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Neural responses to gender-based microaggressions in academic medicine

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Abstract

Gender-based microaggressions have been associated with persistent disparities between women and men in academia. Little is known about the neural mechanisms underlying those often subtle and unintentional yet detrimental behaviors. Here, we assessed the neural responses to gender-based microaggressions in 28 early career faculty in medicine ($N = 16$ female, $N = 12$ male sex) using fMRI. Participants watched 33 videos of situations demonstrating gender-based microaggressions and control situations in academic medicine. Video topics had been previously identified through real-life anecdotes about microaggression from women faculty and were scripted and reenacted using professional actors. Primary voxel-wise analyses comparing group differences in activation elucidated a significant group by condition interaction in a right-lateralized cluster across the frontal (inferior and middle frontal gyri, frontal pole, precentral gyrus, postcentral gyrus) and parietal lobes (supramarginal gyrus, angular gyrus). Whereas women faculty exhibited reduced activation in these regions during the microaggression relative to the control condition, the opposite was true for men. Posthoc analyses showed that these patterns were significantly associated with the degree to which participants reported feeling judged for their gender in academic medicine. Lastly, secondary exploratory ROI analyses showed significant between-group differences in the right dorsolateral prefrontal cortex and inferior frontal gyrus. Women activated these two regions less in the microaggression condition compared to the control condition, whereas men did not. These findings indicate that the observation of gender-based microaggressions results in a specific pattern of neural reactivity in women early career faculty.

KEYWORDS
academic medicine, fMRI, gender-based microaggressions, sex differences

1 | INTRODUCTION

Gender-based microaggressions have been associated with persistent disparities between women and men in academic medicine (Periyakoil et al., 2020; Torres et al., 2019). Microaggressions are "subtle verbal or nonverbal behaviors that may arise from unconscious biases, covert prejudice, or hostility" (Paludi, 2012; Periyakoil et al., 2020). According to Torres et al. (2019), microaggressions could entail (1) *microassaults* that are clearly intended to offend the recipient (e.g., "They are letting women be doctors now?"), (2) more subtle

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and potentially unintentional *microinsults* (e.g., women physicians are confused for the nurse), (3) *microinvalidations* (e.g., invalidating a woman's experience of inequality by calling them oversensitive), and (4) *environmental microaggressions* (e.g., hallways being decorated with pictures of white male surgeons; Torres et al., 2019).

While microaggressions are fleeting, everyday occurrences (Periyakoil et al., 2020) and often consist of unintentional indignities and insults (Sue, 2010), they can have considerable consequences for the receiver. Empirical studies show that gender-based microaggressions decrease (immediate) performance outcomes such as in math tasks (i.e., "stereotype threat"; Spencer et al., 1999), reduce job satisfaction (Chan et al., 2008) and organizational commitment (Foley et al., 2005), lower beliefs in career advancement (Fassiotto et al., 2016; Herrbach & Mignonac, 2012), and take a negative toll on self-esteem (Casad et al., 2019) and income (National Academies of Sciences, Engineering, and Medicine et al., 2017). Extant research in this area also shows that gender-based microaggressions can facilitate the experience of physical pain due to social exclusion (Cogoni et al., 2018; Zhang et al., 2021) and trigger a cycle of rumination and self-doubt that may ultimately result in women choosing to leave their workplace (Kim & Meister, 2022). Moreover, microaggressions have been linked to increased levels of distress (Chan et al., 2008) that can lead to deleterious effects on health outcomes such as depression and anxiety (Feigt et al., 2022; Nadal et al., 2013). Such adversities are likely to be further aggravated for women of color and those with disabilities (Olkin et al., 2019; Wilkins-Yel et al., 2019). Elucidating the neural basis of these biased behaviors can potentially help reduce gender disparities in academic medicine.

