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Original Article

Neural evidence for cultural differences in the valuation of positive facial expressions

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Abstract

European Americans value excitement more and calm less than Chinese. Within cultures, European Americans value excited and calm states similarly, whereas Chinese value calm more than excited states. To examine how these cultural differences influence people's immediate responses to excited *vs* calm facial expressions, we combined a facial rating task with functional magnetic resonance imaging. During scanning, European American ($n = 19$) and Chinese ($n = 19$) females viewed and rated faces that varied by expression (excited, calm), ethnicity (White, Asian) and gender (male, female). As predicted, European Americans showed greater activity in circuits associated with affect and reward (bilateral ventral striatum, left caudate) while viewing excited *vs* calm expressions than did Chinese. Within cultures, European Americans responded to excited *vs* calm expressions similarly, whereas Chinese showed greater activity in these circuits in response to calm *vs* excited expressions regardless of targets' ethnicity or gender. Across cultural groups, greater ventral striatal activity while viewing excited vs. calm expressions predicted greater preference for excited *vs* calm expressions months later. These findings provide neural evidence that people find viewing the specific positive facial expressions valued by their cultures to be rewarding and relevant.

Key words: culture; emotion; ideal affect; reward; positive; expression; striatum

Introduction

People often immediately like and want to approach some people (or inferential 'targets'), but not others. Yet the factors that drive these rapid and often implicit reactions are far from clear. People generally like others that smile but dislike those that frown (Knutson, 1996; Oosterhof and Todorov, 2008; Gill *et al.*, 2014), suggesting that others' emotional facial expressions may play a role. But people may still have variable responses to different positive facial expressions, depending on whether they value the specific positive affective states being expressed. We sought to examine whether cultural differences in the valuation of excitement and other high arousal positive states *vs* calm and other low arousal positive states influence peoples' immediate responses to the excited *vs* calm facial expressions of others.

Although most people say that they want to feel good, people vary in terms of which 'good' states they ideally seek to experience. Affect Valuation Theory proposes that how people ideally want to feel (their 'ideal affect') can differ from how they actually feel (their 'actual affect'), and that culture shapes peoples' ideal affect more than their actual affect. Indeed, across a variety of cultural samples, ideal affect and actual affect can be distinguished, and although most people ideally want to feel more positive and less negative than they actually feel, cultures vary with respect to which specific positive states they value most (Tsai *et al.*, 2006). For instance, European Americans report wanting to feel excited, enthusiastic and other high arousal positive states more than Hong Kong Chinese, whereas Hong Kong Chinese report wanting to feel calm, relaxed and other low arousal positive states more than European Americans (Tsai

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et al., 2006). Within cultures, European Americans report valuing both high and low arousal positive states similarly, whereas Hong Kong Chinese report valuing low more than high arousal positive states. Notably, these cultural differences in ideal affect do not depend on group differences in actual affect or in temperament (Tsai et al., 2006), and are reflected in the content of diverse cultural products including women's magazines, children's storybooks, students' internet pages, and leaders' official photos (Tsai, 2007; Tsai et al., 2007; Tsai et al., in press; Huang and Park, 2013).

People further engage in diverse behaviors to achieve their ideal affect. For instance, people who value high arousal positive states are more likely to engage in high intensity exercise (Hogan et al., 2015) and to choose exciting *vs* calming consumer products (Sims et al., 2014; Tsai, Chim, and Sims, 2015). Ideal affect can also influence social judgments and preferences. For instance, the more people value high arousal positive states, the more likely they are to perceive excited *vs* calm physicians as trustworthy and knowledgeable, and the more likely they are to choose excited *vs* calm physicians to be their primary care provider (Sims and Tsai, 2015; Sims et al., 2014).

Research, however, has not yet explored *how* cultural differences in ideal affect might influence people's immediate responses to others' positive facial expressions. Consistent with Affect Valuation Theory, European Americans might find excited *vs* calm facial expressions more rewarding than Chinese (implicating cultural differences in affective processing). European Americans might also identify more with (i.e. view as more self-relevant) excited *vs* calm facial expressions than Chinese (implicating cultural differences in higher-order cognitive processing). It is also possible, however, that European Americans might simply pay more attention to excited *vs* calm expressions than Chinese (implicating cultural differences in attention to specific faces).

To examine the influence of culture on responses to positive facial expressions, we tracked activity of neural circuits implicated in reward/affect, value integration/identity and attention with functional magnetic resonance imaging (fMRI) while people viewed and rated targets with different positive facial expressions. At a basic level, viewing emotional facial expressions consistent with one's ideal affect might invoke anticipation of *reward* and positive affect. Since previous research has consistently implicated ventral striatal (VS) activity with reward anticipation and accompanying feelings of positive arousal (see Knutson and Greer, 2008 for review), we predicted that European Americans might show greater VS activity in response to excited *vs* calm expressions compared with Chinese. Mirroring ideal affect, within cultural groups, European Americans might show similar levels of VS activity in response to excited and calm expressions, whereas Chinese might show greater levels of VS activity in response to calm *vs* excited expressions. Moreover, this affective responsiveness might even override higher-order identity or social concerns (e.g. related to ethnicity and gender) (Hypothesis 1).

Cultural differences in ideal affect might also invoke higher-order concerns related to *value integration and self-relevance*. In contrast to the VS, which responds to anticipated rewards, medial prefrontal cortical (MPFC) activity has been implicated in value integration (across valences, attributes and options) as well as in consideration of one's own self (Knutson et al., 2005; van den Bos et al., 2007). Therefore, we predicted that MPFC activity might respond not only to targets' emotional facial expressions, but also to their ethnic identity, such that European Americans might show greater MPFC activity in response to excited White targets, while Chinese might instead show greater MPFC activity in response to calm Asian targets (Hypothesis 2).

Cultural differences in ideal affect might also influence whether people visually *attend* more to differentially expressive targets. Increased activity in the fusiform gyrus (FFG) has been associated with greater visual attention to faces (Kanwisher et al., 1997; Grill-Spector et al., 2004). Therefore, European Americans might show greater FFG activity in response to excited *vs* calm facial expressions relative to Chinese. Within cultural groups, European Americans might show similar FFG activity in response to excited and calm facial expressions, whereas Chinese might show greater FFG activity in response to calm *vs* excited facial expressions (Hypothesis 3).

