

Interdependent self-construal and neural representations of self and mother

Rebecca D. Ray,¹ Amy L. Shelton,² Nick G. Hollon,³ David Matsumoto,⁴ Carl B. Frankel,¹ James J. Gross,³ and John D.E. Gabrieli⁵

¹Vanderbilt University, Department of Psychology, Nashville, 37204, ²Johns Hopkins University, Department of Psychological and Brain Sciences, Baltimore, 21218, ³San Francisco State University, Department of Psychology, San Francisco, 94132, ⁴Stanford University, Department of Psychology, Stanford, 94305, and ⁵Massachusetts Institute of Technology, Department of Brain & Cognitive Science, Cambridge, 02139

Representations of self are thought to be dynamically influenced by one's surroundings, including the culture one lives in. However, neuroimaging studies of self-representations have either ignored cultural influences or operationalized culture as country of origin. The present study used functional magnetic resonance imaging to examine the neural correlates of individual differences in interdependent self-construal. Participants rated whether trait adjectives applied to themselves or their mothers, or judged their valence or font. Findings indicated that individual differences in interdependent self-construal correlated positively with increased activation in the medial prefrontal cortex and posterior cingulate cortex when making judgments about one-self vs making judgments about one's mother. This suggests that those with greater interdependent self-construals may rely more upon episodic memory, reflected appraisals, or theory of mind to incorporate social information to make judgments about themselves.

Keywords: interdependence; self; culture; fMRI

INTRODUCTION

One of the central claims of cultural psychology is that an individual's representations of self and others are influenced by that individual's culture of origin (Markus and Kitayama, 1991; Nisbett *et al.*, 2001; Triandis, 1995). More specifically, two cultural models of self- and other-construal have been identified, Independence and Interdependence. These two models of self- and other-construal correspond to the two main cultural descriptors, Individualism and Collectivism (Markus and Kitayama, 1991). Individualistic cultures (e.g. United States) are said to promote independent self-construals, which emphasize internal attributes, the uniqueness of the self and independence from close others (Nisbett *et al.*, 2001; Triandis, 1995; Triandis *et al.*, 1986 and 1988). In contrast, collectivistic cultures (e.g. China and Japan) are thought to foster Interdependent self-construals, which emphasize relatedness, or the interdependence of self with close others.

Neuroimaging studies comparing East Asians and Westerners have provided some evidence that culture influences neural recruitment when making judgments about oneself and a close other (Zhang *et al.*, 2006; Zhu *et al.*,

2007). Using a self-referential processing task, Zhu *et al.* (2007) found that those from a Collectivistic culture (China) recruited regions of the medial prefrontal cortex (MPFC) to the same extent when making judgments about themselves and their mothers. In contrast, the group from Individualistic cultures (Canada, England, America and Australia) recruited regions of the MPFC and rostral anterior cingulate cortex (rACC) more when making judgments about themselves than their mothers. Taking MPFC activation to reflect self-relevant processing, this study supports the idea that those from Collectivistic cultures include representations of close others in representations of the self; whereas those from Individualistic cultures do not.

One puzzle, however, is that studies within Western countries/cultures have produced mixed results when comparing judgments about self vs a familiar other. For example, studies in Canada and USA compared self-reference with the Canadian prime minister (Craig *et al.*, 1999) and American president (Kelly *et al.*, 2002), respectively. Craig *et al.* (1999) observed no difference in MPFC activations for self and prime minister judgments [and both activations were greater than semantic judgments; see also Lou *et al.* (2004) for a converging Danish study], whereas Kelly *et al.* (2002) found greater MPFC activation for self-judgments compared to President judgments, with president equivalent to an orthographic (upper vs lower case judgment) task. A similar discrepancy is evident in studies that have compared self-judgments with judgments about close friends and relatives. In some cases, judgments about oneself and a best friend or

Received 16 March 2009; Accepted 11 August 2009

Advance Access publication 12 October 2009

The authors thank Cendri Hutcherson, Volney Gay, Art Aron, Bethany Michel and Hazel Markus for their helpful comments. The first author was supported by the MH58147 and MH20006 training from National Institute of Mental Health grants during the course of this study.