Functional magnetic resonance imaging (fMRI) provides one approach toward understanding the neural correlates of gender-based microaggressions. Emerging work in this area demonstrates that social exclusion behaviors that target women elicit activation in areas linked to the affective component of pain (i.e., anterior cingulate cortex, paracingulate cortex, anterior insula) in both women and men observers (Cikara et al., 2011; Cogoni et al., 2018; Zhang et al., 2021). Results from fMRI studies also suggest associations between gender-based microaggressions and activation in regions linked to mentalizing[1] processes (i.e., medial prefrontal cortex, posterior cingulate cortex, temporoparietal junction; Cikara et al., 2011; Cogoni et al., 2018). These mentalizing patterns seem less pronounced when visual stimuli involve sexually objectified women (Cikara et al., 2011; Cogoni et al., 2018), suggesting that gender stereotypes can alter neural responses. A third cluster of fMRI studies has linked prefrontal regions (i.e., dorsolateral prefrontal cortex and inferior frontal gyrus) to the cognitive regulation of social exclusion stimuli (Dardenne et al., 2013; Mitchell et al., 2009). Taken together, these early findings suggest that observing gender-based microaggressions can elicit neural responses associated with the affective component of pain, mentalizing processes, and cognitive regulation of social exclusion stimuli. Little is known about how these neural mechanisms translate to gender-based microaggressions, specifically in the context of women in academic medicine, a field in which women do not advance or remain in their careers in parity with men (Fassiotto et al., 2016; Jolliff et al., 2012; Periyakoil et al., 2020). Creating an understanding of neural mechanisms associated with microaggressions, as they are experienced in real life by women faculty, can inform the development of effective behavioral interventions.

Significance

Elucidating the underlying neural mechanisms associated with gender-based microaggressions will generate practical implications for women faculty. Our empirical findings can help craft effective behavioral interventions (e.g., belonging [Brady et al., 2020]) tailored to reduce gender biases in academic medicine. For example, our findings might suggest that women faculty could benefit from repeated exposure interventions that "normalize" gender equity in academia. The results of this study can also inform the development of fNIRS neurofeedback paradigms (e.g., Liu et al., 2016) that can provide women (and men) faculty with vital information to voluntarily regulate their behavior in real-time.

In this study, we assessed neural responses to gender-based microaggressions in women and men early career faculty in medicine across all brain areas using voxel-wise fMRI analyses. We hypothesized that relative to men, women faculty would exhibit a different pattern of neural responding during gender-based microaggressions (relative to control video clips). In secondary analyses, we explored potential group differences in specific brain regions known to subserve the affective component of pain, mentalizing, and the cognitive regulation of social exclusion. Finally, we explored potential associations between questionnaire measures of perceived gender biases and neural functioning.

2 | METHOD AND MATERIALS

2.1 | Experimental subjects

A total of 28 early career faculty in medicine at Stanford University School of Medicine ($N = 16$ female and $N = 12$ male sex; all cis gender) across all faculty lines (i.e., clinical educator line, instructor, medical center line, non-tenure line, and university tenure line) participated in the study. We recruited participants through advertisements in Stanford School of Medicine email lists. All participants were healthy, right-handed, and had normal or corrected to normal hearing and vision. Exclusion criteria for the study comprised: major medical conditions (e.g., diabetes, heart disease, chronic renal disease), neurological conditions (e.g., epilepsy, traumatic brain injury, concussion), learning disabilities, psychiatric conditions (i.e., attention deficit disorder, obsessive-compulsive disorder, bipolar, schizophrenia, anxiety, and major depressive disorder), and MRI contraindications (metallic implants, orthodontia,

pregnancy). All participants were instructors, or assistant or associate professors from the Departments of Anesthesia, Chemical and Systems Biology, Comparative Medicine, Medicine, Neurology and Neurological Sciences, Neurosurgery, Obstetrics & Gynecology, Ophthalmology, Otolaryngology, Pathology, Pediatrics, Psychiatry & Behavioral Science, and Radiology. The mean age of participants was 37.82 ± 6.93 years, and participants held their academic position an average of 2.45 ± 2.14 years. The racial and ethnic composition of the sample was 7% African American/Black, 25% East Asian, 4% Hispanic/Latino, 4% Middle Eastern, 4% Native Hawaiian/Pacific Islander, 14% Southeast Asian, and 42% White/Caucasian.

2.2 | Experimental design and procedures

2.2.1 | Functional MRI task design

Participants watched paired video clips (gender-based microaggressions and matched controls) of real-life situations in academic medicine while being scanned. The video clips were developed by one of the authors (VSP) through "Project Respect" (https://respect.stanford.edu). In the project, real-life anecdotes about microaggressions in academic medicine and healthcare were collected, reenacted with professional actors, and validated. In this study, we used 33 pairs of video clips from the project library that specifically focused on gender issues in academic medicine (Periyakoil et al., 2020). The video pairs contained similar scene settings (e.g., same environment, equal number of actors per scene, and similar number of words spoken). The gender-based microaggression condition displayed videos in which female faculty experienced gender-based microaggressions from fellow male faculty, while the control condition displayed equitable interactions. Figure 1 shows one scene from three example pairs of videos. We presented videos in a pseudorandom order. The selected videos have been validated as stimuli to induce gender-based microaggressions in academic medicine (Periyakoil et al., 2020).

