OXFORD

Social Cognitive and Affective Neuroscience, 2023, **18**(1), 1–10

DOI: https://doi.org/10.1093/scan/nsad068
Advance Access Publication Date: 11 November 2023
Original Manuscript

Cultural variation in neural responses to social but not monetary reward outcomes

Elizabeth Blevins,[1] Michael Ko,[2] BoKyung Park,[3] Yang Qu,[4] Brian Knutson,[1] and Jeanne L. Tsai[1]

[1]Department of Psychology, Stanford University, Stanford, CA 94305, USA
[2]UC San Diego School of Medicine, University of California, La Jolla, CA 92093, USA
[3]Department of Psychology, The University of Texas at Dallas, Richardson, TX 75080, USA
[4]School of Education and Social Policy, Northwestern University, Evanston, IL 60208, USA
Correspondence should be addressed to Elizabeth Blevins, Department of Psychology, Stanford University, 450 Jane Stanford Way, Bldg. 420, Stanford, CA 94305, USA. E-mail: eblevins@stanford.edu; Jeanne L. Tsai, Department of Psychology, Stanford University, 450 Jane Stanford Way, Bldg. 420, Stanford, CA 94305, USA. E-mail: jeanne.tsai@stanford.edu

Abstract

European Americans view high-intensity, open-mouthed ‘excited’ smiles more positively than Chinese because they value excitement and other high arousal positive states more. This difference is supported by reward-related neural activity, with European Americans showing greater Nucleus Accumbens (NAcc) activity to excited (*vs* calm) smiles than Chinese. But do these cultural differences generalize to all rewards, and are they related to real-world social behavior? European American ($N = 26$) and Chinese ($N = 27$) participants completed social and monetary incentive delay tasks that distinguished between the anticipation and receipt (outcome) of social and monetary rewards while undergoing Functional Magnetic Resonance Imaging (FMRI). The groups did not differ in NAcc activity when anticipating social or monetary rewards. However, as predicted, European Americans showed greater NAcc activity than Chinese when viewing excited smiles during outcome (the receipt of social reward). No cultural differences emerged when participants received monetary outcomes. Individuals who showed increased NAcc activity to excited smiles during outcome had friends with more intense smiles on social media. These findings suggest that culture plays a specific role in modulating reward-related neural responses to excited smiles during outcome, which are associated with real-world relationships.

Keywords: culture; ideal affect; smiles; FMRI; reward

Introduction

Seeing another person’s smile can improve people’s mood (Niedenthal *et al.*, 2010; Rychlowska *et al.*, 2017), as reflected by increased neural activity in regions of the brain associated with reward processing, including the Nucleus Accumbens (NAcc) (Bhanji and Delgado, 2014; Ruff and Fehr, 2014; Ueda and Abe, 2021). These good feelings predict people’s behavior toward others: for example, the greater NAcc activity people show in response to others’ smiles, the more likely they are to trust and share resources with them (Moll *et al.*, 2006; Genevsky *et al.*, 2013; Genevsky and Knutson, 2015; Park *et al.*, 2017). Less research, however, has examined how neural responses to smiles might be modulated by cultural factors. Furthermore, few studies have examined whether neural responses to smiles in the laboratory generalize to meaningful social behavior outside the laboratory. Therefore, in the present study, we examined how cultural differences in *ideal affect*, the affective states that people value and ideally want to feel, influence reward-related neural responses to excited and calm smiles and their links to real-world relationships.

The role of ideal affect and culture

While most people ideally want to feel more positive than negative states, there are cultural differences in which specific positive states people value. Based on Affect Valuation Theory, European Americans value and ideally want to feel high arousal positive (HAP) states like excitement more than East Asians do (Tsai *et al.*, 2006; Tsai, 2007, 2017). These cultural differences in ideal affect are reflected in widely distributed products, including children’s storybooks (Tsai *et al.*, 2007), leaders’ official website photos (Tsai *et al.*, 2016) and people’s social media posts (Huang and Park, 2013; Hsu *et al.*, 2021). Indeed, in a recent mega-analysis of 125 datasets, cultural differences in ideal HAP were robust and enduring over time (Tsai *et al.*, 2023).

Importantly, cultural differences in ideal affect can influence people’s judgments of others. Although both European Americans and Hong Kong Chinese rate high-intensity, open-mouthed ‘excited’ smiling faces as more affiliative (e.g. friendly and extraverted) than less-intense, closed-mouthed ‘calm’ smiling faces, European Americans rate excited smiles as significantly more affiliative than Hong Kong Chinese do, in part because they

Received: 4 April 2023; **Revised:** 9 August 2023; **Accepted:** 11 November 2023

value HAP states more (Tsai *et al.*, 2019; Bencharit *et al.*, 2023). Previous studies have documented similar cultural differences in people's judgments of smiles (Matsumoto and Kudoh, 1993; Ozono *et al.*, 2010). Little research, however, has examined the neural mechanisms that support these differences.

Underlying neural mechanisms

Recent evidence demonstrates that European Americans showed increased activity in brain regions associated with reward processing, including the NAcc, when viewing excited (*vs* calm) smiles compared to Chinese (Park *et al.*, 2016). NAcc activity in response to smiles also correlated with European Americans' judgments of excited smiles as more affiliative than calm smiles relative to Chinese (Park *et al.*, 2018) as well as their preference for seeing excited *vs* calm smiles months after scanning (Park *et al.*, 2016).

These cultural comparisons, however, were limited in several ways. First, because previous studies assessed individuals' neural responses while they passively viewed and rated faces, it is not clear whether cultural variation arose from exposure to the faces or in anticipation of viewing the faces. Indeed, increases in NAcc activity have been strongly associated with the anticipation of both monetary (Knutson *et al.*, 2001a, 2001b; Oldham *et al.*, 2018) and social rewards (Spreckelmeyer *et al.*, 2009; Gu *et al.*, 2019; Ueda and Abe, 2021), sometimes even more than the actual outcome or receipt of those rewards.

Second, previous research demonstrating cultural differences in reward-related neural activity focused on smiles, leaving their specificity unclear. Do similar differences emerge in response to seeing other intense emotional expressions such as anger or in response to other types of rewards such as money? Although decades of neuroimaging research suggest that anticipation and receipt of monetary gains can increase NAcc activity in samples around the world (Knutson and Greer, 2008; Oldham *et al.*, 2018), no studies have directly compared these responses between members of different cultures.

Finally, only a handful of studies have linked NAcc activity in response to smiles to ecologically valid social behaviors. For example, among Chinese international students living in the USA, greater NAcc activity in response to viewing in-group (*vs* out-group) backward-masked smiling faces predicted increases in in-group friends 6 months later (Chen *et al.*, 2015b). Furthermore, NAcc responses to receiving positive social feedback about oneself (*vs* another person) have been associated with greater self-reported use of social media (Meshi *et al.*, 2013).

The present study

The present study aimed to address these limitations. First, to distinguish between the anticipation and outcome of receiving a reward, we developed and administered an optimized version of the Social Incentive Delay (SID) task (Spreckelmeyer *et al.*, 2009; Rademacher *et al.*, 2010), in which participants saw cues indicating what kind of face they could see or avoid seeing by responding to a briefly presented target. Second, to examine the specificity of cultural differences in neural responses to smiles, we examined participants' responses to angry faces as well as smiles, and we administered the monetary incentive delay (MID) task (Knutson *et al.*, 2001a, 2001b) to examine their responses to monetary rewards. Finally, to explore whether NAcc activity in response to smiling faces in the SID task was associated with real-world social relationships, we measured participants' friends' emotional expressions on social media.

