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# Self-referential processing and encoding in bicultural individuals

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**Abstract**  Prior neuroimaging evidence suggests that the medial prefrontal cortex (dmPFC and vmPFC) and posterior cingulate cortex (PCC) are involved in self-referential processing and memory, and that the specific patterns of activation differ as a result of culture. In the current study, we used an adjective trait judgment task and a surprise recognition memory task to investigate how bicultural identity influences self-referential processing and memory as compared to a close other (mother) and a distant, familiar other (Gandhi). Contrary to expectations, results indicate that the dmPFC is more engaged for mother-referencing than self-referencing in our sample of bicultural Asian Americans. In terms of subsequent memory, there was increased activation in the PCC for processing of mother-relevant and other-relevant (compared to self-relevant) information that supported the encoding of information into memory. Finally, we observed reversals in the pattern of activity in the dmPFC implicated in subsequent memory for those with a blended bicultural identity versus those with an alternating bicultural identity. These findings suggest that cultural effects, specifically individual differences in bicultural identity,

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modulate neural activity during judgment and encoding of information relevant to the self and others.

## Introduction

Culture has a fundamental influence on the development of the self and can be thought of as a lens for understanding one's environment (Gutchess and Indeck 2009; Markus and Kitayama 1991). It informs our experiences, our conception of self in relation to others, as well as our cognitive functions, such as memory. An important consideration in the study of culture is that as globalization increases, fewer people identify with a single culture, no longer making "culture" a unidimensional term. Of people living in the United States, one out of every four has lived in another country before moving to the United States and likely identifies with both their ethnic (original) culture and the mainstream (host) culture (U.S. Census, 2002, as cited in Benet-Martinez and Haritatos 2005; Berry 1990). As multiculturalism becomes increasingly prevalent throughout the United States and the rest of the world, it is all the more important to understand how the self is represented in the minds of individuals who identify with more than one culture. The purpose of the current study was to investigate the influence of having a bicultural identity on self-referential processing and encoding, and the differences in the neural basis of these processes in Asian Americans, a bicultural group that has seen the highest percentage increase in the last ten years within the U.S. (U.S. Census 2010).

Development of the self has been researched extensively, and inconsistencies emerge between whether the self is a stable, enduring concept or a dynamic entity. Moran et al. (2006) argue that, "a central feature of human existence is the possession of a sense of self that persists across space and time" (p. 1586), whereas others state that the self is dynamic, prone to influence, and inconsistent across environments (Hong et al. 2000; Ng et al. 2010; Sui et al. 2007). Furthermore, evidence suggests that culture influences the self. Markus and Kitayama (1991) propose that people possess either an independent or an interdependent self-concept. Those with independent or individualistic self-concepts define who they are based on individual uniqueness and how they stand out compared to others. In contrast, those with interdependent or collectivistic self-concepts define who they are based on their membership and belongingness to the group and their connections with others. People from individualistic cultures, such as the United States, tend to have a more independent self-concept, while those from collectivist cultures, such as East Asia, tend to have a more interdependent self-concept (Markus and Kitayama 1991; Sui et al. 2007; Triandis 1995).

This East–West difference in endorsing interdependent versus independent selves has been supported by extensive behavioral data, and more recently with neural evidence. Medial prefrontal cortex (mPFC) and posterior cingulate cortex (PCC) are

typically implicated in the self-referential network (Heatherton et al. 2004; Heatherton et al. 2006; Kelley et al. 2002; Macrae et al. 2004; Northoff et al. 2006). There is evidence that activations in these regions are modulated by cultural factors. For example, studies show that both self-referential and mother-referential encoding activate mPFC in Chinese participants, suggesting that the Chinese concept of the self includes or overlaps with that of the mother (Han and Northoff 2009; Zhang et al. 2006). These results also provide a potential explanation for similar enhancements in memory for mother and self that occurs for Chinese, but not Western participants (Zhang et al. 2006; Zhu and Zhang 2002; Zhu et al. 2007). In comparison to Chinese participants, Westerners demonstrate increased mPFC activity for self-judgments and reduced mPFC activity for mother-judgments (Zhu et al. 2007).

It is important to note, however, that the neural evidence does not always support this cultural difference in self-concept. In an fMRI investigation, Ray et al. (2010) had American participants (of various ethnicities) complete an adjective judgment task (self, mother, valence and font) and the self-construal scale, which measures self-construal style in terms of independence and interdependence (Singelis 1994). Contrary to expectations, those with an interdependent self-construal exhibited greater recruitment of mPFC and PCC during self-relevant judgments than mother-relevant judgments. Another study used the self-construal scale with Japanese and American participants and found that the degree of independent or interdependent self-construal style in both Japanese and American participants predicts mPFC activity during general and contextual judgments (Chiao et al. 2009).

