IMPORTANCE Racial discrimination has a clear impact on health-related outcomes, but little is known about how discriminatory experiences are associated with neural response patterns to emotionally salient cues, which likely mediates these outcomes.

OBJECTIVE To examine associations of discriminatory experiences with brainwide response to threat-relevant cues in trauma-exposed US Black women as they engage in an attentionally demanding task.

DESIGN, SETTING, AND PARTICIPANTS A cross-sectional study was conducted from May 1, 2014, to July 1, 2019, among 55 trauma-exposed US Black women to examine associations of racial discrimination experiences with patterns of neural response and behavior to trauma-relevant images in an affective attentional control task. Posttraumatic stress disorder (PTSD) symptoms and trauma exposure were entered as covariates to isolate variance associated with experiences of racial discrimination.

EXPOSURES Varying levels of trauma, PTSD symptoms, and experiences of racial discrimination.

MAIN OUTCOMES AND MEASURES Experiences of Discrimination Questionnaire (EOD) (range, 0-9) for count of the number of situations for which each participant reported having unfair treatment for a racial reason. Experiences of trauma and PTSD symptoms were assessed with the Traumatic Events Inventory (TEI) (number of times the person was exposed to trauma; score range, 0-112) and PTSD Symptom Scale (PSS) (score range, 0-51). Response to trauma-relevant vs neutral distractor cues were assessed via functional magnetic resonance imaging during performance of an affective Stroop (attentional control) task. Statistical analyses were conducted at a whole-brain, voxelwise level with familywise error correction.

RESULTS In this study of 55 Black women in the US (mean [SD] age, 37.7 [10.7] years; range, 21-61 years), participants reported a mean (SD) TEI frequency of 33.0 (18.8) and showed moderate levels of current PTSD symptoms (mean [SD] PSS score, 15.4 [12.9]). Mean (SD) EOD scores were 2.35 (2.44) and were moderately correlated with current PTSD symptoms (PSS total: r = 0.36; P = .009) but not with age (r = 0.20; P = .15) or TEI frequency (r = –0.02; P = .89). During attention to trauma-relevant vs neutral images, more experiences of racial discrimination were associated with significantly greater response in nodes of emotion regulation and fear inhibition (ventromedial prefrontal cortex) and visual attention (middle occipital cortex) networks, even after accounting for trauma and severity of PTSD symptoms (brainwide familywise error corrected; r = 0.33 for ventromedial prefrontal cortex; P = .02). Racial discrimination was also associated with affective Stroop task performance; errors on trials with threat-relevant stimuli were negatively correlated with experiences of racial discrimination (r = –0.41; P = .003).

CONCLUSIONS AND RELEVANCE These findings suggest that experiences of racial discrimination associate with disproportionately greater response in brain regions associated with emotion regulation and fear inhibition and visual attention. Frequent racism experienced by Black individuals may potentiate attentional and regulatory responses to trauma-relevant stressors and lead to heightened modulation of regulatory resources. This may represent an important neurobiological pathway for race-related health disparities.
Racial discrimination, which refers to the differential and unfair treatment because of a person's racial or ethnic background, is increasingly recognized as a substantial influence on physical and mental health outcomes in communities of color. Discriminatory and racial experiences have been defined as both overt and implicit ways in which a person experiences unfair or disadvantaged treatment (within social, occupational, or other situations) as a result of their race/ethnicity. Experiences of racial discrimination are common for racial and ethnic minority populations in the US, with an overwhelming majority (ie, 90%-98%) of Black individuals reporting experiences of racial discrimination during their lives. Prior social neuroscience research has identified neural correlates of prejudicial responses, which primarily encompass stress response networks. However, this research has generally focused on understanding the neural basis of racial prejudice, rather than the effects of such prejudice among racial minority groups.

