Community-level racial prejudice potentiates Whites' neural responses to out-group faces: A spatial meta-analytic approach

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Abstract

A persistent question in social neuroscience is whether the amygdala underlies racial prejudice. Despite decades of research, evidence for a stronger amygdala response to racial out-group versus in-group members has been mixed. Here, we consider a potential explanation for these conflicting results: that neural responses to racial out-group members vary systematically based on the level of racial prejudice of the surrounding community. To test this contextual sensitivity hypothesis, we conducted a spatial meta-analysis that included a comprehensive set of studies ($n=22$) examining neural responses to Black vs. White faces in primarily White participants. We evaluated whether community-level racial prejudice moderated neural activation to Black (vs. White) faces by aggregating individual explicit racial attitudes, obtained from Project Implicit, to the county in which each study was conducted. Multi-level kernel density analysis demonstrated that neural activation to Black (vs. White) faces was significantly higher in the right amygdala, dorsal anterior cingulate cortex, and dorsolateral prefrontal cortex in communities with higher (vs. lower) levels of racial prejudice. This same pattern of neural activation was not observed for income inequality or for the percentage of the population who was Black or college-educated, indicating specificity to community-level prejudice. Our findings highlight the potential utility of spatial meta-analyses for reconciling conflicting results in the social neuroscience literature by identifying features of the broader social context that may moderate neural responses to socially relevant stimuli.

Main Text

Introduction

A persistent question in social neuroscience is whether the amygdala underlies racial prejudice (1–3). Despite decades of research, evidence for a stronger amygdala response to racial out-group compared to in-group members has been mixed (4), with many fMRI studies finding no difference in amygdala response to viewing racial out-group (vs. in-group) members (1). The reasons for these conflicting findings remain inadequately understood. We argue that they could be due, in part, to contextual moderators, such that observed associations are more (or less) pronounced depending on the social context in which participants are embedded (5, 6).

However, few studies have tested this contextual sensitivity hypothesis, particularly in social neuroscience. The main challenge to evaluating this hypothesis is that most neuroimaging studies are conducted in a single community; thus, respondents are ubiquitously exposed to the same macro-social context (7), precluding the possibility of linking contextual variation with neural outcomes.

To address this limitation, we employed a spatial meta-analysis, which allows each study to be characterized in terms of the social context in which it was conducted (8). Emerging literature indicates that community-level measures of racial prejudice are associated with adverse outcomes—including mortality rates among White people and disproportionate lethal force by police against Black people—suggesting that these measures capture important features of the social context as it relates to race in the U.S. (9). Drawing on this work, we hypothesized that White participants' neural responses to racial out-group members would be potentiated in communities whose residents endorsed higher levels of racial prejudice relative to in lower-prejudice communities. To evaluate this contextual sensitivity hypothesis, we linked aggregated measures of community-level racial prejudice to the communities in which a comprehensive set of neuroimaging studies examining neural responses to Black vs. White faces were conducted.

Results

Three clusters of voxels demonstrated significantly greater activation to Black vs. White faces more frequently in studies conducted in counties where community residents explicitly endorsed higher (vs. lower) levels of racial prejudice: left dorsolateral prefrontal cortex (dlPFC; 233 voxels; $t=3.92$), dorsal anterior cingulate cortex (dACC; 173 voxels; $t=3.91$), and right amygdala (116 voxels; $t=2.91$) (Figure 1).

Sensitivity analyses revealed that this pattern of activation was specific to community-level explicit racial prejudice. Community-level income inequality and aggregated implicit racial attitudes were unrelated to the likelihood of activation to Black (vs. White) faces in any region. Moreover, only the left dlPFC was less likely to be activated to Black (vs. White) faces in studies conducted in counties where a higher percentage of the population is Black and college-educated.

