

# The effect of ethnicity and team membership on face processing: a cultural neuroscience perspective

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## Abstract

In-ethnicity bias, as one of the in-group biases, is widespread in different cultures, interfering with cross-ethnicity communication. Recent studies have revealed that an in-ethnicity bias can be reduced by an in-team bias caused by the membership in a mixed-ethnicity team. However, the neural correlates of different in-group biases are still not clear, especially regarding possible cultural differences. A total of 44 participants (20 Chinese and 24 Germans) were recruited and completed a social categorization fMRI-task, categorizing faces according to their ethnicity and a learned team membership. Our behavioral results revealed both in-ethnicity and in-team bias in German participants, but not in Chinese participants. Our imaging results, however, showed both biases across all participants, as reflected in increased dorsal medial frontal cortex (MFC) activation for in-ethnicity, as well as in-team categorizations, while activation in ventral MFC was higher for in-ethnicity faces in Chinese participants than in the German participants. Our results highlight the importance of the dorsal MFC for in-group categorization across cultures and suggest that cultures might modulate in-group biases.

**Key words:** cultural neuroscience; in-group bias; social categorization; medial frontal cortex

## Introduction

People categorize the social world into ‘us’ and ‘them’ for adaptation to the environment (Caporael, 1997), resulting in the so-called in-group bias reflected in perception, attitudes and behaviors (Molenberghs & Louis, 2018). In-ethnicity, or the so-called in-race bias, is one of the most prevalent in-group biases. It has been consistently found in different cultures (Han et al., 2013) and may lead to racial prejudice and stereotypes (Devine, 1989; Ge et al., 2009). Previous studies proposed that the in-ethnicity bias can be reduced by a novel in-group bias derived from the membership in a mixed-ethnicity team, a so-called in-team bias (Van & Cunningham, 2009; Voorspoels et al., 2014). However,

this reduction effect of in-ethnicity bias has been shown to be stronger in western relative to eastern culture (Snibbe et al., 2003; Ng et al., 2016). Further, although a few of recent studies have initiated to explore the neural patterns of in-group biases (Sheng & Han, 2012; Shen et al., 2018), the direct comparison of such neural patterns between cultures within one study is still missing.

The difference between individualistic and collectivistic value systems has been regarded as one of the most popular and significant cultural differences between western and eastern cultures (Li & Aksoy, 2007). Individualism is prominent in western countries and encourages an independent-self that is rather independent of social contexts and of others. In contrast,

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collectivism emphasizes fundamental social connections, resulting in an interdependent view of self, with high prevalence in East Asia (Markus & Kitayama, 2010). Variations in self-construal between individualism and collectivism probably lead to differences in perception and interaction with in- and out-group members (Cheon et al., 2011; Han, 2018). In the present study, we recruited two groups of participants which are from typical individualistic (Germans) and collectivistic (Chinese) culture, investigating possible cultural differences in neural correlates of the perception of in- and out-group members.

In-ethnicity bias, as one of the in-group biases, refers to the phenomenon that people are better and faster at recognizing people from their own ethnicity compared to other ethnicities (Malpass & Kravitz, 1969; Ge et al., 2009). Due to in-depth encoding of in-ethnicity faces (Sporer, 2001; Ratner et al., 2014), the in-ethnicity bias can also be presented in a seemingly paradoxical pattern during categorization processes: people are faster to categorize a face from another-ethnicity than from one's own. This phenomenon is called other-ethnicity categorization advantage which is consistently found across cultures (Ge et al., 2009; Zhao & Bentin, 2011). Thus, we expected to find an other-ethnicity categorization advantage in both cultural groups.

However, as a byproduct of categorization regarding social coalitions, the in-ethnicity bias is not inevitable but rather can be reduced when social coalitions change (Kurzban et al., 2001). Growing evidence suggests that the in-ethnicity bias can be reduced by a novel in-group bias (e.g. by a minimal group effect), caused by the membership in a mixed-ethnicity team, named in-team bias (Van & Cunningham, 2009; Voorspoels et al., 2014). It is assumed that the in-team bias is central to the phenomenon that people show greater resource allocation toward in-team members, once they were assigned to a (arbitrary and novel) team (Tajfel et al., 1971; Ratner & Amodio, 2013). Previous findings suggest that people from individualistic countries define social coalitions by rather broad social collectives, whereas people from collectivistic countries define social coalitions by interpersonal relationships, demanding personal ties to include someone as an in-team member (Brewer & Yuki, 2007). This might suggest that an in-team bias is easier established in people from individualistic than in people from collectivistic countries (Snibbe et al., 2003; Ng et al., 2016). However, recent cultural neuroscience studies with collectivistic samples also showed neural markers of a reduction of the in-ethnicity bias in empathy by manipulating the membership in a mixed-ethnicity group (Sheng & Han, 2012; Shen et al., 2018). Thus, we assumed to find an in-team bias in Germans on the behavioral level and examined if and how the reduction of an in-ethnicity bias differs between cultures.