As such, there is a paucity of data on the effects of racism on the brain, particularly among Black communities that have faced frequent trauma exposure and lifetime adversity; the need for this type of neurobiological research has been recently highlighted. Some evidence suggests that racial discrimination has an adverse, additive effect with respect to existing mental health difficulties. Lower total brain matter volume has been found in adults with depression who reported experiences of racial discrimination. In a study using a social interaction paradigm with Black participants, the authors found increased response in networks associated with pain and emotion regulation (insula, ventrolateral prefrontal cortex, and rostral anterior cingulate cortex) in participants during social exclusion trials and reported that attributions of social exclusion to discrimination were associated with increased activity in regulatory prefrontal brain regions, including the rostral anterior cingulate cortex. Furthermore, a recent study of mostly Black participants observed that greater spontaneous amygdala activation at rest and greater connectivity between the amygdala and regions involved with expression of threat response, such as the dorsal anterior cingulate cortex, were associated with more experiences of racial discrimination. These studies highlight the involvement of threat detection and regulation systems as well as social pain networks in association with experiences of racism.

Prior studies also provide support for the hypothesis that racism, similar to other types of social stress, may have a kindling effect on the brain, specifically with respect to threat-processing networks. A heightened attentional detection of racism-related threat, as well as increased efforts to regulate response to these threats over time, may emerge in people who have been exposed to chronic racism. The kindling hypothesis is also a proposed mechanism for the development of stress-related disorders such as posttraumatic stress disorder (PTSD). Over time, experiences of racism, such as discrimination, may sensitize threat response systems, whereby more frequent exposure to racism produces chronically heightened vigilance for potential threat. Racial discrimination is a form of racism that chronically activates the stress-response system via anticipation of further discrimination, as previously described. This heightened threat vigilance can encumber the body's stress response system, thereby affecting available physical and mental resources. There is some evidence to suggest that exposure to racism depletes cognitive reserve and impairs performance on attentional control and executive functioning tasks, such as the Stroop task. Overall, experiences of racism may adversely impact cognitive and emotional processes (evident in cross-sectional and longitudinal studies) through increased vigilance for racism-related threats and regulation of response to these threats. This experience may enhance the risk for health problems ranging from cardiac and metabolic disorders to infectious disease.

The neuroscience of racism has been extensively investigated from the perspective of the perpetrator (eg, implicit bias experiments with White participants). However, there are few data on how racism affects neural circuitry in the individuals who are targets of racism. These individuals already bear a disproportionate burden of risk for adverse psychological and health outcomes. Racist experiences, via their association with threat vigilance and threat regulation systems, may place a burden on attentional processes. This burden can affect the efficiency of these systems as well as the availability of attentional resources for goal-directed activities.

Although I study has examined associations between racial discrimination and amygdala response at rest, to our knowledge, no studies have examined the unique links between racial discrimination and neural response patterns throughout the brain during attention to threat cues in a trauma-exposed, community sample of Black individuals. Given that threat-processing networks appear to be associated with experiences of discrimination, our goal in this cross-sectional study was to examine the unique associations of racial discrimination with brainwide patterns of response during performance of an attentional control task that includes threat-relevant stimuli: the affective Stroop task. We were interested in exploring brain and behavior responses that were relevant to experiences of discrimination. To isolate the associations of racial discrimination with neural response to threat in our sample, we accounted for variance associated with trauma exposure and PTSD symptoms. We also explored the association between racial discrimination and disruptions in...
attentional control from a behavioral perspective, investigating how racial discrimination was uniquely associated with affective Stroop task performance for threat-relevant trials (with respect to error rates and response times). These data may reveal a way through which cumulative experiences of racial discrimination may be associated with response in regions within networks involved with detection and regulation of threat response, highlighting a potential mechanism for race-related health disparities.

