THE SOCIAL ENVIRONMENT IMPACT: FUNCTIONAL NEUROANATOMY
OF GRIEF AND PERCEIVED DISCRIMINATION IN SOUTH ASIAN WOMEN
IN THE UNITED STATES

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Abstract

Although several studies have characterized common and unique neural circuitry associated with social and non-social emotions, none to date have attempted to differentiate between social emotions that occur in very different contexts. Grieving the death of a loved one and being a target of perceived discrimination may implicate potentially distinct social processes (e.g., attachment versus affiliation). When examined separately, prior neuroimaging research has shown that both grief and perceived discrimination involved diffuse brain regions implicated variously in social stress processing and emotion, however no studies to date have directly compared these experiences. In the present study, we examined neural correlates of grief and perceived discrimination among South Asian women ($n = 10$), using an idiographic emotional imagery task. Grief-related imagery elicited activation in the precuneus, midbrain, dorsal striatum, and thalamocingulate regions, consistent with previous neuroimaging studies of grief and attachment. Participants showed greater activation in the anterior cingulate, hippocampus, occipital cortex, and cerebellum during Grief relative to Discrimination. We observed dorsomedial prefrontal cortex (dmPFC) activation in Discrimination > Neutral, which may reflect greater self-regulatory effort involved in coping with discrimination experiences. Greater temporal pole and amygdala activation in the Discrimination condition were associated with greater lifetime perceived discrimination, poorer self-reported physical health, and more depressive symptoms. Results of this pilot study suggest that there are observable differences in the brain response to these two types of social stressors, suggesting future directions for a more fine-grained view of the mechanisms through which the social environment may influence health and well-being.

The Social Environment Impact: Functional Neuroanatomy of Grief and Perceived

Discrimination in South Asian Women

Humans have an intrinsic drive to form bonds with others (Baumeister & Leary, 1995).

Given the centrality of our ties to others, the rupture of those social bonds, or *social losses*, are

also an inherent part of the human experience. Given the evolutionary significance of social

bonds to our survival, social losses may be uniquely devastating. For example, individuals may

be particularly likely to develop post-traumatic stress disorder after exposure to human-generated

stressors (American Psychiatric Association, 2013; Charuvastra & Cloitre, 2008). Grief and

perceived discrimination (i.e., being rejected, ostracized, and/or receiving unfair treatment based

on aspects of one's identity such as age, gender, national origin, race, or ethnicity) are two

potentially distinct subtypes of social losses that have been relatively understudied in the

emotion and affective neuroscience literature. Both grief and perceived discrimination are

common experiences, with high prevalence rates. Approximately two and half million

individuals die in the United States each year (United States National Center for Health

Statistics, 2013), leaving behind an estimated 10 to 12.5 million grieving survivors.[1] Estimates of

perceived discrimination vary by specific population, but approximately a third of respondents in

a large national survey reported major lifetime discrimination, and nearly two-thirds reported

day-to-day discrimination, with higher rates among socially disadvantaged groups (Kessler,

Michelson, & Williams, 1999). Both grief and perceived discrimination have been shown to

carry serious and detrimental costs to health and wellbeing, including increased risk for

depression, anxiety, and cardiovascular disease (e.g., Berger & Sarnyai, 2015; Chou, Asaani, &

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[1] https://newsinhealth.nih.gov/2009/november/feature1.htm

Hofmann, 2012; Pascoe & Richman, 2009; Stroebe, Schut, & Stroebe, 2007). Discovering how these specific experiences are enacted in the brain may identify the mechanisms linking the two potentially distinct subtypes of social stressors to their downstream consequences.

Several recent neuroimaging studies suggest that 'sociality' may represent a third dimension of emotion, in addition to arousal and valence dimensions, involving separable neural circuitry (e.g., Landa et al., 2013). However, few if any have attempted to distinguish between emotions related to attachment social processes (i.e., grief) versus potentially more affiliation-related processes (i.e., perceived discrimination). Much of our knowledge of neural processes involved in loss-oriented social stressors processing comes from an extensive literature on rejection and exclusion. Experiencing the death of a loved one and being subject to discriminatory treatment may also involve aspects of social stress processing – yet have been studied far less frequently. In stark contrast to multiple investigations concerning the neural correlates of perpetrating prejudicial attitudes and behaviors (see the review by Chekroud et al., 2014), or forming social categories based on race (e.g., Kubota, Banaji, & Phelps, 2012; Phelps, O'Connor, Cunningham, Funayama, Gatenby… & Banaji, 2000), there is at present a single published fMRI study concerning how individuals experience racial discrimination (Masten, Telzer, & Eisenberger, 2011). The grief neuroimaging literature is similarly sparse, with a recent review encompassing only five such studies, all of which were conducted primarily with individuals of European descent, and thus may not be representative of the racially and ethnically diverse US population (Silva et al., 2014; Falk et al., 2013). In the present investigation, I sought to characterize shared and unique neural circuits involved in processing of grief and perceived discrimination in an underrepresented group, through a secondary analysis of neuroimaging data collected as part of a larger study of social stress processing in South Asian women.