These mixed results may be partially explained by the growing prevalence of biculturals, or individuals who are familiar with and knowledgeable about both interdependent and independent self-concepts. Hong et al. (2000) found that bicultural Chinese participants in Hong Kong and America were able to activate both Chinese and American self-concepts depending on external cultural primes. Using cultural primes—external cues that make salient a cultural "mindset"—has been extensively used in social and cultural psychological research of late. According to the "dynamic constructivist" model of culture, culture is much like a schema in that culturally-relevant knowledge and values can be made salient using different primes. Supporting this model, Hong et al. (2000) developed a set of culturally-meaningful pictorial icons to prime Chinese and American cultural schemas among a group of Chinese-American biculturals. Asian cultural cues included icons such as a pair of chopsticks, Chinese calligraphy, and a Chinese opera singer. American cues included icons such as Mickey Mouse, a cowboy, and the Statue of Liberty. This study, and many subsequent studies, have found that such cultural-icons primed culture-specific behaviors—for example, participants who were experimentally exposed to Chinese cultural primes exhibited prototypical Chinese behaviors and cognitions, and participants who were experimentally exposed to American cultural primes exhibited prototypical American behaviors and cognitions (for reviews of this literature, see Benet-Martínez and Lee 2009; Cheng and Lee in press). Extending this set of research, other studies have replicated these findings with different cultural groups (Guan et al. 2012) and with different cultural primes such as culturally-stereotypical words or food items (Cheng and Lee 2009; Guan 2013).

The ability to activate both Chinese and American self-concepts after exposure to external cultural primes, defined as bicultural frame switching, suggests that self-concepts are indeed multifaceted and subject to change based on the situation, underscoring the plasticity of the self. Similar processes have been observed in neuroimaging studies of biculturals; Chiao et al. (2010) exposed bicultural individuals to independent or interdependent primes followed by a self-judgment task during scanning. In the task, they were asked to decide whether a trait applied to them in general or in a specific context. Participants exposed to the independent prime showed greater activation in mPFC for general relative to contextual judgments, and those given the interdependent prime demonstrated greater mPFC activation for contextual relative to general self-descriptions. Activation in the PCC mirrored these findings (Chiao et al. 2010). Another study employed a within-subject design and showed that cultural primes modulate activity in the dorsal portion of the mPFC in Asian Americans performing a trait judgment task (self-relevant, father-relevant, unfamiliar other person-relevant; Harada et al. 2010). Similar findings were obtained in a priming study conducted in Hong Kong where participants are familiar with both independent and interdependent cultural frames (Ng et al. 2010). Participants who received the Western (or independent) prime showed increased activity in ventral medial prefrontal cortex (vmPFC) during self-judgment relative to other-judgment. Following the Chinese (or interdependent) prime, participants did not show differential activation for self versus mother or a non-intimate person.

In this study, we consider how individual differences moderate memory and neural processes underlying bicultural frame switching. Phinney and Devich-Navarro (1997) differentiate between two types of biculturals—those with a "blended" bicultural identity who incorporate both cultural groups into a single, bicultural identity that is different from the two original cultural identities, and those with an "alternating" bicultural identity who switch back and forth between the two cultures to which they belong. To the extent that alternating biculturals retain their original cultural identities and keep them separated, they may be more apt to show bicultural frame switching where they switch back and forth between the different cultural identities. We used the Bicultural Identity Integration Scale (BII) (Benet-Martinez and Haritatos 2005) to measure individual differences in blended versus alternating bicultural identities, where biculturals with high BII perceive their cultural identities as compatible and "blended" (e.g., Chinese-American biculturals with high BII would consider themselves "Chinese-American" rather than a Chinese person living in America). In contrast, biculturals with low BII perceive their cultural identities as separate such that they switch or alternate between their different cultural identities (e.g., biculturals with low BII would feel torn between two different cultural worlds.). We measured neural activity (via fMRI) during a trait judgment task, while participants made judgments about the self, mother, and Gandhi, as a familiar other who was not personally known. Following the scan, memory for the traits was tested. Measures of memory have reliably reflected differences in memory for information relevant to the self versus information relevant to others, most reliably in terms of a self-reference effect, which is an enhancement in memory for information relevant to the self (Rogers et al. 1977).

We were primarily interested in how individual differences in blended (high BII) versus alternating bicultural identities (low BII) affect both behavioral (memory) and neural (fMRI) measures as well as susceptibility to the cultural prime.

In terms of neural activation in mPFC, we expected higher levels of activation for self-relevant information that is subsequently remembered than that later forgotten (Gutchess et al. 2010; Macrae et al. 2004), and this should occur in conjunction with a self-reference effect in memory. It is possible that these effects would be attenuated for those exposed to the Asian prime, as they would be expected to exhibit a mother-reference effect (Sui et al. 2007). Compared to the Asian prime, those exposed to the American prime should show greater differentiation of self from mother as measured by mPFC and PCC, and a larger self-reference effect in memory.