Hypotheses

We predicted that (i) European Americans would ideally want to feel HAP states more than Chinese, (ii) European Americans would show greater NAcc activity than Chinese in response to excited smiles during anticipation and outcome and (iii) these differences would be mediated by ideal HAP. We did not predict cultural differences in NAcc activity in response to angry faces or monetary rewards. Finally, we predicted that (iv) individuals' NAcc activity in response to excited smiles would correlate with the intensity of their friends' smiles in their profile photos on social media.

Methods

Participants

We recruited 34 healthy, right-handed European American and 29 Chinese international ('Chinese') students from e-mail advertisements and an online subject pool. European Americans were required to (i) be born in the USA, (ii) have parents who were born in the USA, (iii) have grandparents who were born in the USA or a Western European country and (iv) speak English as their native language. Chinese were required to (i) be born in mainland China, (ii) have parents and grandparents who were born in mainland China, (iii) speak Chinese as their native language and (iv) have lived in the USA for eight or fewer years. The amount of time Chinese participants lived in the USA ranged from 0.08 to 7.17 years (*Mean [M]* = 1.15, *Standard Deviation [SD]* = 1.46). Additionally, Chinese reported greater orientation to Chinese culture ($M = 3.17$, $SD = 0.76$) than to American culture ($M = 2.71$, $SD = 0.60$), $t(27) = 2.16$, $P = 0.04$, 95% CI = [0.02, 0.91] (Instruments section).

Ten participants were excluded from data analysis: eight for head movement that exceeded 2 mm from one volume acquisition to the next in either task (six European Americans, two Chinese), one for a missing anatomic scan (European American) and one for a dental implant that interfered with image acquisition (European American). Final analyses were conducted on 26 European Americans (50% female, age $M = 20.19$, $SD = 3.16$) and 27 Chinese (66.7% female, age $M = 23.22$, $SD = 3.48$). There were no significant differences in gender distribution between the two cultural groups, $\chi^2(1, N = 53) = 0.91$, $P = 0.34$, but there was a significant difference in age, with European Americans being younger than Chinese, $t(50.84) = -3.32$, $P = 0.002$, 95% CI = [−4.86, −1.20]. We initially included age as a covariate, but the pattern of results remained the same when it was not included, so age was omitted from the final analyses.

We conducted an a priori power analysis in G*Power to determine the minimum number of participants needed to achieve an 80% power at $\alpha = 0.05$ for an interaction in a repeated measures analysis of variance with two groups (culture: European American and Chinese) and two measurements (average NAcc activity: anticipation and outcome). The power calculation revealed that 34 participants were required for a medium effect size ($f = 0.25$). Based on previous studies, however, we estimated that 10–20% of the recruited sample might be excluded during Functional Magnetic Resonance Imaging (FMRI) quality assurance (e.g. due to movement artifacts; Park *et al.*, 2016), and therefore, we increased our target sample size accordingly. We also wanted to ensure that our sample size was comparable to recent FMRI studies comparing neural activity between two separate groups in reward tasks (e.g. $N = 58$ recruited, $N = 48$ analyzed, (Johnson *et al.*, 2019; $N = 45$ recruited, $N = 41$ analyzed, He *et al.*, 2019), given recent criticisms of sample size in neuroimaging studies (Poldrack *et al.*, 2017).

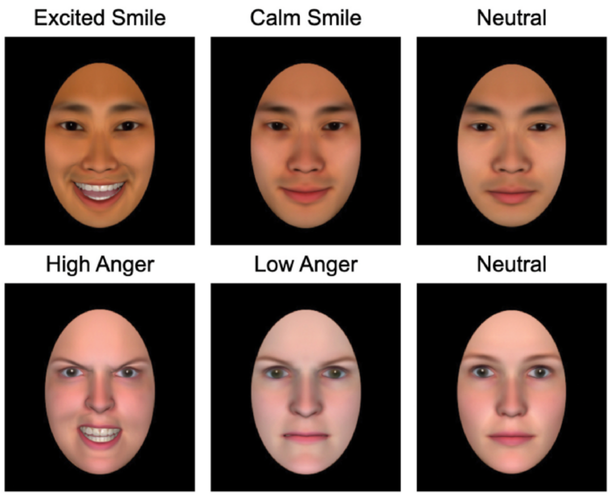

Fig. 1. Examples of facial stimuli, which varied by emotional expression (smile, anger), race (White, Asian), and sex (male, female).

Facial stimuli

We created faces (775 × 775 pixels) in FaceGen Modeller that varied by race (White, Asian), sex (male, female) and emotional expression (for smiles: excited, moderate, calm, and neutral [Park *et al.*, 2016]; for anger expressions: high, moderate, low, and neutral). Based on previous work (Park *et al.*, 2016; Tsai *et al.*, 2019), 'excited' smiles had intense eye wrinkles, an open smile and visible teeth, while 'calm' smiles had less intense eye wrinkles, a closed smile and no visible teeth (Figure 1). Similarly, 'high' anger expressions had intensely furrowed brows, an open mouth and visible teeth, while 'low' anger expressions had mildly intense furrowed brows, a closed mouth and no visible teeth. 'Moderate' smiles and anger expressions fell between excited and calm smiles and high- and low-intensity anger expressions, respectively (see Supplementary Materials Section 1 for examples of moderate faces and FaceGen Modeller parameters). The same set of faces were used in the SID task (described later) for all participants.

SID task

Participants played a revised SID task (Spreckelmeyer *et al.*, 2009; Rademacher *et al.*, 2010), which was adapted from the MID task (Knutson *et al.*, 2001a, 2001b, described later), to measure neural responses during motivation for (anticipation) and receipt of (outcome) social incentives. The current revision of the SID task offered several improvements on previous versions (e.g. Spreckelmeyer *et al.*, 2009). First, different shape cues were used for SID *vs* MID tasks to reduce the possibility of interference across cues and tasks. Second, addition of negative valence (i.e. anger) conditions controlled for potential confounds associated with arousal, sensory salience and motor demands. Third, use of standardized facial expressions controlled for non-prototypical action unit movements commonly observed in naturalistic facial stimulus sets. See Supplementary Materials Section 2 for greater details.

During each SID task trial, participants viewed a cue (2 s). Clover cues (Figure 2A) indicated the possibility of seeing a smile (a social gain), while shield cues (Figure 2B) indicated the possibility of avoiding an angry expression (a social loss). On gain and loss trials ($N = 48$), cues contained a top, middle or bottom horizontal line to indicate a high-, medium- or low-intensity expression, respectively. On non-gain and non-loss trials ($N = 16$), clover and shield cues contained no horizontal line, indicating that participants would see a neutral face. Trial types were presented in the same pseudorandom order for all participants. After the cue, participants saw a fixation point (2 s), followed by a target triangle (∼280 ms).

Participants were instructed to press a button as quickly as possible during presentation of the target triangle (2 s) to either receive the social gain or avoid the social loss outcome. On gain trials, if participants responded on time before the target disappeared (i.e. 'hit' the target), they saw a smile; otherwise, they saw a neutral face. On loss trials, if participants 'hit' the target, they saw a neutral face; otherwise, they saw an angry face. On non-gain and non-loss trials, participants saw a neutral face regardless of whether they hit the target. Importantly, these trials allow for comparisons between hits and misses during the outcome absent of social feedback (i.e. a smiling or angry expression).