Thus, this research targeted three specific neural circuits—the VS, MPFC and FFG—to determine whether reward/affective, value integration/self-relevance and/or attentional mechanisms could best account for cultural differences in immediate responses to excited *vs* calm facial expressions. To assess whether activity in these three circuits correlated with subsequent preferences, participants completed a facial preference task several months after scanning. We then examined whether activity in these three brain areas during scanning predicted later preference for excited *vs* calm facial expressions (Hypothesis 4).

Materials and methods

Participants

Twenty-two European American and 27 Chinese female undergraduate and graduate students (18–28 years old) from universities in the San Francisco Bay Area participated in a study titled 'Rating faces' for a flat fee of $30.00. We recruited only females, since cultural differences in ideal affect do not vary by gender (Tsai et al., 2006), and because we sought to maximize homogeneity within cultural groups given the already large number of tested variables and high cost of scanning.

To ensure that participants came from the targeted cultures of interest, *European American* participants were required to: (1) have been born and raised in the United States, (2) speak English as their primary language, (3) have parents who were born and raised in the United States and (4) have grandparents who were born and raised in the United States or a Western European country (e.g. England). *Chinese* participants were required to: (1) have been born and raised in China, Hong Kong, Taiwan or Singapore, and have moved to the United States or Canada after 18 years of age, (2) have lived in the United States for <5 years, (3) speak Chinese as their primary language and (4) have parents and grandparents who were born and raised in China, Hong Kong, Taiwan or Singapore. All participants were right-handed; none had neuropsychological symptoms or were taking any medication. Eleven participants were excluded from data analysis due to excessive head movement (>2 mm from one scan to the next) (one European American, five Chinese), software malfunction (one European American, two Chinese), missed responses (>15%) (one Chinese) and interrupted protocol (one European American). Excluded participants did not differ from included participants with respect to ideal affect.

Analyses were conducted on the remaining 19 European American and 19 Chinese participants, a sample size comparable to previous fMRI studies that compared cultural groups (*n*'s per cultural group ranged from 10 to 17, e.g. Chiao et al., 2008; Freeman et al., 2009). The cultural groups did not differ in age

(European American Mean = 21.63 years old, s.d. = 2.81, Chinese Mean = 22.79 years old, s.d. = 2.35, $t(36) = -1.38$, $p = 0.177$).

Instruments

Actual and ideal affect. To assess *actual* affect, participants completed the Affective Valuation Index (Tsai *et al.*, 2006), in which they used a rating scale ranging from 1 = *never* to 5 = *all the time* to indicate how often they 'actually felt' 28 affective states 'over the course of a typical week.' To assess *ideal* affect, participants then used the same rating scale to indicate how often they 'ideally wanted to feel' those same states over the course of a typical week. Given previously documented cultural differences in response styles (Chen *et al.*, 1995), we ipsatized actual affect items (i.e. calculated the overall mean and standard deviation for all actual affect items, subtracted this overall mean from each actual affect item and then divided the difference by the overall standard deviation), as in our previous work. We followed the same procedure for ideal affect items. We created actual and ideal high arousal positive affect aggregates [HAP] by averaging ipsatized ratings of actual and ideal *excited*, *elated*, *enthusiastic* and *euphoric* items, respectively (Cronbach's alpha for actual HAP = 0.64 for European Americans, 0.86 for Chinese, Cronbach's alpha for ideal HAP = 0.74 for European Americans, 0.65 for Chinese). Similarly, we created actual and ideal low arousal positive affect aggregates [LAP] by averaging ipsatized ratings of actual and ideal *calm*, *peaceful*, *relaxed* and *serene* items, respectively (Cronbach's alpha for actual LAP = 0.82 for European Americans, 0.88 for Chinese; Cronbach's alpha for ideal LAP = 0.77 for European Americans, 0.82 for Chinese).

Facial stimuli

Static faces were developed using the Facegen Modeler program (http://facegen.com) and framed in an oval keyhole. Faces varied by ethnicity (White, Asian), gender (male, female) and expression (no smile, low intensity smile, moderate intensity smile, high intensity smile), resulting in 16 different target groups (e.g. White female with high intensity smile). For each target group, we created three different faces, resulting in 48 different target faces in total. Sample faces and Facegen modeling parameters for each expression are provided in Supplementary Materials Section 1. Greater detail about the facial stimuli is available upon request. Because our hypotheses focused on excited *vs* calm expressions, we collapsed the four types of expressions into two categories: (1) 'calm expressions' (by aggregating responses to 'no smile' and 'low intensity' smiles) and (2) 'excited expressions' (by aggregating responses to 'moderate intensity' and 'high intensity' smiles). As reported below, analyses that distinguished across the four expressions yielded similar results to those that collapsed the four expressions into two expressive categories.

Facial Rating Task

We designed a Facial Rating Task to elicit neural responses related to reward, value integration/self-relevance and attention, while still requiring a behavioral response on each trial. Participants were presented with one face per trial, and then asked to use a scale ranging from 1 = *not at all* to 4 = *very* to rate either: (1) how good of a *leader* the presented target was, or (2) how *familiar* the presented target was, defined in terms of how close the target seemed to someone participants might see in everyday life. Each target face was presented twice—once with a leadership rating, and once with a familiarity rating—resulting in a total of 96 trials. The presentation order of each target face and question type was randomized for each participant. Although we were also originally interested in potential links between ideal affect and these specific social judgments, because results did not differ as a function of question type (see below), the ratings are not discussed further (more information about the ratings is provided in the Supplementary Materials Section 2).

Each trial began with a target face presented for 2 s. All facial stimuli (i.e. face and keyhole) were 640 × 640 pixels, presented in the center of a black screen on a 47″ LCD display, with a screen resolution of 1920 × 1080 p, and then projected to a 17.78 × 6.35 cm mirror with viewing distance of 15 cm from the eyes. Next, the 4-point scale appeared either with the word, 'LEADER?' or 'FAMILIAR?' to indicate which type of rating participants had to make for 4 s. If participants did not make their ratings within this 4-s window, the trial ended and was counted as 'missed.' The trial ended with a fixation interval that varied in length from 2 to 6 s, with an average of 4 s (Figure 1). Equal numbers of each inter-trial interval were evenly distributed across trial conditions and pseudorandomly ordered. To validate the Facial Rating Task, participants later completed a Facial Preference Task (described below) several months after the scanning session, and we then correlated neural activity during the Facial Rating Task with choices during the Facial Preference Task.

