



Intergroup social influence on emotion processing in the brain

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Emotions usually occur in a social context; yet little is known about how similar and dissimilar others influence our emotions. In the current study, we examined whether ingroup and outgroup members have differential influence on emotion processing at the behavioral and neural levels. To this end, we recruited 45 participants to rate a series of images displaying people engaged in different emotional contexts. Participants then underwent an fMRI scan where they viewed the same images along with information on how ingroup and outgroup members rated them, and they were asked to rate the images again. We found that participants shifted their emotions to be more in alignment with the ingroup over the outgroup, and that neural regions implicated in positive valuation [ventral striatum (VS) and ventromedial prefrontal cortex (vmPFC)], mentalizing [dorsomedial prefrontal cortex (dmPFC), medial prefrontal cortex (mPFC), posterior superior temporal sulcus (pSTS), and temporal pole], as well as emotion processing and salience detection (amygdala and insula), linearly tracked this behavior such that the extent of neural activity in these regions paralleled changes in participants' emotions. Results illustrate the powerful impact that ingroup members have on our emotions.

intergroup social influence | social neuroscience | emotion processing

On an everyday basis, people's emotional experiences are heavily influenced by the emotions of others. Seeing other people unhappy can prompt individuals to become sad. This tendency for emotions to be contagious can be adaptive because emotional convergence serves as a building block for human interactions, as it promotes behavioral synchrony, facilitates rapport, and fosters effective interpersonal processes and social communication (1). However, not everyone influences us in the same way; those more similar to us (ingroup members) are more influential than those who are different (outgroup members). In this study, we aimed to examine the behavioral and neural mechanisms underlying conformity to emotions in an intergroup context.

Social Influence in an Intergroup Context

People's motivations to conform, or change their behavior to match those of others, are shaped by their desire to form accurate perceptions of reality, engage in social affiliation, and maintain positive self-concepts (2). These drivers of conformity are particularly important in intergroup contexts where influence can come from two sources: ingroup and outgroup members (3). People have a greater tendency to change their beliefs, behaviors, and attitudes to be in accordance with the ingroup over the outgroup (2–4).

Theoretically based accounts on the advantages of ingroup conformity are grounded in evolutionary explanations, as conforming to and being more similar to ingroup members serves a more adaptive role compared with outgroup members by increasing chances of survival and reproduction through protection and provision of material resources (5). In addition, self-categorization theory (6) posits that conforming to ingroup (vs. outgroup) members provides individuals with multiple benefits, such as a sense of belonging and self-esteem (7, 8).

These intergroup biases result in people perceiving, evaluating, and behaving more favorably toward ingroup than outgroup members (9, 10). However, although much research has focused on the impact of ingroup and outgroup members on attitudes and behaviors, less is known about how intergroup social influence can have an impact on emotion-related experiences.

Neural Basis of Social Influence and Intergroup Biases

Neuroimaging techniques have begun to provide insights into psychological processes that may be hard to capture through behavioral measures alone. This approach is especially useful when studying intergroup processes, as it allows researchers to investigate the underlying neural representation of biases in behavior and attitudes, which are difficult to capture through self-reports. Neuroimaging techniques are also beneficial when examining social influence, as it allows experimenters to disentangle between different types of conformity, such as public compliance and private acceptance (see refs. 2 and 11). In conjunction with observed behavioral outcomes, neuroscience can shed light on the mechanisms involved in intergroup social influence.

A growing body of research has begun to unpack the neural processes underlying conformity and social influence (for reviews, see refs. 12–16). People's sensitivity to social reward (when conforming) and punishment (when violating a group's norm) shapes their susceptibility to normative influences, and such conformity is mediated by the reward and social pain neural

Significance

People's emotions are heavily influenced by others around them. While previous studies have increased our understanding of the neuroscience of social influence in various contexts, such as music ratings and facial attraction, less is known about the neural basis of social influence on emotion processing and whether the human brain is able to track information from two different sources, such as ingroup and outgroup members. We address these two gaps in the literature by showing that the brain is able to differentially track, on a trial-by-trial basis, social influence of emotions deriving from ingroup and outgroup members. Results contribute to our understanding of the neural representations subserving everyday behaviors, such as people's influence on others' emotions.