Target presentation time in the SID task adapted to speed of response, so that participants hit the target on ∼66% of trials for each type (e.g. high-intensity 'excited' smile gain and low-intensity anger loss), which helped ensure comparable performance across the different trial types. As a result, while all participants saw approximately the same number of calm, moderate and excited smiling targets, the specific race and sex of the targets participants actually viewed varied depending on which trials they successfully hit. We were not concerned about this, however, because in previous work, effects did not vary as a function of target race and sex (e.g. Park *et al.*, 2017; Tsai *et al.*, 2019).

MID task

During each MID task trial, participants viewed a cue (2 s) (Knutson *et al.*, 2001a, 2001b). Circle cues indicated the possibility of receiving money, whereas square cues indicated the possibility of avoiding losing money. On these trials ($N = 48$), cues contained a top, middle or bottom horizontal line to indicate $5, $3 and $1, respectively. On non-gain and non-loss trials ($N = 16$), circle and square cues contained no horizontal line, indicating that participants would receive $0. As in the SID task, trial types were presented in the same pseudorandom order across participants.

Participants then viewed a fixation point (2 s), a target triangle (∼280 ms), to which they were instructed to respond, followed by response feedback (2 s). On gain trials, if participants hit the target, they received money; otherwise, they received $0. On loss trials, if participants hit the target, they received $0; otherwise, they lost money. On non-gain and non-loss trials, participants received $0 regardless of whether they hit the target. As mentioned earlier, target presentation time adapted based on speed of response, so that participants hit the target on ∼66% of trials for each type (e.g. $1 gain and $5 loss). Mean reaction times and success rates for the SID and MID are reported in Supplementary Materials Section 3.

To ensure that participants understood the meaning of the SID and MID cues, participants viewed the cues again after each task and rated their feelings in response to each cue on two 7-point scales, one ranging from 'very negative' to 'very positive' and the other ranging from 'not at all aroused' to 'extremely aroused.' As expected, across cultures, participants differentiated among the cues in each task, and there were no significant cultural differences in ratings of the cues signaling smiling faces, angry faces, monetary gains, or monetary losses (Supplementary Materials Section 4).

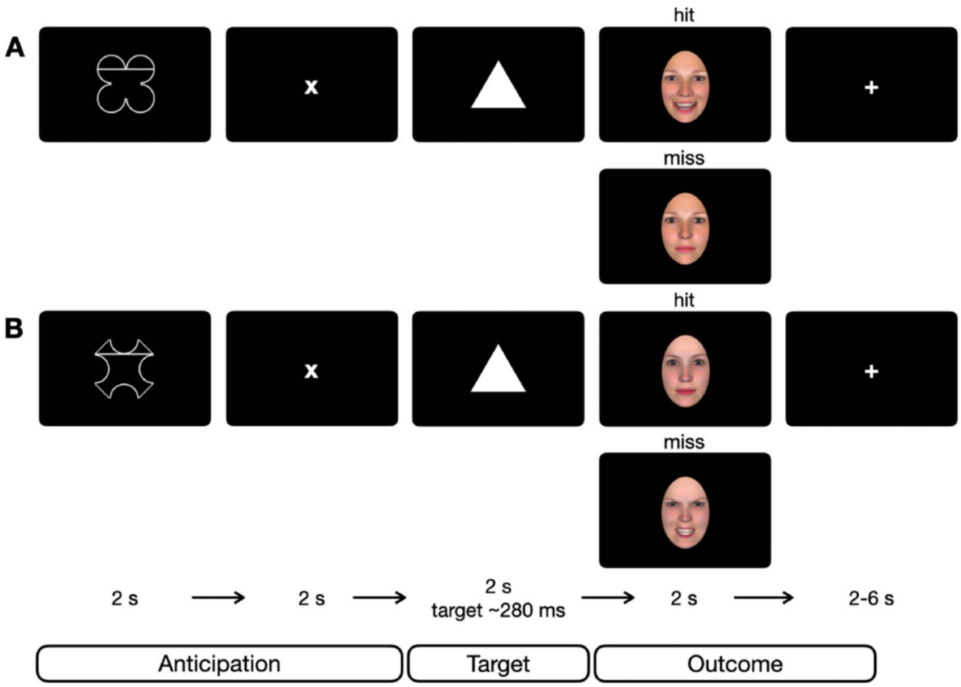

Fig. 2. Trial structure of SID task for a (A) gain trial and (B) loss trial.

Instruments

Study materials were translated and back-translated by bilingual research assistants and administered in participants' native language (Brislin, 1970).

Actual and Ideal Affect

To assess actual and ideal affect, we administered the Affect Valuation Index (AVI; Tsai *et al.*, 2006). Participants reported how much they actually felt 39 different affective states over a typical week using a 5-point Likert scale, ranging from 'never' to 'all the time'. Then, participants reported how much they ideally wanted to feel each state over a typical week using the same scale. We averaged how much participants reported actually feeling and ideally wanting to feel 'excited,' 'enthusiastic,' 'elated' and 'euphoric' to create actual and ideal HAP aggregates, respectively (Cronbach's α for European Americans: actual HAP = 0.81, ideal HAP = 0.89; Chinese: actual HAP = 0.81, ideal HAP = 0.78). To control for cultural differences in response styles (Chen *et al.*, 1995), ratings were ipsatized by calculating the overall mean and standard deviation across all 39 affect terms for each participant, then subtracting their mean and dividing by their standard deviation prior to aggregating. This was done separately for actual and ideal affect.

Demographics

Participants indicated their age, gender, year in school, birthplace, ethnicity and their parents' and grandparents' birthplaces and ethnicities. Chinese participants also rated to what extent they were overall oriented to American and Chinese cultures on a 5-point Likert scale, ranging from 'not at all' to 'extremely' (Tsai *et al.*, 2000).

Friends' emotional expressions

Participants indicated whether they had a social media account, and if so, which platform they used (e.g. Facebook, WeChat). To capture a range of friends, participants identified three of their 'closest' friends and three 'new' friends whose profiles they could view. We asked participants to rate how close they felt to each friend. To maintain confidentiality, we could not obtain friends' photos; therefore, we asked participants to navigate to the profile of each friend, indicate whether they could see their friend's face and if they could, select the graphic that best represented the shape of their friend's mouth (Figure 3), ranging from the most intense negative expression (–3) to the most intense positive expression (+3). To calculate the average of participants' friends' expressions, we summed the ratings and divided by the total number of friends' faces participants saw. We collapsed across the types of friends because the findings did not vary as a function of how close participants reported being to their friends (see Results).

Experimental procedure

Participants took part in a study on 'motivation and decision-making'. Prior to the lab session, each participant completed an online survey, which included the AVI and demographic measures (Figure 4). At the lab session, participants were instructed about the SID task and played eight practice trials, including one of each trial type. During the first scanning run, participants played 64 trials of the SID task. Participants then rated each of the SID cues. After the SID task, participants received instructions about the MID task. They were told that they were playing with actual money and would receive their cumulative earnings in addition to their hourly compensation. Participants' earnings in the MID task ranged from \$4 to \$47 (M = \$20, SD = \$10.28). Participants played eight practice trials of the MID task followed by 64 trials during a second scanning run. Afterward, participants rated each of the MID cues. Outside of the scanner, participants rated their friends' emotional expressions on social media in a private testing room. Finally, they were debriefed and compensated. All procedures were approved by the Stanford Medical and Non-Medical Institutional Review Boards.