We presented the stimuli using E-Prime, version 2 (Psychology Software Tools), using a video projector that illuminated a rear projection screen at the end of the magnet. Participants viewed the stimuli through an adjustable mirror attached to the head coil. We divided the task into two separate runs, in which the video clips were pseudo-randomized to avoid order effects. Each run began and ended with a fixation crosshair for 10 s. Video clips lasted for a mean of 18.5 ± 7.6 s (range: six to 35 s). Two-tailed *t*-tests indicated there were no significant differences between the two conditions regarding video duration ($t(32) = .063$, $p = .950$, microaggression condition: 18.4 ± 7.7 s, control condition: 18.5 ± 8.0 s) or spoken word count ($t(32) = 1.175$, $p = .249$, microaggression condition: 51.8 ± 26.8 words, control condition: 49.9 ± 26.1 words). A rating screen appeared for two seconds following each video clip. Participants indicated using a button press whether they felt "comfortable" or "uncomfortable" while watching each video clip. We separated trials by a variable intertrial interval that ranged from 2 to 30 s.

FIGURE 1 Examples of gender-based microaggressions scenarios (left) and the corresponding social situations of equity (right).

2.2.2 | MRI data acquisition

We obtained functional MRI data using a GE 3T MR750 whole-body MR system with an 8-channel head coil. We coronally acquired T1-weighted structural images of the brain using a fast spoiled gradient (FSPGR) echo sequence, with slice thickness = 1.6 mm, repetition time (TR) = 8.2 ms, echo time (TE) = 3.24 ms, inversion time (TI) = 450 ms, flip angle = 15°, 124 slices, matrix = 256 × 256, and scan duration 7:37 min. We also acquired T2*-weighted functional images of the brain during the performance of each of the two task runs using a spiral in/out sequence with TR = 2000 ms, TE = 30 ms, flip angle = 80°, FOV = 22 cm × 22 cm, 30 slices, matrix = 64 × 64, slice thickness = 4 mm, gap = 1 mm. The scan duration of the first run was 7:41 min. The second run lasted 8:07 min.

2.2.3 | Functional MRI data preprocessing

We preprocessed functional MRI (fMRI) data using FSL (FMRIB Software Library), version 5.0.10, using FEAT (FMRI Expert Analysis Tool), version 6.0.0. We discarded the first three volumes of each scan to allow for the stabilization of longitudinal magnetization and preprocessed the remaining images using a series of steps. First, we removed non-brain material from anatomical and functional images using the Brain Extraction Tool (Smith, 2002). Then, we conducted motion correction to the mean image (Jenkinson et al., 2002), spatial smoothing using a Gaussian smoothing kernel of 6-mm FWHM, and high-pass temporal filtering (Woolrich et al., 2001). We performed linear registration using FMRIB's Linear Image Registration Tool to linearly align each individual's functional data to his/her high-resolution anatomical image (Jenkinson & Smith, 2001) and to align each individual's anatomical image to the Montreal Neurological Institute (MNI) standard space image (Mazziotta et al., 1995, 2001).

2.2.4 | Questionnaire measures (demographics and personality traits)

After completing fMRI scans, participants completed a battery of personality measures, including personality traits, work locus of control, sense of belonging, and a gender judgment questionnaire.

Personality trait

Participants completed the NEO Five-Factor Inventory-3 (NEO-FFI-3) (McCrae & Costa, 2007). We calculated *T*-scores for the Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness subscales.

Work locus of control

Participants completed the Work Locus of Control Survey (Spector, 1988) and we calculated the final score as the sum of all 16 items.

Sense of belonging

Participants rated their sense of belonging based on Walton and Cohen's 6-item social fit scale (Walton & Cohen, 2007) (e.g., "I feel like I belong in my department"; 1 = strongly disagree, 7 = strongly agree; Cronbach's Alpha for the survey was $\alpha = .82$) and we calculated the final score as the average of all six items.

Gender judgment questionnaire

Lastly, participants rated their perceived feeling of being judged in their workplace on the basis of their gender (i.e., "I feel that people in academic medicine will think about my gender when judging me") on a 7-point Likert scale ranging from "strongly disagree" to "strongly agree."

