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Cultural Influences on the Neural Correlate of Moral Decision Making Processes

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Highlights:

- We compared the neural substrate of moral functioning between Koreans and Americans.
- Koreans showed increased activity in the putamen, DLPFC, and postcentral sulcus.
- Americans showed increased activity in the ACC and FPC.
- Results support the idea of interactions between culture, education, and brain.

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Abstract

This study compares the neural substrate of moral decision making processes between Korean and American participants. By comparison with Americans, Korean participants showed increased activity in the right putamen associated with socio-intuitive processes and right superior frontal gyrus associated with cognitive control processes under a moral-personal condition, and in the right postcentral sulcus associated with mental calculation in familiar contexts under a moral-impersonal condition. On the other hand, American participants showed a significantly higher degree of activity in the bilateral anterior cingulate cortex (ACC) associated with conflict resolution under the moral-personal condition, and in the right medial frontal gyrus (MFG) associated with simple cognitive branching in non-familiar contexts under the moral-impersonal condition when a more lenient threshold was applied, than Korean participants. These findings support the ideas of the interactions between the cultural background, education, and brain development, proposed in the field of cultural psychology and educational psychology. The study introduces educational implications relevant to moral psychologists and educators.

Keywords: Moral psychology, Culture, Cultural neuroscience, fMRI, Moral decision making, Moral education

1. Introduction

Recently, there have been various discussions regarding the relation between culture, education and human brain development. Given the previous studies done by cultural neuropsychologists, culture and human brain influence and construct each other through continuous interactions [1-3]. In addition, educational psychologists have recently argued that education significantly shapes human brain, while the brain is also influencing the process of learning [4]. The interactions between the cultural background, education, and brain development have become one of the most important ideas in the field of cultural neuropsychology and educational psychology. This idea proposes that the human brain is not completely determined by genetic factors, and can be changed by external cultural and educational factors [1-3]; on the other hand, it suggests that our cultural backgrounds and learning processes can also be affected by the results of neural level processes [4]. Thus, it may be wise to examine the relations and interactions between these factors to have a better understanding of our socio-cultural behaviors. Neuropsychological studies of socio-cultural psychological processes and cross-cultural neuropsychological investigations will contribute to the development of a better understanding in these fields. Given the idea in the field of cultural and educational psychology, we expect that different cultural and educational backgrounds across different countries could differently influence the development of socio-cognitive psychological processes at the neural level. These cross-cultural differences can be investigated through neuroimaging methods, which enable us to monitor socio-cognitive processes occurring in the human brain non-invasively.

Previous neuroimaging studies have attempted to understand cross-cultural differences in socio-cognitive processes. For instance, the neural substrate of the cultural influence on self-representation [5], intergroup empathy [6] and delay discounting [7] were investigated using neuroimaging methods. However, there have been very few previous human brain studies that have attempted to illuminate the influences of cultural and educational backgrounds on the moral decision making mechanism, which constitutes one of the most important parts of human socio-cognitive psychological processes. Although many scholars in the field of moral and cultural psychology have investigated the differences and similarities in moral judgment and moral development across different cultures (e.g. [8-14]), their previous studies have not examined the differences at the neural level. In addition, previous neuroimaging studies of human morality have investigated the neural substrate of moral processes, while controlling for the cultural background and ethnicity of participants, and have not focused on cross-cultural differences (e.g. [15-19]).

Therefore, we undertook the present study to compare the neural substrate of the moral decision making processes across different cultures, using the functional magnetic resonance imaging (fMRI) method. We presented a series of moral dilemmas to both Korean and American participants, and then investigated how their brains were differently activated when they were solving the presented moral dilemmas. Finally, we interpreted these neural level findings based on the ideas of previous studies in the field of cultural psychology (e.g., [20-26]) and moral psychology (e.g., [8-14]). We expect that there would be several significant differences between Korean and American's neural activity when participants are solving moral dilemmas. Given the previous studies in the field of cultural psychology, Korean participants are predicted to show a more neural activity in brain regions, which are associated with intuition and approximation (e.g., putamen, insula, caudate, postcentral sulcus, parietal lobule); on the other hand, Americans are predicted to show a significant activity in regions associated with formal reasoning, conflict and novelty monitoring (e.g., ACC, frontopolar prefrontal cortex (FPC)).

First, this study considers why Korean participants would show a more active response in regions associated with intuitive processes, while American counterparts are expected to show an increased activity in regions correlated with more slow reasoning processes when they are solving moral dilemmas. Norenzayan, Smith, Kim and Nisbett compared decision making processes between Korean and American participants [20]. In addition, Nisbett, Peng, Choi and Norenzayan suggested that people living in East Asian countries usually "seek intuitive instantaneous understanding through direct perception" toward external situations [21]. Because people living in East Asian societies tend to perceive and solve problems holistically, they become less analytic and think more "big-picture" than Europeans or Americans [21]. This tendency also appeared when a previous study tested the difference in critical thinking patterns between East Asians and European Canadians; the study showed that East Asians more utilized a less exact approximation than European Canadians [22].

Second, American participants would more utilize the conflict monitoring and novelty detecting monitoring mechanisms than Korean participants. The results of previous cultural psychological study showed that people living in collectivistic societies prefer to accommodate conflicting situations and to follow shared values [23,24], or even to avoid possible social conflicts [25] to maintain the harmony in their community, while people who came from individualistic societies tend to directly confront the conflicting situations. Moreover, because Korean society is not a highly multicultural society, Koreans would not frequently experience severe value conflicts between difference socio-cultural values or norms in their everyday life, while Americans would be exposed to such conflicts more frequently around them [26].

2. Materials and Methods

2.1. Participants

<Place Table 1 about here>

Sixteen right-handed adults (aged 21-34 years, mean (±SD) age 28.59 ± 3.18 years; 8 females; 8 Koreans, 8 Americans) participated in the experiment. The number of each gender in each nationality group was equalized (4 males and 4 females in each nationality group). Participants in each group were born in their country of citizenship, and had not been out of the land of their citizenship more than two years. All participants were recruited in Stanford area. Korean participants were staying at Stanford University while we conducted our research. These requirements were to control possible confounding effects of different cultural and educational environments. They provided a written consent approved by the Institutional Review Board at Stanford University, were debriefed, and were compensated for their participation ($60). The participants were recruited via Stanford mailing lists and Facebook. For the additional cultural perspective survey, these sixteen participants were contacted again, and asked to complete two cultural perspective questionnaires about 2-4 weeks after the end of the previous fMRI session. We provided them with $2.5 as compensation. One participant did not complete his questionnaire, so the survey results from fifteen participants were collected and analyzed.

2.2. Dilemma Task

The dilemma set in our study was initially developed by Greene et al [15,16]. It consists of three types of dilemmas: moral-personal, moral-impersonal and non-moral (neutral). Moral-personal dilemmas involve in certain moral violations, which meet these three criteria: "First, the violation must be likely to cause serious bodily harm. Second, this harm must be fall a particular person or set of persons. Third, the harm must not result from the deflection of an existing threat onto a different party. (p. 389)" [16]. A moral violation is impersonal if it fails to meet these criteria. Non-moral or neutral dilemmas consist of general cognitive problems that were not involved in any moral or value judgment, such as a time-scheduling and investment decision. The whole dilemma set consisted of a total of 60 dilemmas. There are 22 moral-personal, 18 moral-impersonal and 20 neutral dilemmas included in the set. We translated them into Korean for Korean participants. Two scholars in the field of moral education and moral psychology translated and edited the dilemmas. Dilemma texts were presented to participants via a projector behind the 3T MR magnet. We used E-Prime 1.2 to display the texts on the projector. The participant was able to evaluate whether the solution presented at the end of each dilemma is "appropriate" or "inappropriate" using a button box, after reading a presented dilemma.

Each dilemma was separated into three slides. Participants were able to proceed to the next slide by pushing any button on a response box. At the end of the third slide, participants were asked to evaluate the presented solution for the dilemma. They were asked to designate the solution as "appropriate" or "inappropriate". Here is an example dilemma presented. At the beginning of each trial in the moral-personal condition:

Enemy soldiers have taken over your village. They have orders to kill all remaining civilians. You and some of your townspeople have sought refuge in the cellar of a large house. Outside you hear the voices of soldiers who have come to search the house for valuables. Your baby begins to cry loudly. You cover his mouth to block the sound. If you remove your hand from his mouth his crying will summon the attention of the soldiers who will kill you， your child， and the others hiding out in the cellar. To save yourself and the others you must smother your child to death. Is it appropriate for you to smother your child in order to save yourself and the other townspeople?

Here are two other example dilemmas in the moral-impersonal and non-moral conditions:

You are a member of a government legislature. The legislature is deciding between two different policies concerning environmental hazards. Policy A has a 90% chance of causing no deaths at all and has a 10% chance of causing 1000 deaths. Policy B has a 92% chance of causing no deaths and an 8% chance of causing 10,000 deaths. Is it appropriate for you to vote for Policy A over Policy B? (Moral-Impersonal)

You are a farm worker driving a turnip-harvesting machine. You are approaching two diverging paths. By choosing the path on the left you will harvest ten bushels of turnips. By choosing the path on the right you will harvest twenty bushels of turnips. If you do nothing your turnip-harvesting machine will turn to the left. Is it appropriate for you to turn your turnip-picking machine to the right in order to harvest twenty bushels of turnips instead of ten? (Non-Moral)

Participants were asked to evaluate whether the presented solution is morally appropriate or inappropriate. On the one hand, if a participant considered that the solution is morally appropriate, it usually required a sacrifice of a certain value; for instance, if a participant wanted to kill a person to save five other people, she should evaluate the solution as appropriate in that case. In most cases, this evaluation was justifiable on utilitarian grounds. On the other hand, if a participant designated the solution as morally inappropriate, this response meant that she denied sacrificing the life of the person as a means to save other people. It could be interpreted as a deontological decision to the presented moral dilemma. In short, utilitarian judgments represent "judgments that maximize aggregate welfare;" whereas deontological judgments are based on a philosophical standpoint that contends "certain rights or duties must be respected, regardless of the greater good that might otherwise be achieved." [16] The participant had a total of 46 seconds to read the presented text and make a decision. 14 seconds of fixations were displayed at the beginning and end of each block and between trials. The whole scanning session consisted of a total of 12 blocks. Each block contained 5 dilemmas. The order of dilemmas was randomized to minimize the possible effect of adaptation to a certain type of dilemma.

2.3. Cultural Perspective Survey

To quantify participants' cultural perspectives, we used two different types of questionnaires. First, to measure participants' perceived tightness-looseness in their country, we used Gelfand et al.'s [27] cultural tightness-looseness questionnaire. It consisted of a total of six questions that asked a participant's perceived degree of the tightness or looseness of the cultural and social norms in their country with 6-point Likert scale. They were asked to write the numbers that represent the degree of their agreement for each statement (e.g., "There are many social norms that people are supposed to abide by in your country", "In your country, if someone acts in an inappropriate way, others will strongly disagree"). As a participant's perceived strength and tightness of social norms in her country become stronger, she gets a higher score. In addition, Self-Construal Scale developed by Singelis, Triandis, Bhawuk and Gelfand was used to measure the degree of each participant's individualistic versus collectivistic self-construal [28]. This measurement quantified how strongly a participant regarded himself/herself as an individualist or a collectivist with 7-point Likert scale. In common with the tightness-looseness measurement, Self-Construal Scale asked participants to rate the degree of agreement to each statement represented either individualism (independent self) (e.g., "I enjoy being unique and different from others in many respects") or collectivism (interdependent self) (e.g., "Even when I strongly disagree with group members, I avoid an argument"). We calculated a participant's "collectivism minus individualism score" to quantify her self-construal on her cultural perspective. The higher score means that he/she was more likely to perceive himself/herself as a collectivist and interdependent person.

2.4. Image Acquisition

Participants were scanned with a 3.0 T General Electric whole-body scanner with an 8-channel birdcage head coil. Head movements were minimized using foam paddings. High resolution T2-weighted fast spin echo structural images (TR = 3000ms, TE = 68ms, FOV = 240mm, matrix = 256 x 256) were acquired for alignment. Thirty-one oblique axial slices were taken parallel to the AC-PC with 4-mm slice thickness, 1-mm inter-slice skip. Functional scans were acquired with a spiral in and out sequence (TR = 2000ms, TE = 30ms, flip angle = 90^{o}) [29]. Thirty-one 4-mm-thick axial slices were acquired per TR, for a total of 157 TRs per functional block with a resolution of 3.75 x 3.75 mm (FOV = 240mm, 64 x 64 matrix) covering the entire brain. An automated high-order shimming procedure based on spiral acquisitions was used to reduce B0 heterogeneity [30]. The total image acquisition time for the functional task was 62-minute and 48-second long. A high resolution T1 volume scan (132 slices, 1.2-mm thickness) was collected for every participant using an IR-prep 3D FSPGR sequence for T1 contrast (TR = 5.8ms, TE = 1.8ms, flip angle = 11^{o}, FOV = 240mm, 256 x 192 x 132 matrix). During the scanning session, the participant's respiration and cardiac pulsatility were measured and recorded using a respiratory belt around the abdomen and a pulse oximeter on the finger of the non-dominant hand.

2.5. Behavioral and Survey Data Analysis

The response time and decision made by participants were statistically analyzed. First, the mean response times under two different conditions (moral-personal versus moral-impersonal) were compared using both ANOVA and t-test. The response time was defined as the time period between the presentation of the third slide, which asks a participant to make a decision, and the button press. These analyses include comparisons between two nationality groups (Korean vs. American), gender groups (females vs. males), and response types (appropriate vs. inappropriate). In addition, participants' responses were compared between conditions and groups using both within and between-group t-tests. Participants' responses were coded in two values: 0 ("appropriate", utilitarian in most cases) and 1 ("inappropriate", deontological in most cases). First, we compared the mean number of responses between two different moral dilemma categories within a group. Because the total number of dilemmas included in each dilemma type group was not identical, we used the percentage of "appropriate" responses to control the dilemma type factor. Second, these mean numbers were compared between Korean and American subjects within each moral dilemma category. Third, we also investigated the gender effect on decisions. For these analyses, non-moral dilemmas are excluded because they were used for a control condition, and they did not contain any moral proposition or moral implication. Instead, we displayed the data of non-moral dilemmas in figures only for demonstration.

For the survey data analysis, the mean tightness-looseness and Self-Construal Scale scores were compared between Korean and American participants using two sample t-tests. In addition, the correlation between the calculated tightness-looseness and Self-Construal score, and the neural activity of each participant was calculated. This correlational analysis process will be described in the next section in detail.

2.6. Imaging Analysis

fMRI data were preprocessed using SPM 8 (Wellcome Department of Cognitive Neurology) and custom MATLAB (Mathworks) routines. To minimize the artifact that might be originated from respiratory and cardiac activities, all acquired images were corrected using the RETROICOR method [31]. During the preprocessing process, functional data were slice-time corrected, realigned within and across blocks to correct for head movement, coregistered with the high-resolution anatomical scan, normalized into SPM8's standard MNI space (79 x 95 x 68, 2 x 2 x 2 mm^3 voxels), and smoothed with a 8-mm full-width at half maximum Gaussian kernel.

Regressors for the corresponding condition blocks were modeled as a boxcar function convolved with the canonical Hemodynamic Response Function (HRF). The HRF was modeled to include eight functional images surrounding the time point of participants' responses (4-scans before, 1 during and 3 after). Statistical analysis at the single-subject level treated each voxel according to SPM8's general linear model (GLM). For the second order (group) analysis, normalized images were analyzed using ANOVA. In this ANOVA, statistical maps of voxelwise F-statistics were thresholded for significance ($p < .01$ familywise error corrected, cluster size ≥ 12 voxels) and cluster size (≥ 12 voxels); however, we applied a more lenient threshold ($p < .05$, familywise error corrected) for exploratory purpose, when we were not able to find statistical significance during the course of ANOVA. Then, these images were compared using planned one sample (within group analysis) or two sample t-test (between group analysis) according to our hypotheses presented in the introduction section. In each t-test, statistical maps of voxelwise t-statistics were thresholded for significance ($p < .001$, uncorrected for multiple comparisons) and cluster size (≥ 12 voxels); however, we applied a more lenient threshold ($p < .005$, cluster size ≥ 12 voxels) for exploratory purpose, when we were not able to find statistical significance. The statistical maps were thresholded for minimal cluster size to minimize false positive probability while preventing the loss of statistical power [32]. Among all four comparisons (moral-personal – neutral, moral-impersonal – neutral, moral-personal – moral-impersonal, moral-impersonal – moral-personal), we focus on two comparisons, moral-personal – neutral and moral-impersonal – neutral because these comparisons would show how each group show a greater activity in a brain region under a given condition; two other comparisons, moral-personal – moral-impersonal and moral-impersonal – moral-personal, are used for exploratory purpose.