The third set of hypotheses predicted that blended versus alternating bicultural identity would moderate neural effects. Specifically, we expected to replicate previous findings that culture modulates activity in the mPFC and the PCC (Harada et al. 2010), but that BII will moderate these trends and influence the effectiveness of cultural priming. We predicted that alternating Asian American biculturals, or those low in BII, would be more susceptible to the influence of primes. Because alternating biculturals keep their two cultural identities separate, they are more likely to exhibit an independent (i.e., American) self-concept in response to American primes, and an interdependent (i.e., Asian) self-concept in response to Asian primes. In short, alternating Asian American biculturals exposed to the American prime would be expected to show differential activity in mPFC and PCC for self versus mother (i.e., self-referencing), whereas those exposed to the Asian prime would *not* differ in this comparison, reflecting their heightened focus on mother-referencing. We also might expect that alternating Asian Americans would show a greater difference in their response to self versus mother than blended Asian Americans, who may not exhibit the culturally-specific patterns revealed in prior studies (e.g., Zhu et al. 2007). This is because blended Asian Americans have an amalgamated self concept that may balance the representations of both self and mother.

## Methods

### Participants

Forty-eight Asian American participants were recruited from the area surrounding Temple University in Philadelphia, PA. Consistent with other research using bicultural individuals (Benet-Martinez et al. 2002), inclusion criteria were that the individuals were born in and had spent at least 5 years in an East Asian country before moving to the United States. We were not interested in recruiting participants based on whether they had strong bicultural identities to begin with, given that we wanted to address individual differences in identity, but simply that they had lived in two cultures. Participants were randomly assigned to three priming conditions: Asian prime, American Prime, or Neutral Prime. Two participants from the Asian Prime

condition and one from the American condition were excluded from all analyses because of imaging data loss for one and excessive movement in the scanner for the other two. After preprocessing, 11 additional participants were excluded for excessive movement. An additional three participants were excluded for poor image quality and artifact during acquisition. This left a total of 31 participants who were used for analysis of neural activity during trait judgment and encoding. There were 18 females and 13 males ($M_{\text{age}}$ = 23.61 years, $SD$ = 7.16 years). The majority of the sample had lived in China (51.6 %), followed by Korea (32.3 %), Taiwan (12.9 %), and Hong Kong (3.2 %). The average number of years since arrival in the U.S. was 7.16 years ($SD$ = 4.49 years), with a range from 2 to 20 years.

The analyses of subsequent memory data are based on a subset ($n$ = 18) of the sample, with 13 participants excluded for having an insufficient number of trials (<6) in at least one condition. This subsample consisted of eight males and ten females ($M_{\text{age}}$ = 23.17 years, $SD$ = 4.66 years), with a distribution of ethnicities and length of time in the U.S. that was similar to the full sample. Written informed consent was obtained from all participants before beginning the experiment.

Procedure

Approximately 2 weeks prior to scanning, participants attended a behavioral session. In addition to providing demographic information, they completed the Bicultural Identity Integration (BII) scale (Benet-Martinez and Haritatos 2005) which included eight items on a 5-point Likert-type scale rated from 1 (completely disagree) to 5 (completely agree). Sample items include: "I am simply an Asian who lives in North America (i.e., I am an Asian who happens to live in the U.S.)" (reverse scored) and "I feel part of a combined culture".

For the scanning session, participants were randomly assigned to one of three priming conditions (Asian, American, or Neutral). In the priming phase, morphed Asian or Caucasian faces of males and females served as primes. Participants made judgments about pictures of individuals from the primed culture (e.g. "Indicate whether or not you like or dislike each face"). Face images were created using the FaceGen Modeller 3.3 (Singular Inversions Inc.), which allowed us to create 100 % Asian faces for the Asian prime, 100 % Caucasian faces for the Caucasian prime, and a blend of 50 % Asian and 50 % Caucasian for the neutral prime. Primes immediately preceded each of two sets of adjective trait judgment tasks. For the trait judgment task of primary interest, the following instructions appeared on the screen, "Now, you'll decide whether the adjective describes you ("Self"), your Mother, or other ("Mahatma Gandhi"). Please press the left (YES) or the right (NO) key for each trial." Gandhi was chosen because he is a familiar target that people do not know personally. The prompt corresponding to the condition appeared on the screen with the adjective for each trial, followed by a fixation cross prompting a judgment before the next word appeared. Fixations were also jittered between trials. There were a total of 144 words, with 48 words in each of the three conditions. All cognitive tasks and primes were presented on E-prime (Psychology Software Tools, Pittsburgh, PA). The adjective task of interest in the current study was completed after two other experimental tasks (The Framed Line Task; Kitayama et al. (2003)

and the animated fish vignette task; Nisbett and Masuda (2003)), which will be analyzed and reported elsewhere. Because these tasks do not assess long-term memory or reflective self-processing, they should not affect the pattern of results reported here.

Outside of the scanner, participants were asked to complete a surprise recognition task for the words from the adjective trait judgment task. There were 288 words presented, 144 old, and 144 new lures, which were counterbalanced across participants. They were asked to identify whether they had seen the word in the previous task. Finally, participants were debriefed, paid and dismissed.