### Methods

#### Participants

This study was conducted from May 1, 2014, to July 1, 2019. Fifty-five Black women in the US aged 22 to 61 years (mean [SD] age: 37.7 [10.7] years) were recruited from a National Institutes of Health–funded study of attentional control in women with PTSD (study MHI01380); this study was part of the Grady Trauma Project, which represents a collaboration of studies investigating risk and resilience for trauma-related disorders (including studies HD071982, MHO71537, and MHO94757). As part of the Grady Trauma Project, participants are approached in the general medical clinics (obstetrics-gynecology, diabetes, and internal medicine) of a publicly funded hospital serving primarily low-income individuals in inner-city Atlanta, Georgia. After participants provided informed consent, clinical assessments, including assessments of trauma and PTSD symptoms, were administered. Participants who reported trauma and either no PTSD symptoms or varying degrees of PTSD symptoms were asked to return for a magnetic resonance imaging (MRI) scan; procedures are further described in the eMethods in the Supplement. Clinical and demographic characteristics are detailed in Table 1. Race was self-identified by participants in this study. The Emory University institutional review board approved this study, and written informed consent was received from all participants.

#### Clinical Assessments

We administered the following assessments, detailed further in the eMethods in the Supplement. The Traumatic Events Inventory (TEI) was administered to measure lifetime trauma exposure, inclusive of childhood and adult trauma; trauma frequency (number of times the person was exposed to trauma; score range, 0-112) was the TEI index included as a covariate in statistical analyses. The PTSD Symptom Scale (PSS; score range, 0-51) was administered on the day of the MRI scan, and the result was used as a covariate for all analyses, given the presence of PTSD symptoms in some participants. Participants also completed the Experiences of Discrimination Questionnaire (EOD). The EOD total score (range, 0-9) reflects a count of the number of situations for which each participant reported having unfair treatment for a racial reason; this score was used as an index of racial discrimination.

#### MRI Acquisition and Image Processing

Magnetic resonance imaging scanning was conducted on a research-dedicated Siemens 3-T TIM-Trio scanner (12-channel head coil) at Emory University Hospital. Acquisition parameters and image-preprocessing details are provided in the eMethods in the Supplement.

#### Functional MRI Task: Affective Stroop Task

The affective Stroop task is a measure of attentional control that has been detailed in earlier studies (further described in the eMethods in the Supplement). Participants were asked to rapidly identify, via button press, the amount of numbers displayed (3, 4, 5, or 6) while ignoring distractor images (trauma-relevant, positive, and neutral scenes) that appeared prior to and after each number stimulus (efigure 1 in the Supplement). In some trials, the amount of numbers was incongruent with the actual number displayed. In addition, the task included trials with no cognitive demands (“view-only” trials). Error rates and response times were recorded and analyzed. Behavioral data were excluded from behavioral data analyses for 2 participants because of excessive errors on trials (>50%); these participants reported that their performance was affected by high levels of anxiety.

#### Functional MRI Data Analysis

We describe patterns of brainwide response in the entire sample to different affective Stroop task trials, including trauma-relevant (eTable 2 and eFigure 2 in the Supplement) and positive distractor trials (eTable 2 and eFigure 3 in the Supplement), in the eResults in the Supplement. Our primary objective was to examine the association between neural responses to trauma-relevant (both number-incongruent and number-congruent trials) vs neutral distractor trials (both number-
incongruent and number-congruent trials) and racial discrimination (EOD total).

To examine blood oxygen–level dependent signal change to task stimuli, a first-level, fixed-effects analysis was conducted. Onset times for each task condition were entered into a general linear model, convolved with a hemodynamic response function, and linear contrasts between conditions were estimated. Participant-specific motion parameters were also included in the model as effects of noninterest. Given our interest in examining neural response to threat-related stimuli, and in accordance with our earlier studies using this task, our primary contrast of interest was trauma-relevant vs neutral distractor trials (including number-incongruent and number-congruent trials, as well as view-only trials).27 Events included the distractor and number stimuli for task trials and distractors for view-only trials.