"Social emotions": Attachment and affiliation

Grief and perceived discrimination may appear at first glance to have little in common beyond their prevalence and consequences. However, both represent *social emotions*: those that arise specifically in response to self-relevant social concerns, such as status, belonging, attachment, or norm violation. In this view, social emotions are qualitatively distinct from non-social emotions in that they occur when individuals judge the appraisals and actions of others to be self-relevant, as well as the real or imagined impact of those appraisals and actions on one's relationships and belonging (see Hareli & Parkinson, 2008, for a review). Thus social emotions may be distinguished from non-social emotions by considering context and function, rather than form (Frewen, Dozois, Neufeld, Densmore, Stevens, & Lanius, 2011). Whereas the primary function of basic emotions, such as happiness, sadness, or fear, is to provide important information for immediate survival, Barrett and Campos (1987) argue that a primary function of social emotions is to facilitate social communication and further more long-term, socially relevant goals, such as influencing others' behavior or choosing a mate. Several neuroimaging studies support this view of social emotions as functionally distinct from non-social emotions, based on evidence of differential activation in brain regions involved in social cognition, self-referential processing, and theory of mind (e.g., Britton et al., 2006; Frewen et al., 2011; Landa et al., 2013). These findings suggest that 'sociality' may be a third emotional dimension, in addition to valence and arousal, and that the 'sociality' dimension may be subserved by separable neural circuitry in affective experiences. Further, Landa and colleagues (2013) suggest that social emotions may differ according to the social/relational context in which they take place. In this definition, *interpersonal emotions* concern one's relationship to a specific individual, while more broadly *social emotions* concern one's relationship to the larger social

context. Diverse experiences sharing the common central quality of threatened social belonging appear to have similar immediate consequences in lowering self-esteem and increasing negative affect. However, "…few efforts have been made to describe ways in which the effects of various types of experiences (e.g., discrimination, ostracism, peer rejection, loneliness) resemble versus differ from one another…" and thus might elicit different responses, such as emotional numbing versus increased motivation to repair relationships (Smart Richman & Leary, 2009, p. 2).

Problematically, the terms "interpersonal" and "social" have generally been used interchangeably in the affective neuroscience literature. Indeed, the NIMH's Research Domain Criteria (RDoC) framework classifies both attachment ("selective affiliation as a consequence of the development of a social bond") and affiliation ("engagement in positive social interactions with other individuals") together as a single construct within the domain of social processes.[2] Despite significant overlap between genetic, molecular, and physiological correlates of attachment-related and affiliative social processes, they may in fact be subserved by related, though non-identical, behavioral systems that fulfill separate phylogenetic needs of the organism (e.g., Bailey, 2004; Baumeister & Leary, 1995; Bowlby, 1969; Sheldon & West, 1989). Attachment and affiliation serve different functions (Bowlby, 1969): in contrast to attachment relationships, through which proximity to a special loved one provides protection from danger and a sense of security, the function of affiliative relationships is to "promote exploration and expansion of interests from the secure base provided by attachment" (Sheldon & West, 1989, p. 20). This may include seeking out like-minded others, engaging in shared activities, and forming alliances against outsiders. With affiliation, the sense of having a positive relationship with others – or social belonging – may be particularly salient for those who historically have been marginalized or subject to negative stereotypes about their group (e.g., Walton & Cohen, 2007).

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[2] http://www.nimh.nih.gov/research-priorities/rdoc/constructs/affiliation-and-attachment.shtml

The experience of being discriminated against may particularly emphasize a loss (or the lack) of connectedness to the larger social group. This communicates different information to marginalized recipients and might differ qualitatively from the sense of loss and threat to belonging that we may feel after the death of a loved one. However, research in the latter area is limited and has seldom employed neuroimaging methods. Comparing neural correlates of grief and perceived discrimination may allow us to better understand if, and how, attachment-related social stressors might differ from more broadly affiliation-related social stressors. Despite their differences, grief and perceived discrimination also appear to have much in common. Both can elicit a wide range of emotions, including anger, sadness, and anxiety, and are hypothesized to potentially activate the same 'neural alarm system' (Eisenberger, 2015; Panksepp, 1998) that serves to alert us to possible threats to our safety and survival – such as losing a parent, being rejected by a mate, or being shunned by one's community.

