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Cultural differences in human brain activity: A quantitative meta-analysis

Shihui Han [a,b,*], Yina Ma [c,**]

[a] Department of Psychology, Peking University, Beijing 100871, China
[b] PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, China
[c] Lieber Institute for Brain Development, Johns Hopkins University School of Medicine, Baltimore, MD 21205, USA

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ABSTRACT

Psychologists have been trying to understand differences in cognition and behavior between East Asian and Western cultures within a single cognitive framework such as holistic versus analytic or interdependent versus independent processes. However, it remains unclear whether cultural differences in multiple psychological processes correspond to the same or different neural networks. We conducted a quantitative meta-analysis of 35 functional MRI studies to examine cultural differences in brain activity engaged in social and non-social processes. We showed that social cognitive processes are characterized by stronger activity in the dorsal medial prefrontal cortex, lateral frontal cortex and temporoparietal junction in East Asians but stronger activity in the anterior cingulate, ventral medial prefrontal cortex and bilateral insula in Westerners. Social affective processes are associated with stronger activity in the right dorsal lateral frontal cortex in East Asians but greater activity in the left insula and right temporal pole in Westerners. Non-social processes induce stronger activity in the left inferior parietal cortex, left middle occipital and left superior parietal cortex in East Asians but greater activations in the right lingual gyrus, right inferior parietal cortex and precuneus in Westerners. The results suggest that cultural differences in social and non-social processes are mediated by distinct neural networks. Moreover, East Asian cultures are associated with increased neural activity in the brain regions related to inference of others' mind and emotion regulation whereas Western cultures are associated with enhanced neural activity in the brain areas related to self-relevance encoding and emotional responses during social cognitive/affective processes.

Introduction

Cultural psychologists have shown ample evidence for differences in cognition and behavior between East Asian and Western cultures (Markus and Kitayama, 1991; Nisbett and Masuda, 2003; Oyserman et al., 2002). For instance, Westerners tend to focus on a salient object independently of its context whereas East Asians tend to attend to the relationship between an object and its context during perception (Nisbett and Miyamoto, 2005). Memory contents tend to focus on events oriented to an individual in Westerners but on events with a group or social interactions in East Asians (Conway et al., 2005). Westerners are inclined to attribute human behaviors predominantly to their internal dispositions while East Asians tend to explain the same behavior in terms of social contexts (Choi et al., 1999). Cultural differences in multiple psychological processes have been explained within a single cognitive framework. For example, Nisbett and colleagues propose that East Asians prefer holistic thoughts that facilitate attending to the entire field and assigning causality to it, whereas Westerners favor analytic thoughts that enhance attention primarily to the object and the categories to which it belongs (Nisbett et al., 2001). Markus and Kitayama (1991) have suggested that East Asians emphasize the fundamental relatedness of individuals to each other whereas Westerners seek to maintain their independence from others and that distinct self-construals can account for cultural differences in cognition, emotion, and motivation.

While cultural differences in multiple psychological processes have been understood within a single cognitive framework, it remains unclear whether cultural differences in distinct psychological processes are mediated by the same or different neural networks in the brain. Functional magnetic resonance imaging (fMRI) studies have revealed several neural circuits that are engaged in different psychological processes (Kennedy and Adolphs, 2012; Lieberman, 2010; Stanley and Adolphs, 2013). Social perceptual tasks, such as face/biological motion perception and action observation, engage the fusiform gyrus, posterior superior temporal sulcus (STS), amygdala, inferior parietal lobule (IPL), and lateral prefrontal cortex (LPFC). Social cognitive tasks, such as inference of others' mental states, self-reflection or self-control, activate the medial prefrontal cortex (MPFC), precuneus/posterior cingulate (PCC),

* Correspondence to: S. Han, Department of Psychology, Peking University, Beijing 100871, China. Fax: +86 10 6276 1081.
** Correspondence to: Yina Ma, Lieber Institute for Brain Development, Johns Hopkins University School of Medicine, 855 North Wolfe Street, Baltimore, MD 21205, USA.
E-mail addresses: shan@pku.edu.cn (S. Han), yina.ma@libd.org (Y. Ma).

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temporoparietal junction (TPJ), temporal pole, IPL LPFC, dorsal anterior cingulate cortex (dACC). Social affective tasks, such as empathy for others' emotional states or social rejection, recruit the dACC, supplementary motor area (SMA), amygdala, anterior insula (AI) and LPFC (see Lieberman, 2010 for review).

These fMRI findings indicate that the neural circuits involved in different task domains (e.g., perceptual, cognitive, or affective) consist of common and distinct brain regions. Thus it is possible that there are specific brain regions that exert cultural modulations of neural activities involved in different task domains. This hypothesis predicts a common neural network or a brain region that differentiates between East Asian and Western cultures across task domains. Alternatively, culture may show task-domain-specific influences on neural correlates of human cognition. This hypothesis predicts distinct neural networks that differentiate between East Asian and Western cultures depending on task domains. Apparently, these hypotheses cannot be clarified by only examining individuals' behavioral performances or by a single neuroimaging study.