Correspondence should be addressed to Rebecca D. Ray, Psychology Department, Vanderbilt University, 111 21st Avenue, 204 Wilson Hall, Nashville, TN 37203, USA. E-mail: rebecca.ray@vanderbilt.edu

relative yielded comparable MPFC and PCC activations (Lou *et al.*, 2004; Ochsner *et al.*, 2005; Schmitz *et al.*, 2004). In other cases, however, judgments about a best friend or one's mother failed to activate MPFC/rACC regions to the same extent as self-relevant judgments (Heatherton *et al.*, 2006; Vanderwal *et al.*, 2008).

One potential explanation for the mixed literature is that (i) prior studies have operationalized culture by country of origin and (ii) individuals may differ in the extent to which they adopt cultural values (Matsumoto *et al.*, 1999). As a result, within a culture, individual variation in cultural affiliation may influence brain functions. In a study reporting level of cultural identification as a factor in neural activation, people from East Asian and Western cultures exhibited different patterns of brain activation depending on whether a simple visuo-spatial task emphasized independent or interdependent stimulus dimensions (Hedden *et al.*, 2008). Within both groups, however, activation differences varied in relation to the degree to which individual participants identified with their culture's typical values. Furthermore, self-referential processing seems to produce different MPFC and PCC recruitment depending on context (general or contextual) and individual differences in cultural self-construal in one study, and cultural prime in another (Chiao *et al.*, 2009a, b). In light of these findings, one notable limitation of prior studies investigating the neural bases of self *vs* close other judgments is the absence of direct measures of individual differences in cultural self-construal.

The present study examined whether individual differences in cultural self-construal were associated with differences in activation between judgments about oneself and a close other. In order to answer these questions, we compared activation associated with judgments about the self-relevance of trait adjectives to that of judgments about the relevance of trait adjectives to a person for whom knowledge is almost always intimate, detailed and long-standing—one's mother. Participants also made valence judgments and baseline orthographic judgments (letter case). To test whether individual differences in measures of cultural self-construal account for variability in activations between self- and mother-judgments, we measured individual differences in interdependent self-construal. Our hypothesis was that if interdependent self-construals conceptually include representations of others into the self, then interdependent self-construals may also materially be processed in the same regions as the self. Specifically, we predicted that greater interdependent self-construals would correlate with smaller differences between making judgments about oneself *vs* one's mother in the recruitment of the MPFC.

METHODS

Participants

Eighteen healthy adult males were recruited from the Stanford, California community (M age = 20.7, SD = 1.3) in compliance with Stanford University's human subjects

guidelines and paid \$75 for their time. All participants were right-handed, US citizens, native English speakers and had no history of neurological problems. Participants reported their ethnicity as 16.7% Asian, 5.5% Hispanic and 77.8% Caucasian. All participants reported that they were at least third generation American citizens. Only males were recruited to hold constant the relationship of the mother to the gender of the child.

Materials

Self and close other reference task. One hundred and sixty abstract trait adjectives selected for their high frequency in the English language (e.g. kind, funny; Anderson, 1968) were divided into four lists, equated for valence, frequency and reading level. Each participant viewed all four lists in a modified Latin square order. Stimulus presentation and behavioral response recording was controlled using E-Prime software (Psychology Software Tools, Pittsburgh, PA). An LCD projector projected images to a screen mounted on the head coil and a mirror reflected them into the participant's visual field. A bite bar restricted head movement and a button box held in the right hand collected behavioral data.

