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Abstract:

Cultural neuroscience investigates whether and how cultural contexts and experiences shape functional organization of the human brain by integrating brain imaging with psychological paradigms such as cross-cultural comparisons and cultural priming. Cultural neuroscience studies have shown ample evidence for cultural group differences in, or cultural priming effects on, neural correlates of cognitive and affective processing. Future cultural neuroscience studies should examine how culture interacts with genes to modulate multiple-level neural mechanisms (from molecules to neural circuits) underlying human cognition and affection and how human behavior in a specific social context is related to cultural effects on brain activity.

Keywords: Affection; Brain imaging; Cognition; Cultural priming; Culture; fMRI; Gene

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Biographical Sketch

Shihui Han is a professor and the director of the Cultural and Social Cognitive Neuroscience Laboratory at the Department of Psychology, Peking University. He is the founding chief editor of 'Culture and Brain' and an associate editor of 'Social Cognitive and Affective Neuroscience' and 'Acta Psychologica Sinica.' Using brain imaging such as fMRI and EEG/ERP, he studies cognitive and neural mechanisms of social cognition such as self-face recognition, self-referential processing, empathy for pain, and death-related thoughts. His research focuses on both cultural and genetic influences on neurocognitive processes of social cognition and how culture interacts with gene to shape the human brain and behavior.

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dt0010 **Event-related potential** Synchronous activities of neuronal populations engaged in specific psychological processing, which are time-locked to stimulus events, can be recorded from electrodes over the scalp, and have high temporal resolution.

dt0015 **Functional magnetic resonance imaging** A noninvasive method for recording blood-oxygenation level-dependent signals that have high spatial resolution and are used to examine brain activations associated with specific stimuli or tasks.

N400 A negative potential that peaks around 400 ms after stimulus onset with the maximum amplitude over the parietal scale site and is sensitive to semantic incongruity between stimuli. dt0020

p0010 Cultural neuroscience is an interdisciplinary field that investigates whether and how cultural contexts and experiences interact with and shape functional organization of the human brain. Cultural neuroscience research emerged during the first decade of the twenty-first century when cognitive neuroscience studies promoted the application of brain imaging (e.g., event-related brain potential (ERP) and functional magnetic resonance imaging (fMRI)) to investigate human brain functions. This allowed social and cultural psychologists to begin to explore neural correlates of social cognition and behavior using brain imaging. Cultural neuroscience integrates several approaches including cultural psychology, social cognitive neuroscience, neuroscience research of neural plasticity, and culture–gene interactions (Chiao & Ambady, 2007; Han & Northoff, 2008; Han et al., 2013). The goal of cultural neuroscience studies is to provide a neuroscientific account of cross-cultural variation in human psychological functions and behaviors by discovering socioculturally patterned neural mechanisms and their development. Au2

p0015 Cultural neuroscience studies view culture as complex, dynamic social environments in which the human brain develops and shares ideas, values, beliefs, and behavioral scripts in people's mind. Rather than being a part of the innate biological condition of humans, culture functions as a dynamic environment and knowledge system that allows the brain to lay out its potential capacity to fit into different sociocultural contexts. This fits with the fundamental neuroscientific proposal of neural plasticity – an intrinsic nature of the human brain that allows the brain to change both structurally and functionally in response to the environment and new experiences (Shaw & McEachern, 2001). However, people from the same geographic region are not necessarily homogeneous in terms of their cultural values. An individual may have multiple cultural systems and switch between different cultural systems in response to specific social contexts and interactions (Hong, Morris, Chiu, & Benet-Martinez, 2000). Rather than attempting to find a 'biomarker' of culture in the brain, cultural neuroscience studies examine how cultural values, beliefs, and practices shared by a social group in daily life influence the functional organization of the human brain and how they might temporarily shift brain activity to reflect specific cultural values and beliefs (Han et al., 2013). Au3