In addition to the whole brain voxelwise cross-cultural t-tests, we conducted correlational analyses between each participant's neural activity, perceived tightness-looseness, and self-construal scale score. First, we conducted whole brain correlational analyses between participants' brain activity, perceived tightness-looseness, and self-construal scale score with a voxelwise significant threshold of $p < .01$ ($r > .62$) for exploratory purpose. Then, our planned correlational analyses focused on a restricted number of a prior ROI voxels with a reduced voxelwise significance threshold of $p < .05$ ($r > .50$). These ROIs were decided according to the result of the previous whole brain voxelwise cross-cultural t-tests; they were voxels that showed a significantly different activity between Korean and American.

In addition to these procedures for imaging analyses to test our hypotheses, we conducted additional analyses to examine the relation between participants' neural activity, gender, and response for exploratory purpose. For the cross-gender analysis, first, we conducted a two-way ANOVA (nationality x gender). F-statistics were thresholded for significance ($p < .01$ familywise error corrected, cluster size ≥ 12 voxels); however, we applied a more lenient threshold ($p < .05$, familywise error corrected) for exploratory purpose, when we were not able to find statistical significance. Then, we compared male and female participants' neural activity with a voxelwise threshold of $p < .001$ (uncorrected for multiple comparisons), and minimum cluster size of 12 voxels. We also compared participants' neural activity between when they made an "appropriate" and "inappropriate" decision with a voxelwise threshold of a same *p* value and minimum cluster size. In addition, we calculated correlational coefficients between participants' neural activity and behavioral data. The correlational coefficients between their neural activity, response time, and the number of utilitarian or deontological decisions that they made were calculated, and a voxelwise significance threshold of $p < .01$ ($r > .62$) was applied.

3. Results

3.1. Behavioral

3.1.1. Response Time

<Place Fig. 1 about here>

First, we examined the difference in mean response times between two nationality groups. The result of ANOVA showed that only the main effect of dilemma type was significant [F (1, 636) = 9.35, $p < .005$], while participants' nationality [F (1, 636) = 2.12, $p >> .05$] and the interaction effect [F (1, 636) = .38, $p >> .05$] were insignificant. Among Korean participants, there was no significant difference in mean response times between moral-personal and moral-impersonal conditions [t (318) = 1.64, $p >> .05$]. However, American responded to moral-personal dilemmas significantly slower than to moral-impersonal dilemmas [t (318) = 2.76, $p < .01$]. In addition, there was no effect of nationality on mean response times in both the moral-personal [t (350) = .58, $p >> .05$] and moral-impersonal conditions [t (286) = 1.57, $p >> .05$].

In addition to the nationality, we examined the effects of both gender and response types on mean response times. First, in case of the gender effect (see Fig. S1), the result of ANOVA showed that both main effects of gender [F (1, 636) = 6.08, $p < .05$] and dilemma type [F (1, 636)

= 9.42, $p < .005$] were significant, while the interaction effect was insignificant [F (1, 636) = 0.45, $p >> .05$]. The results of two group comparisons reported that first, among both females [t (318) = 2.36, $p < .05$] and males [t (318) = 1.97, $p < .05$], the mean response time under the moral-personal condition was significantly greater than that under the moral-impersonal condition; second, when we compared by dilemma types, females responded significantly slower than males to moral-personal dilemmas [t (350) = 2.16, $p < .05$], but not to moral-impersonal dilemmas [t (286) = 1.36, $p >> .05$].

Second, in case of the effect of response type (appropriate vs. inappropriate) (see Fig. S2), the result of ANOVA reported that both main effects of dilemma type [F (1, 636) = 12.5, $p < .0005$] and response type [F (1, 636) = 10.08, $p < .005$], and the interaction effect were significant [F (1, 636) = 11.92, $p < .001$]. However, the mean response time for "appropriate" responses was only significantly greater than that for "inappropriate" responses under moral-personal condition [t (350) = 4.60, $p < .0001$], but not under moral-impersonal condition [t (286) = .21, $p >> .05$]. In addition, the significant differences in the mean response time between moral-personal and moral-impersonal conditions were only appeared for "appropriate" responses [t (284) = 4.50, $p < .0001$], but not for "inappropriate" responses [t (351) = .07, $p >> .05$].

3.1.2. Moral Decision

<Place Fig. 2 about here>

First, we examined the effect of nationality on moral decisions. The results of ANOVA reported that the main effect of dilemma type [F (1, 28) = .00, $p >> .05$] and nationality [F (1, 28) = 1.56, $p >> .05$], and the interaction effect (dilemma type by nationality) [F (1, 28) = .46, $p >> .05$] were insignificant.

Second, we examine the gender effect on decisions (see Fig. S3). The result of ANOVA demonstrated that all effects including the main effects of both dilemma type [F (1, 28) = .00, $p \gg .05$] and gender [F (1, 28) = .00, $p \gg .05$], and the interaction effect (dilemma type by gender) [F (1, 28) = .38, $p \gg .05$] were insignificant.

3.2. Survey Data

<Place Fig. 3 about here>

We compared the mean tightness-looseness and Self-Construal Scale scores between Korean and American participants. First, Korean participants showed a significantly higher mean tightness-looseness than American participants [t (13) = 3.80, $p < .005$]. Second, Korean participants showed a stronger degree of collectivistic and interdependent self-construal tendency than American participants, but the difference was insignificant [t (13) = 0.34, $p = .74$].

3.3. Imaging

<Place Fig. 4 about here>

<Place Table 2 about here>

First, we conducted whole brain voxelwise ANOVAs to identify whether there were significant main and interactional effects. There were voxels that showed significant main effects of both participants' group and a dilemma type, and the interaction effect; however, for the interaction effect, there was no voxel showed statistical significance for $p < .01$ (familywise error corrected), so we applied a more lenient threshold, $p < .05$ (familywise error corrected).

<Place Table 3 about here>

<Place Fig. 5 about here>

<Place Fig. 6 about here>

We conducted whole brain voxelwise planned t-tests for both Korean and American participants to compare the neural activity between moral-personal and neutral conditions, and moral-impersonal and neutral conditions (see Table S1, S2, and Fig. S4, S5). Next, we conducted two sample t-tests to quantify differences in the neural activity between Korean and American using the resulted contrast images. First, in the comparison between moral-personal and neutral conditions, Korean participants showed a significantly stronger signal increase in the right putamen [t (14) = 5.00, $p < .0002$] and right superior frontal gyrus (SFG) [t (14) = 5.07, $p < .0002$] than American. On the other hand, American's brain activation was significantly stronger in the bilateral ACC than Korean in this comparison [t (14) = -5.38, $p < .0001$]. In addition, we conducted correlational analyses between participants' neural activity, cultural tightness-looseness, and self-construal scores under the moral-personal condition (see Table S3 and Fig. S6 for the results of whole brain analyses). Given the results of our planned, ROI-restricted correlational analyses, there were statistically significant correlations between the neural activity in these regions and survey results. There were significant positive correlations between tightness-looseness scores and percent BOLD signal changes in the right putamen [r (13) = .56, $p < .05$] and right SFG [r (13) = .63, $p < .05$]. On the other hand, the signal change in the bilateral ACC was significantly negatively associated with both tightness-looseness (r (13) = -.55, $p < .05$) and self-construal scores [r (13) = -.41, $p < .05$].

<Place Fig. 7 about here>

<Place Fig. 8 about here>

Second, in the comparison between moral-impersonal and neutral conditions, Korean participants showed greater activation in the right postcentral sulcus than American participants [t (14) = 5.02, $p < .0002$]. However, there was no brain region that showed significantly stronger activation in American participants than Korean in this comparison. Hence, we applied a more lenient threshold ($p < .005$) for exploratory purpose. When we applied the more lenient threshold, only the left MFG showed a significantly stronger activity in American participants than in Korean under the moral-impersonal minus neutral condition [t (14) = -3.85, $p < .005$]. In addition, we conducted correlational analyses in the moral-impersonal condition, as we did in the moral-personal condition (see Table S4 and Fig. S6 for the results of whole brain analyses). Given the results of the planned, ROI-restricted analyses, the signal change in the right postcentral sulcus was significantly positively associated with participants' tightness-looseness score [r (13) = .51, $p < .05$]. On the other hand, there were significant negative correlations between the activity in the left MFG, and both tightness-looseness [r (13) = -.46, $p < .05$] and self-construal scores [r (13) = -.50, $p < .05$].

In addition, for exploratory purpose, we compared the neural activity between Korean and American participants for moral-personal minus moral-impersonal, and moral-impersonal minus moral-personal conditions. In the comparison between moral-personal and moral-impersonal, moral-impersonal and moral-personal conditions, there was a significant difference in the bilateral ACC. Korean participants showed a significantly greater activity in their ACC under the moral-impersonal condition than under the moral-personal condition [t (14) = 4.14, $p < .0005$]. Meanwhile, American showed a significantly greater activity in their bilateral ACC under the moral-personal condition than under the moral-impersonal condition [t (14) = -4.14, $p < .0005$]. There were no regions that showed a significantly greater activity among Korean participants under the moral-personal condition than under the moral-impersonal condition; in case of American, there were no regions that showed a significantly greater activity under the moral-impersonal condition than under the moral-personal condition.

Finally, the regions showed the significant main effects of participants' nationality and gender, and their interaction effect was reported in Table S5 and Fig. S7. In addition, the results of the cross-gender comparisons were presented in Table S6 and Fig. S8. Table S7 and Fig. S9 were added to demonstrate the differences in the neural activity between when participants made an "appropriate" and "inappropriate" decision. In addition, the results of additional correlational analyses between each participant's neural activity, response time, and decisions were presented in Table S8, S9, and Fig. S10. We conducted these additional analyses to examine whether the findings of previous fMRI investigations conducted with only Americans (see [15,16,33,34]) were successfully replicated among our cross-cultural participants. The overall results of our analyses successfully replicated the findings of the previous studies [15,16,34].

4. Discussion

First, the behavioral data showed that American participants responded to moral-personal dilemmas significantly slower than to moral-impersonal dilemmas, that is, American participants needed a longer time when they were solving more complicated and emotion-involved dilemmas. This result is in line with a previous cognitive psychology study [20]. Given the previous cognitive psychology study, American relied on a slower decision making mechanism based on a reasoning process, when they encountered emotionally more complicated dilemmas. Unlike American participants, because Korean more utilized intuitive decision making processes, they did not respond to more complicated dilemmas slower than to simple dilemmas. On the other hand, there were no significant effects of dilemma type and nationality on participants' responses.

The results are in line with the universal moral developmental model proposed by moral psychologists; they have argued that moral development and moral judgment are universal across different cultures [10-11]. As proposed by them, although the response time and other internal decision making processes would differ between American and Korean, the resulted moral decisions would not significantly differ from each other.

There were contradicting results in the analyses of the survey data. First, there was a significant difference in the mean tightness-looseness score between Korean and American participants. This difference in the cultural tightness-looseness could result from the differences in socio-cultural backgrounds between Korea and America. Triandis's [35] and Gelfand et al.'s [27] studies suggested that a society with a collectivistic atmosphere and dense population possesses strong and tight social and cultural norms. In fact, Korean society that has a collectivistic tradition based on Confucianism, dense population, and sparse resource comparing to America, possess significantly tighter social and cultural norms; and, Korean participants' perceived degree of cultural tightness is also stronger. However, interestingly, there was no statistically significant difference in the Self-Construal Scale score between Korean and American participants. It means that Korean participants did not perceive themselves as more independent or collectivistic than American participants; it seems to be counterintuitive because various previous cultural psychological studies reported that people living East Asian countries are more interdependent than American (e.g. [36,37]). There could be two reasons. First, we recruited Korean participants at Stanford University, so they could be more individualistic than people living in Korea. Second, we must consider the difference in the nature of questions between tightness-looseness and Self-Construal Scale questionnaires. The former aims to measure the perceived tightness of socio-cultural norms, while the latter asking whether a participant regards herself as either an independent or interdependent person. Thus, there could be a larger individual variance in the result of Self-Construal Scale than the tightness-looseness score; it could be resulted in the small difference in its mean score between two groups. In fact, in Chiao et al.'s [2], there were more Japanese participants placed in the individualistic group than American participants (7 Japanese versus 3 Americans).

There were significant differences in neural activation in some brain regions between Korean and American participants when they were solving moral dilemmas. Although the resulted moral decisions were similar between groups, the internal, neural level mechanism of decision making processes showed differences. The overall results of ANOVAs were in line with our prediction and previous studies. We predicted that Korean participants would show more enhanced activity in brain regions associated with intuitive and approximation processes, while their American counterparts would show stronger activity in the regions associated with reasoning and cognitive processes. In fact, a significant main effect of the group factor was found in the insula, putamen, postcentral sulcus, ACC, and SFG, which are associated with either intuitive, approximation, or reasoning process [38-48]. The result of the ANOVA of the main effect of the dilemma type also successfully replicated the previous fMRI investigation of moral functioning conducted by Greene et al. [15]. As Greene et al. reported, participants' brain regions including the MFG, angular gyrus, and parietal lobe showed the significant main effect of the dilemma type in our experiment. In addition, our additional ANOVA with a more lenient threshold reported that a significant interaction effect was found in the ACC, which is also regarded to be associated with a conflict monitoring and cognitive process that are likely to be influenced by both participants' group and dilemma type [43-45]. Given these results, we found that there would be the meaningful effects of both the nationality group and dilemma type on participants' neural activity, so we proceeded to conduct our planned t-tests to examine the differences in the neural activity under a given dilemma condition between Korean and American participants. In addition to the results of ANOVA, the results of within-group comparisons are also in line with the results shown in Greene et al.'s [15,16] previous studies.

First, under the moral-personal condition, Korean participants showed significantly stronger neural activation in the right putamen and right SFG that corresponds to the dorsolateral prefrontal cortex (DLPFC). Given previous studies of the cognitive functional role of the putamen, the activity in this area is significantly associated with intuitive social decision making and behavioral processes [38,39]. In addition, a previous study suggested that the putamen is associated with automatic emotional responses and processes, in particular, negative emotions, such as hate and disgust [49]. Thus, Korean participants apparently utilized socio-moral intuitive processes more strongly, and they more relied on an emotional intuitive circuit, which is associated with hate and disgust emotions when they were solving complicated and emotionally negative moral dilemmas, as suggested by the increased activity in the putamen. This result is in line with previous studies in the field of cultural psychology [21].

A previous fMRI investigation on socio-moral decision making tasks showed that the involvement of the putamen is significantly associated with the pursuit of efficiency or utilitarian value [50]. However, there was no statistically significant between-group difference in the number of solutions for moral dilemmas that were perceived morally appropriate (in most cases, associated with utilitarianism) by participants in the moral-personal condition. If the activity in the putamen that facilitates an intuitive and utilitarian decision making mechanism was not controlled, then Korean participants should have made more utilitarian responses than American counterparts. The present study supposes that the significantly greater activity in the right

DLPFC among Korean participants is associated with an increased cognitive control over the intuitive activity in the right putamen that is associated with a utilitarian decision. Previous studies showed that the DLPFC is associated with cognitive control over initial intuitive responses and behaviors [16,48]. Thus, the activity in the DLPFC could control the initial intuitive responses of the putamen that is significantly associated with utilitarian decisions, and finally, Korean participants could show a similar response pattern with American participants under the moral-personal condition. This involvement of the DLPFC into the process of moral decision making among Korean participants can be explained by their cultural background. Social and cultural norms in East Asian society that more value the community values than individual desires influence people to more strongly suppress and control their individual, immediate desires and opinions [51]. In addition, Confucian tradition in Korean society teaches that people should control their emotions and feelings [52]. As a result of this cultural experience of Korean, they showed increased activity in the DLPFC region, which is correlated with a cognitive control over their initial emotional intuitive responses toward emotionally complicated moral-personal dilemmas.

This co-activation of both the putamen and DLPFC would seem to be logically inconsistent because the putamen is associated with intuition, while the DLPFC is involved in cognitive control. This situation can be explained by the nature of moral problems, which is different from usual problem sets that were used in the previous study that demonstrated the intuitive nature of Asians (e.g., [20]). The problems that were used in this study were basically mathematical, rather than morality-related; they qualitatively differ from those used in our study. In fact, as Turiel proposed, those two problems are in different domains, and they cause significantly different psychological responses in participants [53]. Morality-involved problems are more associated to emotional aspects that are common across diverse cultures comparing to arithmetic problems, which are relatively free from emotions [54,55]. In addition, as proposed in the introduction, several moral psychologists showed evidence of the universality of human morality and moral development across diverse cultures, including both American and Korean [10,11]. As a result, although Koreans are inclined to activate intuition when they encountered moral dilemmas, as previous cross-cultural cognition studies showed, due to the universality underlies human morality and moral problems, they finally made decisions that did not differ from America's' decisions, as presented in our behavioral data. In this process, Koreans attempt to control their immediate, affective response as influenced by their cultural and educational background (e.g., [51,52]), and as revealed in the activity in the DLPFC. In addition, because the increase of the response time is directly associated with the activity in the ACC, not DLPFC [56], Korean participants show a significantly shorter mean response time than Americans, though they more activated cognitive control processes associated with the DLPFC.