Self-construal scale. The Self-construal scale (SCS) has 24 items measuring two hypothesized orthogonal cultural constructions of self-concept (Singelis, 1994). The interdependent self-construal factor assesses the extent to which the individual views the self as connected to others, flexible across different situations, and emphasizes roles and responding appropriately to the person or situation. This factor is measured using items such as 'Even when I strongly disagree with group members, I avoid an argument'. The independent self-construal factor measures the extent to which one emphasizes one's attributes and abilities. Responses are made using seven-point Likert scales anchored by '1' strongly disagree to '7' strongly agree. The interdependent factor has adequate validity and reliability with an alpha of 0.71 in this sample. The independent factor, while reliable in other samples had an unreliable alpha of 0.53 in this sample. Moreover, the independent factor was not associated with any neural differences. Consequently, only the results from the interdependent factor are presented.

Procedure

Participants completed demographic and individual-difference questionnaires in the laboratory several days before scanning. Each scanning session consisted of a short practice session, a high-resolution three-dimensional anatomy scan, an in plane anatomy scan, the four functional runs, and a recognition memory task (outside the scanner). The in-scan task consisted of four encoding conditions each presented in eight blocks—self-reference, mother-reference, valence judgments and a letter-case baseline. Each block began with an encoding question presented for three seconds: 'Are the next words like you?', 'Are the next words like your Mom?', 'Are the next words nice words?',

'Are the next words lower case?' Each question was followed by the sequential presentation of five trait words randomly selected without replacement. Each word was presented for three seconds with a one second intertrial interval. Participants responded either 'Yes' or 'No' by pressing the buttons on the button box.

Data acquisition and analysis

Functional magnetic imaging was performed on a 1.5 T General Electric Medical Echospeed LX CV/I MR scanner. Twenty-five axial slices (4 mm thick with a 0.5 mm skip) were acquired during the functional scans using a T₂*-sensitive two-dimensional gradient echo spiral in/out pulse sequence (40 ms TE, 2000 ms TR, 90° flip angle, 24 cm field of view, 64 × 64 data acquisition matrix). T₂-weighted flow-compensated spin echo anatomical scans were acquired using the same slice prescription (2000 retention time, 68 echo time, 24 cm field of view, 256 × 256 data acquisition matrix). The three-dimensional high-resolution structural scan used a fast SPGR EDR IrP (15° flip angle, 24 cm field of view, 1.2 mm-thick slices, 256 × 256 data acquisition matrix).

Imaging data was preprocessed and analyzed using SPM2. Functional images were corrected for slice time acquisition and motion using a sinc interpolation and resampled into 2 mm³ voxels. Anatomical images were coregistered to the mean functional image and both the anatomical and functional images were normalized to the MNI template brain and smoothed with a 6 mm full-width at half maximum (FWHM) isotropic Gaussian kernel. A 128 s high-pass filter was applied to exclude low-frequency artifacts. A regressor function was created for the three levels of condition (self, mother, valence). The case judgment task served as the baseline for the model. A 3 s epoch using a boxcar regressor convolved with the canonical hemodynamic response function modeled each word.¹ Modeling each word was a better fit for the data than a classic block regressor. Individual level contrast files were combined to create a second level random effects group analysis. The main contrasts are reported in Ray *et al.* (manuscript under review). Whole-brain regression analysis identified those regions in which the difference between self vs mother referential processing correlated with the measure of self-reported cultural interdependence at a joint voxel threshold of $P < 0.001$, and cluster extent of 60 contiguous voxels. This extent threshold protected against false positives at a cluster level of $P < 0.05$, as indicated by the program AlphaSim in AFNI (Cox and Hyde, 1997).

