported purchasing intention. These neural activities in bilateral MNS indicate embodied mental simulation of others' hand actions and tactile sensations [Ando et al., 2015; Gallese, 2007, 2014; Grafton, 2009]. Such simulated experiences could have provided sensory information about the products, which helped increase participants' purchasing intention. The correlation between the increased purchasing intention and the increased preferences to the TA products (vs. NTA products) suggests that preference of the products might serve as the psychological mechanism behind of increase purchasing intention as function of tactile sensation.

However, this speculation of the psychological mechanisms underlying the effect of vicarious sensory experiences on purchasing intention needs to be tested in further research.

Furthermore, bilateral LOC was also activated when watching touch actions compared with no-touch actions. LOC is known as the central region for shape processing of graspable objects [Kourtzi and Kanwisher, 2001; Kourtzi et al., 2003], perceived through both visual and tactile modalities [Amedi et al., 2002]. On this ground, we propose two possible explanations for the activation of the LOC in our study. First, in contrast to no-touch condition in which the product was shown in front view, in the touch condition the product was seen from different angles. It is possible that LOC activation reflected visually shape processing through observing the products from different angles. The second explanation stems from the idea that, observing others touching the products may have activated the LOC to process the shapes through vicarious tactile sensations rather than a visual process. Visual perspective is a manipulation that may affect vicarious sensations [Canizales et al., 2013] but not visual angles of the products. Thus, if the sole cause of LOC activation in TA vs. NTA contrast was the variance of angles in which observers viewed the products (i.e., products were shown from different angles in TA vs. static front view in NTA condition), then LOC activity should not be sensitive to visual perspective. Given that we found that the functional connectivity of LOC and precuneus was modulated by the interaction of tactility and visual perspective (discussed below), we hold the latter explanation more plausible, that is, LOC activation was at least partially related to vicarious tactile sensations. Nevertheless, the current experimental design does not allow us to fully discriminate whether the LOC activation stems from seeing the products from different angles or from vicariously touching the products; an issue worth investigating in future research.

We also investigated the effect of visual perspectives during the observation of others touching the products. However, behaviorally, the effect of visual perspective on subjective purchasing intention was not significant. Whereas at the neural level, regardless of tactility, 1PP vs. 3PP activated SPL and EBA in left hemisphere. Moreover, the activation of the left SPL in 1PP vs. 3PP was associated with increased purchasing intention in 1PP vs. 3PP. Because the 1PP is congruent to "self" perspective and induces self-attribution of the observed actions or sensations, and the 3PP is more likely to attribute the actions or sensation to others, 1PP was more tightly coupled to MNS than 3PP for stronger mental imagery or simulation of the actions and sensations [Jackson et al., 2006]. The SPL, a core cite in MNS [Iacoboni et al., 1999; Molenberghs et al., 2012] was found to be responsible for motor imagery [Hanakawa et al., 2003]. The EBA was also found to be activated for motor imagery and self-generated body movements [Astafiev et al., 2004]. Thus, the stronger activation of left SPL and EBA suggest a stronger motor imagery or mental

simulation when observing actions in 1PP rather than 3PP. In addition, the left rather than right hemispheric activation in 1PP vs. 3PP was consistent with the findings in Ruby and Decety [2001]. Although the visual perspective did not show significant effect on subjective purchasing intention, we found that stronger activation of the left SPL was correlated with stronger purchasing intention. The correlation results suggest that, compared to 3PP, 1PP benefited purchasing intention through inducing left SPL activation for motor imagery.