On the other hand, American participants showed stronger activity in the ACC under the moral-personal condition. Previous studies of the cognitive role of the ACC showed that the activation in this region is closely associated with conflict-monitoring activities [43,44] and emotional conflict solving [45]. Given these previous studies, American participants could utilize conflict monitoring and resolving mechanisms more when they were coping with emotional and complicated moral dilemmas, and it may be correlated with the stronger activity in the ACC. Because Korean participants have grown up in a collectivistic society that emphasizes the harmony among people living in a same society or community, they might have few chances to utilize this conflict managing mechanisms in their life [26]. This result is also in line with our behavioral-level result that showed that American participants spent significantly longer time to solve moral-personal dilemmas than moral-impersonal dilemmas, while this difference did not appear among Korean participants. The involvement of the ACC during the decision making process to solve emotionally complicated moral dilemmas is associated with a slower processing speed, because its conflict monitoring process requires a longer time when it deals with high-conflict problems [46].

Under the moral-impersonal condition, Korean participants showed a significantly increased neural activity in their postcentral sulcus. Previous studies investigating this region showed that the activity in this region is strongly associated with comparison and approximation, rather than accurate and exact calculation [40,41]. Given the findings of the present study and previous studies, Korean participants utilized more approximation and comparison and less exact calculation processes when they were solving moral-impersonal dilemmas, which do not intensively arouse emotional responses and are not seriously involved in harm to a human. This behavior is also in line with cultural psychological studies that have shown the cultural difference in the reasoning and approximation mechanisms between East Asian and Western societies [21,22].

On the other hand, there was no brain region in American participants that showed a significantly greater activity than Korean participants under the moral-impersonal condition at $p < .001$. However, we attempted to apply a more lenient threshold ($p < .005$) for exploratory purpose. Of course, because we increased the threshold p value, there is a higher possibility of false positive in this analysis, and it reduces the credibility of the result. Thus, the result of this analysis with the more lenient threshold should be exploratory, not confirmatory. The result demonstrated that a part of the MFG, which corresponds to the FPC, showed a substantially stronger activity among American participants. Koechlin and Hyafil proposed that the involvement of the FPC is associated with "the processing of simple cognitive branching," particularly under uncertain situations, but it has a limited capacity, and is related to non-expert cognitive skills [47]. This result could be explained by the national-wide ethics and moral education curriculum in Korea. Korean moral education curriculum provides materials for the development of moral reasoning, and chances to practice moral judgment through various activities including lectures and discussions. All Korean participants in the present study were required to take this ethics and moral education subject at least for ten years, from elementary to high school [57]. As a result, they were able to practice their moral decision making skills through the curriculum, and became more familiar with moral problem solving, and showed less activity in the FPC region. Korean participants showed increased activity in a part of the inferior parietal cortex, postcentral sulcus and inferior parietal lobule that was proved to be associated with trained mental arithmetic abilities [42]. However, this difference did not appear under moral-personal condition. Because ethics and moral education materials in Korea do not include any significantly violent or brutal moral dilemmas similar to the dilemmas used under moral-personal condition that might not be appropriate to children and adolescents [57], and they usually utilize formalized and exemplary socio-moral stories, so Korean participants could show skilled moral decision making abilities only with the moral-impersonal dilemmas, which are similar to what they have been exposed to during ethics and moral education classes.

The correlational analyses between participants' neural activity, tightness-looseness, and perceived self-construal scores were also conducted. In case of the tightness-looseness score, the results were similar to what we expected. The differences in the socio-cultural environment between Korean and American societies (e.g., [23-25,27,36,37]) would be properly reflected into the calculated correlations between the tightness-looseness score and neural activity in selected brain regions as presented in Fig. 6 and 8. However, in case of the correlation between participants' neural activity and self-construal score, there were some inconsistent results. Although there was no significant difference in the mean self-construal score between Korean and American participants, significant correlations between the neural activity and the score was discovered in some brain regions that showed significant cross-cultural differences. It can be interpreted by the influence of participants' self-construal on their decisions and behaviors at both individual and group levels. In fact, Eby and Dobbins's [58] study showed that the perceived individualistic-collectivistic orientation at both levels significantly influence people's behavior. Although the orientation at one level could be independent from that at another level, both factors simultaneously shape people's thought and behavior in a same direction. Likewise, our participants' perceived self-construal—that is an individual-level factor—could be independent from the group-level factor—that is, perceived cultural tightness-looseness, but it could significantly contribute to the difference in neural activity as the group-level factor in a same direction. In fact, the arguments of previous cross-cultural psychological studies regarding people's individualistic-collectivistic orientation, thought, and behavior (e.g., [23-25,35-37]) correspond to the significant correlations between participants' self-construal score and neural activity in their ACC associated with conflict-monitoring and deliberation, and FPC associated with the deliberative processing of unfamiliar problem solving.

In addition to these main findings, we conducted additional analyses on the effects of gender and response type factors at the both behavioral and neural level. The correlation between behavioral and image data were also analyzed to examine whether the present study is consistent with previous studies. First, we examined the effect of gender factor on the mean response time, decision outcome, and neural activity. There was a significant gender effect on these behavioral and neuroimaging data, excepting the mean decision outcome; in addition, a significant interaction effect of participants' nationality by gender was also discovered using ANOVA (See Table. S5, S6, Fig. S1, S3, S7, S8). The cross-gender similarity in decision outcomes are in line with previous moral psychological studies that showed a universal developmental model of morality (e.g., [10]). However, future studies should be conducted to explain the cross-gender differences in the mean response time and brain activity during moral tasks.

Second, in case of the response type, "appropriate (utilitarian)" responses showed a significantly longer mean response time than "inappropriate (deontological)" responses under the moral-personal condition, but not under the moral-impersonal condition. This result is in line with previous fMRI investigations conducted by Greene et al. [15-16] (see Fig. S2). The differences in participants' neural activity when they responded "appropriate" and "inappropriate" to a given dilemma are also in line with Greene et al.'s findings [15-16] (see Fig. S9). They demonstrated that when a participant made a utilitarian (appropriate) decision, his/her bilateral DLPFC was significantly activated particularity under the moral-personal condition. It would correspond to the previous study that showed the involvement of the process of cognitive control, when a person made a utilitarian decision that overridden his/her initial gut-level, immediate emotional response that might lead to a deontological decision [33,34]. In conclusion, the findings of previous studies, which only investigated American, were successfully replicated with our cross-cultural sample.

The results of additional correlational analyses between participants' neural activity, response time and the number of "appropriate" versus "inappropriate" decisions made by them would also replicate previous studies. First, we demonstrated that in both conditions, the engagement of the ACC was significantly associated with the increase of the response time. This result is in line with the previous study of the role of the ACC [46] and the neural correlate of moral reasoning [34]. Because the ACC is associated with conflict monitoring, conflict solving, and "classical cognitive" processes [46], which constitute a moral reasoning mechanism [34], the activity in this region would be positively associated with the response time to a given dilemma. In our study, brain regions other than the ACC, such as the fusiform gyrus, were negatively associated with the response time. This negative correlation is also in line with a Volz and von Cramon's [59] neuroimaging study that showed that the activity in the fusiform gyrus was significantly greater in the intuitive judgment condition comparing to the non-intuitive judgment condition.

Second, under both conditions, as participant made more utilitarian decisions, their neural activity in regions associated with a cognitive control, in particular, the DLPFC significantly increased. On the other hand, the number of deontological decisions was positively correlated with the neural activity in other regions, such as the amygdala and limbic system that are associated with affective and emotional processes (see [33,34]). These differences in the neural activity between utilitarian and deontological decisions were more prominent under the moral-personal condition than the moral-impersonal condition. Because of the nature of each dilemma type, the involvement of either utilitarian or deontological neural mechanism would be stronger in the moral-personal condition (see [15,16]). These results replicated previous neuroimaging investigations on the differences between utilitarian and deontological decisions [33,34].

However, we point out that there is a significant limitation in our study. Due to its small sample size for each group, the volume of each cluster that showed significantly different BOLD activation between Korean and American participants was small; the largest cluster was smaller than 65 voxels (520 mm^3). Because of the relatively modest sample size, we conducted a post-hoc statistical power analysis based on between-group difference in BOLD signal strengths, inter-subject variability and sample size for each group (8 subjects) at a threshold p-value = 0.001 (see [60]). The analysis utilized data from brain regions that showed significantly different activity between Korean and American subjects. The results showed that excepting the MFG, which did not show significantly different activity at the initial threshold $p = .001$, all regions showed statistical power stronger than 80%. In case of the MFG, the power was 71%; although this value is slightly less than the typically accepted value of 80%, it can be deemed an acceptable power [61,62]. Of course, the larger sample size would be helpful to increase the generalizability and statistical power in general [63], but our results based on the sample size are at least acceptable by established norms. To support the main findings of our study, future studies should be conducted to address this problem. A larger sample size would increase the overall statistical power of the comparisons, minimize the possibility of potential type II error, and increase the size of each cluster that shows a significant difference between two groups [63].

In addition, there have been several concerns regarding the moral dilemmas developed by Greene and his colleagues. Among them, Christensen and Gomila pointed out two significant problems. First, the classification between three dilemma types (moral-personal, moral-impersonal, and non-moral) are not fully elaborated; instead, the classification of Greene et al. was preliminary, not final [64]. Second, there is significant within-type variability. For instance, a perceived personal distance [64] in a certain dilemma could significantly differ from another dilemma of the same type, and it could increase within-type variability. Finally, some moral psychologists have contended that because these dilemmas are not realistic, but hypothetical, and contain extreme situations it would be difficult to properly investigate participants' moral thinking in their real, everyday lives using them (e.g., [65]). However, to examine cross-cultural differences and similarities by comparing the findings of the present study with those of previous studies that only targeted American, the present study utilized the dilemmas used in previous studies. Thus, future studies should use improved moral dilemmas. First, philosophical sophistication is needed to address unclear dilemma classification and within-type variability problems (e.g., [66]). Second, more realistic everyday moral dilemmas, such as the dilemmas used in Gilligan's moral decision making study (see [67]), should be utilized.

5. Conclusions

In conclusion, the differences in cultural and educational backgrounds between the two participant groups may be associated with the differences in the pattern of moral decision making processes at the neural level. We compared moral decision making processes at both behavioral and neural levels between Korean and American participants. The findings of the present study support the standpoint in cultural psychology that argues culture-brain co-construction [1,2], and in educational psychology that emphasizes the influences of education to human brain development [4] even in the domain of morality. Socio-cultural and educational factors related to morality are strongly associated with the human brain development, so the difference in these factors could lead to different neural developmental mechanisms. Finally, the differences in the neural developmental courses could be investigated using neuroimaging methods, and could be reflected in the differences in the neural activity during moral decision making tasks as reported in the present study.

As a result, we propose some implications for moral development and education that could be drawn from the findings of the present study. In previous moral psychological and educational studies, scholars have utilized self-reporting paper-and-pencil, or interview-based measurement to investigate participants' moral decision making processes (e.g. Moral Judgment Interview [68], Defining Issues Test [69]). However, this kind of subjective measurement can be susceptible to the deception problem, and cannot show us the underlying mechanism of human moral functioning (see [70]). Thus, this neuroimaging study contributes to the illumination of mechanisms and processes of moral decision making. It is important to properly measure the degree of students' moral development to evaluate the effects of moral educational programs, so this kind of more reliable and valid measurement can give moral educators with more accurate information about how their programs influence on students' moral functioning and which part of the programs should be improved and modified. Given the fact that Korean society is quickly transforming into a multicultural society, this kind of cross-cultural neuroscientific investigation of moral decision making processes may provide moral psychologists and educators with useful inspirations about how to teach Korean students how cope with moral problems occurring in Korean society. Because there is a large possibility that more diverse and severe values conflicts will happen in pluralist, multicultural societies, these functions—value conflict detection, monitoring, and solving—are very crucial to solve various moral problems in multicultural societies where various social, cultural, and moral values originated from different cultures coexist. However, the result of this study demonstrated that Korean participants showed weaker brain activation in the ACC that is associated with the value conflict detection and solving than American participants. Given the result of this study, on the one hand, Korean participants seemed to be less inclined to utilize these functions than American participants when they were solving human value-involved moral dilemmas. Thus, to be prepared for the trend of multiculturalization in Korean and other unicultural and collectivistic society in a transition period, moral psychologists and educators should consider how to improve these functions that seem to be less activated in Korean participants, but are essential to solve moral problems in a multicultural society. In addition, some moral-personal dilemmas could be frequently utilized to promote the development of students' moral deliberation and thinking on the dignity of human life. On the other hand, in American schools where moral education is not provided to student as a form of an individual subject, opportunities for moral discussions and debates regarding various moral issues and dilemmas through all subjects and extracurricular activities should be provided to students. Given the results of the analysis of participants' brain activation, by enhancing access to moral discussions in American schools American students could be familiarized to socio-moral issues as Korean students. In conclusion, moral education should be culturally sensitive to effectively promote students' moral development.

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Tables

No	Nationality	Gender	Degree or Major	Involved in moral studies?
1	Korean	Female	MA in Education	Y
2	Korean	Female	BS in Science	N
3	Korean	Female	BA in Music	N
4	Korean	Female	BS in Engineering	N
5	Korean	Male	MS in Science	Y
6	Korean	Male	MS in Engineering	N
7	Korean	Male	MD	N
8	Korean	Male	MS in Science	N
9	American	Female	College student in Engineering	N
10	American	Female	BA in Psychology	Y
11	American	Female	BA in Psychology	N
12	American	Female	BS in Psychology	N
13	American	Male	Law school student	Y
14	American	Male	MA in Education	N
15	American	Male	MA in Education	N
16	American	Male	BS in Psychology	N

Table 1. Participant demographic information

Condition/Region	*x*	*y*	*z*	Vox	*F*
Main Effects					
Group (Korean vs. American)					
R Inferior Parietal Lobule	54	-28	30	273	17.28
R Precentral G	60	8	18	201	24.08
R Insula, Putamen	34	4	6	124	15.7
R Postcentral S	-58	-60	38	122	19.37
L Medial Frontal G, ACC	-6	58	2	100	16.82
R Hypothalamus	0	-8	-10	96	18.24
R Superior Frontal G	12	56	36	87	31.77
L Medial Frontal G	-6	-16	58	57	16.57
R Inferior Parietal Lobule	42	-42	46	51	14.24
R Middle Temporal G	54	-72	10	44	16.07
L Precentral G	-56	2	10	25	13.82
L Fusiform G	-32	-34	-24	15	12.18
Dilemma Type (Moral-Personal vs. Moral-Impersonal)					
Bi Medial Frontal G, ACC	-8	54	12	1262	48.35
R Superior Parietal Lobule	30	-56	36	981	30.46
L Superior Parietal Lobule	-26	-66	46	238	17.35
L Inferior Parietal Lobule	-38	-40	46	53	13.98
R Middle Temporal G	56	-50	-14	45	17.24
R Inferior Frontal G	50	10	24	38	13.59
R Inferior Parietal Lobule	40	-34	42	26	13.23
Interaction Effect					
Group X Dilemma Type					
Bi Anterior Cingulate Cortex	-2	46	6	99	10.8*
R Inferior Frontal G	52	6	22	15	8.47*

Table 2. Results of whole-brain ANOVA for the main effects of participants' group and dilemma type, and interaction effect , $p < .01$ familywise error corrected, $k \geq 12$. MNI coordinates. (* : $p < .05$ familywise error corrected, $k \geq 12$)

Condition/Region	*x*	*y*	*z*	Cluster size (vox.)	*t*
Korean > American					
Moral-Personal minus Neutral					
R Putamen	30	-16	6	32	5
R Superior Frontal G	12	54	36	14	5.07
Moral-Impersonal minus Neutral					
R Postcentral S	56	-24	38	21	5.02
Moral-Impersonal minus Moral-Personal					
Bi ACC	2	44	10	34	4.14
American > Korean					
Moral-Personal minus Neutral					
Bi ACC	-2	46	8	64	-5.38
Moral-Impersonal minus Neutral					
L Medial Frontal G*	-6	58	4	63	-3.85
Moral-Personal minus Moral-Impersonal					
Bi ACC	2	44	10	34	-4.14

Table 3. Results of whole-brain contrast for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral-impersonal), and (moral-impersonal – moral-personal) between Korean and American participants, $p < .001$, $k \geq 12$. MNI coordinates. (* : $p < .005$, $k \geq 12$)