RESULTS

To investigate whether individual differences in cultural interdependent self-construal were associated with

Table 1 Brain regions which showed a correlation between cultural interdependence and self > mother processing

Region of activation	BA	Coordinates			<i>T</i> -statistic	Number of voxels
		<i>x</i>	<i>y</i>	<i>z</i>		
Medial prefrontal gyrus	R/L 10	6	58	18	5.62	70
Posterior cingulate/precuneus	R 31/7	12	−54	24	6.61	126

Note: * $P < 0.001$ corrected for multiple comparisons $P < 0.05$ at the cluster level.

differential activation during self vs mother-referential processing, a regression analysis was performed on the whole brain using the interdependence (SCS) measure in the context of the Self > Mother contrast. This analysis revealed greater recruitment of MPFC [Brodmann area (BA) 10] and PCC (BA 31/7) when processing trait information about oneself than about one's mother for those individuals who report having a more interdependent self-construal (Table 1 and Figure 1). When applied to the reverse contrast of Mother > Self, there were no significant activations, nor was there any relationship between individual differences in interdependent self-construal and differential activation in the other contrasts (Self > Nice, Mother > Nice).

DISCUSSION

To examine the role of cultural processes in shaping self- and other-representations, we measured individual differences in cultural self-construal and examined brain responses in a self-referential task. Contrary to our hypothesis, individual differences in interdependent self-construal correlated with greater recruitment of the MPFC and PCC/precuneus when making self-relevance judgments than mother-relevance judgments. In previous studies, these MPFC and PCC regions have been identified as being more activated when making self-judgments than close other judgments (Heatherton *et al.*, 2006; Kelley *et al.*, 2002). These findings have implications for the understanding of self-referential processing and cultural self-construals.

The existing literature suggests that the MPFC and PCC are involved in retrieving episodic memories to support and guide trait judgments or evaluations about oneself and others (Cabeza and Nyberg, 2000; Levine *et al.*, 2004; Lou *et al.*, 2004; Zysset *et al.*, 2002). Greater MPFC and PCC recruitment in self-relevance judgments may reflect more effortful episodic memory retrieval. In a study by Zysset and colleagues (2002) they showed these same regions as more active during episodic retrieval than semantic retrieval. In the present study, those with more interdependent self-construals may be basing their self-judgments more upon memories of their behavior in social interactions than upon previously stored semantic knowledge about themselves across situations (Wang and Conway, 2004).

¹We modeled the data in several ways (an impulse function, defined by reaction time, 3 s trial-period). Each model produced the same results. The 3 s trial-period analyses were used because they contained the most time samples, and thus were the most robust.