p0020 One cultural neuroscience approach focuses on differences in neural correlates of cognitive and affective processes between two cultural groups. Using brain-imaging measurements from individuals who are raised in different sociocultural contexts, cultural neuroscientists have shown increasing evidence for cultural group differences in brain activities involved in multiple cognitive and affective processes including perception (Goh et al., 2007, 2010; Gutchess, Welsh, Boduroglu, & Park, 2006; Jenkins et al., 2010), attention (Hedden, Ketay, Aron, Markus, & Gabrieli, 2008; Lewis, Goto, & Kong, 2008), causal attribution of physical events (Han, Mao, Qin, Friederici, & Ge, 2011), semantic relationship processing (Gutchess, Hedden, Ketay, Aron, & Gabrieli, 2010), musical processing (Nan, Knösche, & Friederici, 2006; Nan et al., 2009), mental calculation (Tang et al., 2006), recognition of one's own face (Sui, Hong, Liu, Humphreys, & Han, 2013; Sui, Liu, & Han, 2009), self-reflection on personality traits (Chiao et al., 2009, 2010; Han et al., 2010, 2008; Ma et al., 2013; Zhu, Zhang, Fan, & Han, 2007), perception of bodily expression (Freeman, Rule, Adams, & Ambady, 2009), mental-state reasoning (Adams et al., 2009; Kobayashi, Glover, & Temple, 2006), empathy (de Greck et al., 2012), and trait inference (Na & Kitayama, 2011). Au4 Au5

p0025 Cultural modulations of brain activity exhibit different patterns. One pattern is that neural activity is modulated by a particular task in one cultural group but not in another cultural group (Han et al., 2011; Jenkins et al., 2010; Zhu et al., 2007). For example, reflection of personality traits of oneself and one's mother compared to a celebrity activates a common region in the medial prefrontal cortex and this effect is evident in Chinese individuals but not in Westerners (Wang et al., 2012; Zhu et al., 2007). In addition, decreased lateral occipital activity in response to scenes that are incongruent versus congruent to foreground objects is observed in Chinese but not in Americans (Jenkins et al., 2010). Another type of cultural modulation of brain activity is that two cultural groups show opposite patterns of neural activity during the same task (Freeman et al., 2009; Hedden et al., 2008). For instance, relative to a context-dependent task that requires judgments of whether a box and a line combination matches the proportional scaling of the preceding combination, Americans show greater prefrontal and parietal activity during the context-independent task (which requires judgments of whether the current line matches the previous line), regardless of the size of the accompanying box. In contrast, East Asians exhibit stronger Au6

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activity in the prefrontal and parietal cortices during the context-independent than context-dependent tasks (Hedden et al., 2008). Americans show greater activity in the bilateral Au7 caudate nucleus and MPFC when perceiving people showing dominant versus subordinate gestures, whereas Japanese

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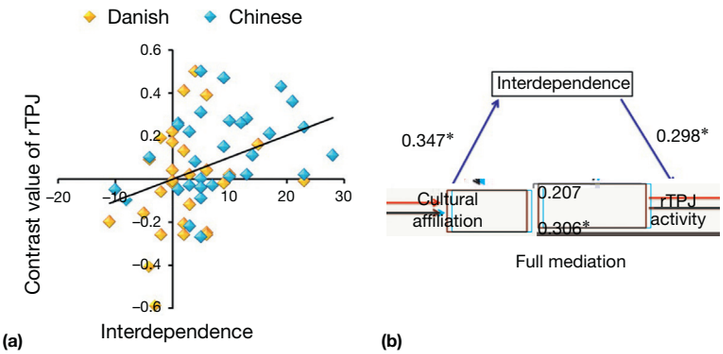

f0015 **2** Illustration of the cultural-value mediation effect on brain activity involved in self-reflection. (a) The temporoparietal junction activity during self-reflection on social roles is positively correlated with the measurement of interdependence. (b) The difference in the temporoparietal junction activity during self-reflection on social roles between Chinese and Danish participants is fully mediated by the degree of interdependence.