## Imaging parameters

Structural and functional images were acquired on a 3-Tesla Siemens Verio whole-body scanner with a standard CP head coil. Participants were scanned with contiguous 5 mm axial high-resolution and T1-weighted structural slices (matrix size $= 256 \times 256$; TR $= 600$ ms; TE $= 2.51$ ms; FOV $= 210$ mm; NEX $= 1$; slice thickness $= 0.9$ mm) were collected for spatial normalization procedures, and overlay of functional data. Precise localization based on standard anatomic markers (AC-PC Line) was used for all participants. Functional scans were acquired with a gradient-echo planar free induction decay (EPI-FID) sequence (T2*weighted: matrix size $= 64 \times 64$; TR $= 2000$ ms; TE $= 30$ ms; FOV $= 210$ mm; NEX $= 1$; slice thickness $= 4.0$ mm) in the same plane as the structural images. Voxel size was 3.33 mm $\times$ 3.33 mm $\times$ 5 mm.

## Data analysis

Preprocessing and analysis of the imaging data was done using SPM8 (Wellcome Trust Centre for Neuroimaging, London, UK). Preprocessing included slice-time correction, realignment to correct for movement, normalization to the Montreal Neurological Institute (MNI) template, coregistration of each participant's structural scan to their mean functional image derived from the realignment step, and spatial smoothing to a 6-mm full-width half maximum isotropic Gaussian kernel. First level analyses were modeled separately to examine processing self versus other-relevant information as well as subsequent memory for this information. First, we modeled data with three regressors corresponding to the self, mother and other trials for the encoding phase of the experiment based on an event-related design. For the analysis of subsequent memory, we modeled each condition by whether the trait was remembered or forgotten (i.e., self remembered, self forgotten, mother remembered, mother forgotten, other remembered, other forgotten). Contrasts of interest at the individual subject level were then entered into the second level analysis, and we tested for significant effects in the ROIs for contrasts at the group level.

For the subsequent memory analysis (Brewer et al. 1998; Wagner et al. 1998), encoding trials were back sorted based on memory performance (i.e., remembered, forgotten) collected during the post-scan memory test. In order to analyze the effect of BII, we performed a median split on these scores to create a high (blended) BII group ($n = 9$; $M = 3.54$, $SD = 0.38$) and a low (alternating) BII group ($n = 9$;

$M = 2.63$, $SD = 0.29$). The median was 3.25 (on a 5 point scale) (see Benet-Martinez et al. 2002, for prior studies categorizing high and low BIIs using this method). As seen in Table 1, there are no significant differences in the number of years spent in the US, gender, or culture of birth between participants in the two groups (there is a trend for an age difference, $p < 0.08$). These data suggest that individuals that fall within these two categories are well matched and only vary in their individual differences in bicultural identity integration.

Based on previous research on self-referential memory (Gutchess et al. 2010, 2007), we created three a priori regions of interest (ROIs). Due to the limited number of participants in each group, an ROI approach was adopted to increase our sensitivity to detect effects in regions expected to be involved in self and other-referential processes based on previous literature. 10-mm spheres were created from the peak voxel coordinates for the three ROIs. We selected regions for the dorsomedial prefrontal cortex (dmPFC) ($-2$, 32, 50) and posterior cingulate cortex (PCC) (6, 36, 50) based on their sensitivity to memory effects in a previous fMRI investigation of self-referential encoding (Gutchess et al. 2010). The coordinates for ventral medial prefrontal cortex (vmPFC) ($-8$, 60, 4) were obtained from a separate self-reference paper (Gutchess et al. 2007) because while vmPFC often emerges as a region activated for subsequent memory (Macrae et al. 2004), it did not emerge in our lab's previous self-referencing subsequent memory study (Gutchess et al. 2010). For the subsequent memory analysis, we were interested in whether cultural identification would modulate the engagement of mPFC during subsequent memory formation for words judged relative to the self, as opposed to mother and distant other. For each analysis, we identified regions that survived our small volume correction (SVC) at the threshold of $p_{FWE} < 0.05$. Once identified, parameter estimates were extracted from the peak voxel to characterize the nature of the effects in our groups of interest. The plotted graphs in Figs. 1, 2 and 3 are the extracted parameter estimates in arbitrary units.

| | Alternating (low) BII | Blended (high) BII |
|---|---|---|
| Years in US | | |
|   Mean | 7.67 (5.32) | 7.67 (4.03) |
| Age | | |
|   Mean | 25.11 (5.67) | 21.22 (2.33) |
| Gender | | |
|   Female | 56 % | 56 % |
|   Male | 44 % | 44 % |
| Birth country | | |
|   China | 44 % | 44 % |
|   Korea | 33 % | 44 % |
|   Hong Kong | 0 % | 11 % |
|   Taiwan | 11 % | 0 % |
|   Other | 11 % | 0 % |