The formation of an in-group bias (including in-ethnicity and in-team biases) has been recently considered a consequence of a dynamically interactive process of bottom-up processing and top-down expectations and motives of perceivers (Freeman & Ambady, 2011; Teufel & Nanay, 2017). This interactive process has been demonstrated in functional imaging studies across cultures. It is assumed that the amygdala response to faces from distinct social groups represents the bottom-up perceptual visual inputs (Van et al., 2008; Rule et al., 2009), while enhanced fusiform gyrus (FFG) and medial frontal cortex (MFC) activation might indicate a top-down deeper process during in-group categorization (Feng et al., 2011; Van et al., 2011; Gamond et al., 2017). Increasing evidence suggests that enhanced activation in FFG and MFC seems to be consistently linked to the response to in-group members (Feng et al., 2011; Van et al., 2011; Gamond et al., 2017). In contrast, the amygdala's sensitivity to in- and out-

group categorization is more complex and flexible, depending on the context/social goals (Molenberghs, 2013). Previous studies found elevated amygdala activation for processing out-ethnicity members when the social coalition (or in other words the group defining feature) was ethnicity (Firat et al., 2017; Sankar et al., 2018), but for processing in-team members when the social coalition switched to team memberships (Van et al., 2008; Rule et al., 2009). Thus, we expected to reveal increased amygdala activation for out-ethnicity and in-team categorization, and increased activation in FFG and MFC for categorizing in-ethnicity and in-team faces. Further, we assumed to observe an over-writing effect of the in-team bias on the in-ethnicity bias.

Besides, while the in-ethnicity bias has been developed since early childhood (Kinzler & Spelke, 2011), referring to a more profound and implicit type of in-group bias (Rule & Sutherland, 2017), the in-team bias is relatively novel and explicit as its formation happened within a short time period. This might indicate that the in-team bias requires more explicit, top-down and deeper processing relative to the in-ethnicity bias (Kawakami et al., 2017; Mattan et al., 2018), which probably reflects in the FFG and MFC activation. However, due to the absence of direct empirical evidence, the neural differences between in-ethnicity and in-team bias are still unclear (Rule & Sutherland, 2017; Mattan et al., 2018). In the present study, we directly compared the neural correlates of in-ethnicity and in-team categorization in one paradigm and hypothesized increased activation in FFG and MFC for the in-team relative to in-ethnicity categorization.

A way to investigate the strength of implicit associations is the so-called implicit association task. Based on the notion that stronger associations cause longer reaction times (RTs) and require more cognitive control during the incongruent than congruent pairings (Greenwald et al., 1998), the extent of automatic associations of in-ethnicity and in-team members can be easily investigated. Previous studies revealed that, by comparing the incongruent and congruent pairings, higher activation in the dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex (PPC) are apparent indicators of stronger implicit associations (Fedorenko et al., 2013; Yan et al., 2019). However, to our knowledge, this approach has not been used to investigate differences in strength of associations in the in-ethnicity vs in-team bias. We assumed that the in-ethnicity bias is more implicit than the in-team bias and expected to observe increased activation in the DLPFC and PPC for categorizing in-ethnicity compared to in-team faces when categorized incongruently.

Prior studies suggest the in-ethnicity bias can be reduced by an in-team bias derived from a novel membership in a mixed-ethnicity group. This reduction effect on in-ethnicity bias, however, is probably modulated by culture, and its corresponding neural differences are still unknown. For exploring the cultural differences, we recruited two cultural groups of participants who are typical for collectivistic (China) and individualistic (German) countries. Referring to the minimal group paradigm (Tajfel et al., 1971), the present cultural neuroscience study created a novel in-team membership for each participant by arbitrary assigning them to a mixed-ethnicity team. We applied the social-categorization task with ethnicity-based and team-based categorizations with congruent and incongruent pairings, respectively. In the congruent session, regarding behavior, we expected to find the in-ethnicity bias in both groups (Ge et al., 2009; Zhao & Bentin, 2011), and the in-team bias in the German group (Ng et al., 2016). Regarding brain activation, we hypothesized to observe increased amygdala activation for out-ethnicity relative to in-ethnicity faces (Firat et al., 2017; Sankar et al., 2018) and for in-team relative to out-team faces (Van et al., 2008). Further,

we assumed to find higher activation in FFG and MFC for in-ethnicity than out-ethnicity faces and for in-team than out-team faces across participants (Feng et al., 2011; Van et al., 2011). Moreover, we attempted to explore the neural differences between in-ethnicity and in-team bias, assuming higher activation in the MFC and FFG for in-team vs in-ethnicity categorization across participants. Further, to explore the possible influence of exposure to the opposite culture on facial perception of other-cultural faces (Derntl et al., 2009, 2012), we recorded the duration of stay in Germany of our Chinese participants. In addition, regarding the comparison between incongruent and congruent sessions, we hypothesized RTs are longer in the incongruent than in the congruent session across participants. On the neural level, we hypothesized to observe that categorizing the in-ethnicity and in-team faces in the incongruent session would result in higher activation of the DLPFC and PPC than in the congruent session across participants. Further, we assumed that Germans would show higher activation in the DLPFC and PPC than Chinese for categorizing the in-team faces in the incongruent vs congruent session.