iconic cultural primes or words that make specific cultural values salient temporarily and then record brain activity underlying cognitive/affective processing. This procedure allows us to examine variations in neural processes as a consequence of cultural priming and reveals a causal link between variations in cultural values and the neural activity during following tasks. To date, there has been evidence for the effects of cultural priming on pain perception (Wang, Ma, & Han, 2013), visual perception (Lin, Lin, & Han, 2008), self-face recognition (Sui & Han, 2007), self-referential processing (Chiao et al., 2010; Harada, Li, & Chiao, 2010; Ng, Han, Mao, & Lai, 2010), motor processing (Obhi, Hogeveen, & Pascual-Leone, 2011), and resting-state activity (Wang, Oyserman, Li, Liu, & Han, 2013). To give an example, it has been found that priming independent self-construals by exposing individuals with independent pronouns (e.g., 'I' or 'me') results in faster behavioral responses to one's own face compared with a familiar face, whereas priming interdependent self-construals by exposing individuals with interdependent pronouns (e.g., 'we' or 'us') leads to slower responses to one's own face relative to a familiar face (Sui & Han, 2007). Moreover, self-construal priming modulates the neural activity in association with self-face recognition. The independent self-construal priming enhances the right middle and inferior frontal activity in response to one's own face. Conversely, the right frontal activity is reduced by the interdependent self-construal priming. Such findings support a cause–effect relationship between culturally specific self-construals and culturally specific styles of neurocognitive processes involved in self-face recognition.

p0045 The findings of cultural neuroscience research have important implications for understanding the human brain and behavior. Current cultural neuroscience research demonstrates that, rather than being doomed by biology, the human brain and neurocognitive processes related to cognition, affection, and behavior are flexible and continuously shaped by long-term and short-term cultural experiences in man-made sociocultural contexts. Besides culturally universal brain mechanisms, the human brain develops culturally specific neural cognitive and affective processes so as to guide appropriate behaviors in a specific cultural context. Cultural neuroscience findings make us rethink the biosocial nature of the brain that may bridge the gap between a biological entity and the social world of the environment and its culture. Cultural neuroscience research also leads us to rethink the nature of culture. If the human brain shows constitutive context dependence, the environment and thus culture, which are created by the human brain, are then not purely social. Instead, culture may then be considered to be sociobiological rather than being an exclusively social construction. Cultural neuroscience research also has practical implications. For example, the findings of cultural differences in neural cognitive and affective processes can help to understand why people from other cultural groups think and behave differently and help to deal with misunderstandings and conflicts between different cultural groups and reduce intergroup conflict and prejudice. At the individual level, since a person usually aims to reach his or her own goals in a specific sociocultural environment, how an individual's brain activity fits with cultural norms and values in that society may strongly influence his or her mental health and well-being. Cultural neuroscience research can help to understand the link between culturally specific neural cognitive and affective processes and an individual's well-being in a specific cultural context.

p0050 There are plenty of questions that can be addressed by future cultural neuroscience studies. To give a few examples, one may ask what kind of experiences during development may facilitate the ability of an individual's brain to fit into a specific culture and to interact with individuals from other cultures. This is an important issue since more and more people emigrate to other cultures and seek future carriers in different cultural environments. It is unknown what allows the brain to adapt to a new culture quickly. It is also interesting to examine whether there are any culturally specific neural or genetic mechanisms of mental disease and whether the association between genotype and mental illness is similar across cultures. Answering these questions may help to determine whether the same treatments are appropriate for mental disorders in different cultures. Another important issue for cultural neuroscience research is how culture may affect or interact with biochemical substances in the brain. Is it possible to trace cultural effects to the neuronal and biochemical levels in order to understand the relationship between culture and microlevel neural processes? Moreover, it is critical to understand whether and how culture and genes interact to affect neural processes in the human brain because this line of

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research may offer a comprehensive description of human nature and provide further challenges for purely biological accounts of the brain.

See also: **Acquisition Methods**: Obtaining quantitative information from fMRI/MRI data (00002); EEG (00007); fMRI Dynamics (00008); **Systems**: Face Processing (00037); Emotion (00055); Memory (00056); Brain at Rest (00060); **Clinical**: Depression (00119); Neurobiology of anxiety (00120); Emotion and stress (00121); Social Perception (00128); Imaging genetics (00130); **Social**: Cooperation & Competition (00143); How the Brain Feels the Hurt of Heartbreak (00144); Prosocial Motivation (00146); Self-knowledge (00149); Mentalizing (00169); Person Knowledge & Attribution (00170); Social Cognition During Social Interactions (00172); Resting State & Social Cognition (00173); Empathy (00177); Social Knowledge (00183); **Anatomy & Physiology**: Functional Connectivity (00212); Insular cortex (00237); Prefrontal Cortex (00241); **Cognitive**: Episodic memory and recollection (00281); Self-insight; Self-regulation; Developmental Approaches to the Self; Amygdala & Social Perception; Genetic Neuroimaging of Social Perception; Cingulate cortex.