Procedure

Before scanning, participants practiced the Facial Rating Task with two faces that were not shown during the actual task. Participants then entered a 3.0-T General Electric Discovery MR750 scanner outfitted with a 32-channel head coil. Once inside, participants underwent 96 trials of the Facial Rating Task (total time = 16 min 20 s) while functional scans were acquired. Forty-six slices of gradient echo T2* weighted echo-planar images (EPI) provided whole brain coverage (axial acquisition from inferior to superior; interleaved EPI; repetition time, 2 s; echo time, 25 ms; flip angle, 77°; in-plane resolution and thickness, 2.9 mm; field of view = [232.0, 232.0]; acquisition matrix = [80, 80]; no gap between slices). Whole-brain T1-weighted structural scans were acquired next (repetition time, 7.2 ms; echo time, 2.8 ms; flip angle, 12°; in-plane resolution and thickness, 0.9 mm; field of view = [255.55, 230.0]; acquisition matrix = [256, 256]), as participants rested.

Immediately after scanning, participants were brought to a nearby testing room and rated the faces they saw in the scanner in terms of affect and various traits. Since those ratings are not the focus of this study, they are not discussed further. Finally, participants completed the Affect Valuation Index and were debriefed and compensated for their participation.

Facial Preference Task

Several months after the scanning session, participants were contacted via phone and/or email to participate in a follow-up Facial Preference Task, which was designed to measure participants' preference for excited *vs* calm facial expressions. On each trial, participants were presented with one face pair (i.e. two faces) and instructed to choose the face they preferred. The facial stimuli were the same 48 targets participants had previously viewed in the scanner. The two target faces in each pair were matched in terms of ethnicity and gender, but varied in terms of expression (no smile, low intensity smile, moderate

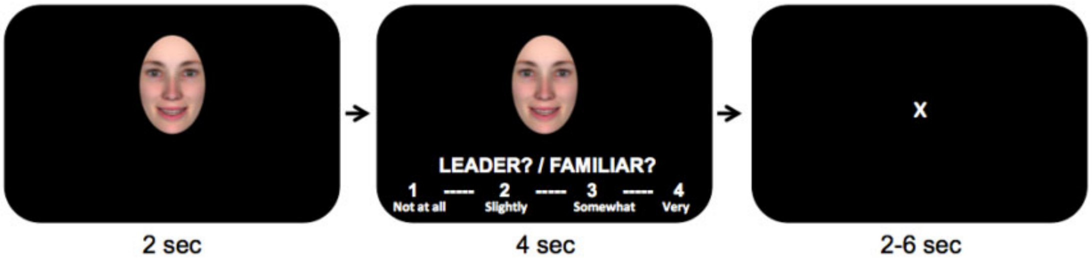

Fig. 1. Facial rating task trial structure.

intensity smile, high intensity smile). Each face pair was presented once, resulting in 24 trials. Sixteen out of 24 trials paired an 'excited' expression (moderate or high intensity smile) with a 'calm' expression (no smile or low intensity smile); the remaining eight compared two 'excited' expressions or two 'calm' expressions. Before beginning the task, participants also completed four practice trials with faces they had never encountered. Trial order was pseudorandomized, and target faces that appeared on the left and right sides were counterbalanced across participants.

At the beginning of each trial, two target faces were presented on either side of a central fixation point superimposed on a black screen for 1 s. Participants pressed the 'Q' or 'P' key if they preferred the left or right face, respectively. The chosen face was then presented in the center of the screen for an additional 2 s followed by a scrambled face presented for an additional 2 s. Finally, a black screen was presented for 1–2 s, with an average of 1.5 s, followed by a central fixation point, which was presented for 2 s. We calculated an average preference for excited *vs* calm faces score by coding choice of the excited face as 1, and choice of the calm face as 0, and then averaging across the excited *vs* calm choices for each participant. To validate preference measures derived from this Facial Preference Task, we also collected similar data on a separate sample of 45 European Americans and 48 Hong Kong Chinese participants who were not scanned.

fMRI data processing and analyses

Whole-brain analysis. Whole-brain analyses were conducted using Analysis of Functional Neural Images (AFNI; 2011_12_21_1014 version) software (Cox, 1996). The first six scans before the task were omitted to compensate for magnet stabilization. All other images were submitted to slice timing correction (using the first slice as reference), motion correction (using the 3rd volume as a reference and Fourier interpolation), spatial smoothing (with 4 mm full width at half maximum kernel), normalization to average percent signal change and high-pass filtering (omitting frequencies <0.01 Hz, as described in Wu *et al.*, 2014).

We constructed a general linear model (GLM, ordinary least-squares regression) including five orthogonal regressors of interest. The first regressor highlighted the first scan acquired during each trial, when faces were presented, but before the appearance of each question. Four additional regressors of interest contrasted different aspects of each face: (1) *ethnicity* (White = +1, Asian = −1), (2) *gender* (male = +1, female = −1), (3) *expression* (excited = 1, calm = −1) and (4) the *interaction* of expression and ethnicity. Eight regressors of no interest were also included: six regressors modeling head movement, one sampling white matter activity and one sampling cerebrospinal fluid activity (Chang and Glover, 2009). We included a regressor for question type (leader = +1, familiar = −1), but there were no significant main effects or interactions involving question type in the specific brain areas of interest, and therefore, we dropped it from the final model. We also ran a full model (see Supplementary Materials Section 3) that included the Target Expression × Target Gender and Target Ethnicity × Target Gender interactions. Because these interactions did not alter the findings, they were not included in the final model.

Before inclusion in the model, regressors of interest were convolved with a canonical gamma variate hemodynamic response kernel to approximate the hemodynamic delay (Cohen, 1997). General linear model *t*-statistic maps of regressors of interest were converted to Z-scores to enhance interpretability, coregistered with structural maps, spatially normalized by warping to Montreal Neurological Institute space (linear to colin27T1_seg template) and resampled as 2.9 mm cubic voxels. To compare European Americans and Chinese, we averaged and then contrasted European American and Chinese coefficient maps for each of the regressors of interest using between groups *t*-tests. These group contrasts were initially voxelwise thresholded (at $p < 0.005$) and then cluster thresholded (cluster size ≥13 continuous 2.9 mm cubic voxels) to yield corrected maps for detecting whole-brain activity ($p < 0.05$ corrected, derived with 10 000 Monte Carlo iterations using AFNI program 3dClustSim).