## Methods

### Participants

A total of 49 healthy participants (24 Chinese and 25 Germans) who met MRI inclusion criteria and had at least obtained a secondary school certificate were recruited and scanned in the Central Institute of Mental Health, Mannheim, Germany. Five of them were excluded, one due to brain abnormalities, and four due to response accuracy around chance (<60% correct) during team-based categorization in the congruent session. Finally, 44 participants (20 Chinese (9 females,  $M_{age} = 26.02 \pm 2.82$ ) and 24 Germans (12 females,  $M_{age} = 25.38 \pm 5.44$ )) were included for data analyses. All participants were right-handed and had normal or corrected-to-normal vision. Groups were matched for age and gender. The study was approved by the local ethics board of the Medical Faculty Mannheim, University of Heidelberg. Before participation, participants were well briefed about the procedures and purposes of the study and provided their written informed consent. All participants completed a digit span forward task, the social categorization fMRI-task and a series of questionnaires, assessing clinical and cultural characteristics as well as personality traits (see Supplementary Text S1). All tasks and questionnaires were presented in participants' native language.

### Procedure and experimental design

After the telephone screening, participants completed a series of online questionnaires. In the laboratory, participants were informed that they had been assigned to one team (team blue or team red), followed by a learning procedure which consisted of two learning sessions and one test session (details of the learning procedure are provided in Supplementary Text S2 and Supplementary Table S2). Participants had to keep learning until they achieved 85% accuracy during the test session. The number of times that each participant completed the test session was recorded. Afterwards, participants had to learn the team memberships (team green or team magenta) of geometric figures (triangles and circles), which were used for the control condition. Here, teams consisted of single geometric figures rather than of mixed geometric figures. For instance, all triangles belonged to team green; correspondingly, all circles to team magenta. For

counterbalancing the possible effect of the names of the team, we equally assigned our participants to each team name.

The social categorization fMRI-task consisted of two sessions, namely the congruent and incongruent session. Each session had four task conditions, presented in blocks: face-team, face-ethnicity, form-team and form-name. Each condition started with an instruction, followed by six pictures consecutively. Participants needed to categorize the picture to the corresponding group, based on the prior instruction. For example, in the congruent face-team condition, participants first saw a sentence on the screen ('which team does this person belong to?'), and then they had to categorize the following six pictures according to the team affiliations that they learned in the learning procedure. In the incongruent session, however, participants had to give the reversed response in each task condition. That means, participants saw the same instruction as in the congruent session, for example in the face-team condition 'which team does this person belong to?' but categorized the following faces to the affiliation which is opposite to the team that they learned in the learning procedure. The emotionally neutral facial stimuli used for the present study were selected from the Karolinska Directed Emotional Faces set for Caucasian stimuli (Goeleven et al., 2008) and from the Chinese Affective Picture System for Asian stimuli (Gong et al., 2011). All stimuli were calibrated in luminance and contrast. We selected only the face region of all stimulus persons to assure categorizations based on facial features. The duration of each session was 16 min, in total of 32 min for the whole task (details of timing and presentation are presented in Figure 1 and Supplementary Text S3).

After scanning, participants were required to complete several additional questionnaires including a manipulation check questionnaire (details are presented in Supplementary Text S4). The results of all questionnaires are presented in Supplementary Table S1.

### Data acquisition

fMRI data were acquired with a 3 Tesla Siemens Tim TRIO whole-body magnetic resonance tomograph (Siemens Medical Systems, Erlangen, Germany; acquisition protocol is provided in Supplementary Text S5).

### Data analyses

Behavioral data were analyzed with SPSS version 23. Due to the experimental design with three within-subject variables (congruency, category and affiliation) and one between-subject variable (group), 2 (congruency: congruency, incongruency)  $\times$  2 (category: team, ethnicity)  $\times$  2 (affiliation: in, out)  $\times$  2 (groups: Chinese and Germans) repeated measures ANOVAs were applied to investigate the differences in task performance between groups. Post-hoc tests were achieved with paired sample t-tests. Pearson correlation was used to explore the associations between task performance and duration of stay in Germany in Chinese participants.

fMRI data analyses were conducted with statistical parametric mapping 12 (SPM12 version 6906). For preprocessing, the functional images were slice-time corrected to the middle (16th) slice, realigned to the first image of the run, then co-registered with the segmented anatomical scan, normalized to the MNI template with a  $3 \times 3 \times 3$  mm<sup>3</sup> resolution, and finally smoothed with a 9 mm full-width half-maximum kernel.

