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Research Report

Cultural Influences on Neural Substrates of Attentional Control

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ABSTRACT—*Behavioral research has shown that people from Western cultural contexts perform better on tasks emphasizing independent (absolute) dimensions than on tasks emphasizing interdependent (relative) dimensions, whereas the reverse is true for people from East Asian contexts. We assessed functional magnetic resonance imaging responses during performance of simple visuospatial tasks in which participants made absolute judgments (ignoring visual context) or relative judgments (taking visual context into account). In each group, activation in frontal and parietal brain regions known to be associated with attentional control was greater during culturally nonpreferred judgments than during culturally preferred judgments. Also, within each group, activation differences in these regions correlated strongly with scores on questionnaires measuring individual differences in culture-typical identity. Thus, the cultural background of an individual and the degree to which the individual endorses cultural values moderate activation in brain networks engaged during even simple visual and attentional tasks.*

Social cognition research differentiates cultural contexts that emphasize ideas and practices of interdependence (e.g., East Asian cultures in China, Japan, and Korea) from those that emphasize ideas and practices of independence (e.g., Western contexts in North America and Western Europe; Markus & Kitayama, 1991; Triandis, 1995). These cultural differences were originally considered in terms of social relations, but subsequent research has shown that they also apply to performance of simple perceptual judgments. People from East Asian cultural contexts perform better on tasks with interdependent (relative or contextual) demands than on those with independent (absolute or context independent) demands; people from Western cultural contexts perform better on tasks with independent demands than on tasks with interdependent demands (Kitayama, Duffy, Kawamura, & Larsen, 2003). These findings suggest that culture influences perception in a fundamental way (Nisbett, Peng, Choi, & Norenzayan, 2001). In the study reported here, we used functional magnetic resonance imaging (fMRI) to examine where in the brain cultural experience alters processing of simple perception in conditions involving independent (absolute) versus interdependent (relative) judgments. On the basis of prior behavioral results, we expected Americans to exhibit culturally preferred processing during absolute tasks and East Asians to exhibit culturally preferred processing during relative tasks. Thus, we hypothesized that cultural experience leads to opposite effects of task conditions on brain activations in these two groups.

A functional imaging study comparing cultural groups during culturally preferred and nonpreferred tasks might identify no group differences in activation, but if significant cultural differences are found, they could take three different forms. First, people from different cultures might exhibit activation in different networks of brain regions. Second, people from different cultures could exhibit activation in similar networks, but with each group showing greater activation during those tasks that are culturally preferred. We did not expect this pattern because task fluency or practice is typically associated with *reduced* activation (Milham, Banich, Claus, & Cohen, 2003). Third, people from different cultures could display activation in similar networks, but with each group exhibiting greater activation for nonpreferred tasks, which would suggest greater demand for attentional control during nonpreferred tasks. Greater activation in attentional control tasks is typically associated with greater task difficulty (Braver et al., 1997). Thus, such a pattern would seem to be most interpretable as indicating that each group has to exert more attentional control during culturally nonpreferred than during culturally preferred tasks.

If there are cultural differences in brain function, their location may indicate whether these differences are manifest in early perceptual or later cognitive stages of processing. If cultural influences occur in early perceptual stages of processing, such