Volume-of-interest analyses. Volume-of-interest (VOI) analyses were then conducted to confirm and clarify the findings from the whole-brain analyses. Spherical VOIs (8 mm diameter) based on contrast maps were centered on bilateral MNI coordinates in the VS (Right VS: 13, 4, −7, Left VS: −22, 4, −3), left caudate (−13, 10, 10) and medial prefrontal cortex (−7, 46, −8; similar to foci described in Knutson *et al.*, 2005). To verify that VOIs included gray matter in the target regions in both groups, VOI masks were warped back into native space, superimposed on each participant's brain and then visually inspected. Percentage signal change was averaged within each VOI, and then activity timecourses were extracted for 20 s following the onset of each face, and averaged for calm *vs* excited target conditions. Measures of peak activity were lagged by 4 s to account for the hemodynamic response. Peak activity was then submitted to repeated measures analyses of variance, followed by *post hoc* comparisons when appropriate.

Results

Do European Americans and Chinese differ in ideal affect and actual affect?

Pairwise comparisons revealed that Chinese participants valued low arousal positive affect more than European Americans

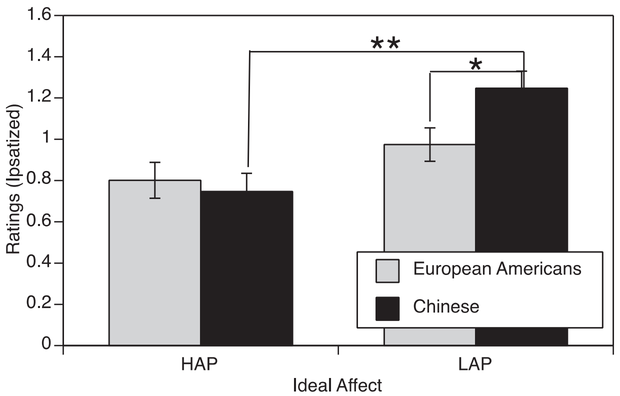

Fig. 2. Group differences in ideal affect. HAP, high arousal positive states; LAP, low arousal positive states. Asterisks indicate significance of simple effects, $^{**}p < 0.01$, $^{*}p < 0.05$.

(European American Mean = 0.97, SE = 0.08; Chinese Mean = 1.25, SE = 0.08, $t[35] = -2.36$, $p = 0.024$). Although European American participants appeared to value high arousal positive affect slightly more than Chinese, this difference was not significant (European American Mean = 0.80, SE = 0.09; Chinese Mean = 0.75, SE = 0.09, $t[35] = 0.43$, $p = 0.667$). Furthermore, as in previous research, Chinese participants valued low significantly more than high arousal positive affect (Ideal LAP Mean = 1.25, SE = 0.08; Ideal HAP Mean = 0.75, SE = 0.09, $t[17] = -3.08$, $p = 0.007$), whereas European Americans valued low and high arousal positive affect comparably (Ideal LAP Mean = .97, SE = 0.08; Ideal HAP Mean = 0.80, SE = 0.09, $t[18] = -1.26$, $p = 0.225$; Figure 2). Similar analyses revealed no significant main effect of Culture on actual affect. Because of the small sample size, we did not control for actual affect when testing ideal affect or the converse, but the pattern of results remained similar after implementing these controls.

Thus, previously documented cultural differences in ideal affect emerged in this study, such that Chinese valued low arousal positive affect more than European Americans, and also valued low more than high arousal positive affect. In contrast, European American valued low and high arousal positive affect to similar degrees. Contrary to previous findings, however, European Americans and Chinese did not differ in their valuation of high arousal positive affect—perhaps because this sample included Chinese who had elected to study and live in the United States and therefore may have placed higher value on high arousal positive affect prior to arriving in the United States. Alternatively, although the Chinese students had spent at most 5 years in the United States, they might have already begun to value higher arousal positive affect to a similar extent as their European American counterparts.

Hypothesis 1: Do European Americans show greater VS activity in response to excited *vs* calm facial expressions than Chinese?

Consistent with Hypothesis 1 (Table 1), whole-brain analyses revealed significant group differences in the expression contrast in the bilateral VS, including the right nucleus accumbens (NAcc) and left putamen. A similar pattern was also observed in the left caudate. Specifically, European Americans showed greater activity in these areas in response to excited *vs* calm facial expressions than Chinese (Figure 3, top left). Interactions between target expression and target ethnicity or target gender were not associated with VS or left caudate activity.

To further decompose these effects, we examined neural responses to excited *vs* calm facial expressions separately in European Americans and Chinese participants (VS activity shown in Figure 3; left caudate activity depicted in Supplementary Materials Section 4). Whereas European American participants' activity in these regions did not vary between expressions (Figure 3, top middle), Chinese participants showed decreased VS and caudate activity in response to excited *vs* calm expressions (Figure 3, top right). This pattern of results mirrored the ideal affect self-report data, in which European Americans valued high and low arousal positive affect to similar degrees, but Chinese valued low more than high arousal positive affect.

VOI analyses were then conducted to confirm and clarify whole brain results. Peak activity in the specific regions of interest (bilateral VS and left caudate) was submitted to 2 (Participant Culture: European American, Chinese) × 2 (Target Expression: Excited, Calm) repeated measures of analyses of variance, with participants' culture as a between-subject factor and target expression as a within-subject factor.

There was a significant main effect of Target Expression on bilateral VS activity when participants viewed faces ($F(1,36) = 10.40$, $p = 0.003$, partial $\eta^2 = 0.22$), but this was qualified by a significant Participant Culture × Target Expression interaction ($F(1,36) = 4.90$, $p = 0.033$, partial $\eta^2 = 0.12$). Pairwise comparisons revealed that European Americans showed marginally significant reduced VS activity in response to calm facial expressions compared with Chinese ($p = 0.104$, 95% CI [−0.087, 0.008]); the two groups, however, did not differ in VS response to excited facial expressions. Chinese, however, did show less VS activity in response to excited targets ($M = -0.07$, SE = 0.01) than to calm targets ($M = -0.01$, SE = 0.02, $p < 0.001$, 95% CI [−0.091, −0.028]), whereas European Americans did not differ in their VS responses to calm ($M = -0.05$, SE = 0.02) *vs* excited targets ($M = -0.06$, SE = 0.01, $p = 0.480$, 95% CI [−0.02, 0.04]. Again, this pattern mirrored cultural differences in ideal affect.