For the first level analysis, general linear models were applied for both congruent and incongruent sessions, each

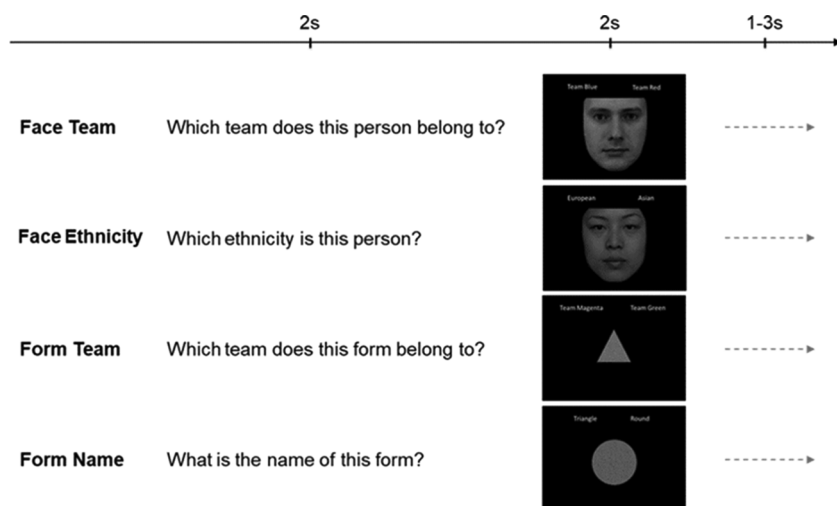


Fig. 1. Social categorization task.

with the 12 experimental conditions as regressors, independent of accuracy of the participants' response: four for team-based categorization (in-team with Asian faces, out-team with Asian faces, in-team with European faces, out-team with European faces), four for ethnicity-based categorization (Asian faces in in-team members, Asian faces in out-team members, European faces in in-team members, European faces in out-team members), four for control condition (team-based categorization for circles and triangles, name-based categorization for circles and triangles), an additional one for the instruction period prior to each block and the six movement regressors derived from the realignment procedure. Linear regression, modeling the hemodynamic response function, was performed at each voxel, using generalized least squares with a global approximate AR (1) autocorrelation model, and the time series was high-pass filtered using a 256 Hz function. Based on the model, contrasts of interest were calculated for the congruent and incongruent session, respectively. The contrasts were as follows: Faces > Forms as manipulation check;  $\text{in\_ethnicity} > \text{out\_ethnicity}$  based on the ethnicity categorization to investigate the in-ethnicity bias;  $\text{in\_team} > \text{out\_team}$  based on the team-based categorization to reveal the in-team bias; and  $\text{in\_team} > \text{in\_ethnicity}$  to explore the neural differences between in-ethnicity and in-team bias. Moreover, we also built corresponding interaction contrasts to explore the neural correlates of implicit associations of the in-ethnicity bias:  $[(\text{incongruent in\_ethnicity} > \text{congruent in\_ethnicity}) > (\text{incongruent out\_ethnicity} > \text{congruent out\_ethnicity})]$ , of the in-team bias:  $[(\text{incongruent in\_team} > \text{congruent in\_team}) > (\text{incongruent out\_team} > \text{congruent out\_team})]$  and of the differences in the in-ethnicity and in-team bias:  $[(\text{incongruent in\_team} > \text{congruent in\_team}) > (\text{incongruent in\_ethnicity} > \text{congruent in\_ethnicity})]$ .

For second-level analyses using random-effects models with ordinary least squares approach, we first applied one-sample *t*-tests to check the basic activation pattern of faces *vs* forms as a manipulation check. For investigating our hypotheses, we considered the number of runs during the test session as a covariate for controlling the effect of familiarity with stimuli. We used one-sample *t*-tests to investigate the neural correlates of in-ethnicity bias, in-team bias, the difference between in-ethnicity and in-team bias and between out-ethnicity and out-team bias in the congruent session, as well as the difference

in brain activation for in- and out-ethnicity bias, and in- and out-team bias between the congruent and incongruent sessions (i.e. interaction effect); the neural differences in these comparisons between groups were analyzed with independent two-sample *t*-tests. The significance threshold for whole brain analyses was set to voxel-wise  $P < 0.05$  FWE-corrected,  $k \geq 10$ . In addition, we applied region of interest (ROI) analyses according to our hypotheses with the masks of amygdala (for the contrasts  $\text{out-ethnicity} > \text{in-ethnicity}$  and  $\text{in-team} > \text{out-team}$ ), FFG and MFC (both for  $\text{in-ethnicity} > \text{out-ethnicity}$  and for  $\text{in-team} > \text{out-team}$ ; as well as for  $\text{in-team} > \text{in-ethnicity}$ ) to the analyses in the congruent session, and with the masks of DLPFC (BA9 and BA46) and PPC (BA7 and BA40) to the interaction analyses. All masks were anatomical masks taken from the WFU pickatlas. The significance threshold for ROI analyses was set to voxel-wise  $P < 0.05$  small volume correction,  $k \geq 10$ . For investigating whether the neural correlates of our interest contrasts vary with duration of exposure to the opposite culture, we first extracted the first eigenvariate of each ROI from each contrast in the congruent session and from the interaction between incongruent and congruent sessions for each Chinese participant (no significance threshold was applied for eigenvariate extraction). Then Pearson correlations were applied to reveal associations between each extracted ROI signal and duration of stay in Germany in Chinese participants, using SPSS version 23.