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Adams, R. B., Jr., Rule, N. O., Franklin, R. G., Jr., Wang, E., Stevenson, M. T., Yoshikawa, S., et al. (2009). Cross-cultural reading the mind in the eyes: An fMRI investigation. *Journal of Cognitive Neuroscience*, *22*, 97–108.

Chiao, J. Y., & Ambady, N. (2007). Cultural neuroscience: Parsing universality and diversity across levels of analysis. In S. Kitayama & D. Cohen (Eds.), *Handbook of cultural psychology* (pp. 237–254). New York: Guilford Press.

Chiao, J. Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D., et al. (2009). Neural basis of individualistic and collectivistic views of self. *Human Brain Mapping*, *30*, 2813–2820.

Chiao, J. Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D., et al. (2010). Dynamic cultural influences on neural representations of the self. *Journal of Cognitive Neuroscience*, *22*, 1–11.

de Greck, M., Shi, Z., Wang, G., Zuo, X., Yang, X., Wang, X., et al. (2012). Culture modulates brain activity during empathy with anger. *NeuroImage*, *59*, 2871–2882.

Freeman, J. B., Rule, N. O., Adams, R. B., Jr., & Ambady, N. (2009). Culture shapes a mesolimbic response to signals of dominance and subordination that associates with behavior. *NeuroImage*, *47*, 353–359.

Goh, J. O., Chee, M. W., Tan, J. C., Venkatraman, V., Hebrank, A., Leshikar, E. D., et al. (2007). Age and culture modulate object processing and object-scene binding in the ventral visual area. *Cognitive, Affective, and Behavioral Neuroscience*, *7*, 44–52.

Goh, J. O., Leshikar, E. D., Sutton, B. P., Tan, J. C., Sim, S. K., Hebrank, A. C., et al. (2010). Culture differences in neural processing of faces and houses in the ventral visual cortex. *Social Cognitive and Affective Neuroscience*, *5*, 227–235.

Gutchess, A. H., Hedden, T., Ketay, S., Aron, A., & Gabrieli, J. D. (2010). Neural differences in the processing of semantic relationships across cultures. *Social Cognitive and Affective Neuroscience*, *5*, 254–263.

Gutchess, A. H., Welsh, R. C., Boduroglu, A., & Park, D. C. (2006). Cultural differences in neural function associated with object processing. *Cognitive, Affective, and Behavioral Neuroscience*, *6*, 102–109.

Han, S., Gu, X., Mao, L., Ge, J., Wang, G., & Ma, Y. (2010). Neural substrates of self-referential processing in Chinese Buddhists. *Social Cognitive and Affective Neuroscience*, *5*, 332–339.

Han, S., Mao, L., Gu, X., Zhu, Y., Ge, J., & Ma, Y. (2008). Neural consequences of religious belief on self-referential processing. *Social Neuroscience*, *3*, 1–15.

Han, S., Mao, L., Qin, J., Friederici, A. D., & Ge, J. (2011). Functional roles and cultural modulations of the medial prefrontal and parietal activity associated with causal attribution. *Neuropsychologia*, *49*, 83–91.

Han, S., & Northoff, G. (2008). Culture-sensitive neural substrates of human cognition: A transcultural neuroimaging approach. *Nature Review Neuroscience*, *9*, 646–654.

Han, S., Northoff, G., Vogeley, K., Wexler, B. E., Kitayama, S., & Varnum, M. E.W (2013). A cultural neuroscience approach to the biosocial nature of the human brain. *Annual Review of Psychology*, *64*, 335–359.

Harada, T., Li, Z., & Chiao, J. Y. (2010). Differential dorsal and ventral medial prefrontal representations of the implicit self modulated by individualism and collectivism: An fMRI study. *Social Neuroscience*, *5*, 257–271.

Hedden, T., Ketay, S., Aron, A., Markus, H. R., & Gabrieli, D. E. (2008). Cultural influences on neural substrates of attentional control. *Psychological Science*, *19*, 12–17.

Hong, Y., Morris, M., Chiu, C., & Benet-Martinez, V. (2000). Multicultural minds: A dynamic constructivist approach to culture and cognition. *American Psychologist*, *55*, 709–720.