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networks (13). The same neural systems that track reward signals, integrate value information, and motivate people to act [e.g., ventral striatum (VS) and ventromedial prefrontal cortex (vmPFC)] (17–19), are also implicated when people update their behavior to be in alignment with that of a group in social conformity contexts (11, 20, 21). Thus, activity in these neural systems might reflect the brain's response to social reward and social bonding that results from conforming with others.

Similarly, social pain and rejection, powerful motivators of people's desire to avoid exclusion and thus conform with others, tend to activate the dorsal anterior cingulate cortex (dACC) and anterior insula, common regions involved in conflict detection (22, 23). For example, increased neural activation in the dACC and anterior insula is present when updating one's behavior if it differs from that of the group (20, 24). Thus, these regions might potentially track the cost of nonconformity to motivate people to change their behavior to be in line with the group.

Finally, regions associated with mentalizing [e.g., dorsomedial prefrontal cortex (dmPFC), medial prefrontal cortex (mPFC), temporoparietal junction (TPJ), posterior superior temporal sulcus (pSTS), and temporal poles] (25, 26), are likely to be involved in an intergroup social influence context. Previous research on the neuroscience of social influence has found that neural regions implicated in mentalizing are involved when conforming to others' feedback (27, 28). Being influenced by others often entails taking the perspective of and making inferences about others' mental states, both of which are critical for empathy and cooperation (29). The degree to which individuals engage in mentalizing and emotional understanding can depend on the source of the targets. For example, previous studies have shown that individuals engage in more individuated judgments about ingroup members compared with more superficial judgment about outgroup members (9, 29, 30). These differences are also reflected in the brain, where individuals recruit mentalizing regions to different extents, depending on the group membership of the target (29, 31, 32). Thus, it would be reasonable to hypothesize that mentalizing regions would be recruited to a greater extent for ingroup than outgroup members in an intergroup social influence context.

Social influence in an emotional context might be particularly strong when negative emotions are involved, as individuals are more likely to attend to and be more influenced by negative than positive information (33), a term referred to as a negativity bias. In emotional contexts, the insula is recruited to a greater extent for negative than positive stimuli (34), and in a social influence context, is associated with discomfort that might result from the mismatch between one's ratings and those of others (24). Moreover, in intergroup contexts, the amygdala tends to be activated for biologically salient and motivationally relevant stimuli, such as ingroup members (35). Therefore, the insula and amygdala are candidate regions for the representation of the negativity bias effect as well as motivationally relevant groups, respectively. Given the importance of studying emotion processing in intergroup contexts, we sought to examine the behavioral and neural correlates of intergroup social influence in negative emotional contexts.

Current Study

In the current study, we designed a social influence task (Fig. 1) to examine how ingroup and outgroup members differentially influence people's emotions. In line with previous evidence suggesting the advantage of ingroup conformity, we hypothesized that participants would be more likely to conform with the ingroup over the outgroup and that this behavior would be represented at the neural level by increased activation when conforming to ingroups over outgroups in areas previously associated with reward, positive valuation, and value integration (VS and vmPFC), mentalizing (dmPFC, mPFC, TPJ, pSTS, and

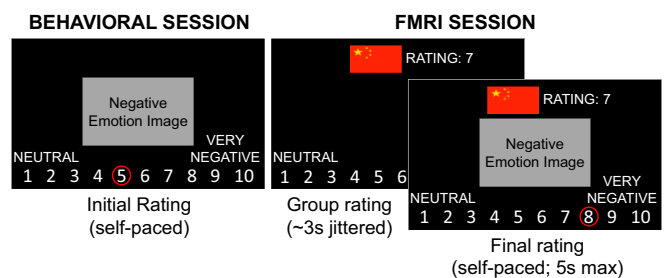


Fig. 1. Overview of experimental design. Participants (American and Chinese) first rated a series of negatively valenced images during a behavioral session. Approximately 1 wk later, they completed the social influence task in the fMRI scanner. For each trial of the social influence task, participants first saw an American or Chinese flag (or no flag) indicating which group the feedback would be coming from along with a score indicating how students from a collaborating university in those countries rated an image (no ratings displayed for neutral trials). Around 3 s later, the image appeared on the screen and participants had a maximum of 5 s to give a final rating for the emotional image using the same scale as in the behavioral session. The images presented during the fMRI session were a subset of the ones participants rated during the behavioral session. We calculated influence scores based on whether participants changed their emotion ratings between the behavioral and scan sessions to conform (or not) with the group feedback.

temporal poles), and emotion and salience processing of biologically relevant stimuli (amygdala and insula).