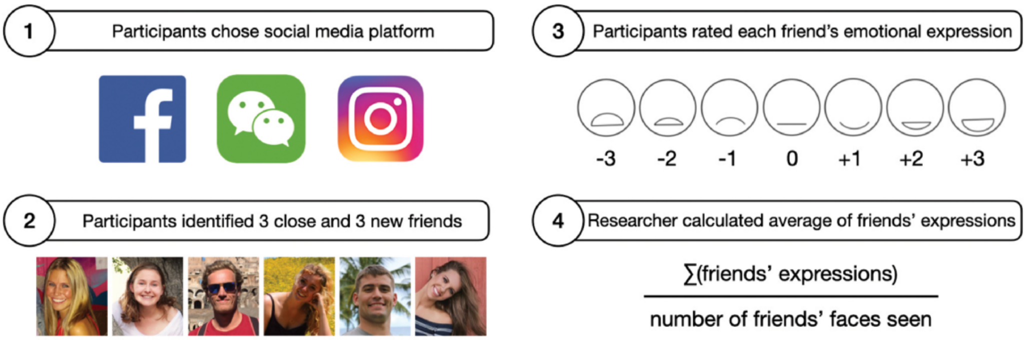

Fig. 3. Measurement of friends' emotional expressions.
Note: Example profile photos were obtained from study participants who provided consent.

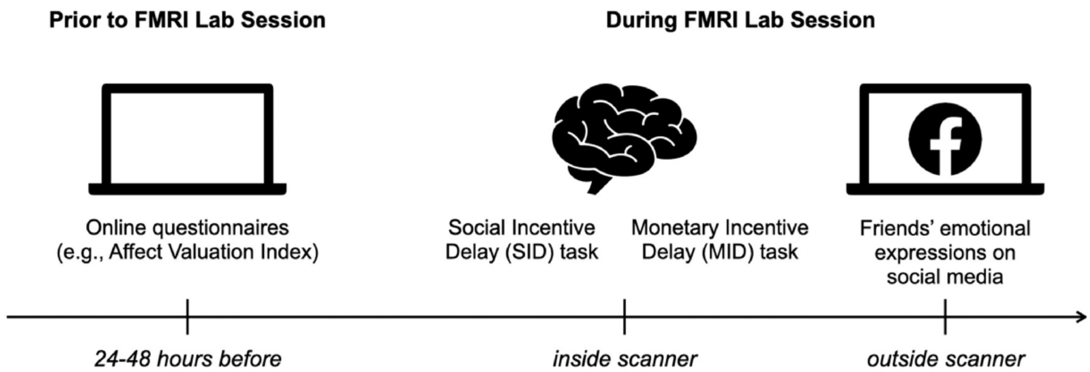

Fig. 4. Overview of the study procedure.

FMRI data processing and analysis

Participants were scanned at the Stanford Center for Cognitive and Neurobiological Imaging in a 3.0T General Electric Discovery MR750 FMRI scanner with a 32-channel head coil. For each functional run, 46 slices of T2*-weighted echoplanar images were acquired according to the following parameters: axial acquisition from inferior to superior, interleaved echoplanar image, no gap, repetition time = 2 s, echo time = 25 ms, flip angle = 77°, in-plane resolution = 2.9 mm, field of view = [232, 232] and acquisition matrix = [80, 80]. Then, whole-brain T1-weighted structural scans were acquired with the following parameters: repetition time = 7.2 ms, echo time = 2.8 ms, flip angle = 12°, in-plane resolution = 0.9 mm, field of view = [256, 230] and acquisition matrix = [256, 256]. These parameters were optimized for resolving subcortical signals (Srirangarajan *et al.*, 2021).

FMRI data were pre-processed and analyzed using Analysis of Functional Neural Images (Cox, 1996) according to procedures outlined in Wu *et al.* (2014). Specifically, we removed the first six volumes before the SID and MID tasks to allow for magnet stabilization. Next, we applied slice timing correction, motion correction (using Fourier interpolation) and spatial smoothing using a Gaussian kernel of a 4-mm full width at half maximum. Finally, we normalized activity to average percent signal change and applied a high-pass filter to omit frequencies lower than 0.011 Hz.

We centered spherical volumes of interest (VOIs) with an 8 mm diameter in predicted coordinates in the bilateral NAcc (Talairach coordinates: ±10, 12, −2). We averaged the percentage signal change within the VOI, extracted activity time courses and averaged activity separately for hits and misses for each trial type. We focused on the 'anticipation' period of all trials (i.e. volumes 3–4) when participants saw the cue, as well as the 'outcome' (i.e. volumes 6–7) after participants successfully hit (or missed) the target and viewed the faces. Activity was lagged by 4 s to account for the hemodynamic response. Findings from an exploratory whole-brain analysis are provided in Supplementary Materials Section 5.

Results

Hypothesis 1: Do European Americans ideally want to feel HAP states more than Chinese?

Since our hypotheses focused on ideal HAP, we ran a one-way analysis of covariance on ideal HAP, covarying for actual HAP. Consistent with predictions and decades of work on ideal affect (Tsai *et al.*, 2023), European Americans ($M = 0.71$, *Standard error [SE]* $= 0.08$) ideally wanted to feel HAP states more than Chinese ($M = 0.46$, $SE = 0.07$), $F(1, 50) = 5.68$, $P = 0.02$ and partial $\eta^2 = 0.10$. Recent work (Tsai, 2017; Tsai *et al.*, 2019; Bencharit *et al.*, 2019) has found no significant cultural differences in ideal low arousal positive (LAP) states, which we also observed here (see Supplementary Materials Section 6 for discussion of findings for ideal LAP).

Hypothesis 2: Do European Americans show greater NAcc activity than Chinese in response to anticipating and viewing smiling faces?

We conducted separate linear mixed effects regressions for average activity during anticipation (volumes 3–4 across all trials) as well as during outcome (volumes 6–7 across 'hit' or 'miss' trials only). We entered Culture (European American [0], Chinese [1]), Emotional Expression (linear contrast: excited [1], calm [0] and neutral [−1]) and their interaction as fixed effects and individual participants and volume as random intercepts. Because