**Table 1** Demographics for the subset of 18 participants used for the analysis of memory data by BII

Means or percentages are presented and standard deviations are in parentheses
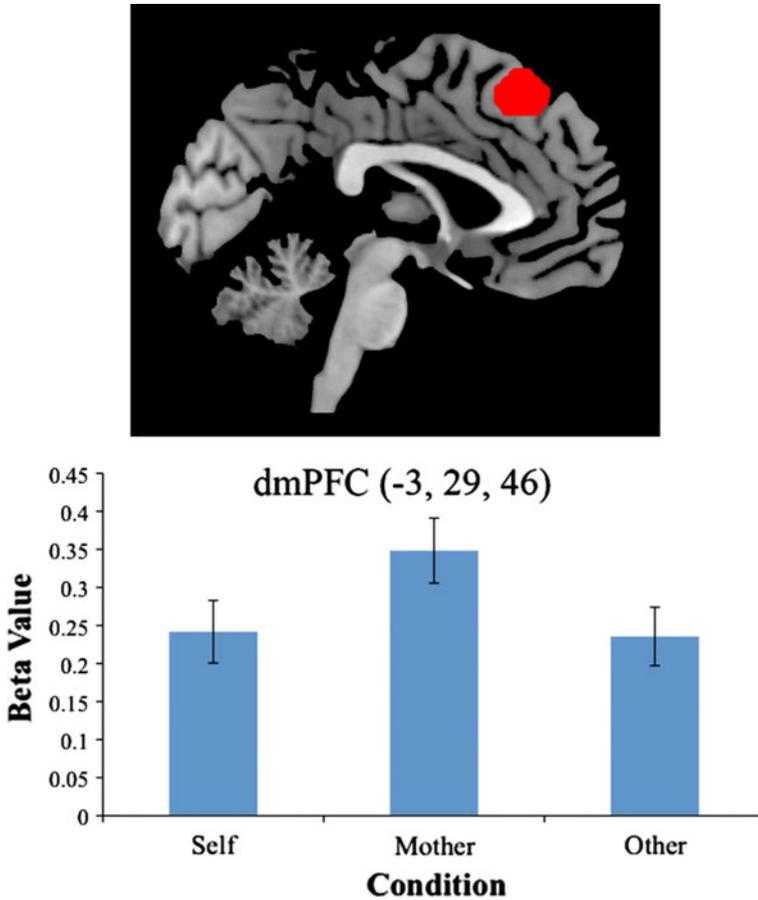
**Fig. 1** Parameter estimates for the peak voxels extracted from significant activations that emerged from the trait judgment and encoding data in the contrast of mother − self

## Results

Behavioral recognition performance

In order to analyze memory performance, we calculated corrected recognition scores using a measure of hits minus false alarms. We used this corrected recognition scores from the restricted sample used for the fMRI analyses ($n = 18$). We submitted the corrected recognition scores to a 3 (condition: self, mother, other) × 3 (prime: American, Asian, neutral) × 2 (BII score: high, low) mixed ANOVA with condition as the within-subjects factor and prime and BII score as between-subjects factors. There was a significant main effect of condition, $F(2,24) = 7.04$, $p < 0.01$, $\eta^2 = 0.37$, driven by significantly better memory for self-relevant adjectives than mother-relevant adjectives $t(17) = 3.85$, $p < 0.01$, and
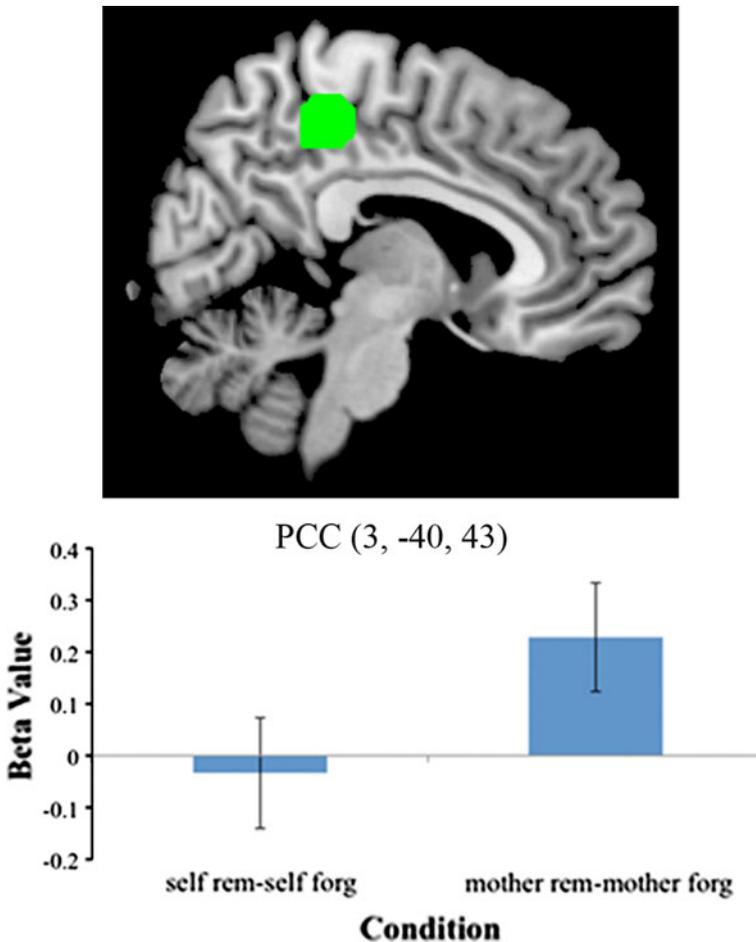
**Fig. 2** Parameter estimates for the peak voxels (labeled *above* the *graph*) extracted from the significant activations that emerged from the subsequent memory data. The *graph* represents the contrast [(mother remembered − mother forgotten) − (self remembered − self forgotten)]

other-relevant adjectives, $t(17) = 3.57$, $p < 0.01$ (see Table 2). Memory for mother-relevant and other-relevant adjectives did not significantly differ; therefore we will not discuss other-relevant effects further. There were no significant interactions or main effects involving prime or BII score.