We were also interested in examining whether culture modulates intergroup conformity. On the one hand, the cultural environment may influence the extent to which people display an ingroup bias in a social influence context. For example, East Asian culture emphasizes interdependence and group harmony, which could make individuals from these cultures more likely to conform to their ingroup compared with Western individuals who are more individualistic (36–38). On the other hand, given the well-established phenomenon that ingroup biases exist across cultures (39), intergroup conformity of emotional processes may exist similarly across cultures. Including culture as a factor in our study of intergroup social influence is important to understand the universality and boundaries of these processes.

Results

Behavioral Conformity to Ingroup over Outgroup Members. We first conducted a manipulation check for our social influence task and found that participants' emotion ratings changed more in trials in which they were presented with group feedback compared with trials in which they were not presented with any feedback (*SI Appendix*). We then examined conformity to ingroup relative to outgroup ratings on trials where their initial ratings were moderate, as extreme scores are less likely to change (*Methods*). On these trials, participants were significantly more likely to be influenced by the ingroup (vs. outgroup), $t(44) = 2.25$, $P = 0.03$ (Fig. 2). Participants shifted their ratings on average by about 1.19 points in the direction of the ingroup and less than 1 point in the direction of the outgroup. Repeated measures ANOVA revealed no differences in ingroup and outgroup influence between American and Chinese participants, $F(1,43) < 0.001$, $P = 0.99$. These results suggest that ingroup conformity to negative emotions may be similar across these two cultural groups, which was further supported by post hoc analyses conducted within each cultural group separately (*SI Appendix*).

Increased Neural Tracking of Social Influence to Ingroup over Outgroup Members. We next investigated whether participants showed different patterns of neural activation when shifting their behavior to be closer in alignment to the ingroup (vs. outgroup). To this end, we conducted a whole-brain one-sample (combining

potentially reflecting the rewarding nature of agreeing with groups that are more relevant to the self.

The VS's role in positive valuation and reward in previous studies (17, 19) might also suggest a difference in valuation occurring when viewing the feedback from ingroups and outgroups, and is consistent with previous evidence suggesting that the subjective value placed on stimuli is sensitive to social feedback (11, 15, 21, 43, 45). VS activity suggests that social influence may have altered the neural representation of value placed on the different stimuli, indicating that participants in our study may have genuinely accepted others' ratings of the emotional images when aligning their own ratings to be in accordance with the ingroup over the outgroup, rather than publicly conforming with ingroups over outgroups but privately holding the same views (11, 46).

dmPFC, mPFC, pSTS, and temporal pole. As hypothesized, we observed increased dmPFC, mPFC, right pSTS, and left temporal pole activation when participants aligned their emotions to go along with ingroup over outgroup members. These regions have been implicated in theory of mind (25, 26), and their pattern of activation in our study suggests that when making the decision on the emotional content of the images, participants were processing the feedback provided by others to a greater extent when conforming to ingroups than outgroups. This is consistent with previous studies demonstrating more mentalizing and individuated (subordinate) levels of processing for ingroup members compared with more deindividuated (superordinate) processing for outgroup members (9, 29–31). In addition, previous studies have found overlapping neural regions between self-related and social-identity processing that involve medial prefrontal and medial parietal areas, including mPFC and dmPFC, and that activation in these regions correlate with ingroup biases (47), which are consistent with findings from our study.