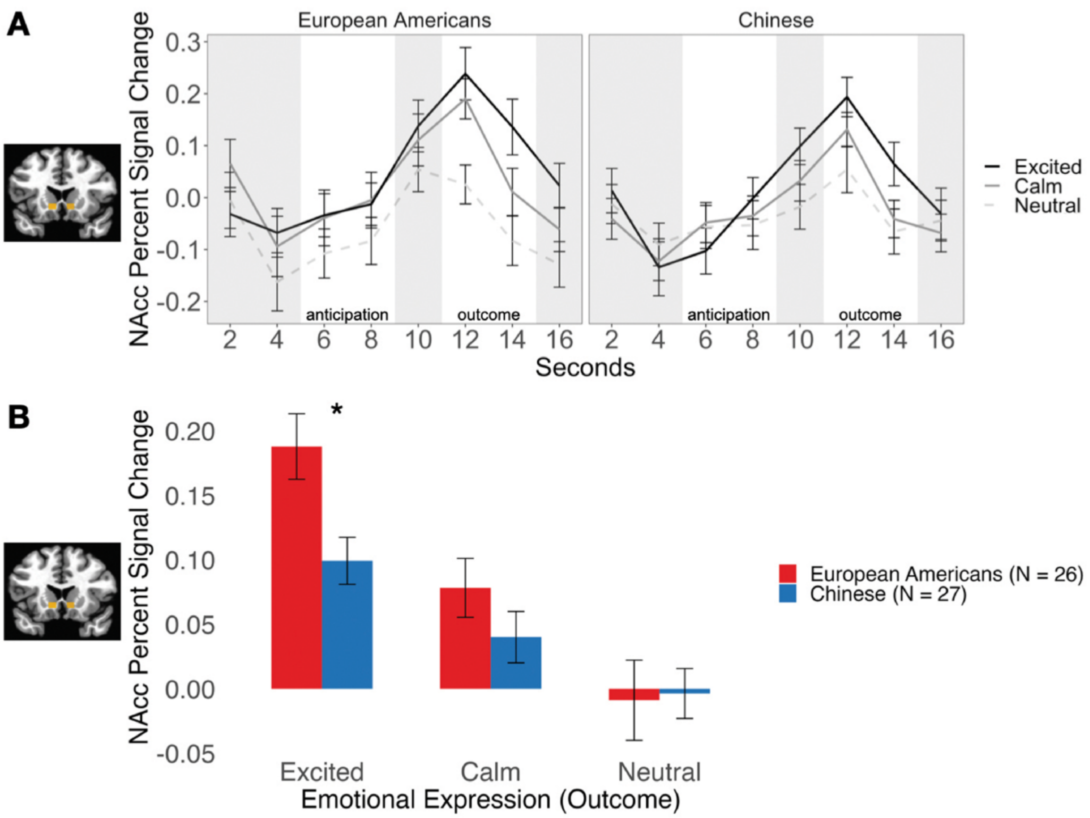

Fig. 5. Cultural differences in NAcc activity during anticipation and outcome in the SID task.

Note: Error bars represent the standard error of the mean. (A) Time courses show NAcc activity averaged across hit trials only. (B) The bar plot shows NAcc activity averaged across hit trials during the outcome period. $^*P < 0.05$.

our hypotheses contrasted NAcc activity differences to excited *vs* calm smiles, and NAcc activity to moderate smiles did not follow a linear trend, we excluded moderate smiles from subsequent analyses (see Supplementary Materials Section 7 for time course data including moderate smiles). The pattern of results was similar, however, when distinguishing among all four expressions. We collapsed across target race and sex because (I) in prior work, target race and sex did not interact with emotional expression (e.g. Park *et al.*, 2017) and (II) participants in this study only saw smiles on 'hit' trials and, therefore, did not see the same subset of faces that varied by race and sex.

Anticipation

The Culture × Emotional Expression interaction was not significant, $P = 0.14$. However, we examined the simple effects within each culture because we had specific a priori predictions about cultural differences and because previous findings suggest that NAcc activity is sensitive to smile intensity during anticipation (Spreckelmeyer *et al.*, 2009). Within cultures, Emotional Expression was significant for European Americans, suggesting that NAcc activity linearly increased as they anticipated faces with greater intensity smiles, $B = 0.04$, $SE = 0.01$, $t(260.00) = 3.27$, $P = 0.001$ (Figure 5A). Emotional Expression, however, was not significant for Chinese, $P = 0.22$. Pairwise comparisons between European Americans and Chinese for excited, calm and neutral faces were not significant ($Ps > 0.06$).

Outcome

The predicted Culture × Emotional Expression interaction was significant for hit trials, $B = -0.05$, $SE = 0.02$, $t(256.10) = -2.07$, $P = 0.04$ (Figure 5B). Within cultures, Emotional Expression was significant for both European Americans and Chinese, but was greater for European Americans (European American: $B = 0.10$, $SE = 0.02$, $t(256.10) = 6.07$, $P < 0.001$; Chinese: $B = 0.05$, $SE = 0.02$, $t(256.10) = 3.24$, $P = 0.001$). To further decompose this interaction, we examined pairwise comparisons across cultures for each expression with post hoc *t*-tests (details of post hoc power analyses are provided in Supplementary Materials Section 8). As predicted, European Americans ($M = 0.19$, $SE = 0.07$) showed greater average NAcc activity during the outcome when they viewed excited faces than did Chinese ($M = 0.10$, $SE = 0.07$), $t(39.06) = 2.47$, $P = 0.02$, 95% CI = [0.02, 0.16], Cohen's $d = 0.68$ (Figure 5B). In contrast, there were no significant cultural differences in response to viewing calm or neutral faces ($Ps > 0.27$).

In summary, European Americans and Chinese showed few significant differences in neural activity while anticipating different smiles. Although European Americans' NAcc activity differed more during anticipation of excited, calm and neutral smiles than Chinese, there were no significant differences in NAcc activity during anticipation of excited, calm and neutral smiles between cultural groups. During the outcome, however, NAcc activity increased linearly for both European Americans and Chinese when viewing smiles of higher intensity, and as predicted, European Americans showed even greater NAcc activity in response to viewing excited smiles than did Chinese. Given that cultural differences in NAcc activity were more pronounced during the outcome (when participants viewed the faces), we focused on NAcc activity during this period.

Hypothesis 3: Are cultural differences in NAcc activity mediated by ideal HAP?

We first examined whether ideal HAP mediated cultural differences in NAcc activity. Contrary to predictions, the mediation model was marginal (for details, see Supplementary Materials Section 9). However, to further test our a priori predictions and examine the direct relationship, we calculated the correlation between ideal HAP and NAcc responses to excited smiles, collapsing across cultural groups. As predicted, ideal HAP was significantly associated with NAcc responses to excited smiles: the more the participants valued HAP states, the greater the magnitude of their NAcc responses to excited smiles, $r = 0.26$, $t(51) = 1.89$, $P = 0.03$ (one-tailed). This raises the possibility that cultural grouping and ideal HAP share variance in predicting NAcc activity to excited smiles.

How specific are cultural differences in NAcc activity to viewing excited smiles?

Next, to explore whether cultural differences in NAcc were specific to viewing excited smiles or whether they also emerged in response to other high-intensity expressions or non-social incentives, we examined whether there were cultural differences during the outcome of viewing angry faces in the SID task and of receiving money in the MID task.

Angry expressions during outcome

In our linear mixed effects regressions, we entered Culture (European American [0], Chinese [1]), Emotional Expression (linear contrast: high anger [1], low anger [0] and neutral [−1]) and their interaction as fixed effects and individual participants and volume as random intercepts. The Culture X Emotional Expression interaction was not significant, $P = 0.89$. There were no significant effects of Emotional Expression ($Ps > 0.41$), suggesting that NAcc activity was not associated with greater intensity anger, and there were no significant cultural differences in average NAcc activity when participants viewed high anger, low anger or neutral expressions ($Ps > 0.14$) Additionally, we examined whether there were cultural differences in anterior insula activity in response to the angry expressions because it has been associated in the literature with social losses (Kohls et al., 2013; Martin et al., 2021), but we again found no significant cultural differences (Supplementary Materials Section 10).

Monetary incentives during outcome

We entered Culture (European American [0], Chinese [1]), Monetary Amount (linear contrast: gain \$5 [1], gain \$1 [0], gain \$0 [−1]), and their interaction as fixed effects and modeled individual participants and volume as random intercepts. The Culture × Monetary Amount interaction was significant, $B = 0.07$, $SE = 0.03$, $t(256.78) = 2.32$, $P = 0.02$ (see Supplementary Materials Section 11 for details on interaction). Within cultures, Monetary Amount was significant for Chinese ($B = 0.06$, $SE = 0.02$, $t(255.10) = 2.74$, $P = 0.01$) but not for European Americans ($P = 0.57$). We also conducted post hoc *t*-tests between cultures for each monetary amount. European Americans ($M = 0.10$, $SE = 0.06$) showed greater average NAcc activity than Chinese ($M = -0.02$, $SE = 0.06$) when they gained \$0 during the outcome, $t(40.11) = 2.73$, $P = 0.01$, 95% CI = [0.03, 0.21], Cohen's $d = 0.77$. Importantly, however, there were no significant cultural differences in average NAcc activity for \$1 or \$5 gains ($Ps > 0.53$).