Recent cultural neuroscience studies have shown increasing evidence for cultural differences in neural correlates of cognition and behavior by comparing fMRI results from East Asians and Westerners or by priming participants with East Asian or Western cultural values (see; Ames and Fiske, 2010; Chiao et al., 2013; Han and Northoff, 2008; Han et al., 2013). However, each of the previous cultural neuroscience studies recruited a specific task and was unable to provide a global view of the relationship between culture and neural correlates of different tasks in a specific domain. A meta-analysis of cultural neuroscience studies allows us to explore cultural differences in neural activity engaged in various tasks in a specific domain and to test whether the same or distinct neural networks underlie cultural variations in human brain activity across different task domains. We summarized 35 fMRI studies of cultural effects on human cognition (published before December 2013) and conducted a whole-brain quantitative meta-analysis that allows for identification of cultural differences in brain activity that are activated in a specific task domain. We included fMRI studies that compared participants from East Asian (Chinese, Japanese, and Korean) and Western (American and European) societies and classified these studies into three domains that employed social cognitive, social affective, and non-social cognitive tasks, respectively. Our meta-analyses focused on brain activity that differentiates between East Asian and Western cultures in these task domains.

Methods

Literature search and selection

A step-wise procedure was used to identify relevant research articles that compared brain activity between individuals from East Asian and Western societies published prior to December 2013. As recent studies have shown that cultural values mediate cultural group differences in neural activity involved in social cognition (e.g., Ma et al., 2014), our meta-analyses also included the studies that examined brain activity coupling with cultural values (i.e., independence vs. interdependence or individualism vs. collectivism) in individuals from the same society. We first selected studies through a standard search in PubMed (http://www.pubmed.gov) and ISI Web of Science (http://apps.isiknowledge.com) using keywords ['cultural' OR 'cultural difference' OR 'cultural influence' OR 'East Asian AND Western' OR 'interdependence, independence' OR 'individualism, collectivism'] AND ['fMRI' OR 'functional MRI' OR 'functional magnetic resonance imaging']. Next, we collected additional studies by reviewing the reference list of the relevant papers found in the first step, or through the 'related article' function of the PubMed database.

A study was considered culture-relevant if it involves a group comparison between East Asians and Westerners, or if it examines cultural effects (e. g., interdependent/independent self-construal, individualism/collectivism) on brain activity using a cultural priming procedure or a whole-brain regression with cultural values. Thus cultural effects were identified in the contrasts between East Asian and Western individuals, between individuals temporally primed with East Asian or Western cultural values, or in the analyses of whole-brain regression with cultural values. The neural activity being positively correlated with individualistic cultural values or negatively correlated with collectivistic cultural values was integrated with those being stronger in Western than East Asian individuals, whereas the neural activity being positively correlated with collectivistic cultural values or negatively correlated with individualistic cultural values was integrated with those being stronger in East Asian than Western individuals. Based on the task employed by each study, we classified studies into 3 categories, i.e., social cognitive studies that used tasks such as self-reflection, theory of mind, face perception, moral judgment, persuasion, and self-recognition; social affective studies that used tasks such as empathy, emotion recognition, emotion, and reward; and non-social studies that used tasks such as visual attention, visual spatial or object processing, arithmetic, and physical causal attribution. We calculated the contrasts of "East Asian versus Western" and "Western versus East Asian" separately to identify stronger neural responses in East Asian and in Western cultures, respectively.

We excluded studies that did not use functional imaging techniques, and did not report coordinates in either Montreal Neurological Institute (MNI; Collins et al., 1998) or Talairach (Talairach and Tournoux, 1988) space. This meta-analysis was limited to regional activation changes, thus studies that focused on functional connectivity, structural data, or resting-state were not included. Consequently, we identified 35 relevant fMRI studies to reveal cultural influence on brain activity (see Table 1 for detailed information about the studies included in our meta-analyses). We included 28 fMRI studies that investigated cultural differences in neural correlates of either cognitive or affective dimension of social cognition, and 7 studies that examined cultural differences in neural substrates underlying non-social processes.

Activation likelihood estimation analysis

Our meta-analysis was based on the Activation Likelihood Estimation (ALE) method (Laird et al., 2005; Turkeltaub et al., 2002), using the revised ALE algorithm (Turkeltaub, 2012) in GingerALE 2.3 (Eickhoff, 2009; Laird et al., 2005; Turkeltaub, 2012). The ALE is a method for performing coordinate-based meta-analysis in order to determine whether there is anatomical convergence among results from different studies. GingerALE switched ALE methods from fixed effects to random effects, incorporated variable uncertainty based on the number of subjects in each study included in the meta-analysis (Eickhoff, 2009), and added the thresholding methods (Eickhoff, 2009; Laird et al., 2005). GingerALE has been applied to reveal between-group brain activity differences in previous meta-analytic studies (Ma, in press; Menzies et al., 2008; Minzenberg et al., 2009).

The procedure involved the modeling of all reported coordinates of the selected contrasts as the peaks of 3D Gaussian probability distribution. We individually screened all the articles for the presence of Talairach or MNI coordinates. Coordinates in Talairach space were converted to MNI coordinates and were reported in the MNI space in the current study. The 3D Gaussian distributions were summed to produce a statistical map that estimated the likelihood of activation for each voxel as determined by all the studies included in the analyses. The ALE value was computed using permutation testing (5000 permutations) against the null-distribution of random spatial associations of foci across contrasts (Eickhoff, 2009). We used a p-threshold corrected for multiple comparisons using the False Discovery Rate (FDR) fixed to 0.05 (Laird et al., 2005). Additionally, all clusters were set to a minimum of 300 mm^3. The thresholded ALE result images were visualized using Mango (rii.uthscsa.edu/mango), and overlaid onto an anatomical template (Colin27_T1_seg_MNI.nii, www.brainmap.org/ale).