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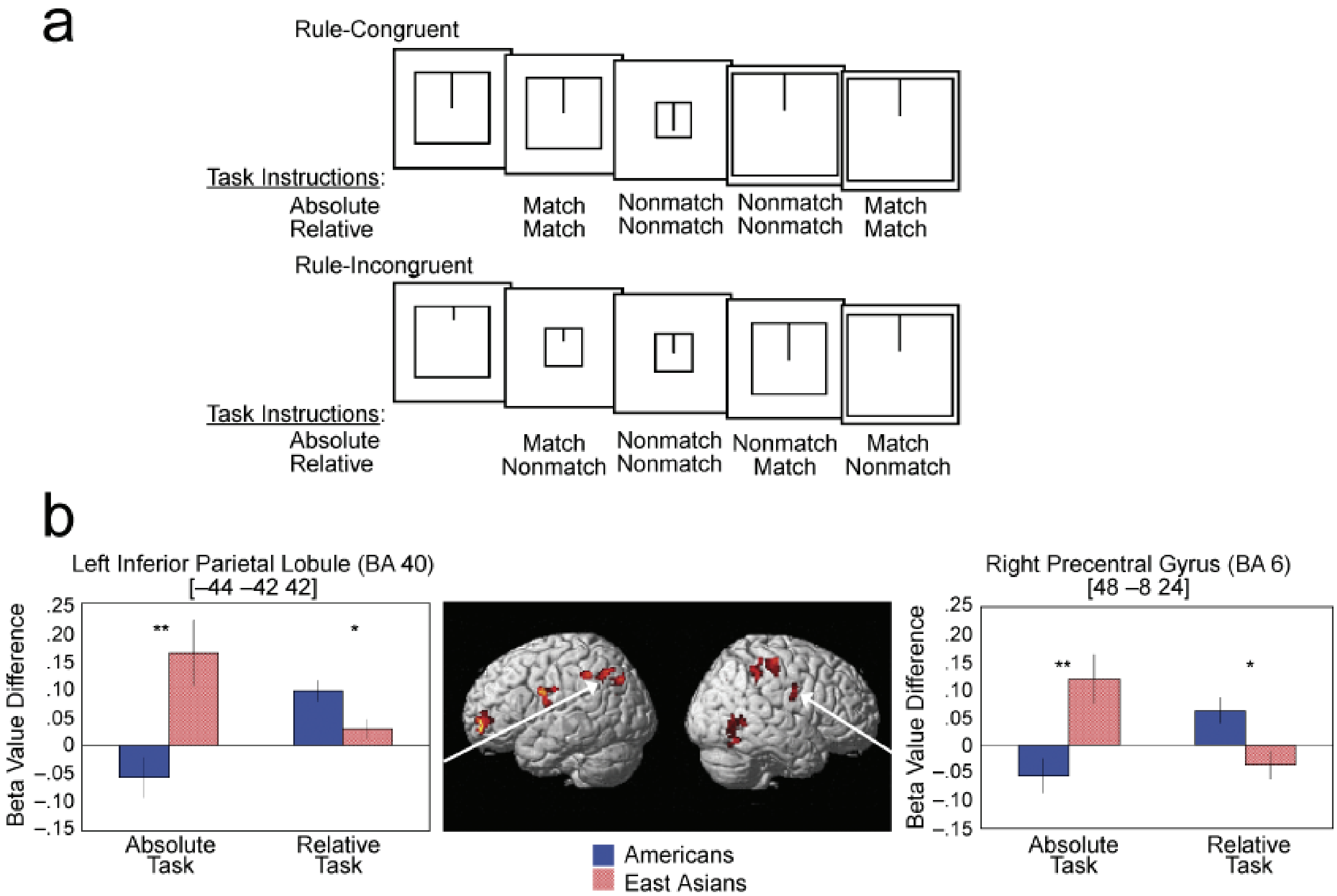

Fig. 1. Illustration of the task (a) and imaging results (b). The task consisted of judging stimuli depicting a vertical line inside a box. In the relative-instruction condition, participants judged whether each box and line combination matched the proportional scaling of the preceding combination; in the absolute-instruction condition, participants judged whether each line matched the previous line, regardless of the size of the accompanying box. In each block of trials, either both instructions led to the same matching response (congruent condition) or both instructions typically led to opposing responses (incongruent condition). The illustration in (b) shows the brain regions identified from the contrast analysis of the nonpreferred task versions (Culture × Instruction × Congruency interaction; uncorrected threshold of $p < .005$, cluster size ≥ 49). The bar graphs show beta-value difference scores (incongruent minus congruent) from representative regions of interest. Each region is identified by Brodmann's area (BA) and Montreal Neurological Institute coordinates. Difference scores are shown as a function of instruction (absolute vs. relative) and culture (American vs. East Asian). Asterisks indicate significant differences between the cultural groups, $^{*}p \leq .05$, $^{**}p \leq .01$.

that individuals in different cultural contexts literally see the world in different ways, cultural differences might be observed in primary or secondary visual areas in the occipital cortex. Alternatively, if cultural influences occur at later processing stages, exerting effects through selective control of attention, cultural differences may be found in high-level association cortices, especially in regions of a frontal-parietal attentional control network (Collette, Hogge, Salmon, & van der Linden, 2006; Wager & Smith, 2003).