The findings regarding tactility and visual perspective interaction in the precuneus, is in line with previous studies investigating perspective taking, that showed precuneus activation when participants incorporated an allocentric viewpoint, or engaged in external agency attribution [Farrer and Frith, 2002; Ruby and Decety, 2001; Sperduti et al., 2011; Vogeley et al., 2004]. For example, Ruby and Decety [2001] asked participants to imagine themselves (1PP) or another person (3PP) performing an object-directed action. The mental simulation in 3PP vs. 1PP activated precuneus, which was said to index the overactivation of self-representation to distinguish self from others in 3PP. In the present study, we found precuneus activation in 3PP vs. 1PP for touch actions, which is consistent with Ruby and Decety [2001]. The lack of precuneus activation during 1PP condition could have been caused by a 'blurred' self-other distinction, as 1PP is congruent with the visual perspective of observing self. Interestingly, we observed a reversed pattern of the precuneus activity in 3PP vs. 1PP when participants observed no-touch actions, thus suggesting that the role of self-other distinction in perspective taking depends on the expected tactile sensations of the action. In our study, vicarious tactile sensations of the products were important towards purchasing, as participants expected tactile contact with products following hand movements. Thus, it is possible that the unexpected lack of contact in the no-touch condition increased self-other distinction and precuneus activity.

In addition, the functional connectivity between precuneus and bilateral LOC also showed tactility x perspective interaction, with an opposite pattern of the activation of the precuneus. Given that the precuneus activity represented self-other discrimination [Kircher et al., 2002; Kjaer et al., 2002; Ruby and Decety, 2001], and LOC activity represented shape processing through tactile sensation [Reed et al., 2004], we speculate that the precuneus-LOC connectivity reflected tactile agency attribution to compensate for the decreased activation of precuneus. Moreover, the association between precuneus-LOC connectivity and purchasing intention was modulated by tactile accessibility. When tactile information was available (touch actions), stronger precuneus-LOC connectivity was associated with stronger purchasing intention, whereas when tactile information was limited (no-touch actions), stronger connectivity was associated with weaker purchasing intention. The results

concerning functional connectivity suggest that observing others touching the products increased purchasing intention not only through vicarious neural activities in MNS (i.e., PMv, SI/SII), but also through precuneus-LOC connectivity which might be related to agency attribution. Nevertheless, the speculation of the functional meaning of the precuneus and precuneus-LOC connectivity requires further investigation.

Of note, no reward-related brain regions were found between conditions in whole brain analysis. One possible reason may be that we only asked participants to rate their purchasing intention, not actually purchase the products or directly rate the extent to which they like/want the products. Up to now, neural mechanism of purchasing decision making has been rarely investigated. There is only one study conducted by Knutson et al. [2007] that showed that nucleus accumbens, insular and medial prefrontal cortex were activated during purchase-related decision making. The activation of nucleus accumbens was correlated with ones' preference for products but not with actual purchase decision. The insular and medial prefrontal cortex were activated for "gain-loss" calculation when the price information was given. For real consumption, price may dominate purchase decision. Thus, in order to obtain the pure effect of vicarious tactile experiences, we did not provide price information. Since price is essential for purchasing decision making and was not provided in our design, we measured purchasing intention instead. Although the relationship between purchasing intention and actual purchase has been shown to be modulated by factors such as the type of product [new vs. existing, durable vs. nondurable; Morwitz et al., 2007], self-reported purchasing intention has been widely used as a proxy measurement for purchase behavior [Chang and Wildt, 1994; Guido et al., 2010; Schlosser, 2003]. An interesting avenue for future research would be to investigate the effects of vicarious tactile experiences in real purchasing decision making towards items whose prices are also manipulated. It would be informative to assess whether the reward system is involved in this process.

One limitation of our study regards the small sample size, i.e., 25 subjects with their age ranging from 19 to 28 years, which might have limited our findings. There might be not enough power to detect effects that could survive conservative correction for multiple tests (i.e., correlation analyses) with a sample of 25 subjects. Thus, the significance of the correlations between purchasing intention and neural activities were reported without correction for multiple tests in different brain regions. In addition, future studies should test larger samples so that individual differences, i.e., gender, income, age, could also be investigated.

In conclusion, our study provided first empirical evidence that vicarious experiences (i.e., tactility) acquired while observing others touching products increased purchasing intention by increasing the neural activity in bilateral MNS. The effect of visual perspective was found in left SPL, and the interaction of tactility and visual

perspective was demonstrated in precuneus activity and precuneus-LOC connectivity. The precuneus-LOC connectivity was associated with purchasing intention but depended on the accessibility of tactility. Our findings help to understand how the human brain functions when a subject observes others' object-directed actions in the context of purchasing. What is more, it allows marketing researchers to develop more effective advertising strategies to stimulate consumption.