2.3 | Statistical analyses

2.3.1 | Questionnaire measures (demographics and personality traits)

We first ran a series of independent t-tests or non-parametric Mann–Whitney U tests for Likert scale metrics to assess whether there were group differences in *age*, *time in rank*, personality traits (i.e., *NEO-FFI-3 T scores)*, *work locus of control*, *sense of belonging*, and *gender judgment*. We conducted all statistical analyses using the Statistical Package for Social Sciences (SPSS version 22.0, IBM Corp., Armonk, NY, USA) and a two-tailed α level of .05.

2.3.2 | Behavioral data analyses (ratings of project respect video clips)

Our next aim was to assess whether there were behavioral differences in video clip ratings between the two groups. Specifically, we were interested in contrasting the condition-rating type "microaggression-uncomfortable" with "control-comfortable." We applied a repeated measures GLM that modeled condition (microaggression, control) as a repeated measure, group (women, men) as a fixed factor, and proportion of video clips rated as comfortable versus uncomfortable as the dependent variable.

2.3.3 | Primary fMRI analyses

To more specifically elucidate neural responses to the videos in our sample, we selected trials for fMRI analyses on an individual participant basis. That is, we only included microaggression trials that were rated as uncomfortable and control trials that were rated as comfortable for initial level analyses for each participant. The aim of these primary fMRI analyses was to compute individual-specific activation summary maps for the microaggression minus control contrast to test for voxel-based group differences in activation.

Because each participant had two task runs, we conducted time-series statistical analyses at a single-run intraindividual level using a generalized linear model (GLM). The GLM modeled each condition and rating type (control-comfortable, control-uncomfortable, microaggression-comfortable, microaggression-uncomfortable) using a synthetic hemodynamic response function and its first derivative. The model also contained motion correction parameters and time points that exceeded a motion threshold (75th percentile plus 1.5 times the interquartile range) defined by FSL's motion outliers tool (http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FSLMotionOutliers). We combined both runs in a fixed effects analysis for each participant to provide individual-specific summaries of activation. We then carried the contrast maps to higher-level random-effects analyses using FMRIB's Local Analysis of Mixed Effects (FLAME; Woolrich, 2008) to assess the interaction of group (men, women) by condition (microaggression, control). We thresholded the resulting statistical images at $Z > 1.96$ and a cluster probability of $p < .01$, corrected for whole-brain multiple comparisons using Gaussian random-field theory (Worsley, 2001).

2.3.4 | Secondary fMRI analyses: Associations between activation and questionnaire measures

We explored potential associations between activation and questionnaire measures. For these analyses, we extracted activation values for the contrast of microaggression versus control separately for every subject from each significant cluster resulting from our primary fMRI analyses. Activation values were then fed into a univariate GLM to test for a main effect of questionnaire score and an interaction effect of questionnaire score and group (men, women). To reduce the number of multiple comparisons, we restricted association analyses to questionnaire measures that varied as a function of group.

2.4 | Secondary fMRI analyses: Regions of interest analyses

We also conducted region of interest (ROI)–based analyses to target brain areas directly involved in the affective component of pain (i.e., anterior cingulate cortex, paracingulate cortex, anterior insula; Cikara et al., 2011; Cogoni et al., 2018; Masten et al., 2011; Zhang et al., 2021), mentalizing (i.e., medial prefrontal cortex, posterior cingulate cortex, temporoparietal junction; Amodio & Frith, 2006; Cikara et al., 2011; Cogoni et al., 2018; Frith & Frith, 2003), and the cognitive regulation of social exclusion stimuli (i.e., dorsolateral prefrontal cortex and inferior frontal gyrus; Amodio, 2014; Aron et al., 2004; Dardenne et al., 2013; Forbes et al., 2012; Hampshire et al., 2010; He et al., 2018; Kubota et al., 2012; Mitchell et al., 2009; Moyal et al., 2014; Richeson et al., 2003; Zhao et al., 2021). Using the Harvard-Oxford cortical and subcortical structural atlases, we identified anatomical subregions in MNI template space. We included voxels having a probability of 25% or greater and split each region into left and right hemispheres. From each of the resulting ROIs, we extracted signal change values for each participant's microaggression versus control contrast from the entire study sample using FSL's featquery tool. We analyzed signal change values for microaggression versus control separately for each region using two-tailed *t*-tests to examine the main effect of group.

