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

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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.

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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

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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, surperior 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

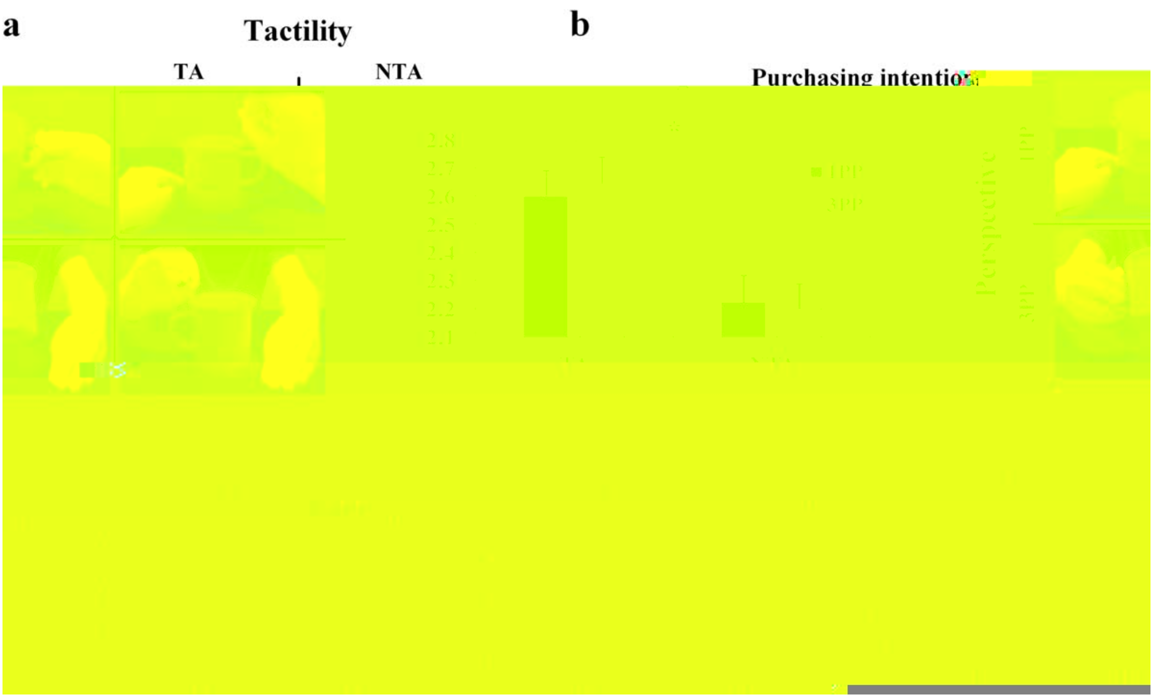

Figure 1.

*P < 0.0

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) × 2 (1PP vs. 3PP) ANOVA on the market price of the products confirmed that the price of the products in 4 conditions were matched ($ps > 0.4$).

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° × 2.7°) 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 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.

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 × 64 × 32 matrix with 3.75 × 3.75 × 5 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 mm^3, 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 mm^3 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 x 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 X	y	z	Cluster Size	Peak Z
B a ac					
TA . 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 . 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
Tac × Pe ec e e ac					
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
F c a c ec ec e					
Tac e × Pe ec e e ac					
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 x Perspective interaction were significant ($Fs < 1$, $ps > .3$). For the familiarity rating scores, neither the main effects nor the interaction were significant ($Fs < 1$, $ps > .4$) (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, $x/y/z = -33/–10/56$, $z = 4.07$,