Figures

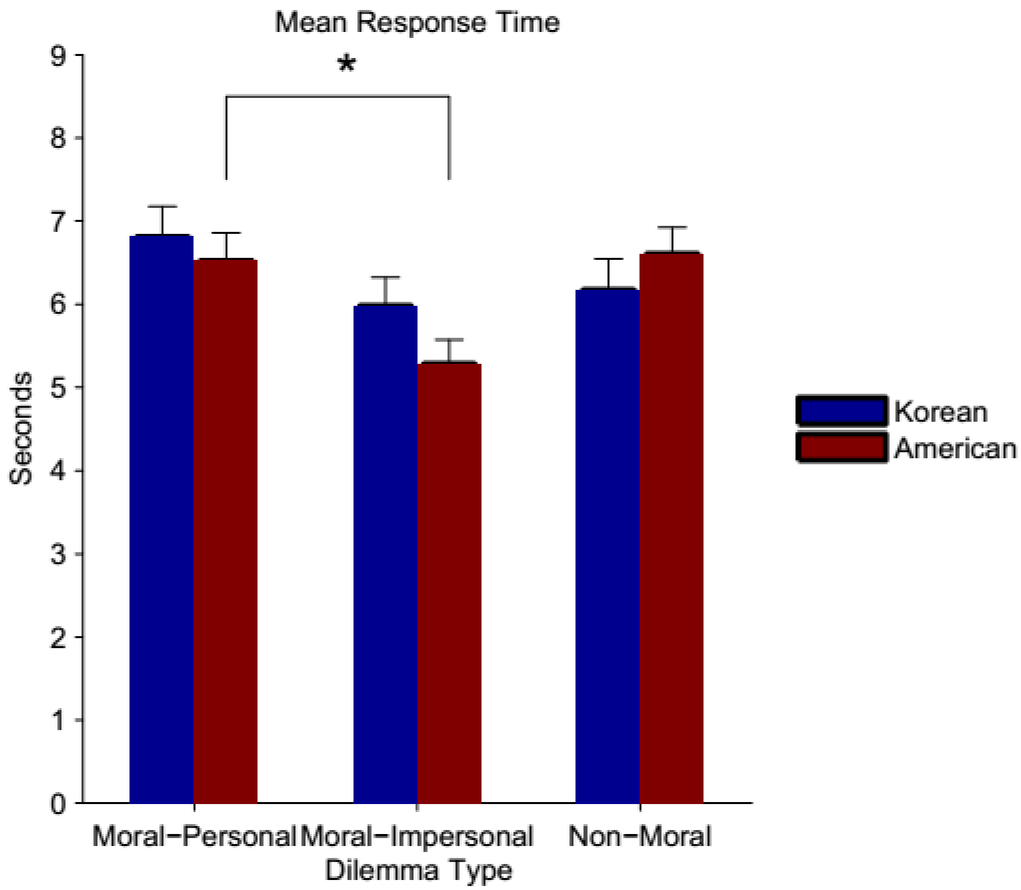

Fig. 1. Results of the comparison of the mean response time between Korean and American participants under three conditions. American participants spent a significantly longer time to solve moral-personal dilemmas than moral-impersonal dilemmas. There was no significant difference among Korean participants.

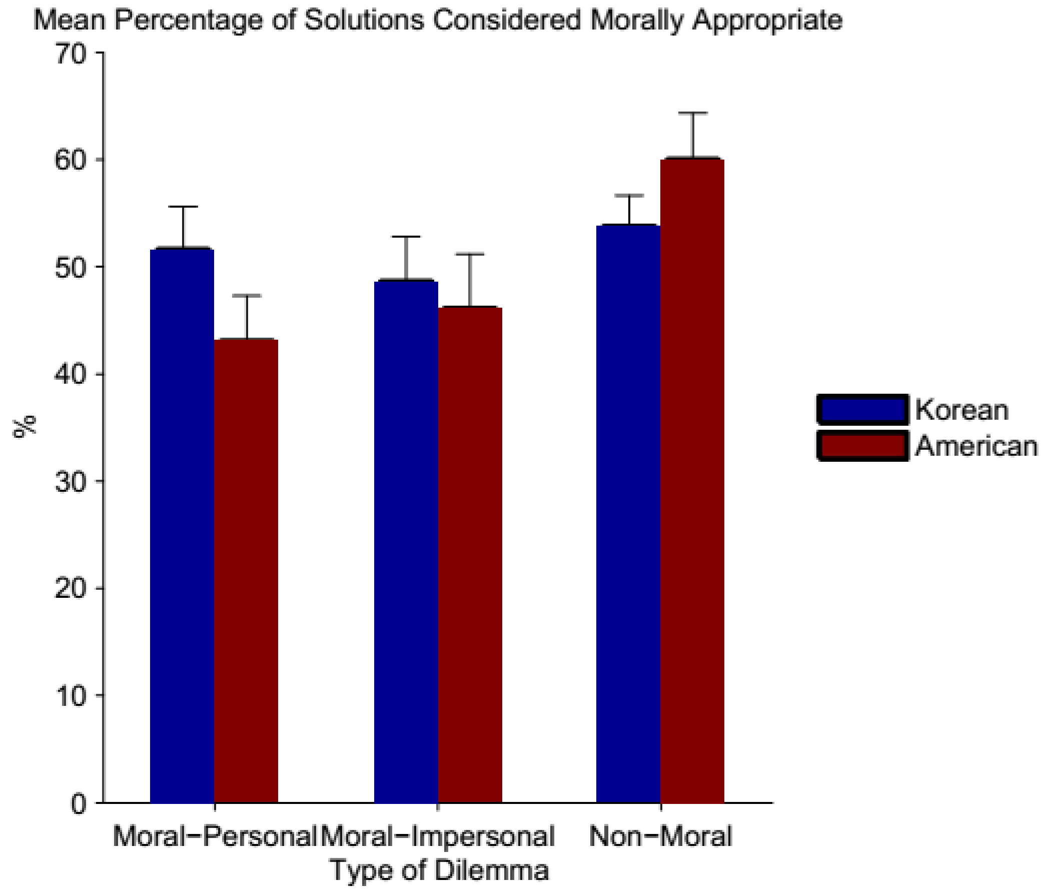

Fig. 2. Results of the comparison of the mean percentages of dilemma solutions that were considered morally appropriate by participants between two groups.

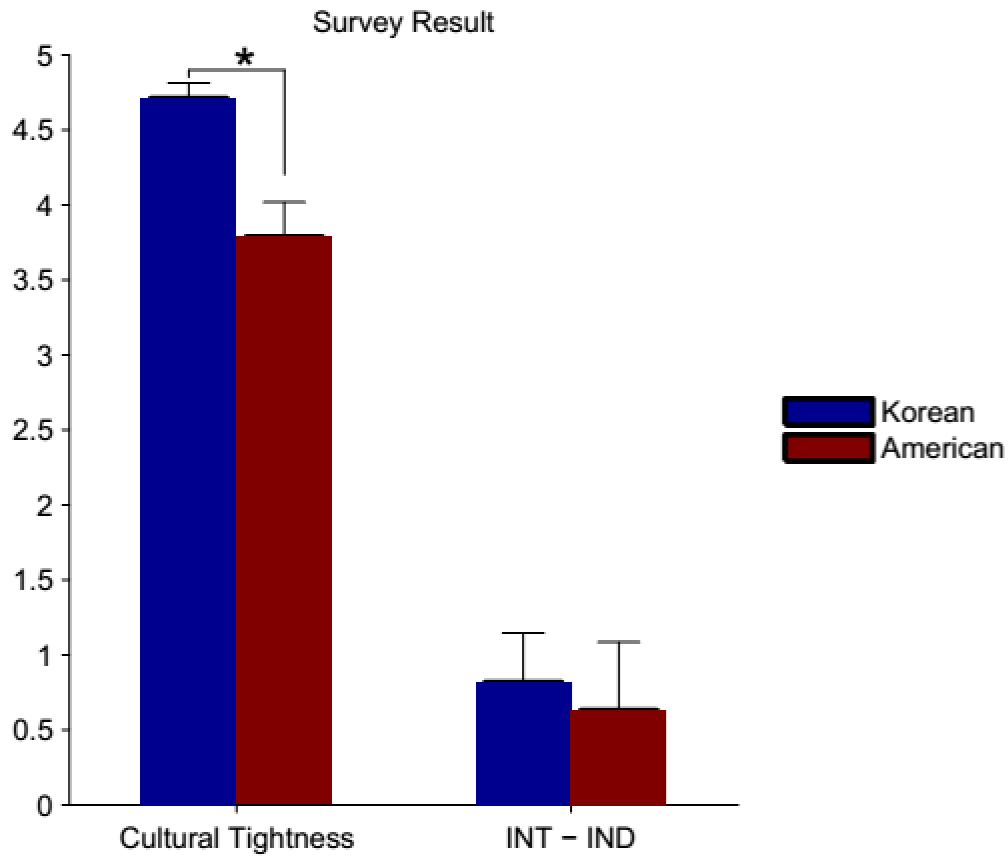

Fig. 3. Results of the comparison of the mean tightness-looseness and Self-Construal Scale scores between Korean and American participants. Korean participants reported higher mean scores in both scales, but only the difference in the mean tightness-looseness score was significant.

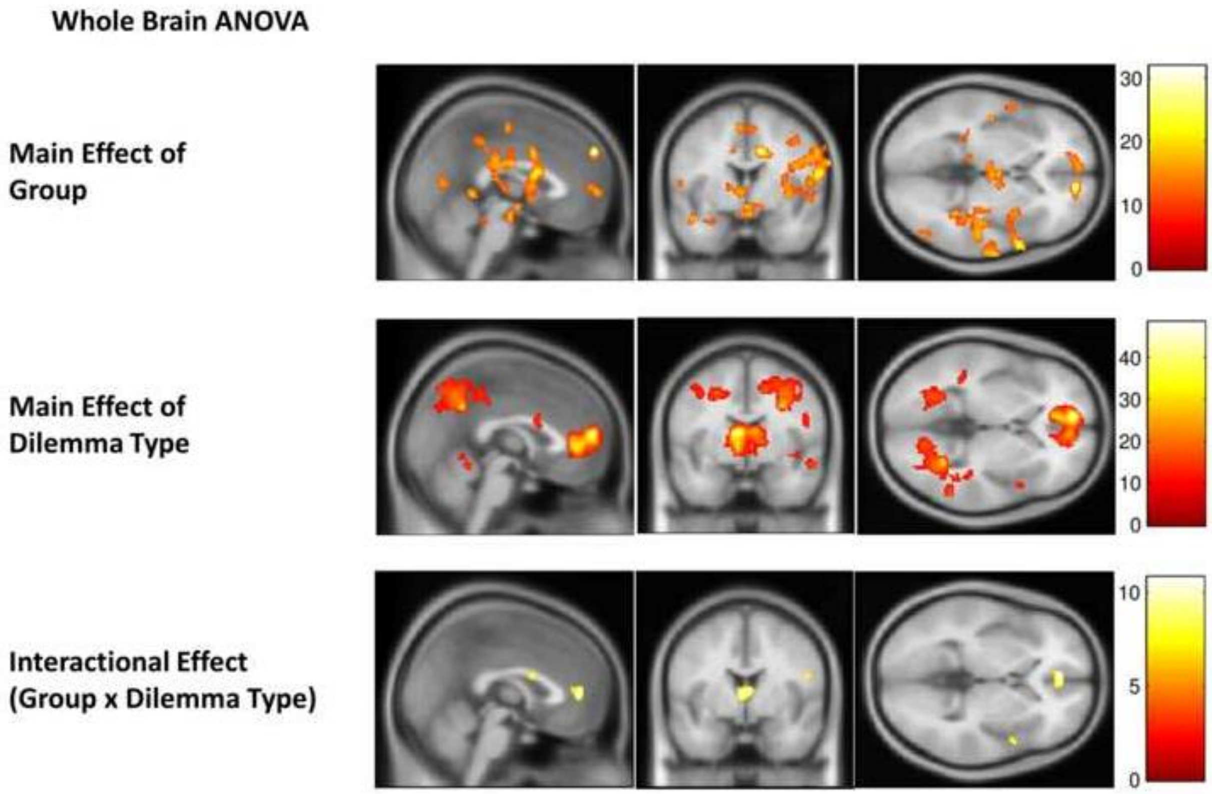

Fig. 4. Results of whole-brain ANOVA for the main effects of nationality group and dilemma type ($p < .01$ (familywise error corrected), $k \geq 12$), and the interactional effect of (nationality group x dilemma type) ($p < .05$ (familywise error corrected), $k \geq 12$).

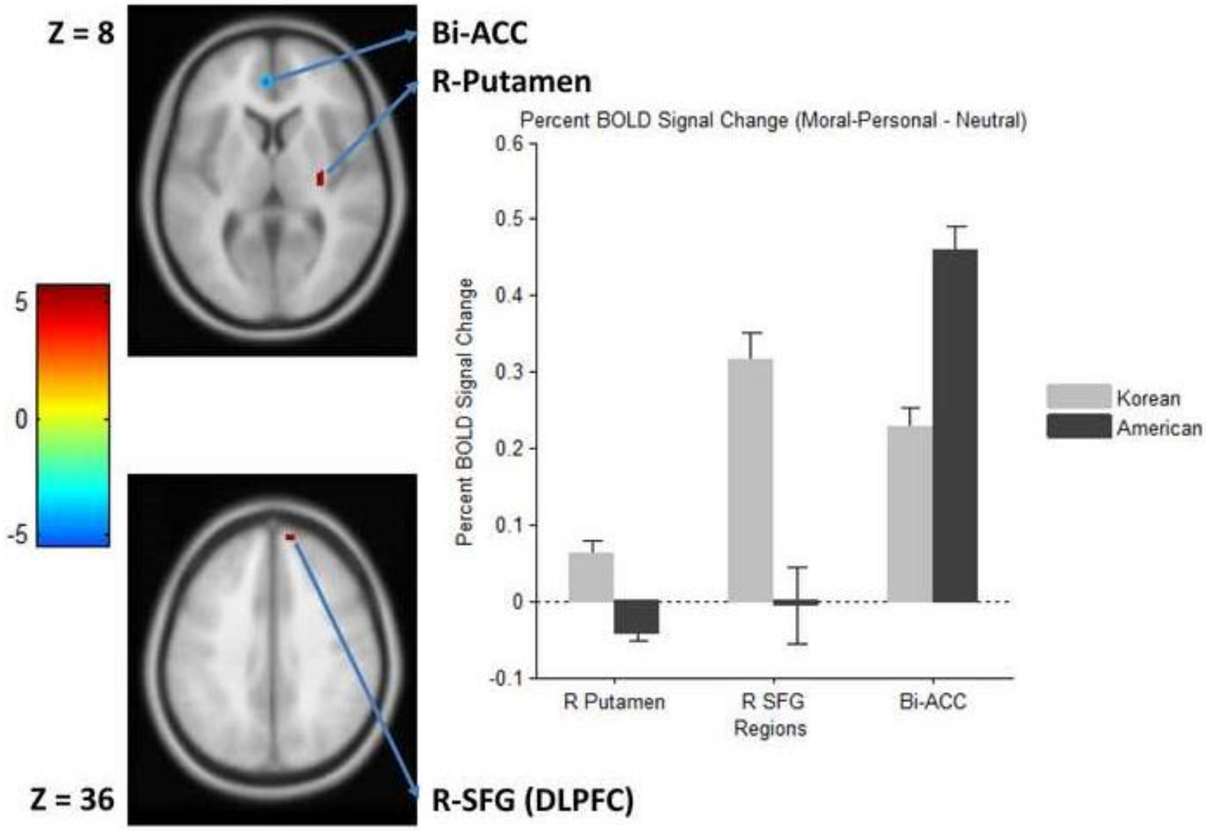

Fig. 5. Results of whole-brain contrast between Korean and American participants for (moral-personal – neutral) condition, $p < .001$, $k \geq 12$. Korean participants showed a significantly stronger activation in their right putamen and right superior frontal gyrus than American participants. American participants showed a significantly stronger activity in their bilateral anterior cingulate cortex than Korean participants.