3 | RESULTS

3.1 | Questionnaire measures (demographics and personality traits)

As shown in Table 1, results showed a statistically significant difference for gender judgment (Mann–Whitney $U = 46.5$, $z = 2.27$, $p = .023$); female faculty indicated that they perceived feeling more judged for their gender in the workplace than did male faculty (mean difference of Likert scale values = 1.56). We did not find a statistically significant difference between women and men for any other questionnaire measure (i.e., *age*, *time in rank*, *NEO-FFI-3 T scores*, *work locus of control, and sense of belonging*).

3.2 | Behavioral data analyses (project respect video clips ratings)

Analysis of video behavioral ratings indicated a significant main effect of condition ($F(1,26) = 5.680$, $p = .025$, Wilk's $\Lambda = .821$, partial $\eta^2 = .179$) across groups. Participants rated significantly more video clips in the control condition as comfortable (i.e., 91.2% ± 6.8% of all control videos were rated as comfortable) relative to video clips in the microaggression condition being rated as uncomfortable (i.e., 86.4% ± 9.2% of all microaggression videos were rated as uncomfortable). The main effect of group and the interaction of group by condition were not significant ($ps > .732$).

3.3 | Primary fMRI analyses

Results from voxel-wise analyses indicated a significant interaction of group by condition in one cluster that was positioned in the right hemisphere that spanned subregions of the frontal (inferior and middle frontal gyri, frontal pole, precentral gyrus, postcentral gyrus) and parietal lobes (supramarginal gyrus, angular gyrus; *x*/*y*/*z* peak MNI coordinates = 46, 36, 24; $k = 5285$ voxels, $p < .001$). We conducted planned post hoc comparisons of activation occurring in this cluster to decompose the significant interaction. Specifically, we conducted these analyses using activation estimates extracted from each significant cluster for every region, condition, and participant. Analysis of these values indicated that women demonstrated reduced activation in the microaggression condition compared to the control condition ($t(15) = 4.109$, $p = .001$). In contrast, men exhibited a trend for

TABLE 1 Description of the participant cohorts.

	Women	Men	Statistical differences
Number of participants	16	12	
Age ($M \pm SD$) in years	36.238 ± 5.90	39.75 ± 7.97	$p = .208$
Race/Ethnicity			
African American/Black	1	1	
East Asian	4	3	
Hispanic/Latino	–	1	
Middle Eastern	–	1	
Native Hawaiian/Pacific Islander	1	–	
Southeast Asian	2	2	
White/Caucasian	8	4	
Rank			
Clinical Educator Line	7	3	
Instructor	3	2	
Medical Center Line	6	4	
Non-Tenure Line	–	1	
University Tenure Line	–	2	
Time in rank ($M \pm SD$) in years	2.31 ± 2.24	2.64 ± 2.10	$p = .690$
NEO-FFI Neuroticism T score ($M \pm SD$)	51.06 ± 11.09	46.70 ± 9.07	$p = .308$*
NEO-FFI Extraversion T score ($M \pm SD$)	50.44 ± 10.83	48.28 ± 8.70	$p = .472$*
NEO-FFI Openness T score ($M \pm SD$)	49.94 ± 10.77	51.55 ± 10.28	$p = .955$*
NEO-FFI Agreeableness T score ($M \pm SD$)	51.58 ± 9.75	50.44 ± 9.49	$p = .674$*
NEO-FFI Conscientiousness T score ($M \pm SD$)	54.17 ± 12.19	52.79 ± 12.95	$p = .726$*
Work locus of control	46.31 ± 7.53	45.92 ± 6.73	$p = .960$*
Average sense of belonging	4.74 ± .84	4.74 ± .85	$p = .995$*
Gender judgment	3.81 ± 1.76	2.25 ± 1.42	$p = .023$*

Note: We used following abbreviations: mean (M), standard variation (SD). p-Values of non-parametric Mann–Whitney U tests are indicated with "*".