A similar pattern of findings emerged for left caudate activity. There was a marginal main effect of Target Expression ($F(1,36) = 3.69$, $p = 0.063$, partial $\eta^2 = 0.09$) that was qualified by a significant Participant Culture × Target Expression interaction ($F(1,36) = 7.64$, $p = 0.009$, partial $\eta^2 = 0.18$). Pairwise comparisons revealed that European American participants showed less left caudate activity in response to calm expressions than Chinese ($p = 0.046$, 95% CI [− .084, −0.001]), but that left caudate activity did not differ between groups in response to excited expressions. Moreover, Chinese participants showed less left caudate activity in response to excited expressions compared with calm expressions ($p = 0.002$, 95% CI [−0.088, −0.021]), whereas European Americans did not differ in left caudate activity in response to calm and excited expressions (see Supplementary Materials Section 4).

Consistent with Hypothesis 1 and cultural differences in ideal affect, European American participants showed greater activity in the VS and left caudate in response to excited *vs* calm expressions than did Chinese. This difference held across target ethnicity and gender, and was primarily driven by the neural responses of the Chinese participants, who showed a reduction in activity in VS and left caudate regions in response to excited *vs* calm expressions. Although these analyses focused on brain activity during face viewing only, similar results were obtained when subjects viewed the face with the rating question.

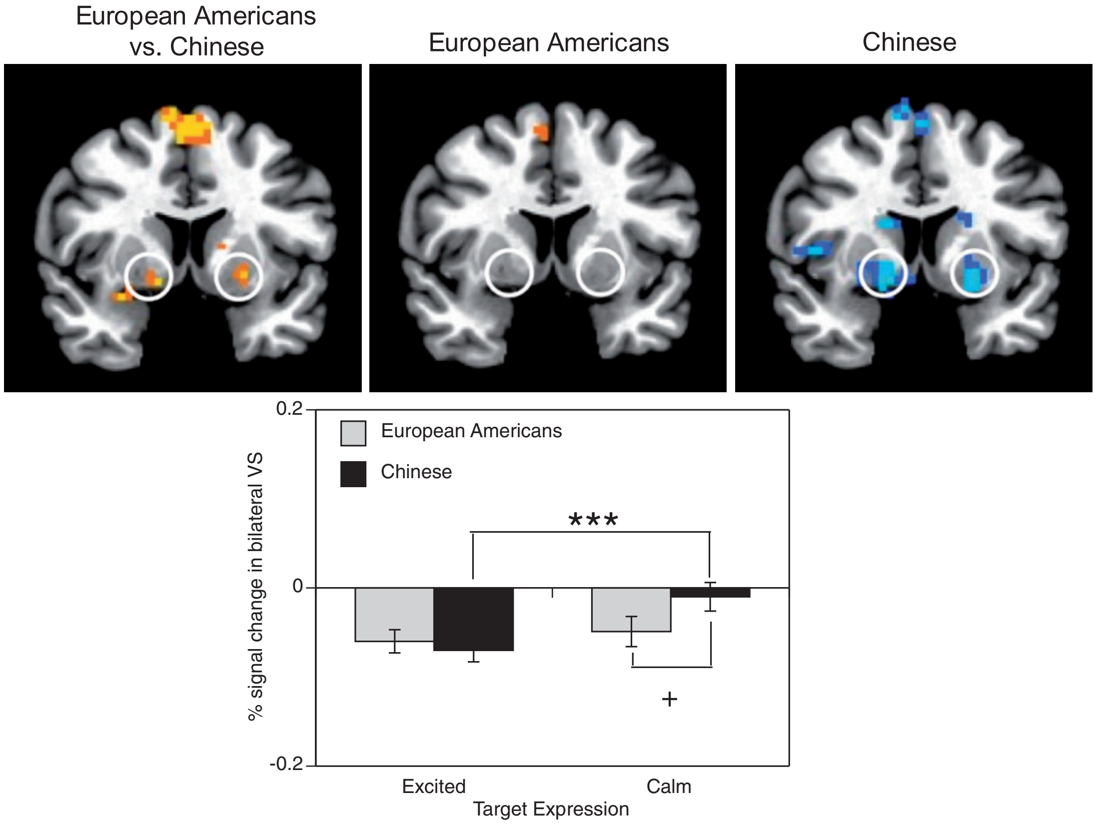

Fig. 3. Ventral striatal (VS) activity in response to excited *vs* calm expressions for European Americans *vs* Chinese (top left), European Americans only (top middle) and Chinese only (top right). VOI percent signal change in bilateral VS by cultural group and target expression (bottom). Asterisks indicate significance of simple effects, $^{***}p < 0.001$, †$p < 0.10$. Warmer colors indicate positive association; cooler colors indicate negative association (thresholded at $p < 0.005$ uncorrected, cluster ≥13 voxels, $p < 0.05$ corrected).

Hypothesis 2: Do European American participants show greater MPFC activity in response to White excited targets, while Chinese show greater MPFC activity in response to Asian calm targets?

As predicted (Table 1), analyses revealed a significant Target Ethnicity by Target Expression interaction for MPFC activity. Further analyses suggested that this difference was primarily driven by MPFC activity in the Chinese group (Figure 4, top right).

To decompose the effect, we conducted a 2 (Participant Culture: European American, Chinese) × 2 (Target Ethnicity: White, Asian) × 2 (Target Expression: Excited, Calm) repeated measures ANOVA on peak activity in the MPFC. There was a significant Target Ethnicity × Target Expression interaction, $F(1,34) = 4.42$, $p = 0.043$, partial $\eta^2 = 0.12$, that was further qualified by a significant Participant Culture × Target Ethnicity × Target Expression interaction, $F(1,34) = 6.83$, $p = 0.013$, partial $\eta^2 = 0.17$. To decompose the interaction, we conducted a repeated measures ANOVA on MPFC activity. Participant Culture was treated as a between subjects factor; Target Ethnicity and Target Expression were treated as within subjects factors. European American participants did not differentiate among White or Asian excited *vs* calm targets (all p's > 0.357); however, Chinese showed greater MPFC activation in response to Asian calm targets ($M = 0.16$, $SE = 0.06$) than Asian excited targets ($M = -0.05$, $SE = 0.04$, $p = 0.001$, 95% CI [−0.33, −0.10]), White calm targets ($M = -0.10$, $SE = 0.05$, $p = 0.002$, 95% CI [−0.41, −0.10]) and White excited targets ($M = 0.00$, $SE = 0.04$, $p = 0.014$, 95% CI [−0.29, −0.03]) (Figure 4, bottom).