We also examined NAcc activity during anticipation of angry faces and monetary incentives. As reported in Supplementary Materials Section 12, we found no differences in NAcc activity during anticipation of angry faces, and while our findings were consistent with previous findings of increased NAcc activity during anticipation of monetary rewards, there were also no significant cultural differences in NAcc activity during anticipation of monetary incentives.

In summary, there were no cultural differences in NAcc activity when participants anticipated and viewed high-intensity angry faces or when they anticipated or received \$1 or \$5. These analyses suggest that cultural differences in NAcc activity are specific to viewing excited smiles.

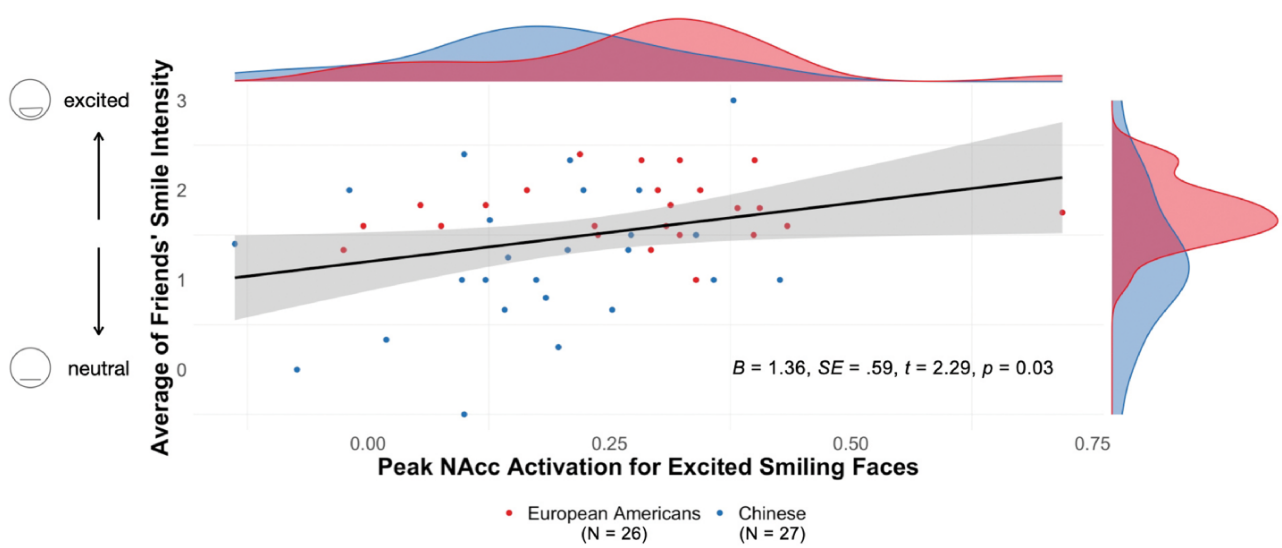

Fig. 6. Association between peak NAcc activation for excited smiling faces in the SID task and friends' smile intensity on social media.

Hypothesis 4: Does NAcc activity in response to excited smiles correlate with individuals' friends' emotional expressions on social media?

We collapsed across ratings for close and new friends because the pattern of results did not vary depending on how close participants reported being to their friends (for more details about the measurement of friends' expressions, see Supplementary Materials Section 13). Among the 25 European American and 27 Chinese participants who had social media accounts, two European Americans and one Chinese participant could not view any of their friends' faces on social media, and therefore, they were omitted from subsequent analyses. Consistent with predictions and prior research on cultural differences in smiling in photos (Huang & Park, 2013; Tsai *et al.*, 2016), European Americans' friends showed higher intensity smiles than did Chinese participants' friends, $t(33.80) = 3.21$, $P = 0.003$, 95% CI = [0.20, 0.88] (European American: $M = 1.80$, $SE = 0.06$; Chinese: $M = 1.26$, $SE = 0.15$). We also conducted an exploratory analysis to examine whether individual differences in cultural orientation within our Chinese sample correlated with friends' expressions. Indeed, the more the Chinese reported feeling oriented to Chinese culture, the less intense their friends' smiles were in their profile photos, $t(24) = -2.10$, $P = 0.047$, $r = -0.39$, 95% CI = [−0.68, −0.007].

We conducted a linear regression with peak NAcc activity to excited smiles as the independent variable and the average intensity of friends' expressions as the dependent variable. While we initially included Culture and its interaction with NAcc activity in the model, the interaction was not significant ($P = 0.27$), and the pattern of results remained similar, so we excluded it for parsimony. As predicted, and shown in Figure 6, participants who showed a greater NAcc response to excited smiles had friends who showed higher intensity smiles in their profile photos, $B = 1.36$, $SE = 0.59$, $t = 2.29$, $P = 0.03$. This association remained significant even after excluding the European American outlier with the greatest NAcc activation, $B = 1.60$, $SE = 0.67$, $t = 2.38$, $P = 0.02$. Importantly, peak NAcc activity in response to gaining $5.00 was not significantly associated with the intensity of friends' expressions, $P = 0.74$. Thus, participants' NAcc responses to excited smiles were significantly and selectively associated with the intensity of their friends' smiles on social media, demonstrating real-world significance.

Discussion

Greater cultural differences in NAcc activity for social than monetary outcomes

To test for cultural differences in neural responses to social rewards, we combined FMRI neuroimaging with an optimized SID task. As predicted, European Americans showed greater NAcc responses while viewing excited smiles than did Chinese, consistent with cultural differences in valuation of ideal HAP. Importantly, cultural differences in NAcc activity did not emerge in response to angry faces or to monetary outcomes, ruling out the possibility that these cultural differences reflected more general responses to intense emotional expressions or other types of rewards. Moreover, across cultures, participants' NAcc responses to excited smiles were associated with having friends on social media who showed more intense smiles.

Previously, European Americans showed greater NAcc responses to excited (*vs* calm) smiles than their Chinese counterparts during passive viewing (Park *et al.*, 2016). We replicate and extend that pattern of results using the SID task, which required participants to rapidly respond to a target to view smiling faces. When participants were actively rewarded with presentation of excited smiles, European Americans showed greater NAcc responses than did Chinese, providing even stronger evidence that cultural differences in the perception of excited smiles are supported by reward-related neural mechanisms.

NAcc activity during social reward outcome

Compared to the MID task, NAcc activity in the SID task peaked in response to outcome rather than anticipation, when cultural differences were most evident. This pattern differs from previous studies using social rewards, where NAcc activity peaked during anticipation of social rewards (Rademacher *et al.*, 2010; Gu *et al.*, 2019). This discrepancy may in part be because while our SID task cues indicated the valence and intensity of emotional expression, they did not indicate race, sex or other facial features (since those features did not influence NAcc activity during passive exposure to faces in previous research; Park *et al.*, 2016). In contrast, monetary outcomes remained constant throughout the MID task. Thus, SID task outcomes may have elicited more surprise than MID task outcomes, which might be related to the shift in peak NAcc activity. Future studies might address this possibility by cuing multiple features of the face in the SID task (although manipulating all at once would likely generate a prohibitively long experiment for neuroimaging) or by giving people more previous experience with the target faces (rather than a few practice trials as we did here).