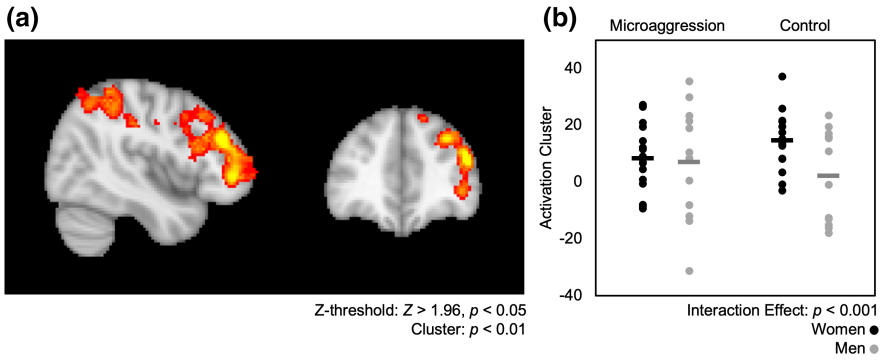

FIGURE 2 Results of primary fMRI cluster analyses. (a) Results showed a significant interaction of group by condition in a cluster in the right hemisphere that spanned subregions of the frontal (inferior and middle frontal gyri, frontal pole, precentral gyrus, postcentral gyrus) and parietal lobes (supramarginal gyrus, angular gyrus). (b) Within-group results showed that women had higher cluster activation in the control condition compared to the microaggression condition. The reverse was true for men. Between-group results indicated significant sex differences for the control condition but not the microaggression condition. Horizontal lines indicate mean values.

increased activation in the microaggression condition compared to the control condition ($t(11) = -1.928$, $p = .080$). Looking within each condition, women demonstrated greater activation during control video clips than did men ($t(17.4) = 2.35$, $p = .031$), while we observed no difference between the two groups for the microaggression video clips ($t(16.5) = .22$, $p = .832$; Figure 2).

3.4 | Secondary fMRI analyses: Associations between activation and perceived judgment

We observed a significant interaction of group by gender judgment ($F(1,24)=4.520$, $p=.040$). Planned posthoc comparisons indicated a negative association between activation and judgment for women ($r=-.400$) and a positive association for men ($r=.398$; Figure 3). In other words, women who reported feeling more judged in academic medicine based on their gender showed lower levels of cluster activation during microaggression relative to control trials, whereas the reverse was true for men.

3.5 | Secondary fMRI analyses: Regions of interest analyses

Secondary analyses also indicated a significant between-group difference in activation occurring during the microaggression condition relative to the control condition in two regions: the right inferior frontal gyrus (IFG, $t(26)=-2.276$, $p=.031$) and the right dorsolateral prefrontal cortex (dlPFC, $t(26)=-2.436$, $p=.022$). While women activated these regions less during microaggression trials relative to control trials, men showed the reverse pattern. There were no significant differences for any other region. We summarize the results in Table S1 in the Supplementary Material.

4 | DISCUSSION

This study assessed the neural correlates of observing gender-based microaggressions in women and men early career faculty in academic medicine. Participants watched videos of real-life gender-based microaggressions and corresponding "control" versions of the same situation (control condition) while undergoing an fMRI scan. Primary analyses revealed a significant interaction of group by condition in a cluster that spanned several subregions of the right frontal and parietal lobes. Women exhibited reduced activation in these regions while observing gender-based microaggressions in the workplace, whereas men demonstrated the opposite pattern. Post hoc exploratory analyses showed that these activation patterns (1) were significantly associated with the degree to which participants reported feeling judged for their gender in academic medicine; and (2) were present in areas associated with the cognitive regulation of social exclusion (i.e., right dlPFC and right IFG). Taken together, our findings indicate that observing gender-based microaggressions results in a specific pattern of neural reactivity in women early career faculty.

The regions identified in our primary analyses (i.e., the right inferior and middle frontal gyri, frontal pole, precentral gyrus, postcentral gyrus, supramarginal gyrus, and angular gyrus) share a strong spatial overlap with the dorsal and ventral attention networks (DAN and VAN, respectively) (Corbetta et al., 2008; Petersen & Posner, 2012). These networks share extensive interconnections yet have specific functions within the domain of attention (Corbetta et al., 2008; Petersen & Posner, 2012). Whereas the DAN is involved in the voluntary allocation of attention, the VAN is responsible for detecting unattended or unexpected stimuli and triggering shifts of attention (Vossel et al., 2014). More specifically, the VAN shows increased responses when behaviorally relevant stimuli occur unexpectedly (Bartolomeo & Malkinson, 2019; Vossel et al., 2014). Functional MRI studies indicate that the attention networks activate during social information processing. For example, various findings demonstrate neural responding in these network regions related to social dominance (Qu et al., 2017), including the explicit representation of ranks based on task performance (Zink et al., 2008), body postures (Marsh et al., 2009; Mason et al., 2014), facial traits (Todorov & Engell, 2008), and psychological (i.e., intelligence) and physical (i.e., height) characteristics (Lindner et al., 2008). Other studies show increased activation in the attention networks in association with self-related information processing (Golubickis et al., 2021; Sui & Rotshtein, 2019; Turk et al., 2011).