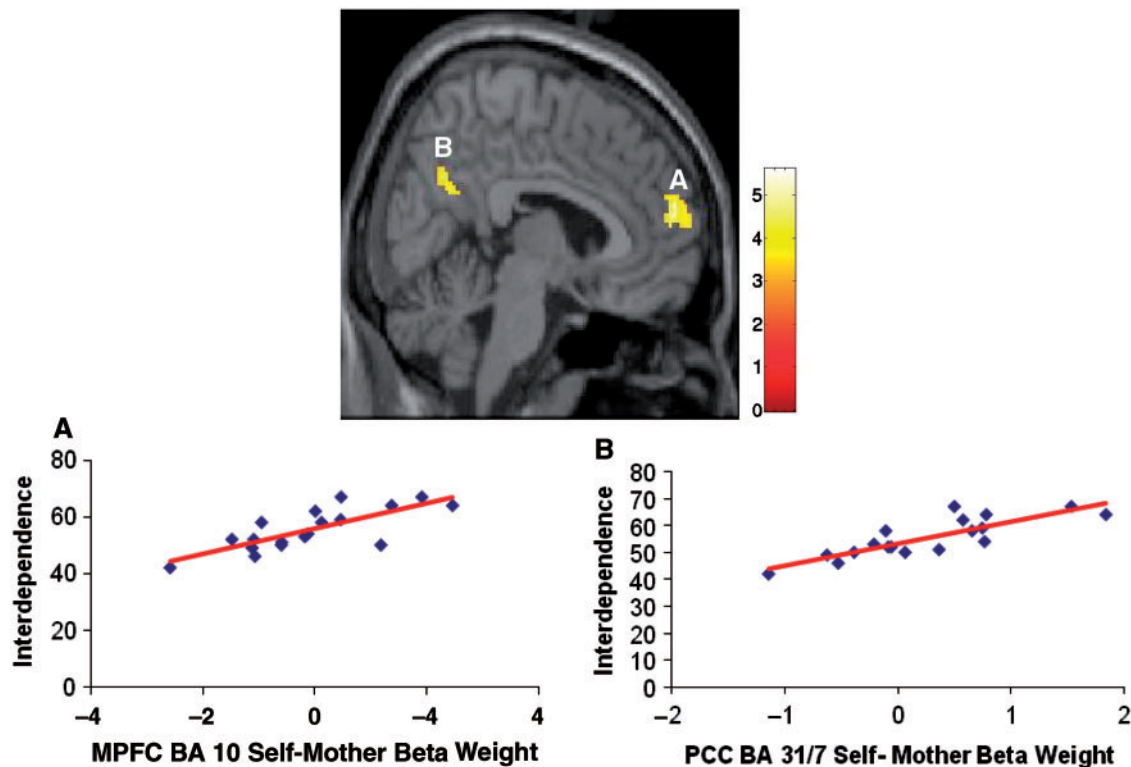


Fig. 1 Statistical map of the correlation of interdependent self-construal with differential activation from the self > mother contrast presented at a $P = 0.001$ threshold corrected for multiple comparisons at the cluster level at $P = 0.05$. The scatter plots are presented for descriptive purposes only. The scatter plots are created from beta weights extracted from the peak (A) MPFC and (B) PCC voxels. The x-axis is the difference between self and mother correlated with individual differences in interdependence on the y-axis.

Additionally, the rostral MPFC region has been identified in studies of theory of mind and reflected appraisals (Gallagher and Frith, 2003; Ochsner *et al.*, 2005). Theory of mind involves estimating the contents of another person's thoughts, emotions and intentions. Reflected appraisals are judgments about what others think of you. In this study, those with more interdependent self-construals may be relying on their ideas as to what other people think of them to make their judgments about whether or not they possess particular traits; whereas, when asked to make judgments about their mothers, those with interdependent self-construals may directly access their own opinions of their mothers, more than estimating how their mothers are perceived by others in the social network. This suggests that individual differences in cultural self-construal subtly affect how participants answer the question almost as if they are creating for themselves either a relational frame or a general frame of reference for the question. This idea is consistent with Chiao *et al.* (2009a, b). In both of these studies, self-construals either primed in biculturals or measured interact with context either relational context or a more general context to produce differential neural activity, MPFC in the cross-cultural sample and MPFC and PCC in the bicultural sample.

The present findings may help to explain why some studies have found regions of the MPFC more responsive

to judgments about one's self than about others (Heatherton *et al.*, 2006; Kelley *et al.*, 2002), whereas other studies have found no differences in the MPFC when responding to the self *vs* other relevance of words (e.g. Craik *et al.*, 1999; Lou *et al.*, 2004; Ochsner *et al.*, 2005; Schmitz *et al.*, 2004; Zhu *et al.*, 2007). Our results suggest a source of difference in the recruitment of the MPFC and precuneus/PCC to be individual differences in one's culturally influenced concept of self. When participants have an interdependent self-construal in which their self-representation contains relationships with a broader category of others than just one's mother, they recruit more MPFC and PCC to make judgments about themselves, possibly because of a more multifaceted self-representation (Cross *et al.*, 2000; Triandis and Gelfand, 1998), which includes facets of episodic memory and of estimates of others' minds. For interdependent individuals, the personal and relational aspects of self may be interacting in a richer, more computationally intensive way, to produce behavior (Brewer and Gardner, 1996). This work along with a growing body of work in cultural neuroscience, demonstrates that basic processes may be influenced by subtle individual differences both within and across cultures. Moreover, this suggests that an important area of research lies in the investigation of cultural differences in basic neural processes.