## Results

### Task manipulation check

Based on the manipulation check questionnaire, all participants remembered their team affiliation after scanning. German participants reported higher sense of affiliation to the novel team, whereas Chinese participants showed better self-reported knowledge of team affiliation of the face stimuli at the end of the experiment (see [Supplementary Text S4](#)).

### Behavioral results

Chinese participants reported higher scores on vertical collectivism than German participants, whereas the German group showed higher scores on horizontal collectivism than the

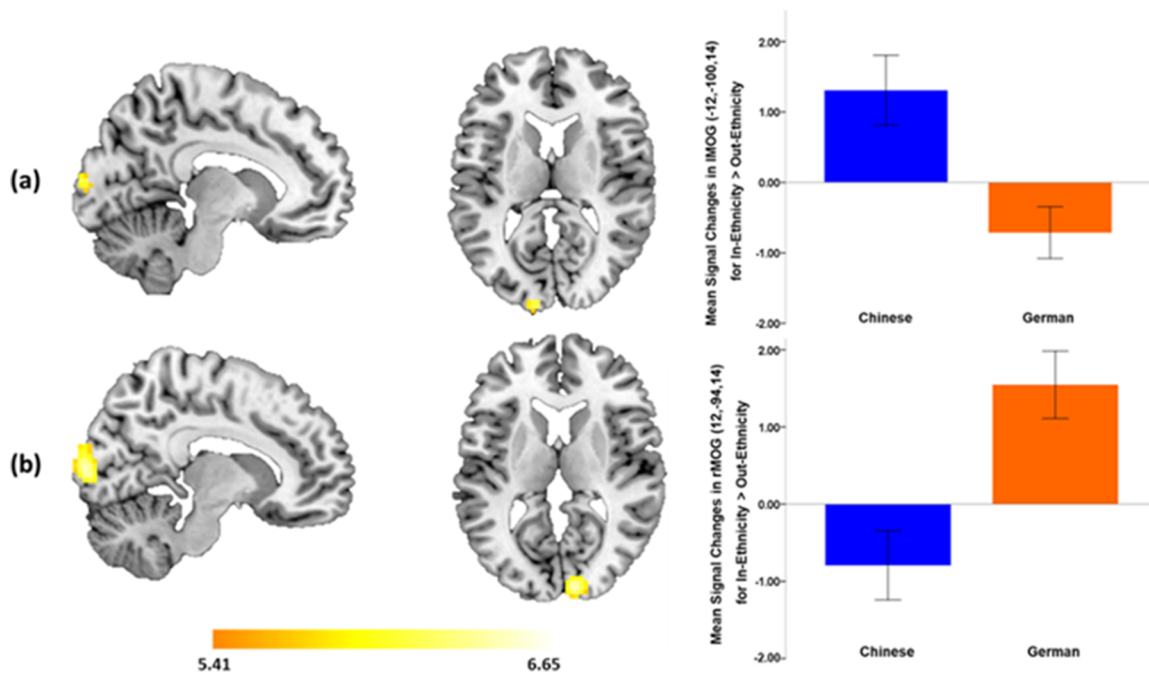


Fig. 2. Neural correlates of cultural differences in the in-ethnicity bias. (a) In comparison to the German group, the Chinese group showed higher activation in the left middle occipital gyrus (MNI coordinates:  $-12, -100, 14$ ) for categorizing the in-ethnicity faces than out-ethnicity faces. (b) In comparison to the Chinese group, the German group showed higher activation in the right middle occipital gyrus (MNI coordinates:  $12, -94, 14$ ) for categorizing the in-ethnicity faces than out-ethnicity faces. Note: lMOG means left middle occipital gyrus and rMOG means right middle occipital gyrus; significance threshold was voxel-wise  $P < 0.05$ , FWE-corrected,  $k \geq 10$ .

Chinese group. No other significant group differences were found with the Self-Construal Scale (see [Supplementary Table S1](#)). Regarding task behavior, our results showed higher accuracy and shorter RTs of categorizations in the congruent session than in the incongruent session. In the congruent session, the other-ethnicity categorization advantage and the in-team bias were found in German but not in Chinese participants. During the team-based categorization, in-ethnicity faces were categorized faster than out-ethnicity faces across participants (see [Supplementary Text S6](#) and [Supplementary Tables S3](#) and [S4](#)). In addition, task performance did not vary with the duration of stay in Germany in Chinese participants.