Interestingly, women demonstrated higher activation in the attention networks during control trials that showed social

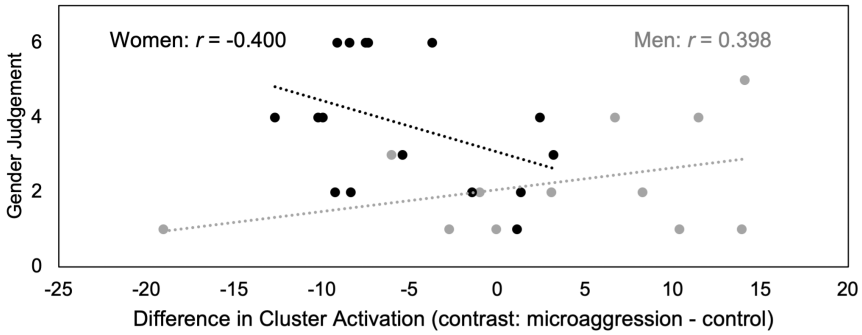

FIGURE 3 Group-dependent associations between cluster activation and gender judgment. Women who reported feeling more judged for their gender in academic medicine showed lower levels of activation during the microaggression compared to control trials. In contrast, men who reported feeling more judged for their gender in the workplace showed higher levels of activation during microaggression compared to control trials.

situations of equity (e.g., women leading discussions and making decisions for the team) compared to microaggression trials. Prior research has shown that women can face social judgment when exhibiting stereotype-incongruent behaviors that violate their prescriptive gender norms (i.e., "assertive, independent, and agentic behavior" versus "helping, caring, and communal behavior"; Hanek & Garcia, 2022; Heilman & Eagly, 2008, 2008; Heilman & Okimoto, 2007; Heilman & Wallen, 2010). Therefore, one interpretation of our findings could be that female participants devoted more attentional neural resources to self-related information in trials with a higher risk of being socially judged (i.e., control condition). A similar effect might apply to male participants who exhibited higher DAN and VAN activation during the microaggression trials compared to the control trials. Our society often stereotypes men as aggressors who conduct microaggressions (Paludi, 2012; Torres et al., 2019). As such, men participants might have devoted more neural resources of attention to self-related information in trials with a higher risk of being socially judged (i.e., microaggression condition). Such an interpretation is supported by our post hoc findings demonstrating group-dependent associations between the difference in cluster activation (contrast: microaggression − control) and the extent to which participants reported feeling judged for their gender in academic medicine. Women who reported feeling more "judged" in academic medicine based on gender showed greater decreases in activation in the attention networks during microaggression relative to control trials, whereas the opposite was true for men. These results hint at potential differences in the social contexts of when men and women participants feel judgment based on their sex. Future research is needed to test these interpretations. These studies could also examine whether repeated exposure interventions that "normalize" gender equity in academia alter the differential activation patterns we observed in men and women participants.

Results from the secondary ROI analyses indicate that the right dlPFC and right IFG are associated with the observation and processing of gender-based microaggressions. Our findings align with previous studies that have identified these regions' involvement in social exclusion studies. For example, increased activation in the bilateral and right dlPFC and IFG has been linked to the cognitive processing and regulation of gender and race stereotypes (Forbes et al., 2012; Kubota et al., 2012; Mitchell et al., 2009; Richeson et al., 2003). The dlPFC and IFG have also been found to be directly involved in the downregulation of negative emotions produced by observing social exclusion (i.e., "social pain"; Koban et al., 2017; Vijayakumar et al., 2017; Wang et al., 2017; Zhao et al., 2021). Researchers have argued that the dlPFC plays a fundamental role in peoples' cognitive control abilities (Crone & Steinbeis, 2017; Zhao et al., 2021), whereas the IFG achieves regulatory goals by selecting goal-consistent responses and inhibiting goal-inconsistent responses in order to reinterpret the affective stimuli (Ochsner et al., 2009, 2012; Wager et al., 2008; Zhao et al., 2021). Indeed, studies have identified relative functional specificity of the dlPFC and IFG for emotional regulation strategies during social exclusion paradigms (Amodio, 2014; Aron et al., 2004; Dardenne et al., 2013; Hampshire et al., 2010; He et al., 2018; Moyal et al., 2014; Zhao et al., 2021). Our findings could therefore indicate that both women and men exhibited neural responses associated with cognitive regulation of social exclusion stimuli, specifically in trials that included the risk of being socially judged (i.e., risk of social exclusion). Future research with larger samples is needed to test this interpretation. Notably, the current study assessed neural responses while participants *observed* gender-based microaggressions within the MRI scanner. Whether similar activation patterns occur during the first-hand experience of gender-based microaggressions is unclear. Future studies that use portable neuroimaging solutions, such as functional near-infrared spectroscopy (fNIRS), could test this possibility. For example, the technical properties of fNIRS could allow for the study of single-brain and inter-brain responses to first-hand experiences of social exclusion in naturalistic social interactions (Balters et al., 2020; Li et al., 2023). Virtual reality methods could also be an effective tool for future studies to induce the experience of social exclusion (e.g., virtual abuse; Seinfeld et al., 2021). Physiological metrics (e.g., heart rate, heart rate variability, galvanic skin response, pupil dilation, etc.) along with behavioral measures (e.g., eye-gaze-tracking, body-motion tracking, analysis of voice, emotional face tracking, etc.) could provide additional data to help elucidate the psychophysiological response underlying social exclusion.