METHOD

Twenty participants (ages 18–26; 11 female, 9 male), 10 East Asians recently in the United States and 10 Americans of Western European ancestry, underwent fMRI while making judgments regarding line lengths. Participants from the two cultures were equated on baseline reading comprehension, $t(18) = 1.51$, $p = .15$, and speed of processing, $t(18) = 0.44$, $p = .66$.

The task (see Fig. 1a) was adapted from the one used by Kitayama et al. (2003). Participants viewed a series of stimuli, each consisting of a vertical line inside a box. In a 2 × 2 design, the stimuli were judged under either relative (attending to context) or absolute (ignoring context) instructions, and judgments were either congruent (easy) or incongruent (difficult). Specifically, in the relative-instruction version of the task, participants judged whether the box and line combination of each stimulus matched the proportional scaling of the preceding combination, and in the absolute-instruction version of the task, participants judged whether the current line matched the previous line, regardless of the size of the accompanying box. A given block of trials was either congruent, meaning that either rule led to the same matching response, or incongruent, meaning that the two rules typically led to opposing matching responses.

In each of two sessions (separated by a 2-min rest), participants completed three blocks in each of the four conditions. Each block contained 5 trials, for a total of 60 trials per session.

After scanning, Americans completed an independence questionnaire (e.g., "I am not to blame if one of my family members fails"; Triandis, Bontempo, Villareal, Asai, & Lucca, 1988), and East Asians completed an acculturation questionnaire (e.g., "How well do you fit when with other Asians of your same ethnicity?"—reverse-scored; Suinn, Ahuna, & Khoo, 1992).

Functional data were acquired with a 1.5-T General Electric Signa MR scanner using a whole-head coil. Sequential spiral-in/spiral-out acquisition sequences were used to measure blood-oxygenation-level-dependent (BOLD) effects (repetition time = 1,850 ms, echo time = 40 ms, flip angle = 70°, 64 × 64 matrix, field of view = 240 mm, twenty-three 5-mm oblique slices). Images were screened for artifacts, motion-corrected, normalized to the Montreal Neurological Institute (MNI) template, and smoothed at 6 mm.

Statistical analyses were conducted using SPM2 (Wellcome Department of Imaging Neuroscience, London) and associated scripts. We conducted a whole-brain analysis on the three-way interaction of culture (American vs. East Asian), instruction (absolute vs. relative), and congruency (incongruent vs. congruent), in order to locate regions demonstrating activation differences across task and culture (whole-brain threshold of $p \leq .05$ corrected, achieved with $p \leq .005$ and cluster size ≥ 49 for normalized, resliced voxels; Forman et al., 1995). For this analysis, we computed the instruction-by-congruency interaction for each individual and entered the resulting contrast images into a group-level contrast. This contrast identified (a) regions in which Americans, compared with East Asians, exhibited greater activation on incongruent trials relative to congruent trials in the relative-instruction condition (Americans' nonpreferred task version) and (b) regions in which East Asians, compared with Americans, exhibited greater activation on incongruent relative to congruent trials in the absolute-instruction condition (East Asians' nonpreferred task version). We also computed the reverse interaction to examine regions in which activation was greater in each culture's preferred task version. Region-of-interest (ROI) analyses were conducted on each functional cluster identified from these group-level interaction contrasts.