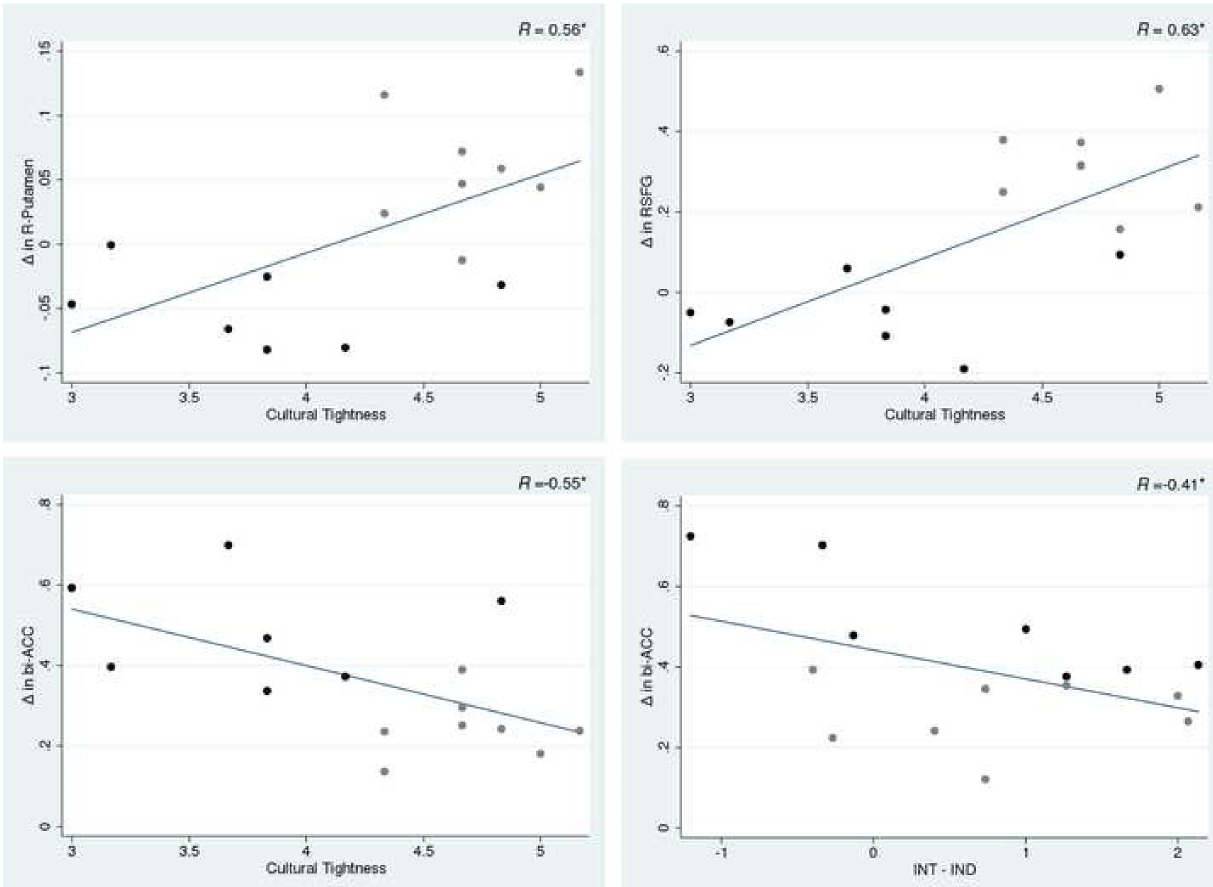

Fig. 6. Results of the correlational analyses between BOLD signal change in each region, tightness-looseness and self-construal scores under the moral-personal condition. There were significant positive correlations between the tightness-looseness score, the signal changes in the right putamen and right superior frontal gyrus. On the other hand, there were significant negative correlations between the signal change in the bilateral anterior cingulate cortex and both scores. A threshold of $p < .05$ was applied. Gray dots represent Koreans, and black dots represent Americans.

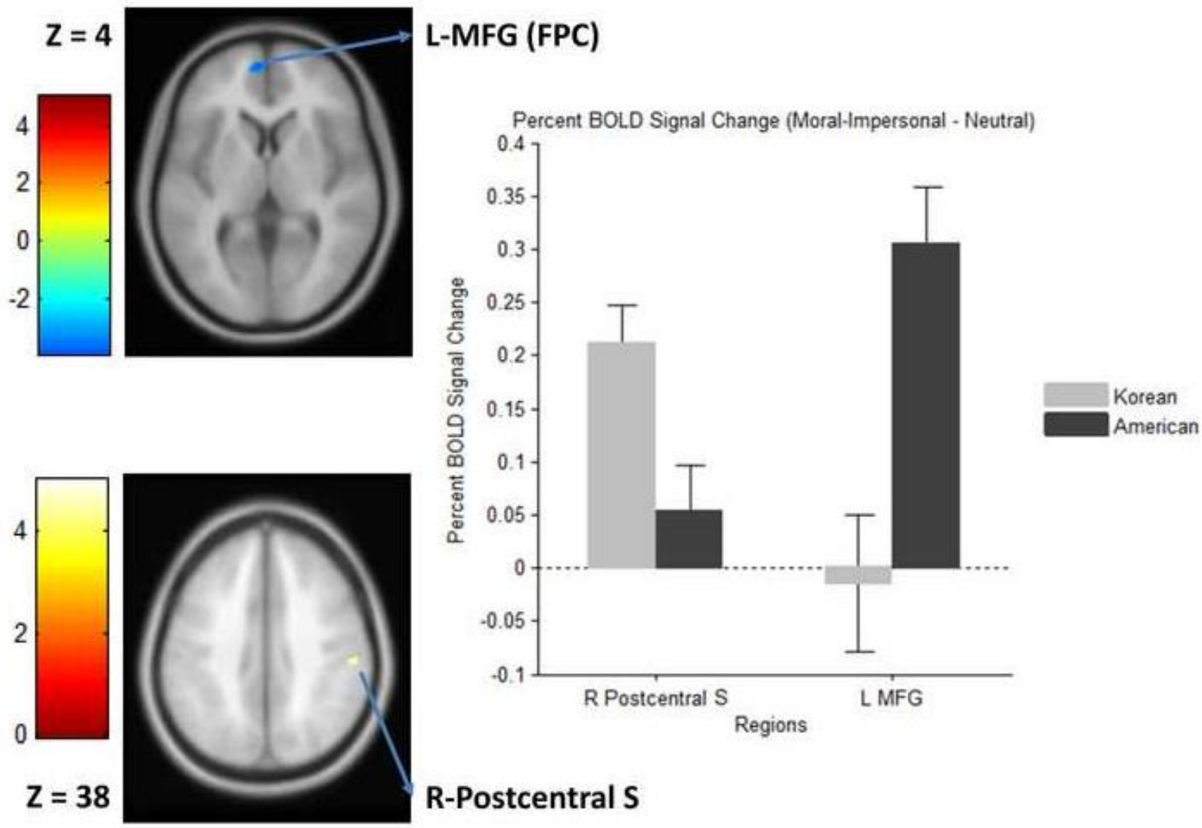

Fig. 7. Results of whole-brain contrast between Korean and American participants for (moral-impersonal – neutral) condition, $p < .001$, $k \geq 12$. Korean participants showed significantly greater activation in their postcentral sulcus. When applied a more lenient threshold ($p < .005$), American participants showed a stronger activity in their left medial frontal gyrus than Korean participants.

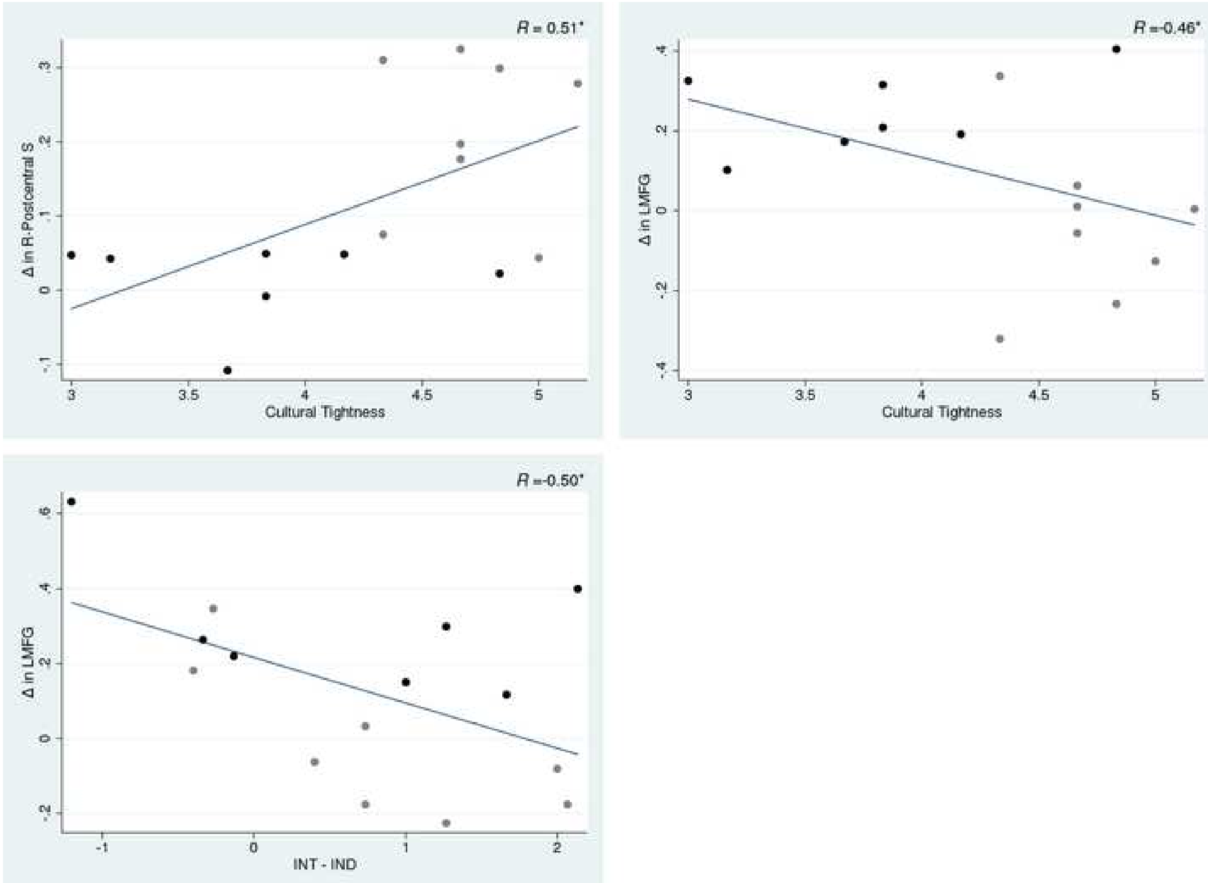

Fig. 8. Results of the correlational analyses between BOLD signal change in each region, tightness-looseness and self-construal scores under the moral-impersonal condition. There was a significant positive correlation between the signal change in the right postcentral sulcus and the cultural tightness score. On the other hand, there were significant negative correlations between the signal change in the left medial frontal gyrus and both scores. A threshold of $p < .05$ was applied. Gray dots represent Koreans, and black dots represent Americans.

Supplementary Materials

Tables

Condition/Region	*x*	*y*	*z*	Cluster size (vox.)	*t*
Moral-Personal minus Neutral					
Bi ACC	8	42	8	1933	20.6
L Precuneus	0	-38	16	734	21.3
R STG	66	-40	13	101	7.39
L Hippocampus	-34	14	-4	89	9.78
L Insula	-28	12	-10	75	8.09
R STS	48	-60	10	73	7.5
R Hippocampus	30	-8	-20	44	11.6
L Occipital Lobe	-52	-70	12	44	6.96
L Postcentral G	-30	-44	70	42	9.11
L OFC	-20	34	-8	27	6.26
R Caudate	16	16	14	25	6.16
L MTG	-40	-60	14	19	6.66
L Medial Frontal G	-6	-14	62	19	5.7
Bi Subcallosal G	0	6	-16	18	8.26
L Caudate Head	-12	20	-6	17	5.53
R STG	36	12	-34	14	5.39
L ACC	-2	16	-8	14	5.25
R Middle Frontal G	28	28	34	13	7.82
Moral-Impersonal minus Neutral					
L Precuneus	-12	-32	40	310	8.19
L Precuneus	-2	-66	32	111	6.44
L Inferior Parietal Lobule	-68	-26	22	80	7.51
R Postcentral G	54	-24	40	49	8.97
Bi Superior Frontal G	4	52	32	49	7.5
R Middle Frontal G	22	32	38	37	10.1
R Supramarginal G	56	-26	26	28	5.39
L Medial Frontal G	-6	52	12	18	6.82
R STG	68	-42	18	15	5.66
L Caudate Head	-12	20	-8	14	6.11
Moral-Personal minus Moral-Impersonal					
Bi Medial Frontal G	8	56	10	481	10.3
R TPJ	60	-66	22	30	6.69
L Superior Frontal G	-12	68	8	16	7.29
Bi Precuneus	2	-62	32	16	5.63
Moral-Impersonal minus Moral-Personal					

R Inferior Parietal Lobule	50	-40	46	98	7.59
R MTG	60	-48	-16	73	9.72
L Inferior Frontal G	-58	12	28	60	8.67
R Inferior Parietal Lobule	42	-58	52	51	5.99
R Inferior Frontal G	50	16	28	45	8.06
L Inferior Parietal Lobule	-38	-52	50	43	5.83
L Middle Frontal G	-42	12	32	35	5.8

Table S1. Results of whole-brain contrast for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral-impersonal) and (moral-impersonal – moral-personal) conditions within Korean participants, $p < .001$, $k \geq 12$. MNI coordinates.

Condition/Region	*x*	*y*	*z*	Cluster size (vox.)	*t*
Moral-Personal minus Neutral					
Bi ACC	-8	38	10	3769	18.8
Bi Precuneus	-4	58	18	386	10.3
L Cingulate G	-16	-34	36	189	12.8
L TPJ	-48	-82	24	146	9.42
L Parahippocampa G	-30	-44	-4	133	14
R Subcallosal G	6	4	-18	87	9.86
R Cingulate G	12	-32	42	86	6.81
L Insula	-36	20	-12	41	8.97
R TPJ	58	-62	6	22	5.43
L Inferior Parietal Lobule	-68	-36	30	17	5.59
Bi OFC	-2	30	-14	15	5.91
Moral-Impersonal minus Neutral					
L Medial Frontal G	-8	60	10	221	10.4
L Parahippocampa G	-22	-38	-32	184	7.76
L Superior Frontal G	-30	28	36	170	8.28
Bi Precuneus	-6	-54	16	134	7.08
L Cingulate G	-16	-34	32	132	8.09
L TPJ	-50	-76	16	125	9.43
R Precuneus	8	-44	46	64	8.06
Bi ACC	-2	34	24	46	9.95
R MTG	56	-62	-10	33	8.89
L Middle Frontal G	-20	-12	62	28	5.57
R Thalamus	16	-28	6	22	8.24
L Superior Frontal G	-20	60	16	21	7.06
R Superior Frontal G	30	34	36	17	6
R TPJ	56	-62	8	16	5.57
R Fusiform G	30	-36	-24	14	6.08
L Precuneus	-4	-52	42	14	5.39
Moral-Personal minus Moral-Impersonal					
Bi ACC	-10	38	8	1328	12.6
Bi Precuneus	-4	-56	22	417	21.6
R Parahippocampa G	18	4	-18	175	14
L Insula	-30	12	-16	94	6.96
R Superior Frontal G	20	46	46	73	9.09
L Cingulate G	-18	-22	38	26	8.57
Moral-Impersonal minus Moral-Personal					
R Precuneus	30	-44	34	734	10.1
L Superior Parietal Lobule	-28	60	42	76	6.01

L Fusiform G	34	-66	-16	51	7.08
L Inferior Frontal G	-40	4	34	45	6.18
L Inferior Frontal G	-56	30	18	27	10.9
L Precuneus	-18	-76	52	15	5.67
L Precuneus	-16	-62	42	14	5.54
R Caudate	16	-8	18	12	5.91

Table S2. Results of whole-brain contrast for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral-impersonal) and (moral-impersonal – moral-personal) conditions within American participants, $p < .001$, $k \geq 12$. MNI coordinates.

Condition/Region	*x*	*y*	*z*	Vox	*p*
Moral-Personal & Tightness					
Positive Correlation					
R Superior Frontal G	10	54	36	696	.0002
L Putamen	-14	6	-8	417	.0008
R Hippocampus	42	-16	-16	143	.0002
R Precentral G	48	0	38	97	.0003
R Cingulate G	18	-46	26	48	.0006
R Middle Temporal G	54	-72	12	47	.005
L Posterior Cingulate Cortex	-26	-64	4	41	.005
L Inferior Frontal G	-42	24	6	40	.002
L Inferior Parietal Lobule	-58	-60	38	37	.001
L Middle Frontal G	-18	10	66	37	.007
L Precuneus	-20	-52	42	35	.002
R Anterior Cigulate Cortex	6	22	-4	32	.01
L Inferior Frontal G	-42	14	14	30	.009
L Inferior Frontal G	-44	32	-10	25	.007
R Putamen	30	-12	4	22	.005
R Lentiform Nucleus	16	-8	2	22	.005
L Cingulate G	-20	-20	46	20	.003
R Meiddle Temporal G	42	10	-34	20	.009
L Middle Frontal G	-42	42	24	14	.009
Negative Correlation					
Bi Anterior Cingulate Cortex	-4	46	2	13	.008
L Superior Temporal G	-50	-32	8	23	.003
R Inferior Frontal G	50	10	30	21	.003
R Middle Frontal G	36	-2	54	13	.01
Moral-Personal & INT - IND					
Positive Correlation (Interdependent)					
R Cingulate G	16	-18	54	797	.0001
L Cingulate G	-12	12	40	459	.0004
R Insula	42	12	-2	249	.002
R Postcentral G	66	-20	34	210	.001
R Middle Frontal G	48	44	24	202	.001
L Insula	-44	12	2	198	.002
R Inferior Frontal G	46	52	8	140	.0002
L Precuneus	-16	-54	64	110	.001
L Insula	-30	4	18	71	.002
R Insula	38	-6	-10	46	.003
L Middle Occipital G	-34	-76	6	41	.003
L Anterior Cingulate Cortex	-12	26	26	35	.005

L Insula	-40	-2	-12	29	.003
R Medial Frontal G	14	4	64	26	.006
R Putamen	30	-22	-4	17	.005
L Insula	-34	10	-14	15	.007
R Medial Frontal G	18	8	50	13	.006
Negative Correlation (Individualistic)					
L Middle Temporal G	-60	-20	-18	42	.004
R Middle Temporal G	62	-32	-16	48	.001
L Middle Frontal G	-38	38	-4	15	.006
L Anterior Cingulate Cortex	-6	26	-2	12	.01
Bi Anterior Cingulate Cortex	-4	26	10	35	.005
L Superior Frontal G	-14	58	24	21	.007
R Superior Temporal G	60	-64	26	16	.002
L Precuneus	-4	-66	28	28	.01
L Angular G	-30	-62	32	27	.008

Table S3. Results of whole-brain correlational analyses between neural activity, cultural tightness, and self-construal score for (moral-personal – neutral), $p < .01$, $k \geq 12$. MNI coordinates.