Functional MRI data

Due to limited final sample sizes, we did not have adequate power to analyze the interaction of cultural priming with bicultural identity integration. Therefore, we collapsed subjects with different primes together and focused on analyzing the effects of bicultural identity integration (blended and alternating).
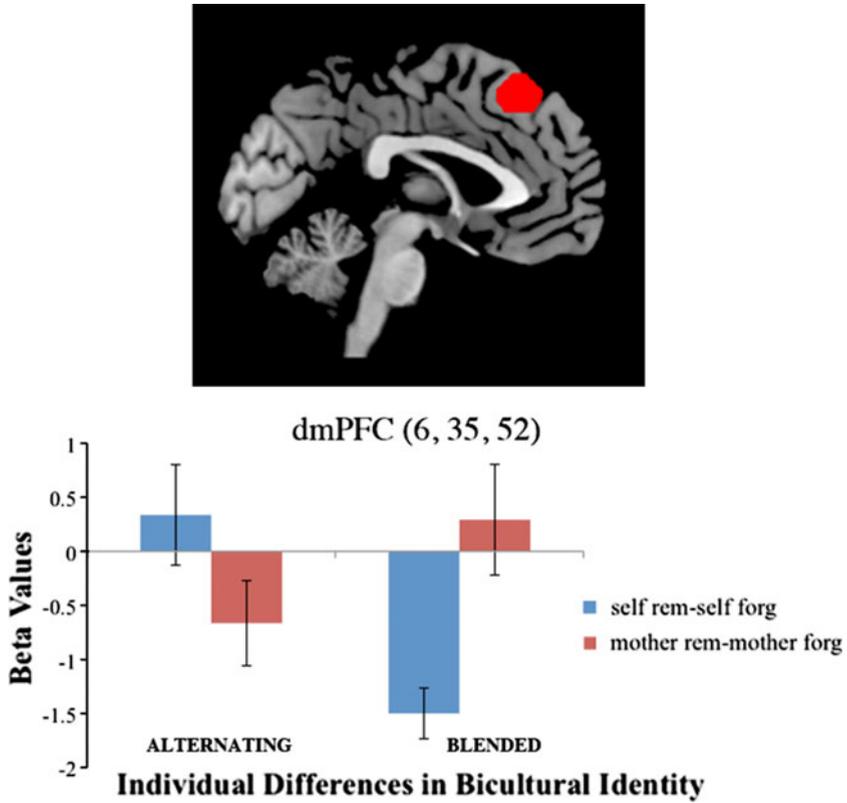
Fig. 3 Parameter estimates for the peak voxels (labeled *above* each *graph*) extracted from the significant activations that emerged from the interaction between subsequent memory data and individual differences in bicultural identity, as measured by BII scores. The contrast shown above is alternating − blended BII: [(self remembered − self forgotten) − (mother remembered − mother forgotten)]

**Table 2** Summary of corrected recognition (hits-false alarms) collapsed across prime and individual differences in bicultural identity and split by individual differences in bicultural identity

|                                                | Self        | Mother      | Other       |
|------------------------------------------------|-------------|-------------|-------------|
| All                                            | 0.36 (0.22) | 0.25 (0.18) | 0.28 (0.18) |
| Individual differences in bicultural identity  |             |             |             |
|   Alternating                                  | 0.35 (0.25) | 0.23 (0.21) | 0.29 (0.20) |
|   Blended                                      | 0.37 (0.18) | 0.27 (0.17) | 0.27 (0.18) |

Means are presented and standard deviations are in parentheses

*Note* $n = 18$

## Trait judgment and encoding

We analyzed these data in the full sample ($n = 31$) in order to determine whether cultural effects influenced the engagement of mPFC and PCC. We predicted that

neural activation during judgments of self-relevant traits would be distinct from mother-relevant traits, collapsing across both prime and BII. The contrasts of self − mother and mother − self were created and tested in each of the three ROIs. Contrary to our expectation, activation was greater for the mother than the self in two distinct activations within our dmPFC region of interest [(−3, 29, 46) and (0, 35, 43)]. There were no significant main effects or interactions involving prime or BII. Beta values were extracted and are plotted in Fig. 1.[1] Somewhat surprisingly these contrasts did not elicit significant differences in vmPFC, although the region did emerge in the expected self versus other contrast at a reduced threshold in an exploratory whole-brain analysis.