RESULTS

Behavior

Participants were faster on congruent than on incongruent trials (congruent: $M = 902$ ms, $SD = 116$; incongruent: $M = 947$ ms, $SD = 133$), $F(1, 18) = 7.64$, $p = .01$. They were also more accurate, as measured by the proportion of correct trials, on congruent than on incongruent trials (congruent: $M = .84$, $SD = .08$; incongruent: $M = .77$, $SD = .08$), $F(1, 18) = 20.39$, $p < .001$. There were no significant behavioral effects involving instruction (relative vs. absolute), which suggests that the instruction conditions were comparable in overall difficulty. No effects involving culture were significant for accuracy or reaction times, which suggests that the two groups performed similarly and engaged successfully in nonpreferred processing when instructed to do so (and that any activation differences were not due to behavioral differences).

Imaging

The incongruent-versus-congruent contrasts showed that both groups exhibited widespread bilateral activations during the culturally nonpreferred task that were greater than the activations found in the other group for the same task (i.e., the culturally preferred version for the latter group; Culture × Instruction × Congruency interaction); these activations were primarily concentrated in prefrontal and parietal areas known to support sustained attentional control (Wager & Smith, 2003; see Table 1 and Fig. 1b). There were no significant differential activations in occipital cortex, where early visual processes are subserved by primary and secondary visual cortices. Only two regions were identified by the reverse interaction (i.e., group differences during the culturally preferred task), and 11 times more above-threshold voxels were identified in the interaction for the nonpreferred task than in the interaction for the preferred task (Table 1).

The incongruent-versus-congruent contrasts showed that each group, examined separately, displayed activation in prefrontal and parietal regions during its nonpreferred task, but little to no above-threshold activation during its preferred task. In direct between-groups comparisons of the two groups' nonpreferred task versions, no above-threshold differences in activation were observed. These analyses indicate that the groups did not differ substantially in activations during incongruent, relative to congruent, blocks during the groups' nonpreferred tasks.

Clusters of activation identified in the interaction analyses were treated as ROIs, and their mean activations (beta values) were examined in a three-way analysis of variance (ANOVA; Culture × Instruction × Congruency) to determine the direction of the interaction effect for each ROI (see Fig. 1b). Within each instruction condition (absolute or relative), activation differences (incongruent minus congruent) were highly intercorrelated across the ROIs (Cronbach's $\alpha = .97$ for the absolute task and .90 for the relative task). This finding indicates strong functional coactivation and allowed us to calculate a summary activation measure for each instruction condition. Weighted means (weighted by cluster size) of the activation differences were computed across the 11 ROIs identified by the contrast for the nonpreferred task. These values were subjected to a two-way ANOVA (Culture × Instruction), which yielded a significant interaction, $F(1, 18) = 26.19$, $p < .001$.[1] Americans displayed a greater activation difference during the relative-instruction

[1]Similar results were obtained using an unweighted mean of each ROI's maximum value, $F(1, 18) = 18.74$, $p < .001$.

TABLE 1
Brain Regions Showing Group Differences in Activation

	Whole-brain analysis							Effect of culture		r value			
			MNI coordinates							Americans		East Asians	
Analysis and anatomical region	Hemisphere	BA	*x*	*y*	*z*	*t* value	Cluster size (voxels)	Abs	Rel	Abs	Rel	Abs	Rel
Nonpreferred-task interaction													
Parietal, temporal lobes	L	7/39	−32	−68	22	3.55	220	**	*	−.33	.33	−.50	.70*
Middle frontal gyrus	L	10	−42	52	0	4.79	209	**	**	−.54	.22	−.48	−.31
Middle temporal gyrus	R	37	46	−52	0	4.91	202	**	**	−.44	.20	−.64*	.33
Precentral gyrus	L	4/6/9	−66	−6	18	4.36	179	**	*	−.45	−.26	−.43	−.18
Inferior parietal lobule	R	40	52	−44	50	3.67	116	**	**	−.57	.82*	−.57	.37
Postcentral gyrus	R	3	48	−24	52	3.75	102	*	**	−.70*	.56	−.68*	.08
Inferior parietal lobule	L	7/40	−44	−58	42	3.58	97	**		−.67*	.19	−.69*	.18
Superior parietal lobule	R	7	20	−60	38	3.76	68	**	*	−.83*	.75*	−.73*	.63*
Inferior parietal lobule	L	40	−44	−42	42	3.86	67	**	*	−.55	.63*	−.58	.57
Cingulate gyrus	L	24/32	−16	2	36	4.07	51	**	**	−.76*	.48	−.24	.57
Precentral gyrus	R	6	48	−8	24	3.60	49	**	*	−.70*	.44	−.46	.37
Composite ROI								**	**	−.65*	.43	−.70*	.34
Preferred-task interaction													
Middle temporal gyrus	R	21	54	6	−20	4.75	68	**	**	−.30	−.06	−.42	−.06
Anterior cingulate	M	24/32	0	30	26	4.06	52		**	−.58	−.41	−.57	−.05