Thus, observed MPFC activity partially supported Hypothesis 2, with Chinese participants showing greater MPFC activity in response to Asian calm targets. European Americans, however, did not show the predicted greater MPFC activity in response to White excited targets.

Hypothesis 3: Do European Americans show greater FFG activity in response to excited vs. calm expressions than Chinese?

Contrary to this hypothesis, groups did not show FFG activity that correlated with either the Target Expression main effect or Target Expression × Target Ethnicity interaction, suggesting an absence of cultural differences in perception of and attention to excited *vs* calm expressions. Thus, although the task elicited FFG activity in responses to faces across participants, there were no cultural differences in the magnitude of that activity.

The findings for bilateral VS, left caudate, MPFC and FFG were confirmed with hierarchical linear modeling, which accounts for within person variation (see Supplementary Materials Section 5). Similar findings also emerged when we conducted whole-brain and VOI analyses on all four types of expressions (see Supplementary Materials Sections 6–8).

While not predicted, whole brain analyses also revealed significant cultural group differences in superior frontal gyrus

Table 1. Activation foci from contrast of whole brain activity for European American vs Chinese groups

Region	x	y	z	Peak Z	Voxels
Target expression					
L SFG	−4	7	64	4.933	207
R VS (R NAcc)	**13**	**4**	**−7**	**3.483**	**23**
L middle frontal gyrus	−25	−8	56	4.113	21
L SFG	−22	42	31	3.626	19
L caudate	**−13**	**10**	**10**	**3.243**	**16**
L VS (L putamen)	**−22**	**4**	**−3**	**3.720**	**14**
Target Expression × Target Ethnicity					
MPFC	**−7**	**46**	**−8**	**−4.132**	**31**
R postcentral gyrus	48	−24	37	4.072	15
R postcentral gyrus	36	−31	36	3.951	15
Target Ethnicity					
L precuneus	−10	−68	53	3.534	19
R precentral gyrus	45	−4	50	3.611	16
R medial frontal gyrus	19	−5	56	3.256	16
R insula	30	−23	14	4.201	13
Target gender					
L superior temporal gyrus	−58	−59	12	−4.297	169
L precentral gyrus	−36	8	39	−4.460	44
R middle temporal gyrus	42	−63	28	−3.716	37
R middle temporal gyrus	63	−53	4	−4.165	34
L precentral gyrus	−42	−11	50	−3.532	26
R middle frontal gyrus	36	14	36	−3.531	23
L medial frontal gyrus	−1	−12	69	−3.375	19
L paracentral lobule	−19	−44	51	−3.605	19
L middle frontal gyrus	−45	17	26	−3.822	16
L posterior cingulate gyrus	−1	−30	30	−3.292	15
Face presentation					
L postcentral gyrus	−25	−35	65	−4.326	208
R middle frontal gyrus	42	−1	47	−4.598	205
L culmen	−19	−45	−34	−4.477	181
R postcentral gyrus	19	−35	61	−4.972	160
L cingulate gyrus	−1	−10	46	−4.235	140
R brain stem	4	−22	−16	−3.724	85
L anterior cingulate	−4	16	−6	−4.022	76
R culmen	22	−40	−30	−3.874	58
L parahippocampal gyrus	−22	−25	−12	−4.253	55
R anterior cingulate	10	31	8	−4.043	48
L culmen	−7	−50	1	−3.647	46
R postcentral gyrus	52	−19	49	−3.461	36
L precuneus	−7	−57	35	−4.033	32
L anterior cingulate	−10	30	11	−4.245	31
L precentral gyrus	−42	−4	31	−3.523	28
R insula	36	−24	17	−3.435	26
R putamen	30	−16	−8	−3.306	25
R thalamus	10	−16	−5	−3.417	23
L anterior cingulate	−1	40	14	−3.745	22
R thalamus	19	−32	10	−3.685	21
L postcentral gyrus	−45	−25	52	−3.139	15
R precuneus	19	−60	22	−3.545	13

Note Voxelwise $p < 0.005$ uncorrected, cluster corrected $p < 0.05$, minimum cluster size 13 $2.9 \times 2.9 \times 2.9$ mm^3 continuous voxels; x = right; y = anterior; z = superior in Montreal Neurological Institute coordinate space; bold indicates activation of a predicted VOI.

(SFG) activity (Table 1). Separate group analyses revealed that European Americans showed greater SFG activity in response to excited *vs* calm expressions, whereas Chinese showed less SFG activity in response to excited *vs* calm expressions. Since these findings were not initially predicted, this difference in neural activity deserves further scrutiny in follow-up studies.

Hypothesis 4: Does VS or MPFC activity during the Facial Rating Task predict preferences for positive facial expressions months later?

Fourteen European Americans and 15 Chinese participants completed a follow-up facial preference task several months after the scanning session (Mean = 21.81 months, s.d. = 7.97 months, Range = 6.30–29.73 months). The other nine participants did not respond to subsequent email messages or phone calls.

To examine whether there were cultural differences in preference for the more excited *vs* more calm expressions within each pair, we calculated the average proportion of times participants chose the more excited *vs* more calm expression across the trials. Although the means were in the predicted direction, there were no significant cultural differences in preference for excited *vs* calm expressions (European American Mean = 0.62, SE = 0.07; Chinese Mean = 0.55, SE = 0.06, $t[27] = 0.74$, $p = 0.463$), perhaps due to our relatively small sample size. Indeed, administration of the Facial Preference Task to a separate sample of 45 European American university students and 48 Hong Kong Chinese university students living in China indicated that European Americans preferred excited *vs* calm expressions significantly more than Hong Kong Chinese (European American Mean = 0.62, SE = 0.03; Hong Kong Chinese Mean = 0.50, SE = 0.03, $t[91] = 2.63$, $p = 0.010$). Specifically, whereas European Americans preferred excited *vs* calm expressions at greater than chance levels (0.50), $t(44) = 3.61$, $p = 0.001$, 95% CI [0.56, 0.68], Hong Kong Chinese did not, $t(47) = 0.16$, $p = 0.877$, 95% CI [0.45, 0.56] (See Supplementary Materials Section 9). Together, these findings support cultural differences in preference for excited *vs* calm expressions, but also suggest that power to detect such an effect in the neuroimaging sample was low.