### Imaging results

**Manipulation check.** Enhanced activation in the fusiform face area and occipital face area was found for face relative to form processing across participants and sessions, indicating the paradigm worked well and can differentiate faces and forms (see [Supplementary Table S5](#) and [Supplementary Figure S5](#)).

### Neural correlates of the in-ethnicity bias and its cultural differences

In the congruent session, ROI analyses revealed increased activation in right dorsal MFC for in- vs out-ethnicity categorization. Regarding group differences, Chinese, compared to Germans, showed higher activation in the left occipital lobe for categorizing in-ethnicity than out-ethnicity faces with whole brain analyses (see [Figure 2](#)), whereas Germans showed higher activation in the right occipital lobe in comparison to Chinese (see [Figure 2](#)). ROI analyses revealed that Chinese showed higher activation in the right ventral MFC for categorizing in- vs out-ethnicity faces than Germans (see [Figure 3](#) and [Supplementary Table S6](#)).

When comparing the incongruent and congruent session, no significant results were found for categorizing the in- vs out-ethnicity faces across participants. However, our results revealed that the in-ethnicity faces, relative to the out-ethnicity faces, resulted in stronger activation in the left occipital lobe in Chinese than Germans, but in the right occipital lobe in Germans than in Chinese (see [Supplementary Table S6](#)). No other significant results were found with this contrast.

### Neural correlates of the in-team bias and its cultural differences

In the congruent session, we found enhanced activation in the left dorsal MFC for categorizing in- relative to out-team faces across participants with ROI analyses. No significant group differences were found with this contrast (see [Supplementary Table S7](#)).

No significant activation differences were found for categorizing the in- vs out-team faces when comparing the incongruent and congruent session, neither across participants nor between groups.

### Neural differences between the in-ethnicity bias and in-team bias

In the congruent session, for in-ethnicity vs in-team categorizations, whole brain analyses revealed increased activation in regions of default mode network including posterior cingulate cortex and medial prefrontal cortex, and middle temporal gyrus across participants (see [Supplementary Figure S6a](#) and [Supplementary Table S8](#)), whereas enhanced activation was found for categorizing in-team vs in-ethnicity faces mainly in regions of frontal (including insula), parietal and occipital lobe (see [Supplementary Figure S6b](#) and [Supplementary Table S9](#)).

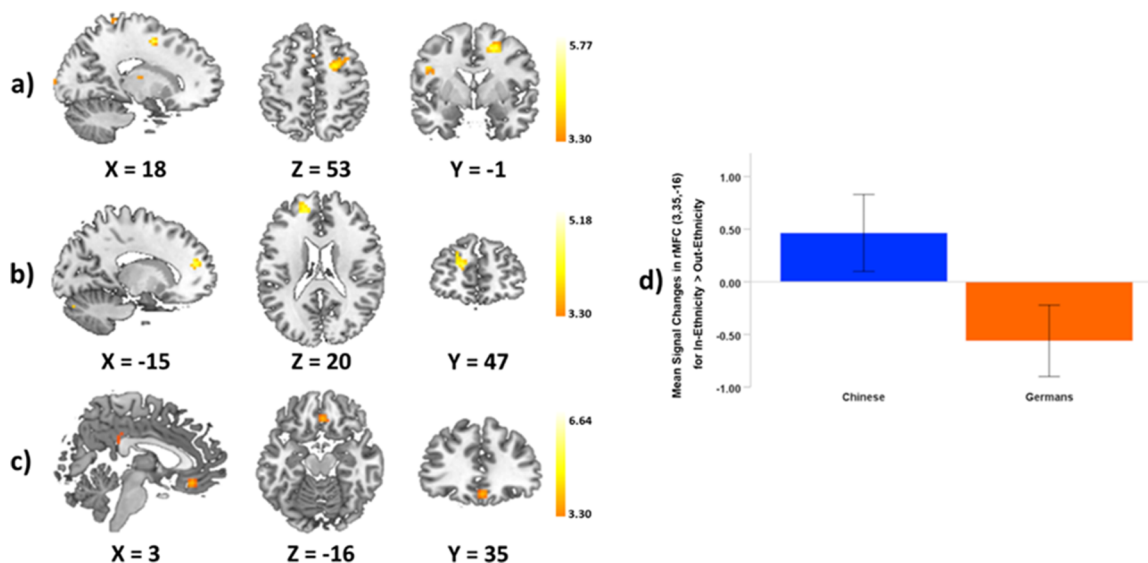


Fig. 3. Neural correlates of ethnicity and team categorization. (a) Increased activation in the posterior MFC for categorizing faces from their own ethnicity compared to those from another ethnicity. (b) Increased activation in the medial prefrontal cortex for categorizing faces from the own team in comparison to those from the other team. Both (c) and (d) show higher activation in the MFC for categorizing faces from their own ethnicity compared to those from another ethnicity in Chinese than Germans. Note: threshold for displaying is voxel-wise  $P < .001$  uncorrected,  $k \geq 10$ ; rMFC indicates right MFC.