Note. The table shows statistics for peak voxels and surrounding regions of interest (ROIs) identified in the contrasts for the interaction of Culture × Instruction × Congruency. Interactions were computed from group-level contrasts of the individual first-level contrasts using the following values: absolute task, incongruent condition (AI) = 1; absolute task, congruent condition (AC) = −1; relative task, incongruent condition (RI) = −1; and relative task, congruent condition (RC) = 1. The nonpreferred-task interaction contrast was defined as East Asian > American for (AI > AC) > (RI > RC) and identified activations greater in each culture for that culture's nonpreferred task. The preferred-task interaction contrast was defined as American > East Asian for (AI > AC) > (RI > RC) and identified activations greater in each culture for that culture's preferred task. Each cluster of activation from the interaction was treated as an ROI, and its mean activation (beta value) in each of the four experimental conditions was examined. For each ROI and for the composite (weighted mean) of the 11 ROIs, the table indicates the significance of the simple effect of culture (*t* test) on the mean activation difference (incongruent minus congruent) in the absolute-instruction (Abs) and relative-instruction (Rel) conditions (*$p < .05$, **$p < .01$). The table also presents, for each culture, the *r* value for the correlation between the activation difference (incongruent minus congruent) in each task and cultural-identity scores (independence for Americans, acculturation to American culture for East Asians). BA = Brodmann's area; MNI = Montreal Neurological Institute; L = left; R = right; M = midline.

condition ($M = 0.08$, $SD = 0.05$) than during the absolute-instruction condition ($M = -0.06$, $SD = 0.10$), $t(9) = 3.56$, $p = .006$; East Asians displayed the opposite pattern, that is, a greater activation difference during the absolute-instruction condition ($M = 0.12$, $SD = 0.10$) than during the relative-instruction condition ($M = -0.03$, $SD = 0.04$), $t(9) = 3.68$, $p = .005$.

Of the 11 ROIs identified in the interaction contrast for the nonpreferred task, 5 were centered in the frontal lobes, 5 in the parietal lobes, and 2 in the temporal lobes (extending into the fusiform gyrus). All 11 of these ROIs displayed a significant simple effect of culture in the absolute-instruction condition. Ten showed a significant effect of culture in the relative-instruction condition (see Table 1).

We further examined the relation of cultural context to brain function by correlating individual scores on the cultural-identity questionnaires with activation in a composite of the 11 ROIs identified in the contrast for the nonpreferred task (see Table 1 and Fig. 2). For Americans, higher scores for independence correlated significantly with less activation in the absolute-instruction (culturally preferred) condition ($r = -.65$, $p = .04$) and nonsignificantly with greater activation in the relative-instruction (culturally nonpreferred) condition ($r = .43$, $p = .21$). For East Asians, less acculturation to American values correlated significantly with greater activation in the absolute-instruction (culturally nonpreferred) condition ($r = -.70$, $p = .03$), and nonsignificantly with less activation in the relative-instruction (culturally preferred) condition ($r = .34$, $p = .34$).[2] When all items relevant to comfort or ability with English were removed from the analysis of the acculturation questionnaire, the analysis yielded virtually identical results; *r*s = −.69 and .34, respectively. Table 1 provides the individual ROI correlations.[3] For both groups, greater affiliation with American culture correlated with reduced activation in the absolute-instruction contrast. This finding suggests that across groups, greater affiliation with American culture made the absolute task easier to process.