*Subsequent memory analysis*

We first examined memory effects collapsed across prime and BII, expecting that dmPFC, vMPFC, and PCC would be engaged more during self-relevant trials that were subsequently remembered than forgotten. In order to address this question, we created the contrast of [(self remembered − self forgotten) − (mother remembered − mother forgotten)] and the reverse contrast. We expected to see a self-reference effect in memory, such that activation in the mPFC and PCC would be greater for items relevant to the self (vs. mother) that were later remembered compared to those later forgotten. However, we only found significant activation in the PCC for the [(mother remembered − mother forgotten) − (self remembered − self forgotten)] contrast. As can be seen in Fig. 2, these activations reflect greater engagement of the PCC for mother items later remembered, rather than forgotten, as compared to the self condition.

*Culture effects on subsequent memory*

Culture effects were tested as a function of prime and BII. Given that no regions survived the SVC in the contrasts that compared prime, we only discuss the interactions with BII. In order to measure cultural effects on subsequent memory, we measured effects in the selected ROIs (i.e., vmPFC, dmPFC, and PCC). We tested for effects of BII in the following contrasts: high BII − low BII: [(self remembered − self forgotten)] − (mother remembered − mother forgotten)] and the reverse (i.e., low BII − high BII). A significant interaction emerged in the dmPFC (See Fig. 3). Participants with high BII scores (or blended biculturals) had greater activation in the dmPFC for mother-relevant information that was later remembered (vs. forgotten), relative to the self-referenced items. The pattern was reversed for alternating biculturals, or participants with low BII scores, such that they engaged the region more for self-relevant items that were later remembered (vs. forgotten), as compared to mother-relevant information (see Fig. 3).[2]

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[1]  Note: We have only plotted the most significant activation (−3, 29, 46) because the pattern is similar for the neighboring activation.

[2]  To substantiate this finding in light of potential concerns about small sample sizes and the reduced sensitivity of a median split analysis, we conducted an additional analysis treating BII as a continuous variable. Based on the 18 participants in the subsequent memory analyses, a Pearson's correlation (two-tailed) revealed a significant

## Discussion

In the current study, we sought to investigate the effects of biculturalism on processing and memory for the self in relation to other people. Consistent with our hypothesis, we found evidence that individual differences in bicultural identity influence activation in the dmPFC, such that there was an interaction between BII (blended vs. alternating) and subsequent memory for items relevant to the mother versus self. Whereas we had predicted that neural activity across conditions may differ less for individuals with blended than alternating identities, we found that the groups differed in which conditions engaged neural regions. Dorsal mPFC was activated during encoding trials that were subsequently remembered for mother judgments in those with a blended bicultural identity, and for self judgments in those with an alternating bicultural identity. Among blended biculturals, this finding is consistent with the trait judgment and encoding data, which showed greater dmPFC activation for the mother than the self. However, the pattern was reversed for alternating biculturals, such that there was increased activation in the dmPFC for self-relevant items (rather than mother-relevant) that are subsequently remembered (vs. forgotten).

Gutchess et al. (2010) found similar reversals in a study comparing aging effects on memory for self versus other-relevant information. Blended biculturals in our study showed the same pattern as young adults in their study and alternating biculturals showed a pattern similar to older adults. These authors speculated that the reversals reflected differences in what qualities older and younger adults attend to during information processing, which also seems plausible in our task. Perhaps the relationship with the mother differs across blended versus alternating biculturals, or they reflect on different knowledge and encounters with her during the judgments. Blended and alternating biculturals engaged the same region (dmPFC) for successful encoding, but there was a distinction between the judgment (self vs. mother) that engages the region during encoding.

Our study provided evidence for a self-reference effect in memory (Rogers et al. 1977) across primes and individual differences in bicultural identity, with self-relevant adjectives being remembered better than those related to the mother and other. This finding contradicts past research in which memory performance was better for both words about the self and the mother as compared to another person for participants from East Asian countries (Sui et al. 2007). While our behavioral memory data would predict heightened engagement of self-referential regions (vmPFC and dmPFC) during self processing relative to the mother and other, we observed increased neural activity for

judgments regarding the mother more than the self, when collapsed across prime and individual differences in bicultural identity. This is inconsistent with previous research showing increased activation in this area for self-relevant processing in European Americans and Canadians (Craik et al. 1998; Heatherton et al. 2004; Heatherton et al. 2006; Northoff et al. 2006). East Asians typically engage the regions similarly for both self and mother (Han and Northoff 2009; Zhang et al. 2006; Zhu et al. 2007), but in our Asian American bicultural sample we find increased activation for mother over self. This pattern of activation and the lack of a mother-reference effect in memory could reflect the wide individual differences in cultural identification, based on the number of years in the U.S. or bicultural identity. Additionally, our data were collected in the United States while previous research was done in China (Sui et al. 2007).

While the mPFC is widely accepted as a region implicated in self-relevant processing, both dorsal and ventral regions are also engaged during mentalizing, or thinking about the mental states of another person (Mitchell et al. 2005). Particularly when thinking about dissimilar others, the dorsal region of the mPFC is more engaged than when thinking about similar others (Mitchell et al. 2006). We speculate that in the current study it is possible that participants are engaging these regions more for mother-relevant information because they are employing mentalizing during trait judgments and encoding, rather than more traditional self-referential processing. These findings may be influenced by the fact that these participants are all bicultural East Asians living in the United States, outside of their native countries. Additional systematic comparisons of sample characteristics and environmental influences (e.g., testing location) are needed for future studies.