ROI analyses showed enhanced activation in bilateral amygdala for categorizing in-ethnicity relative to in-team faces across participants (see [Supplementary Table S8](#)), whereas higher activation in bilateral FFG and MFC was found for categorizing in-team relative to in-ethnicity faces (see [Supplementary Table S9](#)).

We found a comparable pattern for out-team vs out-ethnicity, as for in-team vs in-ethnicity. These results are presented in the supplement (see [Supplementary Figure S7](#), [Supplementary Tables S10](#) and [S11](#)). Since these results suggest that team categorizations were more difficult than ethnicity categorizations, independent of the in- or out-group status, further corresponding comparisons between the congruent and incongruent session and between groups would not reveal specific insight into overcoming the in-ethnicity bias, and thus are not presented.

## Discussion

The present study aimed at investigating cultural differences in in-ethnicity and in-team bias and how in-ethnicity bias can be reduced by the in-team bias. Behaviorally, we found the in-ethnicity and in-team bias only in Germans. Our neural results highlight the importance of the MFC activation in group categorization and reflect neural differences in the in-ethnicity bias between groups. In addition, our results suggest that the in-ethnicity bias is not easily over-written by the in-team bias across groups.

We found the in-ethnicity bias only in Germans but not in Chinese, which is inconsistent with prior studies showing an in-ethnicity bias in both cultures ([Zhao & Bentin, 2008, 2011](#)). Besides, we did not reveal differences in core cultural values between groups. These findings might attribute to the recruitment of Chinese participants who have lived in Germany. With increasing frequency of contacting people from the opposite culture, the in-ethnicity bias and their collectivistic cultural values might be weakened ([Chance et al., 1975](#)). In line with

previous studies ([Feng et al., 2011](#)), we found increased activation in dorsolateral MFC for in- vs out-ethnicity categorization across participants. The activation occurred in a dorsal part of the MFC that is known to be associated with memory ([Euston et al., 2012](#)) and self-identity processes ([D'Argembeau et al., 2007](#); [Jenkins & Mitchell, 2011](#)). Increased dorsal MFC activation for in-ethnicity faces may reflect an increase in self-related processing, demonstrating a close association of the participants with people from their own culture.

Compared to Germans, Chinese showed higher ventral MFC activation for in- vs out-ethnicity categorization. As the ventral MFC is linked to represent the preference of stimuli ([Van et al., 2008](#)), even if the task did not require subjects to explicitly think of the extent of preference of the stimuli ([Levy et al., 2011](#)). Thus, our finding might be interpreted as higher preference of in-ethnicity members in Chinese. However, this neural pattern of higher preference for in-ethnicity members was not reflected in behavior.

Interestingly, for in- vs out-ethnicity categorizations, we found higher activation in the left visual cortex in Chinese than Germans but higher activation in the right visual cortex in Germans than Chinese. Prior cross-cultural studies suggested that in-ethnicity faces are processed via holistic information across cultures, whereas feature-detection processing was used for out-ethnicity faces ([Ge et al., 2009](#); [Zhao & Bentin, 2011](#)). Our results regarding German participants are consistent with previous findings of studies with individualistic samples that holistic processing relies more on the right hemisphere and the feature-detection processing on the left hemisphere ([Rossion et al., 2000, 2003](#)). However, based on our knowledge, only one fMRI study has focused on the categorization of in-ethnicity faces with a collectivistic sample ([Feng et al., 2011](#)), and their findings are consistent with ours, discovering higher left visual cortex activation for in- vs out- ethnicity categorization in Chinese. It may imply a different hemisphere functioning for holistic and feature-detection processing during face perception between cultures. Importantly, with reversing responses to categorize faces based on ethnicity during the incongruent

condition, the neural patterns have also presented in a reversed way when we compared the in- vs out-ethnicity categorization in incongruent vs congruent pairings. These findings might represent the brain's capacity of flexibly switching processing modes for in- and out-ethnicity faces, according to the focus of in- vs outgroup, and may suggest differences in processing of faces of the own ethnicity between cultures. However, the result might also be the effect of less differences in brain activation between incongruent and congruent pairings in one of the groups. Thus, it should be kept in mind that these are complex interactions which need replication and should be interpreted with caution.

Consistent with our hypothesis, our results show an in-team bias in Germans (Van et al., 2008; Voorspoels et al., 2014), but not in Chinese (Ng et al., 2016). As mentioned, people from individualism interpret social groups as broad social collectives, implying that they treat strangers who share the group membership with them as 'in-group' members (Brewer & Yuki, 2007). In contrast, people with a collectivistic background consider the social network as interpersonal relationships, demanding personal ties to include others as in-group member (Brewer & Yuki, 2007). The team membership in the present study was established without pre-existing personal ties and contact. Thus, it seems harder for Chinese than for Germans to develop the in-team bias.