Given that our primary objective was to examine associations between racial discrimination and response to threat-relevant vs neutral images, the EOD total score was entered as a participant-level regressor in a multiple regression model in SPM8 software (The Wellcome Centre for Human Neuroimaging, UCL Queen Square Institute of Neurology). Given that some participants reported current PTSD symptoms, we accounted for the effects of PTSD symptoms in analyses; PSS total scores were entered as covariates for this contrast of interest. Statistical analyses were conducted at a whole-brain, voxelwise level for this contrast; given that few studies examined neural responses associated with racism, we did not restrict analyses to any particular regions of interest. To reduce type I error inflation due to multiple comparisons testing, we used a whole-brain statistical threshold of $P < .05$ with voxelwise, familywise error (FWE) correction (provided in SPM8). To account for the possible effects of trauma, we repeated this analysis using trauma exposure (TEI frequency) as a covariate; given that trauma exposure and PTSD symptoms are collinear in this population,28 including this sample ($r = 0.32; P = .02$), these covariates were entered in 2 separate models to avoid model overfitting.

**Statistical Analysis**

Partial correlations were completed to explore associations between racial discrimination and affective Stroop task performance (error rate and response time) during trauma-relevant trials (number-congruent and number-incongruent trials combined). Similar to functional MRI analyses, we accounted for variance associated with PTSD symptoms and trauma exposure in 2 separate models. Given that the covariates were examined in separate models, we used a Bonferroni-corrected threshold of $P < .025$, 2-tailed, to define statistical significance. Analyses were conducted with SPSS, version 25 (IBM Corp).

### Results

#### PTSD Symptoms, Trauma, and Racial Discrimination

Descriptive statistics on trauma exposure, PTSD symptoms, and racial discrimination for this sample of 55 Black women living in the US (mean [SD] age, 37.7 [10.7] years; range, 21-61 years) are provided in Table 1. Participants reported a mean (SD) TEI frequency of 33.0 (18.8) (similar to previous Grady Trauma Project studies28-30) and showed moderate levels of current PTSD symptoms (mean [SD] PSS, 15.4 [12.9]). Racial discrimination (EOD) scores ranged from 0 to 9 and were moderately correlated with current PTSD symptoms (PSS total: $r = 0.36$; $P = .009$), but not with age ($r = 0.20$; $P = .15$) or TEI frequency ($r = -0.02$; $P = .89$).

#### Functional MRI Data

After accounting for current PTSD symptoms, greater racial discrimination experiences were significantly associated with increased blood oxygen level–dependent (BOLD) responses within visual attention regions (middle occipital cortex) and emotion regulation and fear inhibition regions (ventromedial prefrontal cortex [vmPFC]) during trauma-relevant distractor trials vs neutral distractor trials (Table 2). Figure 1A illustrates the regions that showed significant positive correlations with EOD score during these trauma-relevant vs neutral distractor trial conditions. These findings were sustained when analyses were repeated with trauma exposure as a covariate (Table 3). Figure 1B illustrates the correlation between vmPFC activation and EOD score ($r = 0.33$). Activation in this region was not associated with age ($r = 0.07; P = .62$). In terms of negative correlations, no results survived the voxelwise FWE threshold.
Behavioral Data

Descriptive statistics on affective Stroop task performance, including mean error rates and response times to affective Stroop task trials, are provided in eTable 1 in the Supplement. We examined associations between experiences of discrimination and affective Stroop task performance. After accounting for current PTSD symptoms (PSS total), racial discrimination experiences (EOD total) were associated with significantly fewer overall errors on trauma-relevant distractor trials ($r = -0.41; P = .003$; partial correlation plot with residuals provided in Figure 2). Similarly, after accounting for trauma exposure (TEI frequency), racial discrimination experiences were associated with significantly fewer overall errors in trauma-relevant distractor trials ($r = -0.39; P = .004$). No significant correlations were observed between discriminatory experiences and response time for trauma-relevant distractor trials after accounting for PTSD symptoms or trauma experiences.