[2]Similar correlations were obtained using an unweighted mean of each ROI's maximum value (Americans: −.75 for the absolute task and .42 for the relative task; East Asians: −.87 for the absolute task and .29 for the relative task).

[3]No significant correlations were observed for either culture between behavioral performance and activation, or between performance and questionnaire scores.

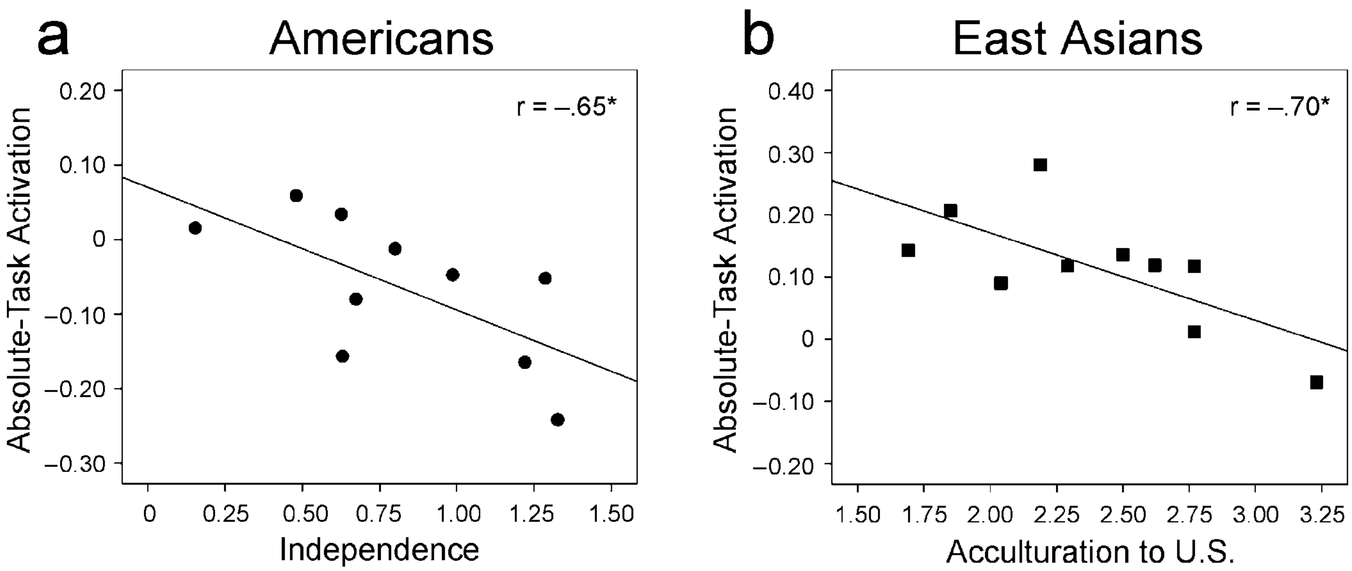

Fig. 2. Scatter plots of the correlations between cultural-identity scores and activation differences (beta-value difference scores: incongruent minus congruent) in the absolute-instruction task. The graph in (a) shows the correlation between activation and independence scores among Americans. The graph in (b) shows the correlation between activation and acculturation to American culture among East Asians. Asterisks indicate significant correlations, $*p \leq .05$.

DISCUSSION

Many ideas and practices prevalent in American cultural contexts require separating objects from their contexts and making independent or absolute judgments. In contrast, many ideas and practices prevalent in East Asian cultural contexts require connecting objects to their contexts and making interdependent or relative judgments (Nisbett et al., 2001). The present results provide evidence that cultural differences in the preferred and encouraged judgment style powerfully influence brain function, completely reversing the relation between task and activation across a widespread brain network. Individuals who had habitually engaged in American cultural contexts exhibited greater activation during the culturally nonpreferred relative task, whereas individuals who had habitually engaged in East Asian cultural contexts exhibited greater activation during the culturally nonpreferred absolute task. This interactive effect of culture and task on brain activation was so strong that it was statistically significant for 11 brain regions identified via a whole-brain analysis. Further, magnitudes of activation for culturally preferred and nonpreferred tasks varied as a function of individuals' degree of culture-typical identity, as measured by independence for Americans and acculturation to American culture for East Asians. This convergence between overall differences and individual differences provides strong support for a brain-behavior relation (Kosslyn et al., 2002; Omura, Aron, & Canli, 2005).