These findings have implications for cultural psychology and cultural neuroscience. For example, our findings suggest that interdependence may be understood not only as a set of attitudes, beliefs and behaviors, but also as a way the brain's computational resources are marshaled (e.g. episodic memory, theories of others' minds) in order to realize those attitudes, beliefs and behaviors. Neuroscience provides another level of analysis to understand the flexible interchange between the cultural, social, individual and biological.

A second important implication of this work is the need to understand the similarities and differences between culture operationalized as country and culture operationalized as a person's attitudes and beliefs. Variability of culture beliefs within a country may either limit the generalizability of studies in which culture is operationalized as country, or mask interesting cultural effects. This by itself could explain why our results are not consistent with those of Zhu *et al.* (2007) whom operationalized culture as country. The present study measures interdependence in young men within an Individualistic culture. One may find that the overall cultural effect is modulated by the degree to which individuals hold the dominant cultural beliefs. Therefore, it is important to have both transcultural studies as well as studies on the individual differences of cultural beliefs within countries to fully understand the effects of culture on neural processing.

While taking an important first step, the present study has important limitations. The first is the absence of judgments about a less familiar person, whether that is a privately or publicly known individual. To understand the extent to which cultural models of self-representation shape neural responses, inclusion of judgments about another, less familiar person within one's identified group could, add information about what dimension of judgment best explains midline activations. Another limitation is the use of only males in order to control for parent child relationship. Because females being the same gender as their mothers may have a different kind of relationship, and also because females report more interdependence, future studies may demonstrate important gender differences in the neural correlates of interdependent self-construals when processing self vs mother information (Cross *et al.*, 2000). A third limitation is that we measured only Interdependence. Independence was not used as a regressor in the neural data because the factor was not reliable. Future studies should work toward understanding the effects if any of independence on the neural bases of self and close other processing. Finally, this work examines individual differences in interdependence within an 'Individualistic' culture. It will be important to examine these same individual differences within a 'Collectivistic' culture to see how variations in self-construal are associated with different cognitive processes across cultures.

The relationship between representations of oneself and close others continues to be of great interest to psychologists

and neuroscientists alike. Using neuroimaging and individual differences in cultural self-construal, the present study supports a model in which midline brain regions are differentially engaged in judgments about oneself and a close other, one's mother as function of one's self-construal. In making judgments about themselves, Interdependent individuals exhibit greater recruitment of brain regions associated with access to episodic memory, self-reflection and with estimation of the contents of others' minds. Further investigation is needed to reveal how this difference operates during and influences self-relevant encounters with the world.