Discussion

The objective of the present study was to identify unique associations of racial discrimination with neural responses during performance of an affective attentional control task in a community sample of Black women living in the US exposed to trauma. To our knowledge, this is the first study to examine associations of racial discrimination experience with brainwide patterns of neural response to emotionally salient images among a Black population with high trauma exposure. We observed that, compared with participants who reported fewer racially discriminatory experiences, participants who reported more racial discrimination experiences showed heightened reactivity to trauma-relevant images in components of visual attention and emotion regulation and fear inhibition networks, including the vmPFC, even after accounting for variance associated with PTSD symptoms or trauma experiences.
experiences of racism are associated with greater vigilance for relevant (ie, threat) cues within regions of the visual attention network, which engage to deploy attentional resources to salient stimuli, and the vmPFC is involved with regulation of threat response. In the present analyses, we observed an association between racially discriminatory experiences and neural reactivity to trauma-relevant (ie, threat) cues within regions of the visual attention network, including middle occipital gyrus regions, as well as the vmPFC. Taken together, our findings suggest that experiences of racism are associated with greater vigilance for potential threat and heightened response within threat-inhibition networks in response to threat cues. As such, these discriminatory experiences may be associated with greater preparedness for threat and suppression of the threat response.

We observed a negative association between discriminatory and affective Stroop task performance on more difficult threat-relevant distractor trials. Thus, experiences of racism were not associated with deficiencies in attentional control, but rather with heightened activation in emotion regulation and threat inhibition regions, which can disproportionately encumber and drain these resources over time. One proposed pathway linking racism to adverse health outcomes is via increased self-regulation (ie, heightened attempts to manage responses to racism). Experiences of racism have a resource cost, both with respect to threat detection and regulation of threat response, and some studies have shown that racial experiences adversely affect performance on attention and executive functioning tasks, such as the Stroop task. Although discriminatory experiences were not associated with poorer Stroop performance in our study, it is possible that, in participants with more discriminatory experiences, task performance was preserved at the cost of efficiency in regulatory networks. The use of compensatory strategies at the cost of efficiency is also observed in the context of general anxiety. Attentional control theory describes ways in which high anxiety may not impair performance effectiveness on attentional control tasks, but the use of compensatory strategies encumbers attention network efficiency.

There are different potential pathways through which racism can exert adverse effects on biological systems, including chronic overactivation of the hypothalamic-pituitary-adrenal axis and subsequently high allostatic load. Theoretical models applied to anticipatory race-related stress, such as prolonged activation theory, elaborate on ways in which racism can be associated with overburdened systems via increased vigilance for racism-related threat; this stress may, in turn, increase vulnerability for physical and mental health problems.

Our findings complement a growing literature on the associations between disparate stressor exposure and neurobiological outcomes in marginalized racial/ethnic groups. Although the prevalence of PTSD symptoms clearly differs between Black and White individuals in the US, limited studies have investigated how differences in response to stressors play a role in these disparities. Disproportionate stressor exposure has been reported to be linked to racial differences in neural reactivity to threat within key nodes such as the vmPFC. Our findings demonstrate that racial discrimination—a stressor experienced by an overwhelming majority of Black individuals—was associated with increased vmPFC activity to trauma-relevant cues. Racial discrimination is known to be associated with biological stress systems, and can exacerbate the development and expression of PTSD symptoms. Given the critical role of the vmPFC in PTSD, our findings suggest that racism has unique associations with the function of this regulatory region, which has implications for the neurobiology of PTSD and threat response in general in marginalized populations. These data highlight the need for further PTSD research that addresses the association of the intersection of trauma and racial inequities with neurobiological response.
Alternatively, the proportionally greater vmPFC response observed in association with discrimination may represent a resilient adaptation to stress. Prior literature on trauma exposure and PTSD symptoms suggest that increased vmPFC response (and volume) reflects resilience to trauma and adaptive threat response, including efficient extinction of conditioned fear responses. As such, it is possible that the findings observed in this study indicate a relatively enhanced ability to manage stress related to discrimination experiences. Coupled with the behavioral data that demonstrated better attention performance on threat-relevant affective Stroop task trials in association with discrimination experiences, the functional MRI findings may illustrate a biological marker of resilience and/or protective adaptation in the face of racism-related stressors in this sample of Black women in the US exposed to trauma.