However, we observed the in-team bias across all participants on the neural level. In line with prior findings (Molenberghs & Morrison, 2014; Gamond et al., 2017), we found higher dorsal MFC activation for categorizing in-team vs out-team faces across cultures. As mentioned, dorsal MFC activation has been associated with self-referential processing (D'Argembeau et al., 2007; Molenberghs & Morrison, 2014). Our results may reflect an increase in self-related brain activation toward in-team than out-team members. Moreover, no significant neural differences in processing in-team faces were found between cultures, probably suggesting a common neural code for processing in-team members across cultures. In short, combined with the finding of in-ethnicity bias, we suggest that dorsal MFC represents a core brain area for in-group categorization independent of social coalitions (i.e. based on ethnicity and on team membership).

In line with previous findings (Van et al., 2008), we found that RTs were around 300 ms faster in in-ethnicity than in-team categorization, suggesting that in-ethnicity categorization is easier than the latter. In addition, the RTs were faster in in-ethnicity than out-ethnicity categorization during the team-based categorization reflecting an in-ethnicity bias rather than other-ethnicity categorization advantage. These findings demonstrate that the team-based categorization probably requires additional memory retrieval than the ethnicity-based categorization, which may reflect the former representing higher-order processing (e.g. face recognition). This seems plausible when considering that team members were learned directly before the experiment, whereas the connection with own-ethnicity members developed since early childhood (Kinzler & Spelke, 2011). Our fMRI results mostly point to differences in the cognitive demands of the categorization tasks. We found enhanced activation in regions of default mode network (Buckner et al., 2008) and amygdala, suggesting that compared to the team-based categorizations, ethnicity-based categorizations require less attentional control and rely largely on bottom-up visual attention. By contrast, we observed increased activation in the anterior insula, MFC and FFG for the categorization of the in-team vs in-ethnicity, and of out-team vs out-ethnicity faces, suggesting that the in-team categorization might require more top-down attentional

control than the in-ethnicity categorization (Mattan et al., 2018). However, since we found a comparable activation pattern for out-team vs out-ethnicity judgments, we cannot draw specific conclusions about the processing of different in-groups but can only conclude about team vs ethnicity processing in general. In consequence, we omitted planned comparisons of in-team vs in-ethnicity comparisons between the congruent and incongruent session, as well as the corresponding group comparisons, because they would reflect interactions based on differences in task difficulty, but not specifically of over-writing in-ethnicity bias.

While we recruited participants who were socialized in two different cultures, collectivism and individualism, our work did not reveal an in-ethnicity bias in Chinese behaviorally and we also did not discover the expected differences in the core cultural values between the two groups (see Supplementary Text S1). These findings may be attributed to the recruitment of both groups in Germany. As exposure to the opposite culture may alter the cultural representation (such as self-construal; Yamada & Singelis, 1999), the cultural values in our Chinese group may have been altered toward the German group since they arrived in Germany. Besides, cultural identity in people studying or living in other cultures might be prone to that culture, even before leaving for there. This might also explain why we found no associations between task performance and duration of stay. Thus, it is necessary for future studies to establish the cultural groups by recruiting participants living in their own culture. Further, future studies might refer to questionnaires that are more sensitive to the cultural background of the participants, in addition to assessing their current cultural values. Interestingly, German participants reported higher sense of affiliation to the novel team, whereas Chinese participants showed better self-reported knowledge of team affiliation of the face stimuli after the fMRI session. It seems that better self-reported knowledge of team affiliation of the face stimuli did not increase the sense of affiliation to the novel team in the Chinese group. Our behavioral, as well as our neural, data suggest that team and ethnicity categorizations may reflect distinct levels of processing with a higher-order processing of team than ethnicity categorizations. Since we found a comparable pattern for in-group (in-ethnicity vs in-team), as for out-group (out-ethnicity vs out-team) comparisons, the minimal group approach (Brewer & Yuki, 2007) that we chose might not be optimal for investigating the neural bases of team vs ethnicity processing. Together these results suggest that future studies might use paradigms that are based on already existing ties, such as memberships in mixed sport teams in which participants know their team members before joining the study. In addition, our results of different hemispheric functions in the visual cortex between cultures while categorizing faces according to their ethnicity warrant replication.

With the cultural neuroscience approach, we revealed that the dorsal MFC may present a common neural code for in-group biases across cultures. In addition, our findings shed light on the cultural effect on in-ethnicity biases, suggesting ventral MFC and visual cortex as targets for a deeper understanding of differences in in-ethnicity biases between cultures. Our results also suggest that the in-ethnicity bias is not easily overcome by the in-team bias. Future studies should extend the present study by developing suitable experimental paradigms allowing the differentiation between different types of in-group biases to (i) explore mechanisms of overcoming in-group bias and (ii) gain deeper knowledge on cultural differences in in-group biases.

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