Condition/Region	*x*	*y*	*z*	Vox	*p*
Moral-Impersonal & Tightness					
Positive Correlation					
L Putamen	-14	6	-8	417	.001
R Insula	30	-30	16	193	.002
Bi Superior Frontal G	2	62	32	179	.001
R Hippocampus	38	-24	-12	152	.0008
R Cingulate G	8	4	34	131	.0002
L Cingulate G	-18	-22	44	110	.007
L Parahippocampa G	-32	-52	-12	107	.003
R Precentral G	36	-10	30	106	.005
R Caudate	16	8	22	101	.003
R Postcentral S	50	-16	22	96	.004
L Insula	-32	10	0	95	.0009
R Putamen	30	6	6	93	.005
R Inferior Frontal G	64	8	16	81	.002
L Middle Temporal G	-62	-26	-16	76	.001
L Precentral G	-62	6	16	71	.002
L Middle Frontal G	-32	42	-8	61	.003
L Subcallosal G	-18	12	-18	50	.005
R Superior Frontal G	10	4	66	33	.001
L Inferior Parietal Lobule	-54	-62	40	33	.003
L Inferior Frontal G	-46	36	-12	31	.004
R Insula	30	20	14	28	.004
R Cingulate G	20	2	48	23	.005
R Parahippocampa G	30	-36	-8	19	.003
L Precentral G	-60	4	36	18	.003
R Anterior Cigulate Cortex	4	30	0	18	.01
R Medial Frontal G	16	40	20	17	.007
R Inferior Frontal G	60	6	36	17	.007
R Precentral G	66	-16	40	12	.007
Moral-Impersonal & INT - IND					
Positive Correlation (Interdependent)					
R Middle Frontal G	44	38	22	13	.01
R Inferior Parietal Lobule	42	-48	48	23	.01
Negative Correlation (Individualistic)					
R Corpus Callosum	4	18	6	74	.005
L Middle Temporal G	-56	-68	14	37	.001
Bi Cingulate G	-4	-2	26	362	.0001
L Thalamus	-8	-18	18	24	.006
L Cingulate G	-12	-32	42	14	.007

Bi Precuneus	0	-46	48	91	.001

Table S4. Results of whole-brain correlational analyses between neural activity, cultural tightness, and self-construal score for (moral-impersonal – neutral), $p < .01$, $k \geq 12$. MNI coordinates.

Condition/Region	*x*	*y*	*z*	Vox	*F*
Moral-Personal					
Main Effects					
Group (Korean vs. American)					
R Putamen	30	-18	6	44	35.49
R Postcentral G	68	-12	28	20	35.5
R Superior Frontal G	12	56	38	20	30.24
R Precentral G	60	4	40	16	21.43
Gender (Male vs. Female)					
L Middle Frontal G	-30	46	6	39	25.14
R Hippocampus	32	-12	-24	12	24.03
Interaction Effect					
Group X Dilemma Type					
L Precentral G	-26	-18	50	332	56.89
Bi Medial Frontal G	12	2	54	102	22.99
Bi Thalamus	2	-24	14	87	24.1
R Subcallosal G	6	6	-16	85	30.6
Bi Anterior Cingulate Cortex	4	36	-8	43	28.25
R Caudate	18	16	16	42	25.54
L Middle Frontal G	-24	36	40	18	27.07
Moral-Impersonal					
Main Effects					
Group (Korean vs. American)					
Bi Medial Frontal G*	-12	56	8	64	12.31
R Inferior Parietal Lobule*	54	-42	24	47	11.12
L Superior Frontal G	-24	16	54	34	16.4
R Superior Parietal Lobule*	24	-66	48	20	9.283
L Precentral G*	-36	-20	52	15	11.3
L Precentral G*	-44	-20	62	12	12.45
Gender (Male vs. Female)					
L Caudate	-22	-10	24	94	31.49
L Precentral G	-34	-20	50	49	27.4
R Lingual G	2	-80	-20	47	17.96
R Fusiform G	36	-68	-20	34	19.66
R Superior Frontal G	6	12	46	19	15.39
Interaction Effect					
Group X Dilemma Type					
L Caudate	-16	22	14	228	56.16

R Anterior Cingulate	22	40	12	164	79.66
R Substania Nigra	10	-14	-12	30	25.26
Bi Posterior Cingulate Cortex	2	-62	8	20	26.96
L Superior Temporal G	-44	-36	4	20	17.77
L Caudate	-18	-26	26	13	22.62

Table S5. Results of whole-brain ANOVA for the main effects of participants' group and gender, and interaction effect, $p < .01$ familywise error corrected, $k \geq 12$. MNI coordinates. (* : $p < .05$ familywise error corrected, $k \geq 12$)

Condition/Region	*x*	*y*	*z*	Vox	*t*
Moral-Personal					
Male > Female					
L Middle Frontal G	-30	48	8	17	4.23
Female > Male					
R Transverse Temporal G*	68	-10	14	44	4.35
R Transverse Temporal G*	46	-26	12	30	3.35
L Medial Frontal G*	-6	30	-18	15	3.31
Moral-Impersonal					
Male > Female					
L Precuneus	-16	-60	38	382	6.32
R Precuneus	4	-76	46	93	4.86
L Precuneus	-14	-86	38	91	5.14
L Middle Frontal G	-34	-22	48	91	4.91
R Insula	44	-14	-12	23	5.20
R Fusiform G	24	-82	-22	18	4.40

Table S6. Results of whole-brain contrast for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral-impersonal) and (moral-impersonal – moral-personal) conditions between males and females, $p < .001$, $k \geq 12$. MNI coordinates. (* : $p < .005$, $k \geq 12$)

Condition/Region	*x*	*y*	*z*	Vox	*t*
Moral-Personal					
Appropriate (Utilitarian) > Inappropriate					
L Medial Frontal G	-26	40	12	391	6.93
R Middle Frontal G	32	44	-2	281	6.88
L Inferior Parietal Lobule	-56	-54	44	242	6.75
R Medial Frontal G	10	-34	60	69	4.72
L Precentral G	-14	-28	68	44	4.55
L Middle Frontal G	-42	54	14	18	4.05
Inappropriate (Deontological) > Appropriate					
L Superior Temporal G	-48	-48	12	146	4.54
L Middle Temporal G	-56	-4	-12	120	4.49
L Cuneus	-6	-94	6	65	4.69
R Superior Temporal G	48	20	-32	27	4.91
R Superior Temporal G	46	-38	4	21	4.00
L Precentral G	-52	-4	50	13	4.26
Moral-Impersonal					
Appropriate > Inappropriate					
R Precuneus	24	-60	40	132	4.77
R Middle Frontal G	48	22	24	127	4.64
L Medial Frontal G	-16	44	20	54	4.74
L Supramarginal G	-62	-48	30	41	4.37
L Cingulate G	-20	-46	38	33	5.60
L Fusiform G	-44	-46	-22	27	5.60
R Inferior Parietal Lobule	48	-42	22	12	4.15
Inappropriate > Appropriate					
R Insula	46	-2	2	27	5.22

Table S7. Results of whole-brain contrast for appropriate vs. inappropriate responses under both conditions, $p < .001$, $k \geq 12$. MNI coordinates. (* : $p < .005$, $k \geq 12$)

Condition/Region	*x*	*y*	*z*	Vox	*p*
Moral-Personal & Response Time					
Positive Correlation (Slower)					
Bi Cingulate G (Anterior + Posterior)	-14	-14	26	2358	.0001
R Inferior Frontal G	48	44	10	62	.001
R Hippocampus	26	-36	8	33	.009
R Inferior Frontal G	42	12	12	88	.0001
R Cingulate G	18	-20	30	87	.002
L Medial Frontal G	-20	36	32	12	.01
Negative Correlation (Faster)					
R Superior Temporal G	48	10	-22	194	.001
R Fusiform G	52	-8	-26	16	.004
L Middle Temporal G	-56	8	-16	146	.0005
L Inferior Temporal G	-48	-38	-20	48	.001
L Inferior Temporal G	-54	-22	-18	21	.01
L Lingual G	-6	-86	-21	107	.0003
L Fusiform G	-26	-76	-10	120	.005
L Middle Occipital G	-30	-96	4	67	.006
Bi Superior Frontal G	-6	68	14	412	.0003
L Precentral G	-66	-2	16	15	.004
L Precuneus	-10	-72	24	61	.004
R Precuneus	14	-70	26	211	.001
R Inferior Parietal Lobule	48	-50	44	27	.007
R Inferior Frontal G	46	6	40	13	.01
L Precentral G	-56	0	44	37	.002
L Superior Frontal G	-12	50	44	20	.003
L Superior Parietal Lobule	-34	-72	50	22	.008
L Middle Frontal G	-32	-8	66	15	.008
Moral-Impersonal & Utilitarian Decisions					
Positive Correlation					
R Precuneus	20	-68	50	103	.002
R Superior Frontal G	22	56	24	76	.006
R Superior Frontal G	30	42	32	54	.005
L Precuneus	-20	-74	34	41	.009
Bi Medial Frontal G	0	46	15	32	.009
R Middle Temporal G	32	48	8	23	.009
L Inferior Temporal G	-52	-48	-18	14	.01
Negative Correlation					
L Caudate	-4	2	16	248	.001
R Lentiform Nucleus	24	-4	-6	207	.0009

L Lentiform Nucleus	-32	-2	-12	180	.001
R Inferior Parietal Lobule	44	-36	42	174	.0009
R Inferior Frontal G	56	10	26	118	.002
L Thalamus	-28	-24	-2	117	.0006
R Caudate	6	8	4	100	.001
L Insula	-30	-24	16	87	.002
R Thalamus	6	-32	4	64	.004
L Corpus Callosum	-6	-30	22	48	.004
R Insula	44	-6	-8	28	.007
L Superior Temporal G	-46	-10	-10	25	.002
L Insula	-48	-42	22	18	.003
L Caudate	-10	22	10	17	.005
L Insula	-32	16	16	16	.007

Table S8. Results of whole-brain correlational analyses between neural activity, response time, and the number of utilitarian decisions for (moral-personal – neutral), $p < .01$, $k \geq 12$. MNI coordinates.

Condition/Region	*x*	*y*	*z*	Vox	*p*
Moral-Impersonal & Response Time					
Positive Correlation (Slower)					
R Anterior Cingulate Cortex	18	44	12	157	.0001
L Superior Temporal G	-50	14	-28	98	.002
R Caudate	2	12	8	69	.002
L Thalamus	0	-18	6	65	.0005
Bi Cingulate G	0	-18	46	52	.003
R Caudate	6	10	-10	36	.002
L Superior Frontal G	-22	46	24	23	.003
R Parahippocampa G	14	-8	-18	21	.008
L Middle Temporal G	-60	-66	10	14	.008
L Cingulate G	-10	-26	44	12	.007
Negative Correlation (Faster)					
R Superior Temporal G	48	10	-22	194	.001
R Fusiform G	52	-8	-26	16	.004
L Middle Temporal G	-56	8	-16	146	.0005
L Inferior Temporal G	-48	-38	-20	48	.001
L Inferior Temporal G	-54	-22	-18	21	.01
L Lingual G	-6	-86	-21	107	.0003
L Fusiform G	-26	-76	-10	120	.005
L Middle Occipital G	-30	-96	4	67	.006
Bi Superior Frontal G	-6	68	14	412	.0003
L Precentral G	-66	-2	16	15	.004
L Precuneus	-10	-72	24	61	.004
R Precuneus	14	-70	26	211	.001
R Inferior Parietal Lobule	48	-50	44	27	.007
R Inferior Frontal G	46	6	40	13	.01
L Precentral G	-56	0	44	37	.002
L Superior Frontal G	-12	50	44	20	.003
L Superior Parietal Lobule	-34	-72	50	22	.008
L Middle Frontal G	-32	-8	66	15	.008
Moral-Impersonal & Utilitarian Decisions					
Positive Correlation					
R Insula	42	-6	-10	20	.002
R Inferior Frontal G	50	42	12	227	.006
R Inferior Parietal Lobule	54	-52	52	135	.005
R Postcentral G	58	-26	52	38	.009
L Inferior Parietal Lobule	-54	-40	54	16	.009
Negative Correlation					

L Fusiform G	-38	-52	-30	143	.001
L Hippocampus	-22	-18	-6	48	.0009
L Lingual G	-4	-58	-4	37	.001
R Cingulate G	18	20	36	16	.0009
L Cingulate G	-20	4	44	63	.002
L Cingulate G	18	-16	52	98	.0006
R Precuneus	24	-82	44	99	.001

Table S9. Results of whole-brain correlational analyses between neural activity, response time, and the number of utilitarian decisions for (moral-impersonal – neutral), $p < .01$, $k \geq 12$. MNI coordinates.

Figures

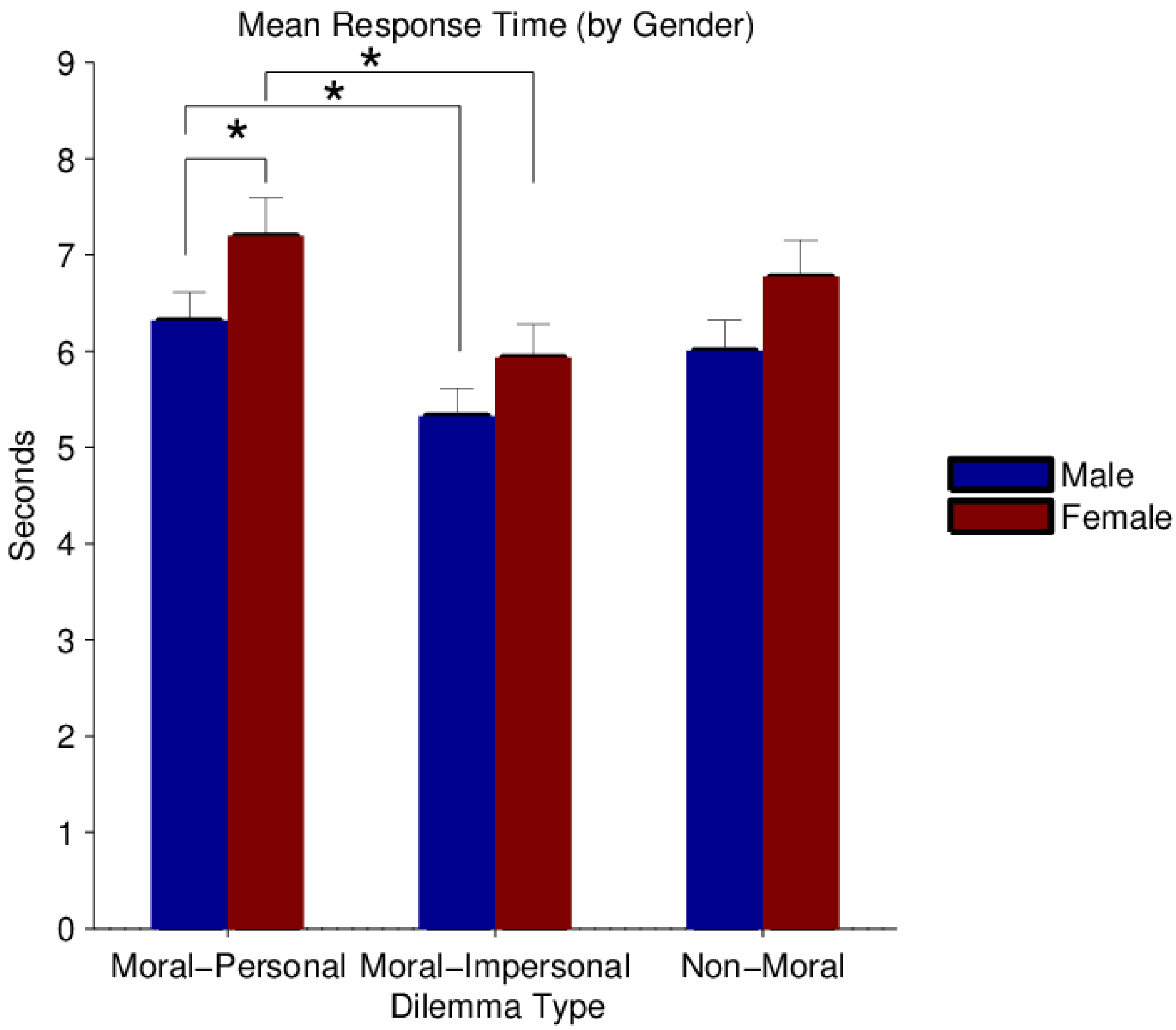

Figure S1.Results of the comparison of the mean response time between Korean and American participants under three conditions.