Discussion

In a recent review of the social neuroscience of prejudice, Amodio and Cikara (1) argued that as the field continues to develop, “it must make connections to real life forms of prejudice that persist in society...[which] will require new methods [and] greater ecological validity.” Heeding this call to action, we explored whether Whites’ neural responses to racial out-group members vary systematically based on the level of racial prejudice endorsed by residents of the surrounding community. Our results support this hypothesis: living in an environment characterized by higher (vs. lower) levels of racial prejudice modulated the magnitude of Whites’ neural response to racial out-group members not only in the amygdala, but also in a region of dACC involved in salience processing as well as dlPFC. One possible interpretation is that racial out-group members are more salient or are associated with greater uncertainty for Whites living in contexts with higher levels of racial prejudice, although caution is warranted in interpreting psychological states from neural activation patterns (10).

These findings suggest several avenues for further study. One concern in observational studies is whether associations are due to the independent variable or to factors correlated with it. Our sensitivity analyses showed that the pattern of neural activation was specific to community-level racial prejudice and was not observed for other community-level characteristics that may be causes or consequences of prejudice, thereby strengthening our inferences. Nevertheless, future studies would benefit from the use of additional methods for exploring this question. Second, our sample includes a restricted range of community-level racial prejudice scores based on all possible counties from the Project Implicit dataset. Because this restricted range would have reduced statistical power, our estimates are likely conservative. However, the restricted range also reduces generalizability, indicating the need for future studies with more sites. Third, we are limited by the data that could be reliably coded across studies included in our spatial meta-analysis, which precluded us from adjusting for some potential study-level confounders. Although most confounders—including differences across sites in scanner type or pre-processing pipelines—would be unlikely to generate the specific pattern of neural activation observed herein, future studies are needed to explicitly test these alternative explanations.

Materials and Methods

Article Selection. We compiled all papers from a review by Kubota et al. (2) as well as papers categorized as “race” from a meta-analysis on the neural underpinnings of intergroup social cognition (11). We included three additional papers that did not appear in either review, for a total of 22 studies (Table 1). Papers met the following inclusion criteria: majority White sample; conducted within the U.S.; and reported whole brain main effect contrast for Black versus White faces. We coded the zip code of the IRB-approving institution or imaging center, which were linked to county identifiers.

Community-level racial prejudice. This measure came from Project Implicit, a publicly available dataset that links respondents to state- and county-level identifiers. We used the 20 indicators of aggregated explicit racial attitudes that have loaded highly in unidimensional factor models for state-level racism in a prior pre-registered analysis (12) to generate model-based factor scores of community-level racial prejudice (Table 1) for each county (N=1,829 in Project Implicit). We aggregated all responses to the county level irrespective of year queried, consistent with other studies (11, 12).

Additional area-level moderators. Our inferences are strengthened if the observed pattern of neural activation is specific to community-level racial prejudice and not to factors that may be correlated with it. To examine this question, we re-ran our analyses with 4 alternative moderators: a general indicator of inequality (i.e., income inequality); two community-level factors that may influence racial prejudice (i.e., the percentage of the population who is Black or college-educated); and an aggregated measure of implicit racial bias. Details on these measures are provided in the Supplement.

Statistical analysis. We used multilevel kernel density analysis (MKDA) (13) to identify brain areas that consistently show activity to Black vs. White faces. Data were extracted from 24 contrasts in 22 studies with sample sizes ranging from 7 to 60 participants (Table 1). The 2 studies that included 2 contrasts had a fast (~30 ms) and slow (~500 ms) presentation of faces. Peak coordinates were extracted for each significant cluster in which activation was greater to Black than White faces. In MKDA, a 10 mm spherical kernel is then convolved around each of the

peak coordinates from the included studies. A weighted average is then calculated of the resulting contrast indicator maps (CIMs) for each study, where the weight is the square root of the sample size, with studies that used fixed effects instead of random effects analyses down-weighted. Peak coordinates are nested within study CIMs, which are treated as random effects, accounting for the multi-level nature of the data and ensuring that no single study CIM can disproportionately contribute to the meta-analytic result. The resulting weighted average CIM is then compared to a null hypothesis in which peak coordinates are randomly distributed across gray matter (13).

We ran a weighted logistic regression using the `glmfit` function in matlab across every voxel in the contrast indicator maps (CIMs) for the 24 contrasts. Only voxels that were active in at least three CIMs were included. The independent variable was community-level racial prejudice. The outcome variable was whether there was significantly greater activation to Black vs. White faces in a voxel within 10 mm of that voxel in any given study. Weights were applied as described above. In the sensitivity analyses, community-level racial prejudice was replaced by the 4 alternative moderators described above.