Next, we examined whether neural activity during the Facial Rating Task could predict choice during the later Facial Preference Task. Since cultural groups did not differ in FFG activity, we focused on VS and MPFC activity. As predicted, greater bilateral VS activity in response to excited *vs* calm face presentation correlated with choice of excited *vs* calm expressions months later, $r = 0.35$, one-tailed $p = 0.030$, one-sided 95% CI [0.05, 1.00] after 1000 bootstrapped samples. Moderation analyses revealed that these findings held across cultural groups and were not diminished after controlling for the amount of time that elapsed between scanning and the Facial Preference Task. MPFC activity, however, did not correlate with subsequent choice (all one-tailed p's > 0.301). Thus, across cultural groups, greater VS activity in response to excited *vs* calm expressions predicted preference for excited *vs* calm expressions several months later.

Does the Facial Rating Task elicit neural responses in predicted regions?

We predicted that aspects of the Facial Rating Task would activate brain regions relevant to reward/affect, value integration/self-relevance and visual attention. To validate that these neural responses were relevant to the predicted constructs, we compared our findings with the Neurosynth database, which summarizes associations between localized brain activity and terms used over hundreds of neuroimaging studies (Yarkoni *et al.*, 2011). The main effect of Target Expression contrasted between cultural groups differentially activated foci in the VS (MNI: 13, 4, −7), which has been associated with 'reward' (posterior probability of 0.88). The Target Expression by Target Ethnicity interaction contrasted between cultural groups differentially activated foci in the

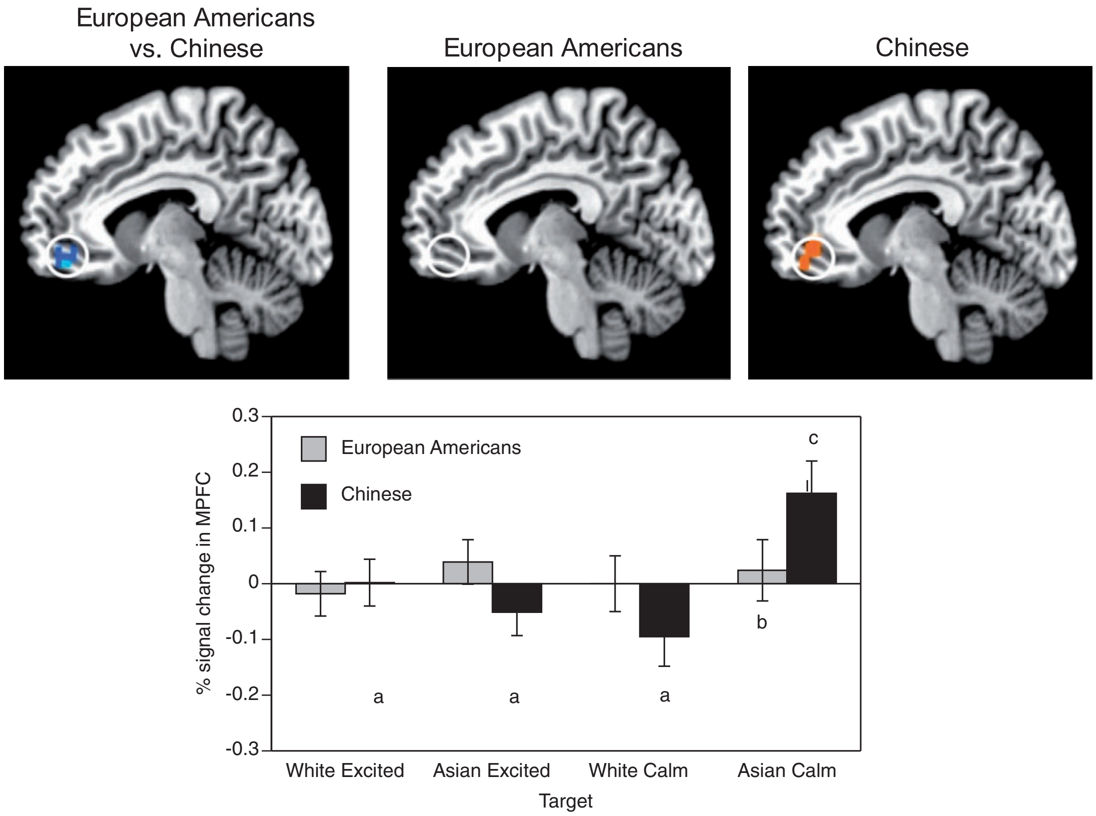

Fig. 4. Medial prefrontal cortical (MPFC) activity in response to White and Asian excited *vs* calm targets for European Americans *vs* Chinese (top left), European Americans only (top middle) and for Chinese only (top right). VOI percent signal change in MPFC by cultural group, target expression and target ethnicity (bottom). Different letters indicate significant differences at $p < 0.05$ (see text for precise significance levels for each pairwise comparison). Warmer colors indicate positive association; cooler colors indicate negative association (thresholded at $p < 0.005$ uncorrected, cluster ≥13 voxels, $p < 0.05$ corrected).

medial prefrontal cortex (MNI: −7, 46, −8), which has been associated with 'self' (posterior probability of 0.72), 'self referential' (posterior probability of 0.81) and 'reward' (posterior probability of 0.70). The main effect of viewing faces activated foci in the right (MNI: 36, −44, −20) and left (MNI: −36, −46, −21) fusiform gyri, which have been associated with 'face' (posterior probabilities of 0.84 and 0.77, respectively). These mappings suggested that task components activated brain regions associated in previous studies with reward/affect, value integration/self-relevance and visual attention to faces.