In the analysis of neural activity related to subsequent memory, we expected to see increased dmPFC activity for self-relevant items that were subsequently remembered than forgotten (Macrae et al. 2004) and PCC activation, as it has been implicated in memory-related processes (Wagner et al. 2005) and self-referential processing (Kelley et al. 2002; Sajonz et al. 2010; Whitfield-Gabrieli et al. 2011). We found a larger subsequent memory effect for mother, as compared to self, judgments in only the PCC (not mPFC). Engagement of the PCC seems to be related to effective encoding for mother conditions but reflects impaired engagement during encoding in the self condition (directionally negative bars in Fig. 2). Johnson et al. (2006, 2009) have suggested that there is a dissociation between medial frontal and posterior cingulate activity in self-reflective processing based on two distinct agendas—hopes and aspirations (promotion focus), and duties and obligations (prevention focus). Posterior cingulate seems to be engaged during prevention-focused self-reflection, consistent with the idea that considering duties and obligations necessitates a more social, outward focus. East Asians tend to be more prevention-focused (emphasizing duties and obligations) whereas Americans are more promotion-focused (concentrating on hopes and aspirations; Heine 2005), which is in line with our findings of PCC, but not mPFC, activity during the effective encoding of mother-relevant information.

The engagement of the dorsal mPFC during self-evaluation and especially the interaction with bicultural identity is consistent with Chiao et al.'s (2010) finding that culture modulates dorsal, rather than ventral, regions of the mPFC. Activation in this region supports processes that benefit memory for mother, and hurt memory for self

in the participants that have a blended bicultural identity. These participants may be engaging in more perspective taking or mentalizing, as supported by activation in the dorsal mPFC for subsequently remembered information relevant to their mother, as compared to the self. Alternating biculturals or those who are low in BII seem to be using this region for more traditional self-relevant processing regardless of prime. This distinction in dmPFC activation between blended and alternating biculturals suggests that culture, specifically individual differences in bicultural identity, may be modulating the activity in this region.

Touryan et al. (2007) suggest that information about others and our understanding of them may be framed by a regulatory focus that is determined by social interactions. Social interactions are largely influenced by cultural norms, and therefore our participants may have different regulatory focus based on their cultural background, which may influence encoding of, and memory for self or other relevant words. Blended biculturals may have closer relationships with their mothers, which has directed their regulatory focus and facilitated their ability to merge and integrate their cultural identities. Alternating biculturals may have a more self-directed regulatory focus, which hinders their ability to integrate both cultural identities. Future research is needed to examine this possibility.

Because much of the previous research on self-referential processing and memory has used European American participants, the ROIs we selected may not be ideal for Asian American participants. Due to our reduced sample size, it was necessary to focus on select regions drawn from the literature, but future research should employ larger samples so that additional regions can be identified in a whole-brain exploratory analysis of an East Asian sample.

In addition, the limited sample size and high percentage of unusable data prevented us from investigating prime in conjunction with BII. In the reduced sample used for subsequent memory analyses, the neutral prime was underrepresented ($n = 2$), compared to the American prime ($n = 7$) and the Asian prime ($n = 9$). Future work should investigate whether individual differences in bicultural identity affect the neural response to primes. Though we were unable to measure the interaction between BII and prime, making the current study exploratory in nature, the results indicate that individual differences in bicultural identity modulate neural activity.

Another potential concern is about unintended contributions of prime to the results. While we acknowledge this as a limitation, the lack of any effects of prime seem to indicate that this factor does not account for our results. The presence of primes also does not act as a confound with BII because there are similar distributions of the prime conditions across each BII group. It is possible that our priming manipulation, using faces, was not particularly robust. The priming manipulations most commonly employed in the literature (i.e., images of cultural icons or thinking about the independent vs. interdependent nature of an individual), may be more promising to use in future investigations.

Notwithstanding the limitations, the current study makes some unique contributions to the literature. In terms of neural activations, this particular sample shows preferential engagement of regions associated with self-referencing for the mother during the adjective judgment task. In terms of subsequent memory, our data show

greater involvement of areas implicated in memory processes for the mother and other as compared to the self. Both of these findings contrast prior findings on self-referencing, suggesting a substantial role for cultural background in the engagement of neural regions during self and other processing. Our results indicate a relationship between cultural effects and subsequent memory, suggesting that individual differences in bicultural identity, as assessed by BII scores, modulate neural activation during successful encoding of information relevant to the self and other. While we have focused on bicultural identity integration, using the BII scale, there are a number of ways in which biculturalism can be defined and operationalized (see Nguyen and Benet-Martinez 2007 for a discussion of this topic). Much more work is needed to further explore the ways in which different aspects of the complex concept of bicultural identity impact memory and neural activity. The current study provides preliminary evidence that there is differential engagement of the mechanisms related to mentalizing and memory across people with different bicultural identities while processing and encoding of information relevant to the self or mother.

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