Additional details are in the Supplement. Data and code are available at:

https://github.com/dgweissman/stigma_mkda.

Acknowledgments

The authors acknowledge research assistance from Six Yu, Sarah McKetta, and Micah Lattanner.

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Figures

Figure 1. Clusters Where Significant Activation to Black vs. White Faces was More Commonly Observed in Studies Conducted in Counties with Higher Explicit Racial Prejudice

Notes. Based on a meta-analytic voxel-wise weighted logistic regression analysis within the multi-kernel density analysis framework. dlPFC = dorsolateral prefrontal cortex; dACC = dorsal anterior cingulate cortex.

Tables

Table 1. Studies Included in Spatial Meta-Analysis by Location and Community-Level Racial Prejudice

Study	N	Number of Contrasts	Number of Significant Clusters	Study location	Community-Level Racial Prejudice Score
Richeson et al., 2003	15	1	2	Grafton County, NH	-0.444
Brosch et al., 2013	19	1	0	New York County, NY	-0.226
Stanley et al., 2012	40	1	2	New York County, NY	-0.226
Hart et al., 2000	8	1	3	Suffolk County, MA	-0.195
Cunningham et al., 2004	13	2	13	New Haven County, CT	-0.117
Phelps et al., 2000	14	1	0	New Haven County, CT	-0.117
Contreras et al., 2013	17	1	2	Middlesex County, MA	-0.073
Wheeler et al., 2005	7	1	5	Mercer County, NJ	0.003
Hughes et al., 2019	18	1	6	Multiple counties MA	0.039
Brown et al., 2017	19	1	0	Santa Clara County, CA	0.078
Cloutier et al., 2014	45	1	1	Cook County, IL	0.087
Forbes et al., 2011	21	2	11	Pinta County, AZ	0.087
Li et al., 2016	44	1	0	Cook County, IL	0.087
Mathur et al., 2010	28	1	7	Cook County, IL	0.087
Mathur et al., 2012	20	1	2	Cook County, IL	0.087
Mattan et al., 2018	60	1	2	Cook County, IL	0.087
Richeson et al., 2008	9	1	1	Cook County, IL	0.087
Firat et al., 2017	13	1	0	Johnson County, Iowa	0.094
Lieberman et al., 2005	20	1	4	Los Angeles County, CA	0.144
Losin et al., 2012	20	1	16	Los Angeles County, CA	0.144
Losin et al., 2014	20	1	17	Los Angeles County, CA	0.144
Ronquillo et al., 2007	11	1	1	Los Angeles County, CA	0.144

Note: Community-level racial prejudice was mean-centered for analysis. References are provided in the online supplement.

Supplementary Information Text

Materials

Community-Level Racial Prejudice

As described in the main text, we used indicators of aggregated explicit attitudes ($N=20$) from Project Implicit (e.g., “It would not bother me if my new roommate was Black,” “It is likely that Black people will bring violence to neighborhoods when they move in”) that have loaded highly in unidimensional factor models for state-level racism in a prior pre-registered analysis (See Table S1 in reference 12). In that analysis, a factor score was created for each state using exploratory factor analysis with a factor loading cutoff of 0.40. The factor analysis was run iteratively and variables were excluded until all items met the 0.40 threshold. The analysis was performed using PROC FACTOR in SAS 9.4, with the prior communality estimate fixed at squared multiple correlations with all other variables. A 1-factor solution emerged, indicating that these items loaded onto a single construct of state-level racism.

Because in the current study we had county-level identifiers, which are more proximal than state-level identifiers, we developed indicators of community-level racial prejudice at the county level. To do so, we used responses from individuals in the Project Implicit dataset who were queried in the 50 United States and Washington, D.C., between 2002 and 2019. We coded all indicators such that higher values corresponded to higher levels of racial prejudice, then averaged individual responses across 2002-2019 to the county level and mean-standardized those values such that each county had one mean-standardized average value for each indicator. To be consistent with previous work, we factor analyzed the same 20 indicators at the county, rather than the state, level. From this analysis, we generated model-based factor scores of community-level racial prejudice for each unique county ($N=1,829$ in Project Implicit).