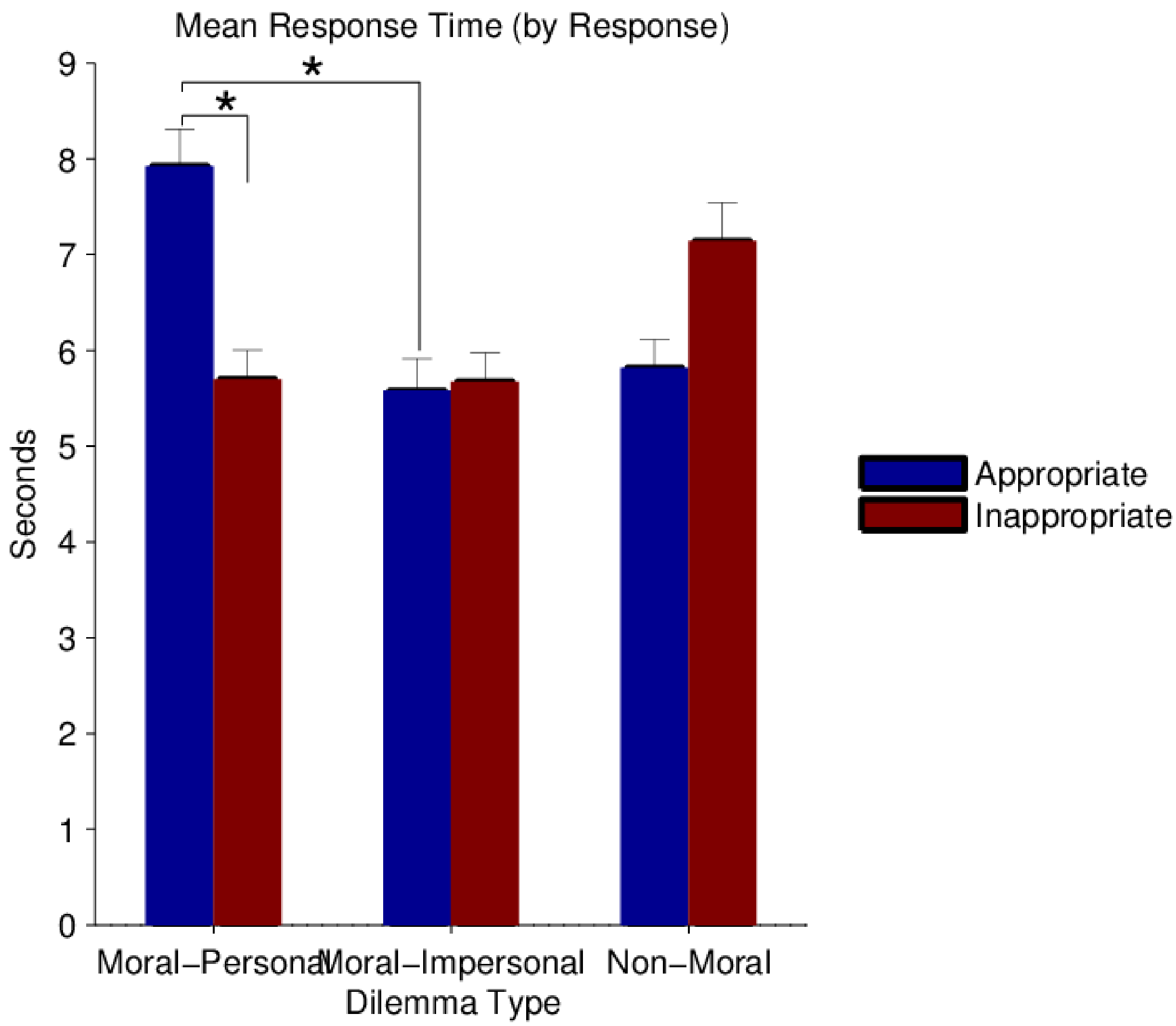

Figure S2. Results of the comparison of the mean response time to two different responses under three conditions.

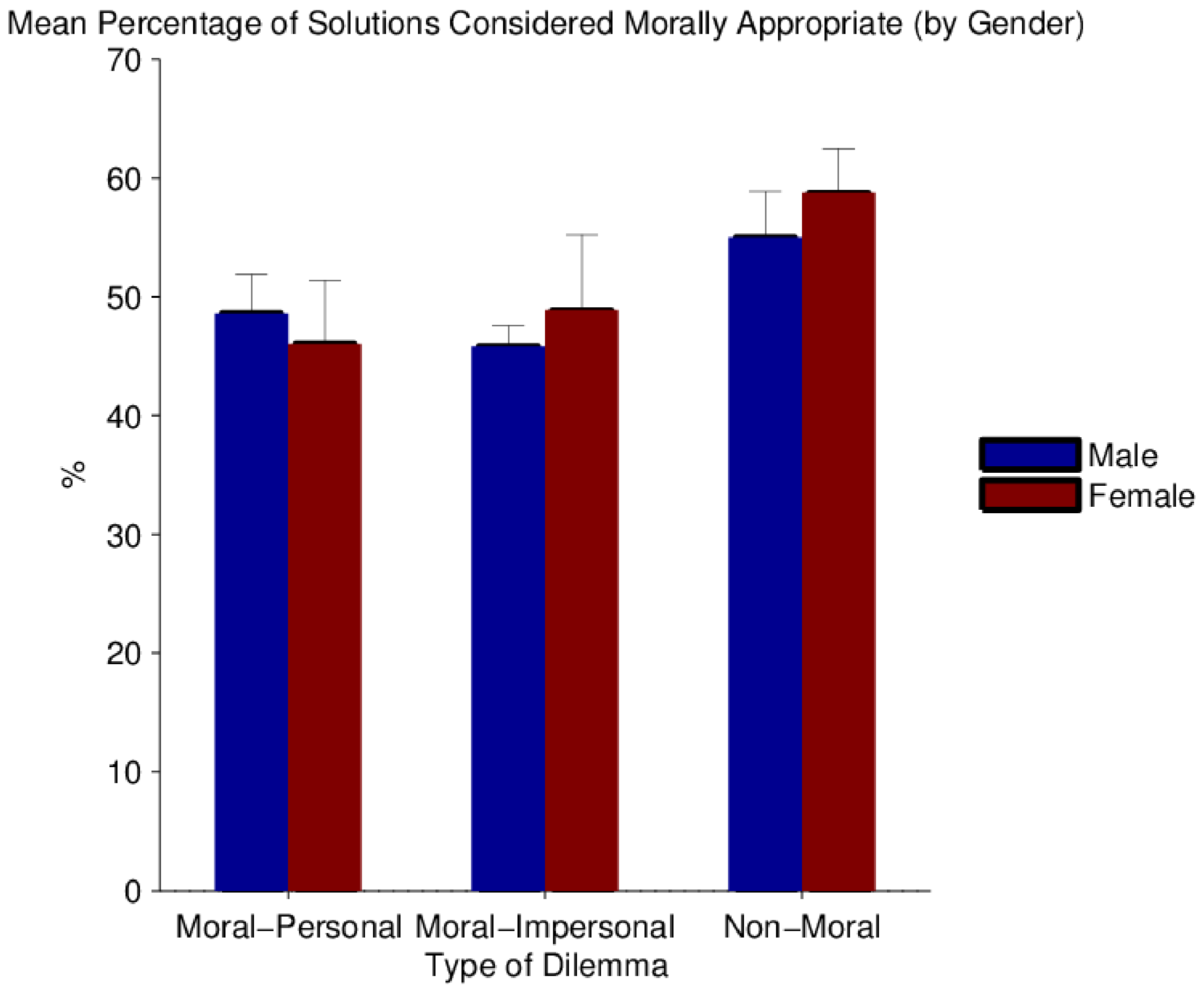

Figure S3. Results of the comparison of the mean percentages of dilemma solutions that were considered morally appropriate by participants between two gender groups.

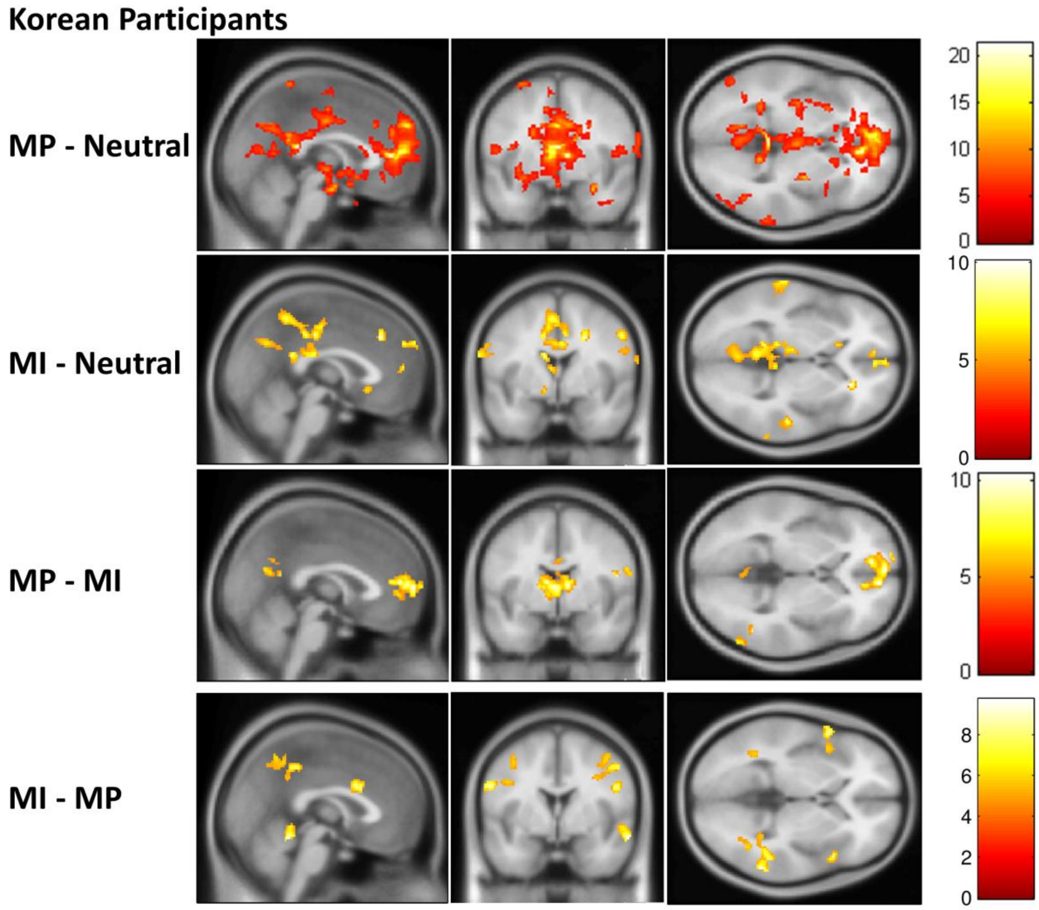

Figure S4. Results of whole-brain contrast within Korean participants for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral impersonal), (moral-impersonal – moral personal) conditions, $p < .001$ (uncorrected), $k \geq 12$.

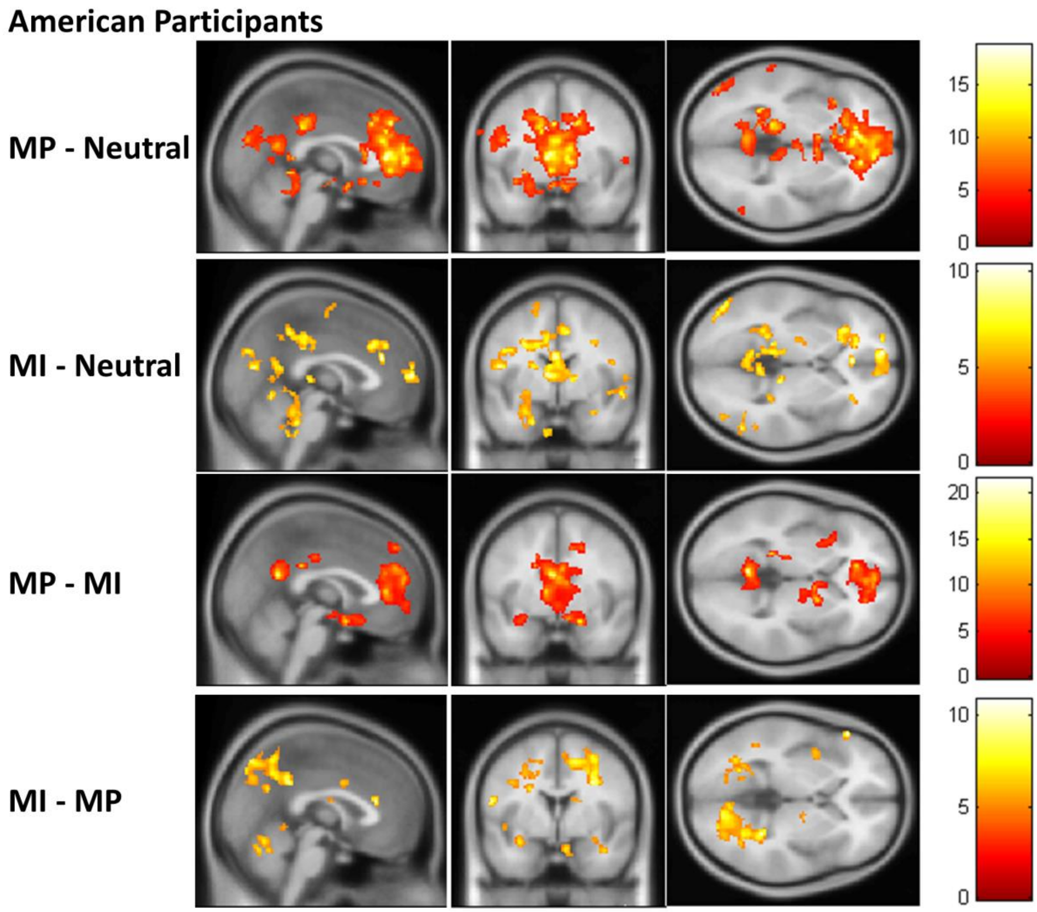

Figure S5. Results of whole-brain contrast within American participants for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral impersonal), (moral-impersonal – moral personal) conditions, $p < .001$ (uncorrected), $k \geq 12$.