REFERENCES

- Anderson, N.H. (1968). Likableness ratings of 555 personality-trait words. *Journal of Personality and Social Psychology*, 9, 272–9.
- Brewer, M.B., Gardner, W. (1996). Who is this "we"? Levels of collective identity and self representations. *Journal of Personality and Social Psychology*, 71, 83–93.
- Cabeza, R., Nyberg, J. (2000). Imaging cognition II: an empirical review of 275 PET and fMRI studies. *The Journal of Cognitive Neuroscience*, 12, 1–47.
- Chiao, J.Y., Harada, T., Komeda, H., et al. (2009a). Dynamic cultural influences on neural representations of the self. *Journal of Cognitive Neuroscience* (in press).
- Chiao, J.Y., Harada, T., Komeda, H., et al. (2009b). Neural basis of individualistic and collectivistic views of self. *Human Brain Mapping*, 30, 2813–20.
- Cox, R.W., Hyde, J.S. (1997). Software tools for analysis and visualization of fMRI Data. *NMR in Biomedicine*, 10, 171–8.
- Craik, F.I.M., Tulving, E. (1975). Depth of processing and retention of words in episodic memory. *Journal of Experimental Psychology: General*, 104, 268–94.
- Cross, S.E., Bacon, P.L., Morris, M.L. (2000). The relational-interdependent self-construal and relationships. *Journal of Personality and Social Psychology*, 78, 791–808.
- Gallagher, H.L., Frith, C.D. (2003). Functional imaging of 'theory of mind'. *Trends in Cognitive Science*, 7, 77–83.
- Heatherton, T.F., Wyland, C.L., Macrae, C.N., Demos, K.E., Denny, B.T., Kelley, M.W. (2006). Medial prefrontal activity differentiates self from close others. *Social Cognitive and Affective Neuroscience*, 1, 18–25.
- Hedden, T., Ketay, S., Aron, A., Markus, H.R., Gabrieli, J.D.E. (2008). Cultural influences on neural substrates of attentional control. *Psychological Science*, 19, 12–17.
- Kelley, W.M., Macrae, C.N., Wyland, C.L., Caglar, S., Inati, S., Heatherton, T.F. (2002). Finding the self? An event-related fMRI study. *Journal of Cognitive Neuroscience*, 14, 785–95.
- Levine, B., Turner, G.R., Tisserand, D., Hevenor, S.J., Graham, S.J., McIntosh, A.R. (2004). The functional neuroanatomy of episodic and semantic autobiographical remembering: a prospective functional MRI study. *Journal of Cognitive Neuroscience*, 16, 1633–46.
- Lou, H.C., Luber, B., Crupain, M., et al. (2004). Parietal cortex and representation of the mental Self. *Proceedings of the National Academy of Science of United States of America*, 101, 6827–32.
- Markus, H.R., Kitayama, S. (1991). Culture and the self: implications for cognition, emotion, and motivation. *Psychological Review*, 98, 224–53.
- Matsumoto, D., Kouznetsova, N., Ray, R., Ratzlaff, C., Biehl, M., Raroque, J. (1999). Psychological culture, physical health, and subjective well being. *Journal of Gender, Culture, and Health*, 4, 1–18.
- Nisbett, R., Peng, K., Choi, I., Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review*, 108, 291–310.

- Ochsner, K.N., Beer, J.S., Robertson, E.R., et al. (2005). The neural correlates of direct and reflected self-knowledge. *Neuroimage*, 28, 797–814.
- Schmitz, T.W., Kawahara-Baccus, T.N., Johnson, S.C. (2004). Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage*, 22, 941–7.
- Singelis, T.M. (1994). The measurement of independent and interdependent self-construals. *Personality and Social Psychological Bulletin*, 20, 580–91.
- Triandis, H.C. (1995). *Individualism and collectivism*. Boulder, CO: Westview.
- Triandis, H.C., Bontempo, R., Betanourt, H., et al. (1986). The measurement of the etic aspects of individualism and collectivism across cultures. *Australian Journal of Psychology*, 38, 257–67.
- Triandis, H.C., Bontempo, R., Villareal, M. J., Asai, M., Lucca, N. (1988). Individualism and collectivism: Cross-cultural perspectives on self-in-group relationships. *Journal of Personality and Social Psychology*, 54, 328–338.
- Triandis, H.C., Gelfand, M.J. (1998). Converging measurement of horizontal and vertical individualism and collectivism. *Journal of Personality and Social Psychology*, 74, 118–28.
- Vanderwal, T., Hunyadi, E., Grupe, D.W., Connors, C.M., Schultz, R.T. (2008). Self, mother and abstract other: An fMRI study of reflective social processing. *NeuroImage*, 41, 1437–46.
- Wang, Q., Conway, M.A. (2004). The stories we keep: autobiographical memory in American and Chinese middle aged adults. *Journal of Personality*, 72, 911–38.
- Zhang, L., Zhou, T., Zhang, J., Liu, Z., Fan, J., Zhu, Y. (2006). In search of the Chinese self: An fMRI study. *Science in China: Series C Life Sciences*, 49, 89–96.
- Zhu, Y., Zhang, L., Fan, J., Han, S. (2007). Neural basis of cultural influence on self-representation. *NeuroImage*, 34, 1310–16.
- Zysset, S., Huber, O., Ferstl, E., von Cramon, D.Y. (2002). The anterior frontomedian cortex and evaluative judgment: an fMRI study. *NeuroImage*, 15, 983–91.