The results are most interpretable as reflecting an increased need for sustained attentional control during tasks requiring a processing style for which individuals are less culturally prepared. The large majority of culturally influenced activation differences were in frontal and parietal regions that regularly exhibit greater activation for more demanding tasks, and are therefore thought to mediate cognitive control over working memory and attention (Badre & Wagner, 2004; Smith & Jonides, 1999; Wager & Smith, 2003). Across groups, regions activated by the culturally nonpreferred task (absolute for East Asians, relative for Americans) were substantially similar, with no above-threshold voxels differing between groups. This suggests that the same attentional control network is engaged by individuals in the two cultural contexts, but that the need for such attentional control in a given condition is moderated by what individuals have been prepared for by their particular cultural contexts.

The findings also suggest that cultural influences on brain functions engaged by these tasks occur primarily during late-stage attentional processing, rather than early-stage perceptual processing. Culturally influenced activations were found in higher-order cortices (frontal, parietal, temporal) associated with cognitive control, attention, and working memory. There were no cultural influences on primary or secondary areas of the occipital cortex associated with early-stage perceptual processing. Culturally moderated activations were observed in the fusiform gyrus, a region that is associated with late-stage identification of visual objects and whose activation is modulated by attention (Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; Yi, Kelley, Marois, & Chun, 2006). Our study focused on incongruent versus congruent stimuli; nevertheless, when cultural differences between the absolute-instruction and relative-instruction conditions were examined independently of congruency, above-threshold activations were still not observed in visual regions associated with early-stage processing. Other tasks might identify cultural influences on primary or secondary perceptual cortices, but in the current study, even a relatively simple stimulus evoked cultural differences only in higher-order associative or tertiary cortices.

The lack of significant group differences in behavioral responses may reflect lack of power or sensitivity in the behavioral measures. Prior findings of a behavioral difference on a similar task (Kitayama et al., 2003) may have been due to the use of a more demanding procedure (reproducing line drawings) measured with absolute error. Our procedure involved simple recognition over seconds, and match/nonmatch judgments. Notably, the lack of behavioral differences between cultures suggests that the observed cultural differences in brain activation cannot be ascribed to time spent on task, error monitoring, or other behavioral effects of difficulty. Rather, the best explanation for members of the two cultures exhibiting increased activation in opposite task conditions is that each culture exhibits a preferred processing mode (relative for East Asians, absolute for Americans). Thus, the opposing mode is cognitively more demanding, but equivalent performance can be achieved when instructions are explicit and relevant brain regions are more intensively recruited.

We observed striking cultural modulation of brain responses during simple visual tasks that involved culturally preferred and nonpreferred processing modes. These findings complement those of behavioral studies and provide important and novel neurobiological insights into cultural differences. First, the same neural systems were recruited by people from the two cultures. This finding supports the view that the same kinds of cognitive processes are invoked across cultures, albeit to different magnitudes according to the relation between task demands and cultural preferences. Second, the localization of cultural interactions to frontal-parietal regions, rather than to early visual regions, suggests that the processes most affected by cultural experience are primarily related to high-level attentional modulation mediated by association cortices, rather than to early-stage encoding of inputs mediated by primary perceptual cortices. Third, the relation between neural activation and cultural-affiliation scores suggests that individual differences in engagement with the ideas and practices of a given cultural context influence the extent to which individuals are able to fluently process task versions favored by that culture. In summary, these findings show how experience in and identification with a cultural context may shape brain responses associated with attentional control even during a relatively simple and abstract task.

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