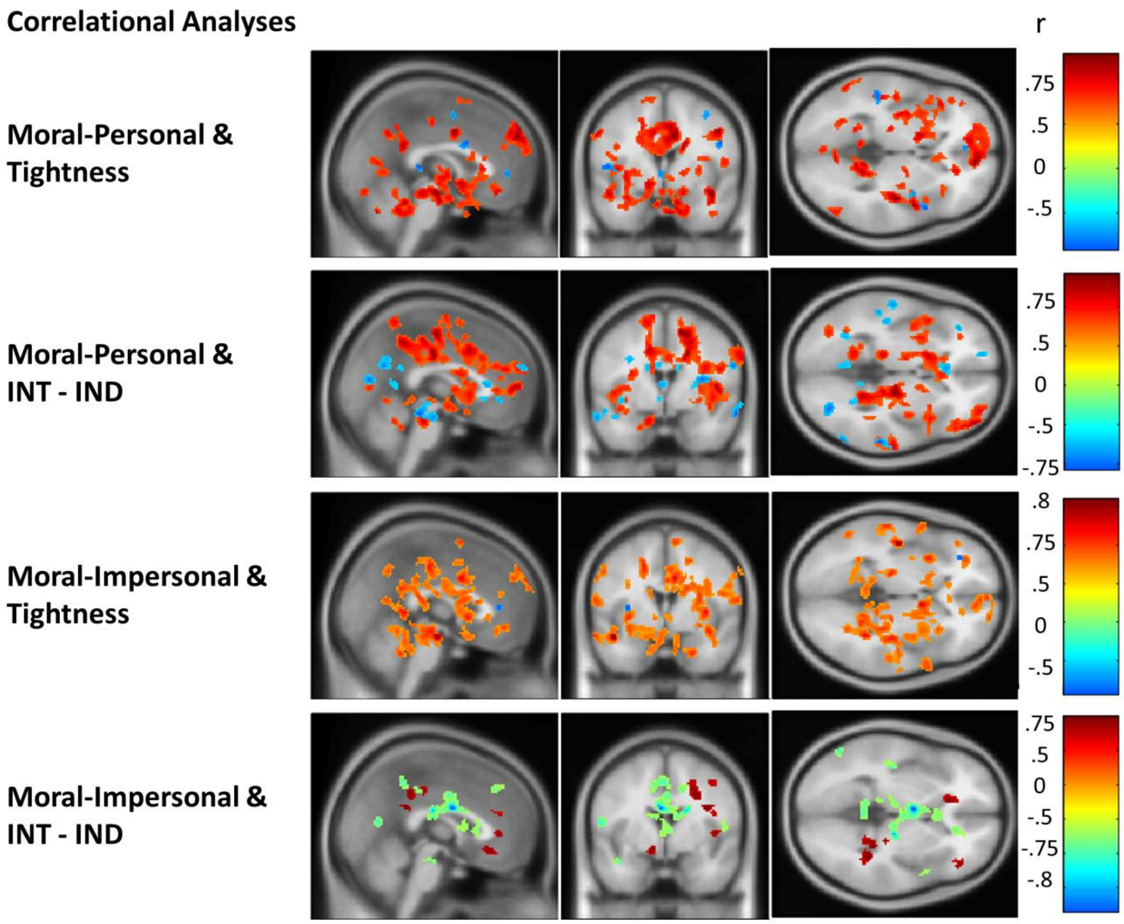

Figure S6. Results of whole-brain correlational analyses between neural activity, cultural tightness, and self-construal score under for both (moral-personal – neutral) and (moral-impersonal – neutral), $p < .01$ (uncorrected), $k \geq 12$.

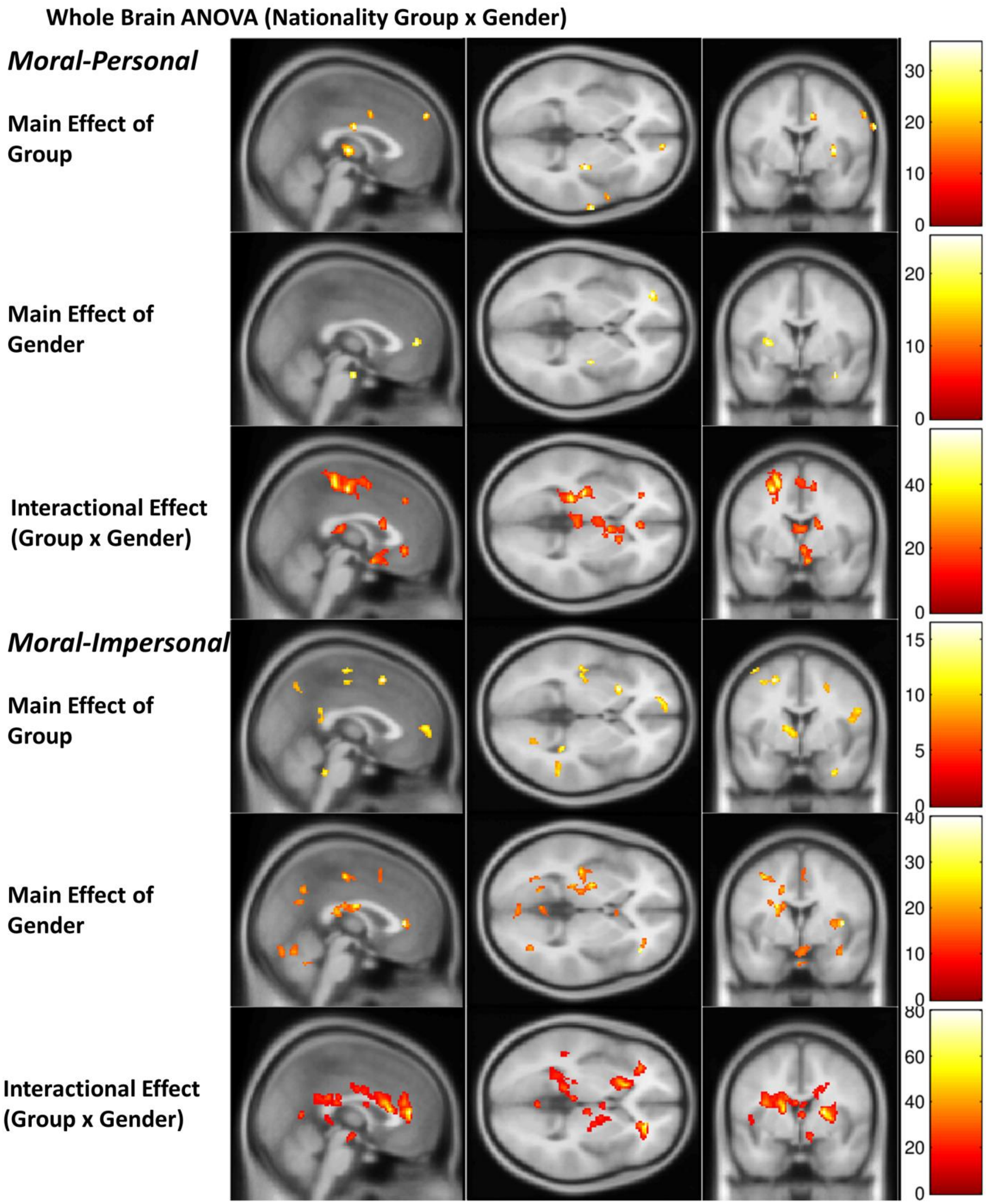

Figure S7. Results of whole-brain ANOVA for the main effects of nationality group and gender, and the interactional effect of (nationality group x dilemma type) ($p < .01$ (familywise error corrected), $k \geq 12$) under both conditions. In case of the moral-impersonal condition, for the main effect of participants' nationality, a more lenient threshold was applied for exploratory purpose ($p < .05$ (familywise error corrected), $k \geq 12$).

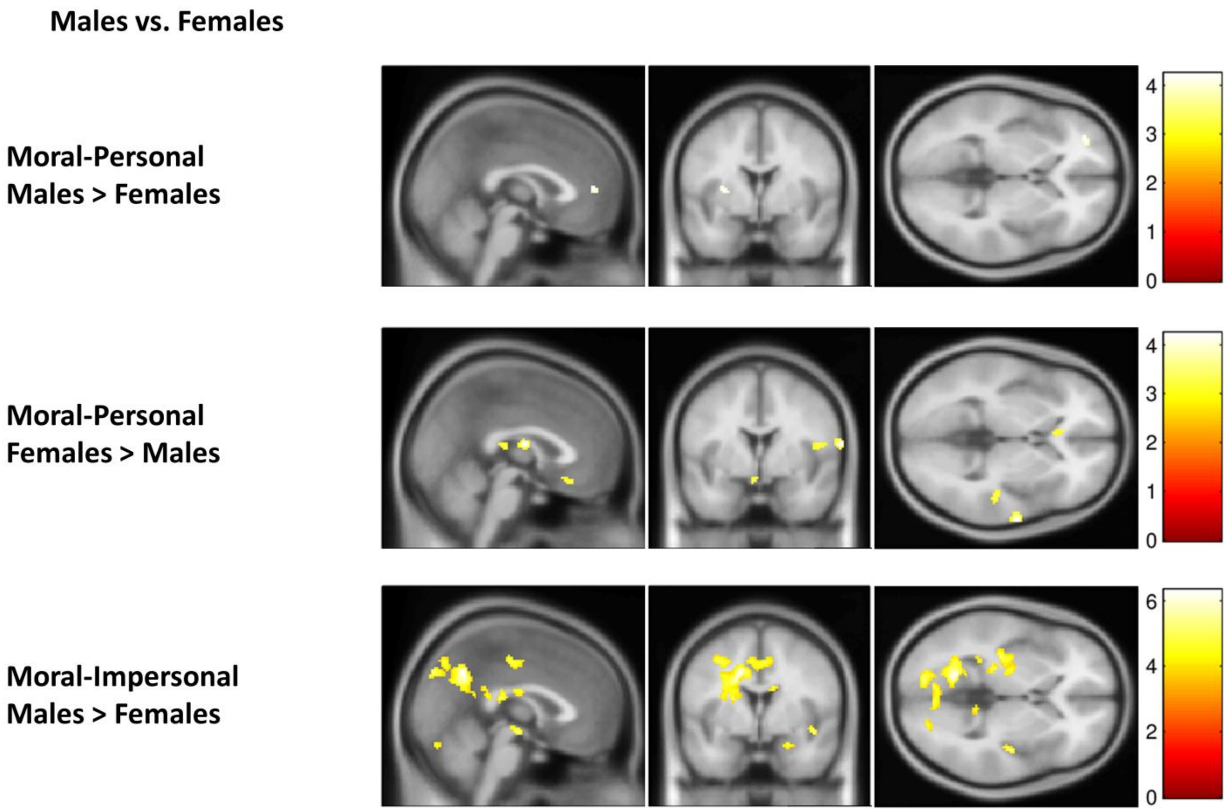

Figure S8. Results of whole-brain contrast for (moral-personal – neutral), (moral-impersonal – neutral), (moral-personal – moral-impersonal) and (moral-impersonal – moral-personal) conditions between males and females, $p < .001$, $k \geq 12$. MNI coordinates. ($p < .005$, $k \geq 12$ for moral-personal, females > males)

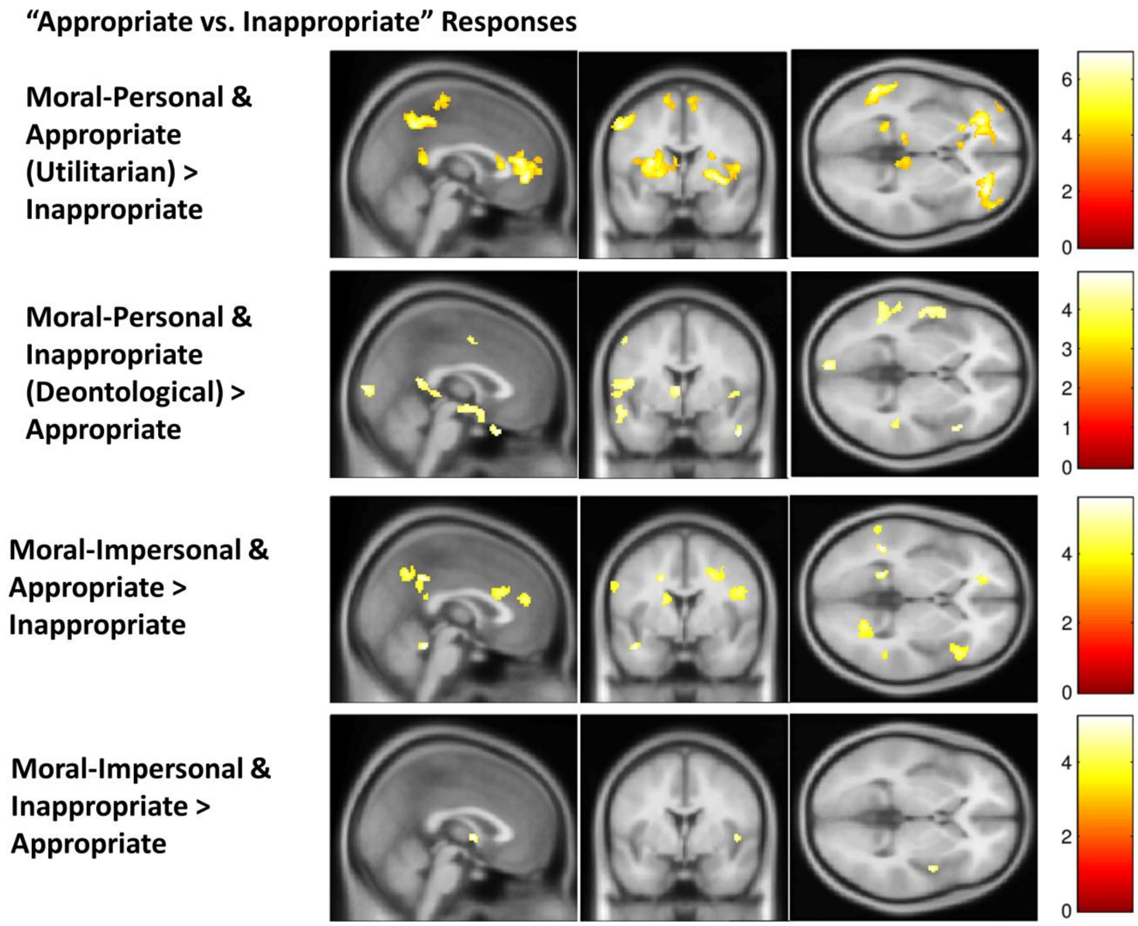

Figure S9. Results of whole-brain contrast for "appropriate" and "inappropriate" responses under two conditions, p < .001, k ≥ 12. MNI coordinates.

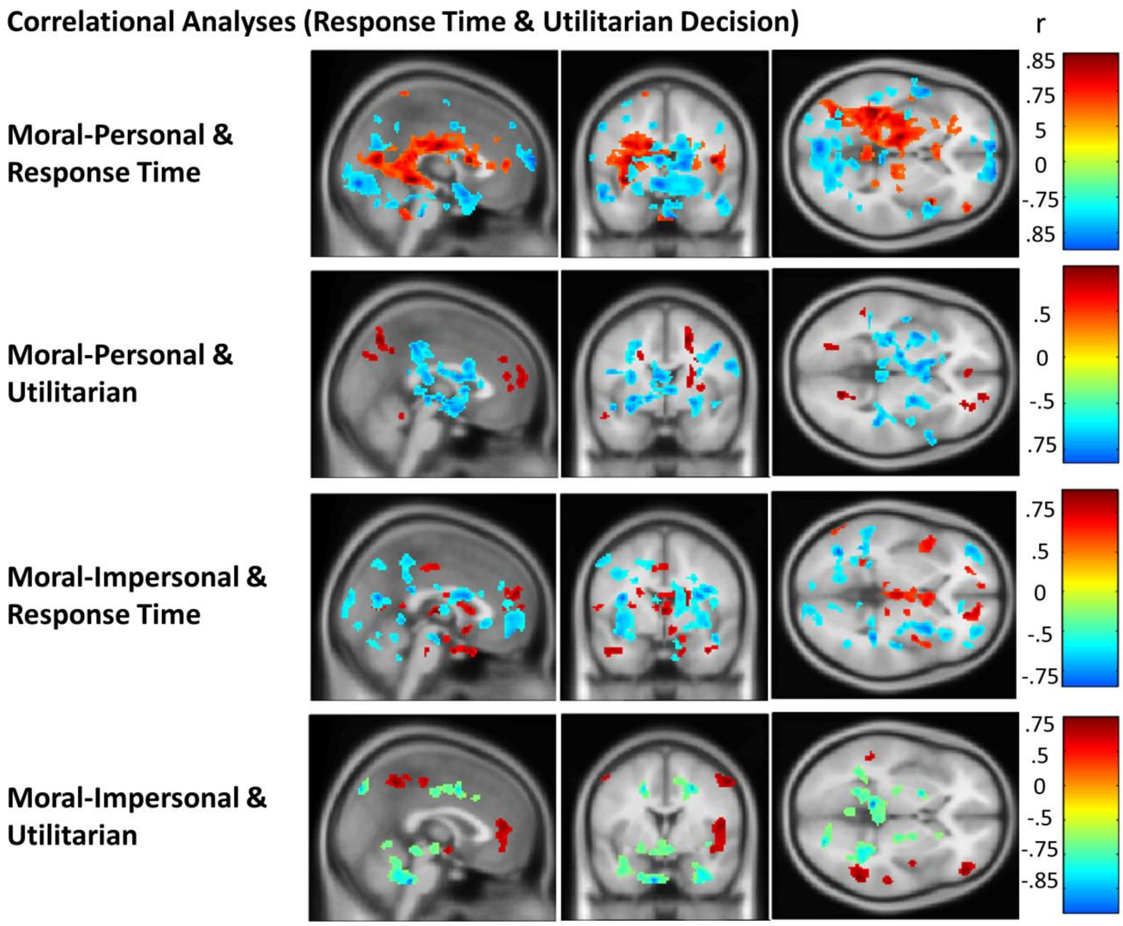

Figure S10. Results of whole-brain correlational analyses between neural activity, response time, and the number of utilitarian decisions under for both (moral-personal – neutral) and (moral-impersonal – neutral), $p < .01$ (uncorrected), $k \geq 12$.