Kitayama, S., & Uskul, A. K. (2011). Culture, mind, and the brain: Current evidence and future directions. *Annual Review of Psychology*, *62*, 419–449.

Kobayashi, C., Glover, G. H., & Temple, E. (2006). Cultural and linguistic influence on neural bases of 'Theory of Mind': An fMRI study with Japanese bilinguals. *Brain and Language*, *98*, 210–220.

Lewis, R. S., Goto, S. G., & Kong, L. L. (2008). Culture and context east Asian American and European American differences in P3 event-related potentials and self-construal. *Personality and Social Psychology Bulletin*, *34*, 623–634.

Lin, Z., Lin, Y., & Han, S. (2008). Self-construal priming modulates visual activity underlying global/local perception. *Biological Psychology*, *77*, 93–97.

Ma, Y., Bang, D., Wang, C., Allen, M., Frith, C., Roepstorff, A., et al. (2013). Sociocultural patterning of neural activity during self-reflection. *Social Cognitive and Affective Neuroscience*, .

Au10

Ma, Y., Wang, C., & Han, S. (2011). Neural responses to perceived pain in others predict real-life monetary donations in different socioeconomic contexts. *NeuroImage*, *57*, 1273–1280.

Na, J., & Kitayama, S. (2011). Spontaneous trait inference is culture-specific: Behavioral and neural evidence. *Psychological Science*, *22*, 1025–1032.

Nan, Y., Knösche, T. R., & Friederici, A. D. (2006). The perception of musical phrase structure: A cross-cultural ERP study. *Brain Research*, *1094*, 179–191.

Nan, Y., Knösche, T. R., Zysset, S., & Friederici, A. D. (2008). Cross-cultural music phrase processing: An fMRI study. *Human Brain Mapping*, *29*, 312–328.

Ng, S. H., Han, S., Mao, L., & Lai, J. C.L (2010). Dynamic bicultural brains: A fMRI study of their flexible neural representation of self and significant others in response to culture priming. *Asian Journal of Social Psychology*, *13*, 83–91.

Obhi, S. S., Hogeveen, J., & Pascual-Leone, A. (2011). Resonating with others: The effects of self-construal type on motor cortical output. *Journal of Neuroscience*, *31*, 14531–14535.

Shaw, C., & McEachern, J. (2001). *Toward a theory of neuroplasticity*. London, England: Psychology Press.

Sui, J., & Han, S. (2007). Self-construal priming modulates neural substrates of self-awareness. *Psychological Science*, *18*, 861–866.

Sui, J., Hong, Y. Y., Liu, C., Humphreys, G. W., & Han, S. (2013). Dynamic cultural modulation of neural responses to one's own and friend's faces. *Social Cognitive and Affective Neuroscience*, *8*, 326–332.

Sui, J., Liu, C. H., & Han, S. (2009). Cultural difference in neural mechanisms of self-recognition. *Social Neuroscience*, *4*, 402–411.

Tang, Y., Zhang, W., Chen, K., Feng, S., Ji, Y., Shen, J., et al. (2006). Arithmetic processing in the brain shaped by cultures. *Proceedings of the National Academy of Sciences of the United States of America*, *103*, 10775–10780.

Varnum, M. E.W, Na, J., Murata, A., & Kitayama, S. (2012). Social class differences in N400 indicate differences in spontaneous trait inference. *Journal of Experimental Psychology: General*, *141*, 518–526.

Wang, C., Ma, Y., & Han, S. (2013). Self-construal priming modulates pain perception: Event-related potential evidence. *Cognitive Neuroscience*, .

Wang, G., Mao, L., Ma, Y., Yang, X., Cao, J., Liu, X., et al. (2012). Neural representations of close others in collectivistic brains. *Social Cognitive and Affective Neuroscience*, *7*, 222–229.

Wang, C., Oyserman, D., Li, H., Liu, Q., & Han, S. (2013). Accessible cultural mindset modulates default mode activity: Evidence for the culturally situated brain. *Social Neuroscience*, *8*, 203–216.

Zhu, Y., Zhang, L., Fan, J., & Han, S. (2007). Neural basis of cultural influence on self representation. *NeuroImage*, *34*, 1310–1317.

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