We note five limitations of this study. First, this study comprised a relatively small sample size, and findings should be considered preliminary. Future research that includes a larger number of participants across various academic institutions is needed to replicate and assess the generalizability of the current study findings. Larger samples will also allow us to study the influences of other important variables, such as race/ethnicity, sexual orientation, and physical disabilities, which can contribute to unique social exclusion experiences (i.e., "demographical intersectionality"; Fourie et al., 2019; Olkin et al., 2019; Wilkins-Yel et al., 2019). Second, our fMRI statistical analyses included only trials in the microaggression condition that participants rated as "uncomfortable" and trials in the control condition that participants identified as "comfortable." Although the two groups in our sample did not differ in the number of videos rated as comfortable or uncomfortable, we cannot exclude the possibility that variations in ratings (and, therefore, the specific trial type and number) may have slightly impacted our results. It may also be possible that some trials were neither "comfortable" nor "uncomfortable" to participants. Without a third rating option of "neutral," we could not assess this possibility. Third, it may be possible that neural activation at discrete epochs within a trial varied between men and women. Future studies that assess activation time course differences between groups can help assess this possibility. Fourth, we used a single question as the metric of gender judgment as an initial stage of research development. Future research should include multidimensional assessments of gender judgment (e.g., gender discrimination inventory) to elucidate the nature and effects of experienced

discrimination (e.g., current work environment vs agglomerated experiences over multiple sites (de la Torre-Pérez et al., 2022). Lastly, although videos in the microaggression condition depicted social signals of inequity toward women, we acknowledge that microaggressions are not sex-bound regarding which genders constitute the "aggressor" and "victim."

In conclusion, this study provides evidence that the observation of gender-based microaggressions differentially elicited activation in men and women within regions of the brain that subserve cognitive attention to self-related information. These gender-specific patterns were significantly correlated with participants' subjective rating about how judged they feel in academic medicine based on their gender. These findings suggest that both sexes paid specific attention to scenarios where their sex was at risk of being judged (i.e., men for being stereotyped as the aggressors of gender-based microaggressions and women for stepping out of stereotyped behaviors). Lastly, our results indicate that observing scenarios in which one's own sex is at risk of being judged (i.e., socially excluded) can prompt neural activation associated with cognitive regulation strategies. Future research is of interest that examines whether these sex-specific activation differences normalize following targeted interventions aimed at reducing gender biases in academic medicine.

AUTHOR CONTRIBUTIONS

SB: Formal Analysis, Methodology, Visualization, Writing - Original Draft Preparation, Writing - Review & Editing; LFR: Formal Analysis, Methodology, Visualization, Writing - Original Draft Preparation, Writing - Review & Editing; JB: Conceptualization, Data Curation, Investigation; VSP: Conceptualization, Funding Acquisition, Methodology, Resources, Writing - Review & Editing; HV: Conceptualization, Funding Acquisition, Methodology, Resources, Writing - Review & Editing; ALR: Conceptualization, Funding Acquisition, Methodology, Resources, Writing - Review & Editing.

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PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data is available on request due to privacy/ethical restrictions.

ENDNOTE

[1] Mentalizing refers to the human ability to attribute inner mental states to other persons, such as thoughts, emotions, moods, or intentions (Amodio & Frith, 2006; Frith & Frith, 2003).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Statistical results of the secondary fMRI ROI analyses.

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