Limitations
We acknowledge some limitations to the present study. For one, only Black women were included in the sample, thus precluding our ability to assess potential sex differences in behavioral or neural responses associated with discrimination. Future studies should seek to replicate these findings in larger, racially, ethnically, and sexually diverse cohorts. Furthermore, we did not examine mechanistic pathways for the outcomes observed; promising avenues of future investigation include investigations of the association of discrimination with stress regulation and the immune system. The current analysis also used a broad assessment of racial discrimination. A more detailed measurement of racist acts and behaviors, as well as identification of events linked to rumination, is warranted to characterize specificity of neurobiological response to these stressors. Furthermore, experimental manipulations, including social interaction tasks, may reveal ways in which experiences of discrimination (occurring in real time) may be associated with goal-directed attention.

Conclusions
This cross-sectional study of 55 Black women in the US exposed to trauma found that in the context of attention to threat-relevant stimuli, those who experienced more racism showed increased response within key nodes of visual attention and emotion and fear regulation network regions, even after accounting for variance associated with trauma and PTSD symptoms. These findings highlight the value of assessing racial discrimination in trauma research, and demonstrate associations between racism and responses to threat stimuli. Taken together, the results of this study reveal how racial discrimination is associated with threat vigilance and modulation of attentional response. The findings suggest a potential pathway through which health disparities may emerge for Black individuals; conversely, these data could also illustrate an adaptive calibration to racism-related stress.

ARTICLE INFORMATION
Accepted for Publication: April 19, 2021.
Published Online: July 28, 2021.

Author Contributions: Dr Fani had full access to all of the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Fani, Carter, Bradley.

Acquisition, analysis, or interpretation of data: Fani, Carter, Harnett, Ressler.

Drafting of the manuscript: Fani, Carter, Harnett.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Fani, Carter, Harnett.

Obtained funding: Fani, Ressler.

Administrative, technical, or material support: Fani, Carter, Bradley.

Supervision: Fani, Ressler, Bradley.

Conflict of Interest Disclosures: Drs Fani, Carter, and Harnett reported receiving grants from the National Institutes of Health (NIH/National Institute of Mental Health and National Cancer Institute) during the conduct of the study. Dr Ressler reported serving on scientific advisory boards for Janssen, Takeda, and Verily; receiving grants from the NIH and Brainsway; and receiving personal fees from Janssen, Alkermes, Genomind, and Bioxcel outside the submitted work. Dr Bradley reported receiving grants from the NIH during the conduct of the study. No other disclosures were reported.

Funding/Support: This study was supported by grants MH08380, MH071537, MH094757, MH119603 from the National Institute of Mental Health; grant HD071982 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development; the Emory Medical Care Foundation; the American Psychological Association; the Society for Clinical Neuropsychology; grant CA220254-02 from the National Cancer Institute, and the Frazier Foundation Grant for Mood and Anxiety Research at McLean Hospital.

Role of the Funder/Sponsor: The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Contributions: We thank the members of the Grady Trauma Project and the Fani Affective Neuroscience Laboratory for their assistance with data collection. We thank Timothy Ely, BS, Department of Psychiatry and Behavioral Sciences, Emory University, for his technical assistance; his assistance was part of his work as a neuroimaging data analyst, which is a paid position. We thank the participants of the Grady Trauma Project for their time and involvement in this study.

REFERENCES


9. Masten CL, Telzer EH, Eisenberger NI. An fMRI investigation of attributing negative social

jamapsychiatry.com

© 2021 American Medical Association. All rights reserved.