In the context of social conformity, the dmPFC has been found to track cognitive inconsistency, and the larger this activation when viewing the preferences of others, the more likely individuals are to align their behavior to go along with (liked) others (40). The results from our study are in line with this hypothesis, as increased dmPFC activity when conforming to ingroup over outgroup members could represent a neural error signal that indicates deviation from others, a signal that is stronger for ingroup than outgroup members and motivates individuals to distinctively conform with different groups. dmPFC activation in our study, therefore, likely serves both mentalizing and tracking of cognitive imbalance functions, both processes likely involved in reinforcing behavioral adjustment to align with ingroup over outgroup members.

Insula and amygdala. Results also indicated more insula and left amygdala activation when aligning emotions to go along with ingroup over outgroup members. Previous studies on the neural bases of social influence have interpreted insula activation as tracking an error occurring from a mismatch between an individual's preference and a group's behavior (15, 48, 49) that can result in arousal and negative affect (24) and ultimately facilitates behavioral alignment with the group (42). The current study suggests that these signals tracking deviations from others' ratings and the ensuing negative affect might be stronger for ingroup than outgroup members. In addition, amygdala findings in our study could indicate higher depth of processing for motivationally relevant ingroup over outgroup members (35), with one implication being that emotion processing might occur at a deeper level when it is influenced by ingroup than outgroup members.

vlPFC. We also observed increased activation in the vlPFC when participants adjusted their emotion ratings to go along with ingroup over outgroup members. The vlPFC has been implicated in cognitive control and emotion regulation (50). While this neural activation was not predicted a priori, previous studies have found increased vlPFC activation in relation to susceptibility to social influence (28). Our findings could suggest that

participants directed their attention and engaged in more self-control to a greater extent when conforming to the emotions of ingroup over outgroup members.

Limitations and Future Directions. The design of our study has several methodological strengths compared with previous studies examining the neural basis of social conformity (e.g., refs. 11, 20, 21, 24, 40, and 41). Mainly, participants made their initial and postsocial influence final ratings in two separate sessions days apart and were not reminded of their initial ratings during the scan session. In conjunction with the nature of our task that focused on emotions, these differences in experimental design may be why the main effect of influence (collapsing across ingroup and outgroup trials) vs. no-influence trials did not reveal divergent engagement of neural regions (*SI Appendix*), which suggests that our results might be more specific to how people respond to ingroup (vs. outgroup) influence rather than how they respond to social influence (vs. no influence) more generally. This paradigm minimizes demand characteristics that might result from completing initial and postgroup feedback ratings in the same experimental session by lowering the pressure to superficially comply with the ratings of others. It strengthens the claim that ingroup and outgroup members had divergent impacts on emotion processing both behaviorally and at the neural level, though our results suggest that at least at the behavioral level, this might be specific to situations where people's initial ratings are moderate and not extreme (*SI Appendix*).

Our results on social influence in negative emotional contexts are consistent with previous research that found that people tend to have a negativity bias. Focusing on negative aspects of their environment might be particularly relevant in intergroup contexts, wherein strong and salient emotions might heighten the relevance of the ingroup. However, it would be interesting to explore whether the results from our study would hold for other emotions, such as positive, neutral, or even different kinds of negative emotions, such as anger, fear, and sadness.

The lack of cultural differences suggests that intergroup influences on emotion processing might be present both in Chinese and American cultures. Previous studies examining intergroup cultural influences on neural processing in other domains, such as empathy and prosociality, have found differential neural responses for ingroups and outgroups across cultures (51, 52). However, given that social influence is a powerful determinant of people's behaviors and emotions, the results from our study suggest that social influence in an intergroup context might be just as powerful in individualistic and interdependent cultures when emotions are involved. Previous neuroimaging studies have examined the psychological and neural mechanisms involved in social influence, but research examining intercultural variation in these processes has lagged behind. Thus, while we did not find cultural differences, we highlight the importance of including culture as a factor for determining the universality of research findings.

Similar studies with participants from other sociocultural environments and from different age groups could also give us a more complete picture of the behavioral and neural substrates of social influence in intergroup contexts. Intra- and interindividual variability in the samples that are studied will help in addressing some of the lingering questions regarding the specific role of the neural systems involved in social conformity, such as whether value-related activation tracks conformity, valuation, or an interaction between the two, depending on the context (see ref. 12).