Associations with real-world social behavior

These findings demonstrate that even neural responses to computer-generated faces can have real-world correlates, consistent with views of the 'brain as a predictor' of behavior (Berkman and Falk, 2013). While other studies have found that NAcc activity is associated with decisions to purchase products (Knutson *et al.*, 2007), engagement in risky behaviors (e.g. MacNiven *et al.*, 2018) and social media use (Meshi *et al.*, 2013), the current study is the first to demonstrate that individuals' NAcc responses to excited smiles are associated with the intensity of their friends' emotional expressions on social media. Future research, of course, is needed to determine the causal direction of this association.

Limitations and future directions

This study had several limitations, which should be addressed in future research. First, while both the SID and MID tasks were identical in structure, the outcome of the SID task was not incentive-compatible like the MID task, possibly compromising ecological validity. To address this limitation, participants might be given a chance to virtually 'interact' with an agent expressing the emotion depicted during a randomly selected trial.

Second, while the facial stimuli in the SID task were carefully controlled, participants viewed avatar faces, and they viewed smiling faces more frequently than angry ones. Since we controlled for relative frequency in our analyses by comparing neural activity in response to 'hits' (or 'misses') separately, we do not believe that this explains our main findings. However, it is important for future research to examine whether the findings generalize to realistic faces and in tasks where participants view smiling and angry faces at a similar rate.

Third, while NAcc responses to expressive faces were related to the smiles of the participants' friends on social media, participants selected their own friends, so it is unclear how representative these friends are of participants' social networks. To address this, we asked participants about their new and close friends to capture a range of their friendships. Because the cultural differences in participants' friends' emotion expressions observed here are consistent with previous results comparing the emotional expressions of US Americans and Taiwanese on Facebook (Huang & Park, 2013), we believe that participants' ratings were valid. It also remains unclear whether NAcc activity in response to excited smiles is associated with actual social engagement or behavior. Future studies might explore these associations.

Finally, researchers might explore the conditions under which European Americans show greater NAcc activity when viewing excited smiling faces in comparison with Chinese. For instance, this cultural difference might be attenuated if individuals were provided with more direct information about how affiliative targets were (e.g. Cachia *et al.*, 2023) or if they are given a chance to deliberate about the targets. Future research might also examine whether similar results extend to other types of smiles (Martin *et al.*, 2021) and other cultures that differ in their valuation of HAP (Senft *et al.*, 2021).

Implications for social and cultural neuroscience

Despite these limitations, the present research makes several novel contributions to social, affective and cultural neuroscience. First, this research contributes to growing evidence that cultural differences in psychological processes can be assessed with neural activity (Han *et al.*, 2013; Chen *et al.*, 2015a; Kitayama and Salvador, 2017) and more specifically neural mechanisms associated with reward (Kitayama and Uskul, 2011). Second, the work demonstrates the specificity of cultural differences in NAcc response to excited smiles during outcome—ruling out differences during anticipation, in response to other high-intensity expressions, and in response to other types of reward outcomes. While this level of specificity is uncommon in cultural neuroscience studies, it is needed to understand the significance of observed effects. These findings suggest that cultural differences may be greater for social than monetary reward outcomes and, among social reward outcomes, positive over negative emotional expressions. Finally, given their association with friends' emotional expressions on social media, these findings demonstrate the ecological validity of neural responses in the scanner.

Supplementary data

Supplementary data is available at *SCAN* online.

Data availability

The data and code for analyses presented in this study as well as the SID task are available online in the Open Science Framework (https://osf.io/82974/).

Funding

This work was supported by the National Science Foundation (BCS-1324461 to J.T. and B.K.). Additionally, E.B. was supported by the Melvin and Joan Lane Fellowship in Science and Engineering as well as the Ric Weiland Graduate Fellowship in the Humanities and Sciences at Stanford University.

Conflict of interest

The authors declared that they had no conflict of interest with respect to their authorship or the publication of this article.

Acknowledgements

We thank C. Chen, A. Lee, S. Lin, M. McNulty, C. Shen, M. Seitz, B. Wang and A. Yang for assistance with translations and running human subjects; J. Leong, K. MacNiven and L. Tong for guidance on neuroimaging analyses and members of the Stanford Culture and Emotion Lab and SPAN Lab for feedback on earlier versions of this manuscript.

References

Bencharit, L.Z., Ho, Y.W., Fung, H.H., *et al.* (2019). Should job applicants be excited or calm? The role of culture and ideal affect in employment settings. *Emotion*, **19**(3), 377–401.

Bencharit, L.Z., Ko, M., Blevins, E., *et al.* (2023). *People choose leaders who match cultural ideals during growth more than crisis* [Manuscript submitted for publication].

Berkman, E.T., Falk, E.B. (2013). Beyond brain mapping: Using neural measures to predict real-world outcomes. *Current Directions in Psychological Science*, **22**(1), 45–50.

Bhanji, J.P., Delgado, M.R. (2014). The social brain and reward: Social information processing in the human striatum. *Wiley Interdisciplinary Reviews: Cognitive Science*, **5**(1), 61–73.

Brislin, R. (1970). Back translation for cross-cultural research. *Journal of Cross-Cultural Psychology*, **1**(3), 186–216.

Cachia, J.Y.A., Blevins, E., Chen, Y.C., *et al.* (2023). *Cultural variation in the smiles we trust: the effects of reputation and ideal affect on resource sharing* [Manuscript submitted for publication].

Chen, P.-H.A., Heatherton, T.F., Freeman, J.B. (2015a). Brain-as-predictor approach: an alternative way to explore acculturation processes. In: Warnick, J.E., Landis, D., editors. *Neuroscience in Intercultural Contexts*. New York, NY: Springer, 143–70.

Chen, C., Lee, S.Y., Stevenson, H.W. (1995). Response style and cross-cultural comparisons of rating scales among East Asian and North American students. *Psychological Science*, **6**(3), 170–5.

Chen, P.-H.A., Whalen, P.J., Freeman, J.B., Taylor, J.M., Heatherton, T.F. (2015b). Brain reward activity to masked in-group smiling faces predicts friendship development. *Social Psychological and Personality Science*, **6**(4), 415–21.

Cox, R.W. (1996). AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. *Computers and Biomedical Research*, **29**(3), 162–73.

Genevsky, A., Knutson, B. (2015). Neural affective mechanisms predict market-level microlending. *Psychological Science*, **26**(9), 1411–22.

Genevsky, A., Västfjäll, D., Slovic, P., Knutson, B. (2013). Neural underpinnings of the identifiable victim effect: affect shifts preferences for giving. *Journal of Neuroscience*, **33**(43), 17188–96.

Gu, R., Huang, W., Camilleri, J., *et al.* (2019). Love is analogous to money in human brain: coordinate-based and functional connectivity meta-analyses of social and monetary reward anticipation. *Neuroscience and Biobehavioral Reviews*, **100**, 108–28.

Han, S., Northoff, G., Vogeley, K., Wexler, B.E., Kitayama, S., Varnum, M.E. (2013). A cultural neuroscience approach to the biosocial nature of the human brain. *Annual Review of Psychology*, **64**, 335–59.

He, Z., Zhang, D., Muhlert, N., Elliott, R. (2019). Neural substrates for anticipation and consumption of social and monetary incentives in depression. *Social Cognitive and Affective Neuroscience*, **14**(8), 815–26.

Hsu, T.W., Niiya, Y., Thelwall, M., Ko, M., Knutson, B., Tsai, J.L. (2021). Social media users produce more affect that supports cultural values, but are more influenced by affect that violates cultural values. *Journal of Personality and Social Psychology*, **121**(5), 969–83.

Huang, C.M., Park, D. (2013). Cultural influences on Facebook photographs. *International Journal of Psychology*, **48**(3), 334–43.