To evaluate the reliability of our measure of community-level racial prejudice, Cronbach's alpha was calculated. Using this metric, the measure showed high internal consistency (standardized $\alpha=0.88$). Evidence for the construct validity of aggregate regional measures of explicit racial bias, such as the ones used in the current study, comes from previous studies, which have documented both convergent validity (i.e., associations with other, theoretically

relevant outcomes, including racially charged internet searches) and discriminant validity (i.e., lack of associations with theoretically unrelated outcomes, such as birth rates) (9).

Community-level racial prejudice scores were linked to individual study sites in the meta-analytic database based on county-level identifiers of the study sample (if provided in the individual study) or the research institution of the first author (if not provided in the individual study). For studies that described samples encompassing multiple geographies (i.e., “the greater Boston area”), community-level racial prejudice was scored using the average values for all counties described in that sample.

In the analytic sample (representing N=16 unique counties), the community-level racial prejudice scores ranged from a low of -0.90 to a high of -0.31 (Table 1). These were subsequently mean-centered for the purposes of analysis. Our analytic sample includes a restricted range of possible scores of community-level racial prejudice across US counties in the Project Implicit dataset (low: -1.76, high: 7.09), reflecting that the counties where the target neuroimaging studies were conducted were characterized by lower community-level racial prejudice, on average, than reflected across the entire U.S.

We aggregated all responses to the county level irrespective of year queried. Although this approach reduces measurement error by allowing for all counties to have a sizable number of respondents, regardless of yearly sampling variation, it does not capture temporal trends in community-level racism. However, while explicit racial prejudice has declined nationally over time, the relative levels of prejudice at aggregated units (e.g., states’ rankings relative to other states) have remained highly stable (12), suggesting that a time-invariant measure represents a valid approach.

Additional Area-Level Moderators

To examine whether the observed relationship was specific to community-level explicit racial prejudice, we examined associations using other moderators that are common causes or consequences of racial animus. These were: 1) income inequality, assessed using the GINI which measures area-level income maldistribution, ranging from 0 to 1, where 0 is perfect inequality and 1 is perfect equality; 2) community-level racial composition, operationalized as the

percentage of the total population who is Black; and 3) community-level education, operationalized as the percentage of the adult population over the age 25 who have a college degree or higher. These variables were continuously measured at the county level and made available by the 2010 American Community Survey (ACS) for all US counties. Each was negatively correlated with community-level explicit racial prejudice, with Pearson correlation values of $r = -0.06$ (for income inequality, $p < 0.01$), $r = -0.00$ (for community racial composition, $p = 0.92$), and $r = -0.23$ (for education, $p < 0.01$).

We additionally examined associations with county-level implicit attitudes, measured using an Implicit Association Test (IAT) that assessed the implicit positive preference for White versus Black faces, made available through Project Implicit (14). To assess implicit attitudes at the county level, we aggregated IAT scores from the respondent level, averaged these to the county level across all included study years (i.e., 2002 to 2017), yielding an average score for each county, and mean-standardized these values. The range in our sample was from -0.640 (low) to 0.325 (high).

Statistical Analysis

As described in the main text, we ran a weighted logistic regression using the `glmfit` function in matlab across every voxel in the contrast indicator maps (CIMs) for the 24 contrasts included in the meta-analysis. Only voxels that were active in at least three CIMs were included in analyses. The resulting map was then mapped back in to MNI space using the tool `iimg_reconstruct_vols.m` (<https://github.com/canlab/CanlabCore>).

For the purposes of these analyses, a threshold of $t > 2.81$ ($p < .01$ on 23 df, two-tailed), with a minimum cluster size of $k > 100$ 2-mm voxels was used. This threshold is based on the cluster extents from the traditional MKDA analysis, which are based on Monte Carlo simulations (13), and consistent with the estimated minimum cluster size generated by the original version of Afni's 3dClustSim (15) using a smoothing kernel density of 10 mm, the spherical kernel size used to generate the CIMs.

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