Conclusion

We explored the behavioral and neural mechanisms underlying intergroup social influence in an emotional context. We show that those similar to us are more likely to be influential than those different from us and we provide evidence that the neural

representations subserving behavioral conformity in emotional contexts are also different, depending on the group membership of the influencers. This research improves our understanding of social influence on intergroup emotion processing by demonstrating that the brain is able to track social influence from different sources in emotional contexts, and that this might be a shared phenomenon across different cultures. In an increasingly globalized world, examining intergroup influence on emotion processing is a step forward for improving intergroup emotional understanding.

Methods

Participants. Forty-five individuals participated in the study, including 22 American and 23 Chinese participants (mean age = 19.42 y, SD = 0.63, 24 female). All American participants were White/Caucasian and all Chinese participants were born in China and had been in the United States for less than 1 y. Participants were paid for their participation or given course credit, whichever the participant preferred. Subjects provided written consent and all procedures were approved by the University of Illinois's Institutional Review Board.

Participants came for two separate sessions (a behavioral and an fMRI session), each about 1 wk apart. Instructions and materials for the study were translated and back translated to Chinese by bilingual speakers (53). American participants completed the English version of the tasks and questionnaires, and Chinese participants completed the Chinese version of the tasks and questionnaires.

Procedures.

Behavioral session. In the first session, participants were presented with 100 images of people in negative contexts, such as an earthquake aftermath, at a funeral, or in the hospital. They were asked to imagine that they were the person in the picture and indicate, on a scale from 1 (neutral) to 10 (very negative), how they feel. Half of the targets in the pictures were Asian and half White. The task was self-paced.

fMRI session. Approximately 1 wk after the behavioral session, participants underwent an fMRI scan while completing a social influence task (Fig. 1). In this task, participants viewed how ingroup and outgroup members (as defined by culture) rated a subset of the images they had rated during the behavioral session and were asked to rate the images again. In reality, group ratings were experimentally manipulated based on the participants' initial ratings during the behavioral session. In total, each participant saw 24 ingroup, 24 outgroup ratings, and 12 no-rating trials. See *SI Appendix* for more details about the task and for information about the baseline ratings of the images that were used in the scan session (*SI Appendix*, Fig. S2).

fMRI Data Acquisition, Preprocessing, and Analysis. All imaging data were acquired using a 3 Tesla Siemens Trio MRI scanner. T2*-weighted echoplanar images (EPs) [slice thickness = 3 mm; 38 slices; repetition time (TR) = 2 s; echo time (TE) = 25 ms; matrix = 92 × 92; field of view (FOV) = 230 mm; voxel size 2.5 × 2.5 × 3 mm³] were acquired during the fMRI task. For the structural scans, a T2*-weighted, matched bandwidth (MBW), high-resolution, anatomical scan (TR = 4 s; TE = 64 ms; matrix = 192 × 192; FOV = 230 mm; slice thickness = 3 mm; 38 slices) and a T1* magnetization-prepared rapid-acquisition gradient echo (MPRAGE) (TR = 1.9 s; TE = 2.3 ms; matrix = 256 × 256; FOV = 230 mm; sagittal plane; slice thickness = 1 mm; 192 slices) were acquired for each participant. The MBW and EPI scans were oriented at an oblique axial angle to maximize brain coverage and reduce signal dropout.

Neuroimaging data were preprocessed using the FSL FMRIBs Software Library (FSL v6.0; <https://fsl.fmrib.ox.ac.uk/fsl/fslwiki>). For each participant, motion correction was performed using MCFLIRT (54). Spatial smoothing was applied using a Gaussian kernel of full width at half maximum (FWHM) of 6 mm. High-pass temporal filtering was then conducted with a filter width of 128 s (Gaussian-weighted least-squares straight line fitting, with sigma = 64.0 s) and images were skull stripped using FSL's Brain Extraction Tool (55) based on the parameters suggested by ref. 56. Each functional image was registered to standard Montreal Neurological Institute (MNI) 2 mm brain through T2- and T1-weighted structural images using FLIRT (54, 57). An individual-level independent component analysis denoising procedure was also conducted using MELODIC (58) in conjunction with an automated signal classification toolbox (classifier Neyman–Pearson threshold = 0.3; see ref. 59 for more details) to remove motion- and physiological-related artifacts.