The role of individual differences in ideal affect

Although this study lacked sufficient power to examine individual differences in ideal affect, given the implications of Affect Valuation Theory and consistency with the neural results, we explored whether valuing low arousal positive states (ideal LAP) was correlated with bilateral VS activity in response to excited *vs* calm facial expressions and preference for excited *vs* calm facial expressions among the subsample of participants who provided choice data ($n = 29$). Because there were no cultural group differences in valuing high arousal positive states (ideal HAP), we did not examine links between ideal HAP, bilateral VS activity, and preference. Ideal LAP collected after the preference task was negatively correlated with bilateral VS activity in response to excited *vs* calm expressions when participants saw the faces ($r = -0.436$, $p = 0.02$). These findings are consistent with the notion that individuals who ideally wanted to feel low arousal positive affect more found excited *vs* calm faces less rewarding. Ideal LAP was also directionally negatively correlated with preference for excited *vs* calm faces ($r = -0.10$, $p = 0.610$), but this association was not significant. Given the small sample size typical of neuroimaging studies, this correlation may have been underpowered. Future research with larger samples will need to test further predictions about individual differences in ideal affect.

Discussion

This research presents a first attempt to examine whether cultural differences in ideal affect are reflected in neural responses to different positive facial expressions. Consistent with predictions of Affect Valuation Theory (Tsai *et al.*, 2006), cultural differences in response to excited *vs* calm faces emerged in brain circuits implicated in reward and affect (Knutson and Greer, 2008; Freeman *et al.*, 2009). Within cultural groups, while European Americans showed similar VS activity to excited and calm faces, Chinese showed reduced VS activity in response to excited *vs* calm faces. These neural patterns were consistent with cultural differences in self-reported ideal affect. Further, cultural differences in VS activity held regardless of targets' ethnicity or gender. Finally, across European American and Chinese participants, VS activity in response to the excited *vs* calm facial expressions predicted preference for viewing excited *vs* calm facial expressions months later.

Cultural differences also emerged in MPFC responses, but unlike VS responses, MPFC responses were qualified by targets' ethnicity as well as expression. As predicted, Chinese showed greater MPFC activity in response to Asian calm targets *vs* other targets. European Americans did not differ, however, in their

MPFC response to different targets. Although participants were recruited according to specific cultural criteria, European American residents of the multicultural San Francisco Bay Area may have more exposure to diverse targets and therefore identify with Asian targets. Regardless, MPFC responsiveness to a combination of target expression and ethnicity in Chinese participants aligns with the notion that this region processes an integrated combination of value *and* self-relevance (van den Bos *et al.*, 2007). Importantly, cultural groups did not differ in their recruitment of circuits implicated in perception of and attention to faces (i.e., the FFG), suggesting that both groups similarly perceived and attended to positive facial expressions.

Implications for culture, emotion and social judgment

These findings suggest that cultural differences in ideal affect shape immediate responses to positive facial expressions via mechanisms involving affect and reward as well as higher-order mechanisms implicated in value integration and identity. These findings are consistent with an account in which ideal affect is transmitted and reinforced through social interaction. This cultural transmission might occur implicitly as well as explicitly. For instance, Chinese may avoid targets who express more excitement than calm, and consequently, culturally sensitive targets may learn over time to express less excitement and more calm. The findings also demonstrate the importance of distinguishing among different types of positive facial expressions in research on facial expression and social judgment. Interestingly, the influence of type of emotional expression overwhelmed that of ethnicity, suggesting an important role for emotional expressions in responding to others. Finally, these findings contribute to an emerging literature suggesting that cultural differences are reflected in deep brain activity—potentially influencing, but not necessarily depending on self-report and behavior (e.g. Zhu *et al.*, 2007; Chiao *et al.*, 2008, 2009; Hedden *et al.*, 2008; Freeman *et al.*, 2009; Immordino-Yang *et al.*, 2014; see Han *et al.*, 2013 for review). Notably, cultural groups did not differ in attentional responses to excited *vs* calm expressions, suggesting that some neural processing mechanisms may not vary as a function of culture.

Limitations and future directions

Some limitations of this study raise important questions for future research. First, to ensure precise control of emotional expressivity, we used computer-generated facial stimuli. Future research should replicate these findings using more realistic faces. Second, to equate neuroimaging assessments across cultural groups, we recruited Chinese students living in the United States who were actively adjusting to American life. Thus, Chinese and European American may have differed less in their valuation of high arousal positive affect. Indeed, in larger samples, European Americans reported that they valued high arousal positive affect more than a Chinese comparison group from Hong Kong (Tsai *et al.*, 2006). Future studies might compare neural responses to excited *vs* calm facial expressions between European Americans living in the United States and Chinese individuals living in China. Further, to reduce heterogeneity in each cultural sample, we focused on females; however, future studies should include male participants. Third, future studies might explore whether individual differences in ideal affect are related to neural responses to faces and subsequent preference in larger samples. Fourth, while this research focused on neural responses to different positive emotional expressions, negative emotional expressions might provide an interesting target for future research. Fifth, while the sample size was sufficient to reveal cultural differences in neural response, it was not sufficiently powered to reveal cultural differences in preference. Indeed, in an additional larger sample, cultural differences in responses to the Facial Preference Task emerged. This discrepancy raises the interesting possibility that neural data might enable investigators to deconstruct decision processes (e.g. preference judgments *vs* integrated assessments) and more directly assess the most relevant components (e.g. Lebreton *et al.*, 2009; Tusche *et al.*, 2010; Genevsky and Knutson, 2015). Future studies are needed to test these predictions. Sixth and finally, future studies might explore the behavioral implications of different cultural responses to positive facial expressions in practical settings (e.g. business, education). For instance, employers may be more likely to value, prefer and even ultimately hire people who express the emotions valued by their culture, which may inadvertently place those who value different emotions at a disadvantage.

In summary, European Americans showed greater ventral striatal responses associated with reward and affect to excited vs calm expressions than Chinese. While European Americans showed similar ventral striatal responses to excited and calm expressions, Chinese showed greater ventral striatal responses to calm vs. excited expressions. These findings held across target ethnicity and gender. Chinese did, however, show greater medial prefrontal responses implicated in value integration and self-relevance, specifically to Asian calm targets. Together, these findings provide neural evidence consistent with the notion that people prefer and value others who express the positive emotions most valued by their culture.

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Supplementary data

Supplementary data are available at *SCAN* online.

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