CONFLICT OF INTEREST

We have no conflicts of interest to declare.

REFERENCES

- Agnew ZK, Wise RJ, Leech R (2012): Dissociating object directed and non-object directed action in the human mirror system; implications for theories of motor simulation. *PLoS One* 7: e32517.
- Amedi A, Jacobson G, Hendler T, Malach R, Zohary E (2002): Convergence of visual and tactile shape processing in the human lateral occipital complex. *Cereb Cortex* 12:1202–1212.
- Ando A, Salatino A, Giromini L, Ricci R, Pignolo C, Cristofanelli S, Ferro L, Viglione JD, Zennaro A (2015): Embodied simulation and ambiguous stimuli: The role of the mirror neuron system. *Brain Res* 1629:135–142.
- Astafiev SV, Stanley CM, Shulman GL, Corbetta M (2004): Extrastriate body area in human occipital cortex responds to the performance of motor actions. *Nat Neurosci* 7:542–548.
- Canizales DL, Voisin JL, Michon PE, Roy MA, Jackson PL (2013): The influence of visual perspective on the somatosensory steady-state response during pain observation. *Front Hum Neurosci* 7:849.
- Chang TZ, Wildt AR (1994): Price, product information, and purchase intention: An empirical study. *J Acad Mark Sci* 22:16–27.
- Ebisch SJ, Perrucci MG, Ferretti A, Del Gratta C, Romani GL, Gallese V (2008): The sense of touch: Embodied simulation in a visuotactile mirroring mechanism for observed animate or inanimate touch. *J Cogn Neurosci* 20:1611–1623.
- Escalas JE (2004): Imagine yourself in the product: mental simulation, narrative transportation, and persuasion. *Journal of Advertising* 33:37–48.
- Farrer C, Frith CD (2002): Experiencing oneself vs another person as being the cause of an action: The neural correlates of the experience of agency. *Neuroimage* 15:596–603.
- Gallese V (2007): Embodied simulation: From mirror neuron systems to interpersonal relations. *Novartis Found Symp* 278: 3–12. discussion 12–19, 89–96, 216–221.
- Gallese V (2014): Bodily selves in relation: Embodied simulation as second-person perspective on intersubjectivity. *Philos Trans R Soc Lond B Biol Sci* 369:20130177.
- Gallese V, Keysers C, Rizzolatti G (2004): A unifying view of the basis of social cognition. *Trends Cogn Sci* 8:396–403.
- Gazzola V, Keysers C (2009): The observation and execution of actions share motor and somatosensory voxels in all tested subjects: Single-subject analyses of unsmoothed fMRI data. *Cereb Cortex* 19:1239–1255.
- Grafton ST (2009): Embodied cognition and the simulation of action to understand others. *Ann N Y Acad Sci* 1156:97–117.
- Guido G, Peluso AM, Provenzano M (2010): Influence of brand personality-marker attributes on purchasing intention: The role of emotionality. *Psychol Rep* 106:737–751.
- Hanakawa T, Immisch I, Toma K, Dimyan MA, Van Gelderen P, Hallett M (2003): Functional properties of brain areas associated with motor execution and imagery. *J Neurophysiol* 89: 989–1002.
- Iacoboni M, Dapretto M (2006): The mirror neuron system and the consequences of its dysfunction. *Nat Rev Neurosci* 7:942–951.
- Iacoboni M, Woods RP, Brass M, Bekkering H, Mazziotta JC, Rizzolatti G (1999): Cortical mechanisms of human imitation. *Science* 286:2526–2528.
- Jackson PL, Meltzoff AN, Decety J (2006): Neural circuits involved in imitation and perspective-taking. *Neuroimage* 31:429–439.
- Keysers C, Gazzola V (2009): Expanding the mirror: Vicarious activity for actions, emotions, and sensations. *Curr Opin Neurobiol* 19:666–671.
- Keysers C, Wicker B, Gazzola V, Anton JL, Fogassi L, Gallese V (2004): A touching sight: SII/PV activation during the observation and experience of touch. *Neuron* 42:335–346.
- Kilner JM, Friston KJ, Frith CD (2007): Predictive coding: An account of the mirror neuron system. *Cogn Process* 8:159–166.
- Kilner JM, Neal A, Weiskopf N, Friston KJ, Frith CD (2009): Evidence of mirror neurons in human inferior frontal gyrus. *J Neurosci* 29:10153–10159.
- Kircher TT, Brammer M, Bullmore E, Simmons A, Bartels M, David AS (2002): The neural correlates of intentional and incidental self processing. *Neuropsychologia* 40:683–692.
- Kjaer TW, Nowak M, Lou HC (2002): Reflective self-awareness and conscious states: PET evidence for a common midline parietofrontal core. *Neuroimage* 17:1080–1086.
- Knutson B, Rick S, Wimmer GE, Prelec D, Loewenstein G (2007): Neural predictors of purchases. *Neuron* 53:147–156.
- Kourtzi Z, Erb M, Grodd W, Bulthoff HH (2003): Representation of the perceived 3-D object shape in the human lateral occipital complex. *Cereb Cortex* 13:911–920.
- Kourtzi Z, Kanwisher N (2001): Representation of perceived object shape by the human lateral occipital complex. *Science* 293: 1506–1509.
- Krishna A (2012): An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. *J Consum Psychol* 22:332–351.
- Krishna A, Schwarz N (2014): Sensory marketing, embodiment, and grounded cognition: A review and introduction. *J Consum Psychol* 24:159–168.
- Lunneborg CE (1985): Estimating the correlation coefficient: The bootstrap approach. *Psychol Bull* 98:209–215.
- McLaren DG, Ries ML, Xu G, Johnson SC (2012): A generalized form of context-dependent psychophysiological interactions (gPPI): A comparison to standard approaches. *Neuroimage* 61: 1277–1286.
- Molenberghs P, Cunnington R, Mattingley JB (2012): Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neurosci Biobehav Rev* 36:341–349.
- Morin O, Grezes J (2008): What is “mirror” in the premotor cortex? A review. *Neurophysiol Clin* 38:189–195.
- Morwitz VG, Steckel JH, Gupta A (2007): When do purchase intentions predict sales? *Int J Forecast* 23:347–364.
- Peck J, Childers TL (2003): To have and to hold: The influence of haptic information on product judgments. *J Marketing* 67:35–48.
- Reed CL, Shoham S, Halgren E (2004): Neural substrates of tactile object recognition: An fMRI study. *Hum Brain Mapp* 21:236–246.