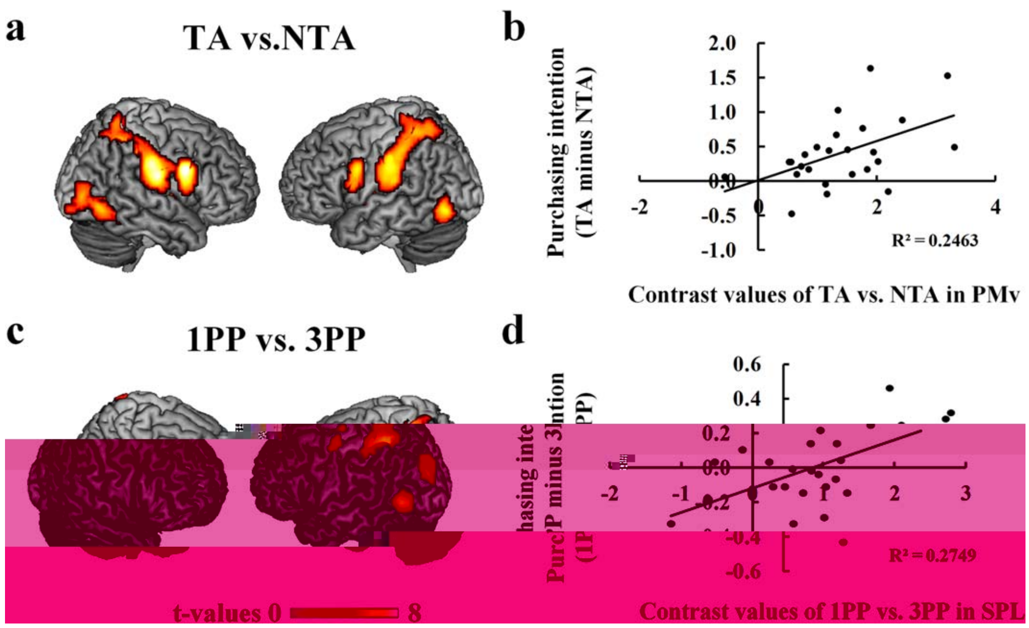

Figure 2.

[illegible]

$k = 75$) (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 x 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 x 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 × 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

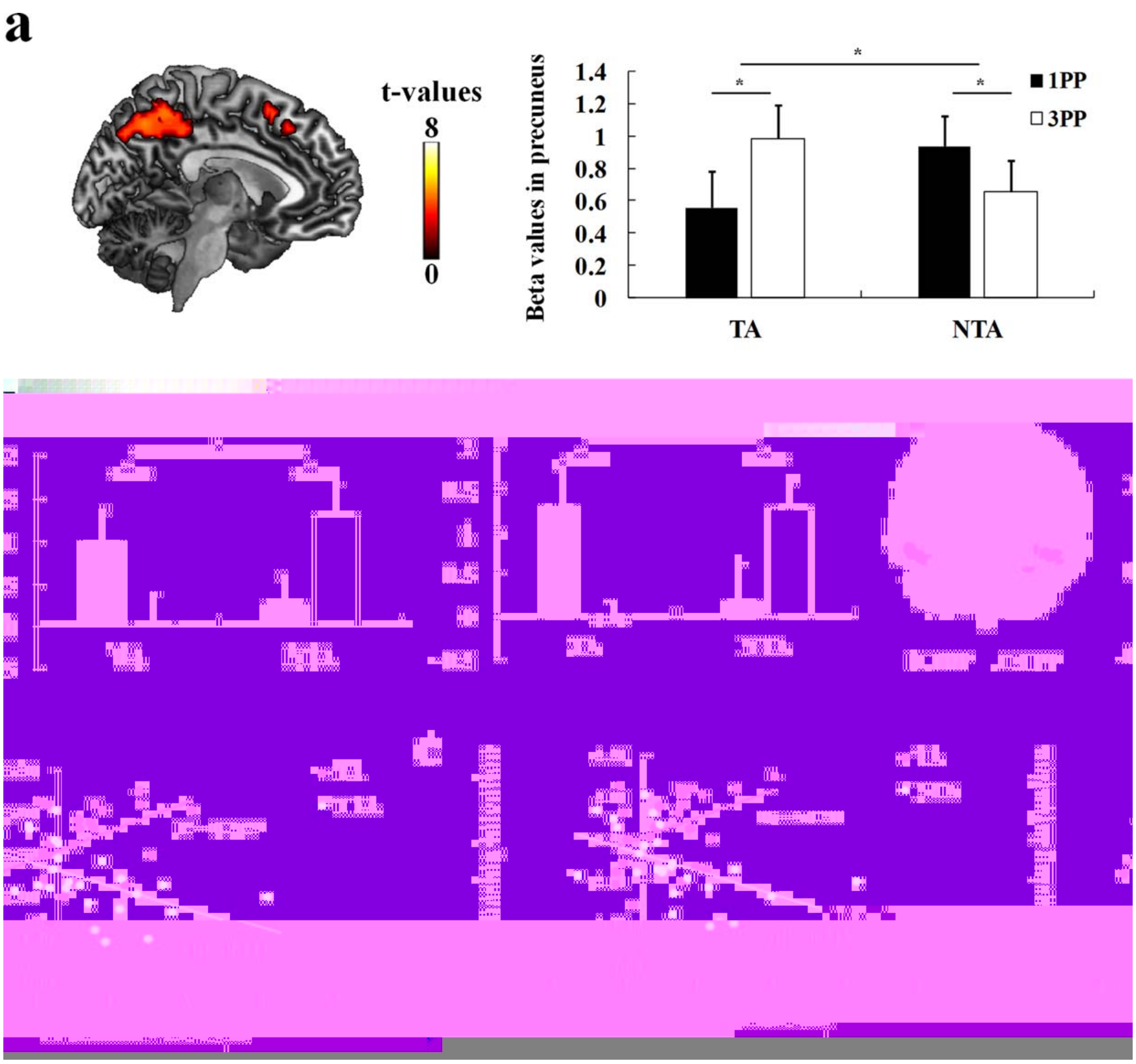

Figure 3.

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 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 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.

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