Statistical analyses were performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). At the first level, each trial was modeled

by convolving it with the canonical hemodynamic response function. In each participant's fixed-effects analysis, a general linear model (GLM) was set up with the regressors of interest to separate different events, which included social influence from ingroup members, outgroup members, and no influence. The task was modeled as an event-related design and the duration of each trial was modeled from the initial presentation of the group rating (presentation of group rating or no rating) to the participant's response. The jittered intertrial intervals were not explicitly modeled and thus constituted an implicit baseline.

For each trial, we also included a parametric modulator (PM) to track the participants' change in initial to final rating in relation to the group rating. The PM was computed as follows: for those trials where participants saw a group rating, a 2 indicated if they moved fully in the direction of the group rating (changed their rating to be the same or more in the direction of the group rating), a 1 indicated partial movement toward the group rating (changed their rating to be in the direction of the group rating but still not as high or as low as the group rating), a 0 indicated they did not move at all, and a -1 indicated they moved in the opposite direction from the group rating. We chose to include 2 as the maximum score, as many of the scores were constricted to 2 points of movement. We stopped the parametric modulator at -1, given that there were not as many trials in which participants moved in the opposite direction of the influence group, as there were trials in which participants moved in the direction of the influence group, and such trials where they moved in the opposite direction had a smaller relative change. As an example of how trials were coded, if a participant initially rated an image as a 5 in the behavioral session, then provided a rating of an 8 following a group rating presentation of 8 during the scan, then that trial was coded as a 2. If the participant had provided a final rating of 7, then that trial was coded as 1. If they rated it a 5, then the trial was coded as 0, and if the participant rated it a 3, then it was coded as -1. For trials where participants did not see ratings from others (no group rating present), the PM was calculated based on the change from final to initial rating (*SI Appendix*). By including the PM representing change in ratings, we were able to examine how brain regions tracked the amount of social influence to in- and outgroups.

Linear contrast images comparing each of the conditions of interest were created based on the parameter estimates resulting from the GLM. Random effect analyses were then conducted by submitting the individual subject contrasts to the second level for group analyses. At the group level, we ran whole-brain, one-sample (combining American and Chinese participants) and two-sample *t* tests (American vs. Chinese participants) to examine similarities and cross-cultural differences in the neural correlates underlying intergroup social influence using the contrast (ingroup - outgroup).

We conducted a Monte Carlo stimulation to compute a cluster threshold to correct for multiple comparisons using the updated (April 2016) 3dFWHMx (-acf option) and 3dClustSim implemented in the AFNI software package (60), and the group-level brain mask for analyses of interest. The simulations indicated a voxel-wise threshold of $P < 0.005$ in combination with a minimum cluster size of 231 voxels for the one-sample *t* tests and 226 voxels for the two-sample *t* tests, corresponding to $P < 0.05$, family-wise error corrected. All results are available on NeuroVault (61); see <https://neurovault.org/collections/RHJBYKGGH>.

Behavioral Data Analysis. At the behavioral level, we computed an influence score on a trial-by-trial basis to calculate how much, for a given stimulus image, the participant was influenced by the group rating. This social influence score was calculated based on the difference in participants' initial rating during the behavioral session and final rating after viewing the group rating during the fMRI scan. If the participant modified their rating to be away from the group feedback, then the corresponding influence score was negative. If they shifted their rating to be toward the group feedback, then the corresponding influence score was positive. Influence scores could not be calculated for no-influence trials, since no group feedback was provided. Because people are more likely to be influenced by others when their initial ratings are moderate and fall in the middle of the scale rather than at the extremes (2, 62), we only computed influence scores looking at trials where their initial ratings were moderate (e.g., between 3 and 8), as extreme scores (e.g., 1, 2, 9, and 10) are less likely to change (see *SI Appendix* for moderate vs. extreme trial comparisons in our data and *SI Appendix*, Fig. S3 for distributions of raw influence scores for ingroup and outgroup feedback trials).

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