Johnson, S.L., Mehta, H., Ketter, T.A., Gotlib, I.H., Knutson, B. (2019). Neural responses to monetary incentives in bipolar disorder. *NeuroImage: Clinical*, **24**, 102018.

Kitayama, S., Salvador, C.E. (2017). Culture embrained: going beyond the nature-nurture dichotomy. *Perspectives on Psychological Science*, **12**(5), 841–54.

Kitayama, S., Uskul, A.K. (2011). Culture, mind, and the brain: current evidence and future directions. *Annual Review of Psychology*, **62**, 419–49.

Knutson, B., Adams, C.M., Fong, G.W., Hommer, D. (2001a). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience*, **21**(16), RC159.

Knutson, B., Fong, G.W., Adams, C.M., Varner, J.L., Hommer, D. (2001b). Dissociation of reward anticipation and outcome with event-related fMRI. *Neuroreport*, **12**(17), 3683–7.

Knutson, B., Greer, S.M. (2008). Anticipatory affect: neural correlates and consequences for choice. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **363**(1511), 3771–86.

Knutson, B., Rick, S., Wimmer, G.E., Prelec, D., Loewenstein, G. (2007). Neural predictors of purchases. *Neuron*, **53**(1), 147–56.

Kohls, G., Perino, M.T., Taylor, J.M., *et al.* (2013). The nucleus accumbens is involved in both the pursuit of social reward and the avoidance of social punishment. *Neuropsychologia*, **51**(11), 2062–9.

MacNiven, K.H., Jensen, E.L., Borg, N., Padula, C.B., Humphreys, K., Knutson, B. (2018). Association of neural responses to drug cues with subsequent relapse to stimulant use. *JAMA Network Open*, **1**(8), e186466.

Martin, J.D., Wood, A., Cox, W.T., *et al.* (2021). Evidence for distinct facial signals of reward, affiliation, and dominance from both perception and production tasks. *Affective Science*, **2**, 14–30.

Matsumoto, D., Kudoh, T. (1993). American-Japanese cultural differences in attributions of personality based on smiles. *Journal of Nonverbal Behavior*, **17**(4), 231–43.

Meshi, D., Morawetz, C., Heekeren, H.R. (2013). Nucleus accumbens response to gains in reputation for the self relative to gains for others predicts social media use. *Frontiers in Human Neuroscience*, **7**(439), 1–11.

Moll, J., Krueger, F., Zahn, R., Pardini, M., de Oliveira-souza, R., Grafman, J. (2006). Human fronto–mesolimbic networks guide decisions about charitable donation. *Proceedings of the National Academy of Sciences*, **103**(42), 15623–8.

Niedenthal, P.M., Mermillod, M., Maringer, M., Hess, U. (2010). The Simulation of Smiles (SIMS) model: Embodied simulation and the meaning of facial expression. *Behavioral and Brain Sciences*, **33**(6), 417–33.

Oldham, S., Murawski, C., Fornito, A., Youssef, G., Yücel, M., Lorenzetti, V. (2018). The anticipation and outcome phases of reward and loss processing: a neuroimaging meta-analysis of the monetary incentive delay task. *Human Brain Mapping*, **38**(8), 3398–418.

Ozono, H., Watabe, M., Yoshikawa, S., *et al.* (2010). What's in a smile? Cultural differences in the effects of smiling on judgments of trustworthiness. *Letters on Evolutionary Behavioral Science*, **1**(1), 15–8.

Park, B., Blevins, E., Knutson, B., Tsai, J.L. (2017). Neurocultural evidence that ideal affect match promotes giving. *Social Cognitive and Affective Neuroscience*, **12**(7), 1083–96.

Park, B., Qu, Y., Chim, L., Blevins, E., Knutson, B., Tsai, J.L. (2018). Ventral striatal activity mediates cultural differences in affiliative judgments of smiles. *Culture and Brain*, **6**(2), 102–17.

Park, B., Tsai, J.L., Chim, L., Blevins, E., Knutson, B. (2016). Neural evidence for cultural differences in the valuation of positive facial expressions. *Social Cognitive and Affective Neuroscience*, **11**(2), 243–52.

Poldrack, R.A., Baker, C.I., Durnez, J., *et al.* (2017). Scanning the horizon: towards transparent and reproducible neuroimaging research. *Nature Reviews Neuroscience*, **18**(2), 115–26.

Rademacher, L., Krach, S., Kohls, G., Irmak, A., Gründer, G., Spreckelmeyer, K.N. (2010). Dissociation of neural networks for anticipation and consumption of monetary and social rewards. *NeuroImage*, **49**(4), 3276–85.

Ruff, C.C., Fehr, E. (2014). The neurobiology of rewards and values in social decision making. *Nature Reviews Neuroscience*, **15**(8), 549–62.

Rychlowska, M., Jack, R.E., Garrod, O.G., Schyns, P.G., Martin, J.D., Niedenthal, P.M. (2017). Functional smiles: tools for love, sympathy, and war. *Psychological Science*, **28**(9), 1259–70.

Senft, N., Campos, B., Shiota, M.N., Chentsova-Dutton, Y.E. (2021). Who emphasizes positivity? An exploration of emotion values in people of Latino, Asian, and European heritage living in the United States. *Emotion*, **21**(4), 707–19.

Spreckelmeyer, K.N., Krach, S., Kohls, G., *et al.* (2009). Anticipation of monetary and social reward differently activates mesolimbic brain structures in men and women. *Social Cognitive and Affective Neuroscience*, **4**(2), 158–65.

Srirangarajan, T., Mortazavi, L., Bortolini, T., Moll, J., Knutson, B. (2021). Multi-band FMRI compromises detection of mesolimbic reward responses. *NeuroImage*, **244**, 118617.

Tsai, J.L. (2007). Ideal affect: cultural causes and behavioral consequences. *Perspectives on Psychological Science*, **2**(3), 242–59.

Tsai, J.L. (2017). Ideal affect in daily life: implications for affective experience, health, and social behavior. *Current Opinion in Psychology*, **17**, 118–28.

Tsai, J.L., Ang, J., Blevins, E., *et al.* (2016). Leaders' smiles reflect cultural differences in ideal affect. *Emotion*, **16**(2), 183–95.

Tsai, J.L., Blevins, E., Bencharit, L.Z., Chim, L., Fung, H.H., Yeung, D.Y. (2019). Cultural variation in social judgments of smiles: the role of ideal affect. *Journal of Personality and Social Psychology*, **116**(6), 966–88.

Tsai, J.L., Chen, D., Yang, A., Cachia, J., *et al.* (2023). *Two decades of ideal affect: enduring and emerging patterns* [Manuscript in preparation].

Tsai, J.L., Knutson, B., Fung, H.H. (2006). Cultural variation in affect valuation. *Journal of Personality and Social Psychology*, **90**(2), 288–307.

Tsai, J.L., Louie, J., Chen, E.E., Uchida, Y. (2007). Learning what feelings to desire: Socialization of ideal affect through children's storybooks. *Personality and Social Psychology Bulletin*, **33**(1), 17–30.

Tsai, J.L., Ying, Y.W., Lee, P.A. (2000). The meaning of 'being Chinese' and 'being American' variation among Chinese American young adults. *Journal of Cross-Cultural Psychology*, **31**(3), 302–32.

Ueda, R., Abe, N. (2021). Neural representations of the committed romantic partner in the nucleus accumbens. *Psychological Science*, **32**(12), 1884–95.

Wu, C.C., Samanez-Larkin, G.R., Katovich, K., Knutson, B. (2014). Affective traits link to reliable neural markers of incentive anticipation. *NeuroImage*, **84**, 279–89.