- Rizzolatti G, Craighero L (2004): The mirror-neuron system. *Annu Rev Neurosci* 27:169–192.
- Ruby P, Decety J (2001): Effect of subjective perspective taking during simulation of action: A PET investigation of agency. *Nat Neurosci* 4:546–550.
- Schaefer M, Xu B, Flor H, Cohen LG (2009): Effects of different viewing perspectives on somatosensory activations during observation of touch. *Hum Brain Mapp* 30:2722–2730.
- Schlosser AE (2003): Experiencing products in the virtual world: The role of goal and imagery in influencing attitudes versus purchase intentions. *J Consum Res* 30:184–198.
- Schutz-Bosbach S, Prinz W (2007): Perceptual resonance: Action-induced modulation of perception. *Trends Cogn Sci* 11: 349–355.
- Sperduti M, Delaveau P, Fossati P, Nadel J (2011): Different brain structures related to self- and external-agency attribution: A brief review and meta-analysis. *Brain Struct Funct* 216:151–157.
- Vandenbroucke S, Crombez G, Loeyes T, Goubert L (2015): Vicarious experiences and detection accuracy while observing pain and touch: The effect of perspective taking. *Atten Percept Psychophys* 77:1781–1793.
- Vogeley K, May M, Ritzl A, Falkai P, Zilles K, Fink GR (2004): Neural correlates of first-person perspective as one constituent of human self-consciousness. *J Cogn Neurosci* 16:817–827.
- Wolpert DM, Ghahramani Z, Jordan MI (1995): An internal model for sensorimotor integration. *Science* 269:1880–1882.
- Yoon S-J, Park JE (2012): Do sensory ad appeals influence brand attitude? *J Bus Res* 65:1534–1542.