Neuroimaging grief

Panksepp's (2004; 2011) affective neuroscience perspective categorizes emotions within systems, derived from subcortical brain regions common to all mammals. Socially-oriented emotions are implicated in several of these systems, but particularly in the "separation-distress/PANIC [GRIEF]" system, which represents an important evolutionary mechanism for humans and other species that depend on social ties in order to survive. The role for a 'neural alarm system' within this evolutionary mechanism is supported by converging evidence from pharmacological, neuropsychological, and neuroimaging studies that appear to show considerable overlap between neural representations of social distress and physical pain (i.e., another aversive experience that signals potential threat to survival) (Kross, Berman, Mischel, Smith & Wager, 2009; see Eisenberger, 2015 for a review). Perhaps for this reason, the death of

an attachment figure is rated as one of the most stressful life experiences. Indeed, evidence from both human and animal studies suggests, "effects [of social stress] are more dependent on the *disruption of a social bond between a significant pair* than objective isolation per se" (Cacioppo, Cacioppo, Capitanio, & Cole, 2015, p. 733 [emphasis added]). Based on studies of separation and bereavement in both humans and non-human animals, the role of attachment occupies a central place in models of grief (e.g., Shear & Shair, 2005). Prairie voles (*Microtus ochrogaster)* form long-term, monogamous bonds with a partner vole, and therefore have been used widely to study neurobiological consequences of separation distress and grief. When male prairie voles are separated from their mates in models of partner loss, they exhibit anxiety- and depression-like behaviors, greater passive stress-coping behaviors, and neuroendocrine dysregulation similar to that observed in bereaved individuals (e.g., Bosch et al., 2009; Sun et al., 2014). For example, female voles chronically deprived of a partner showed a significant increase in cardiovascular contractility and in the heart-to-body weight ratio (Peuler et al., 2012), not unlike the potential cardiovascular sequelae of bereavement in humans such as hypertension (e.g., Buckley, McKinley, Tofler, & Bartrop, 2010; Jones, Bartrop, Forcier, & Penny, 2010).

Bereaved individuals typically experience intense sadness, yearning, and other painful emotions following the loss of a significant loved one. The grieving process is associated with psychological distress, poorer physical health, and excess risk of mortality (Stroebe et al., 2007). Acute grief in the early months is associated with disturbances in sleep and immune function, as well as alterations in hemodynamic and neuroendocrine processes (Buckley, Sunari, Marshall, Bartrop, McKinley, & Tofler, 2012). Bereavement is also associated with increased risk for a wide range of psychiatric disorders (e.g., Keyes, Pratt, Galea, McLaughlin, Koenen, & Shear, 2014). However, relative to other 'basic' emotional states such as sadness or anger, few studies

have employed neuroimaging methods to parse how grief is represented in the brain. In their systematic review, Silva and colleagues (2014) reported on five neuroimaging studies. All studies concerned grief in response to the death of a loved one, though the specific relationship varied both within and between studies – for example, the love ones who died ranged from any first-degree relative (O'Connor, Gündel, McRae, & Lane, 2007), to only mothers and sisters (O'Connor, Irwin, & Wellisch, 2009), to pets (Freed, Yanagihara, Hirsch, & Mann, 2009). Taken together, the results of these studies found that grief-related neural activity largely involved the same brain areas (e.g., anterior cingulate cortex [ACC], prefrontal cortex [PFC], insula) as in more studied social stressors like rejection and exclusion. However, at least in certain contexts, grief-related neural circuitry may involve different brain regions than other forms of social loss. One study found that women with complicated grief – but not those with non-complicated grief – showed neural activity in the nucleus accumbens, a small area of the ventral striatum, in response to images of the deceased (O'Connor et al., 2008). The nucleus accumbens, as well as caudate and putamen regions in the dorsal striatum, feature a high density of receptors for oxytocin, a neuropeptide implicated in attachment (e.g., pair-bonding and maternal behavior; Insel & Young, 2001; Olazabal & Young, 2006). Given that existing neuroimaging studies of grief have almost exclusively employed neutral stimuli as the alternate condition, comparing grief to another socially-oriented emotional experience such as perceived discrimination would enable us to test how grief might differ from other negative social emotions such as discrimination.

Neuroimaging discrimination

Discrimination is "*the process by which a member, or members, of a socially defined group is, or are, treated differently (especially unfairly) because of his/her/their membership of that group*" (Krieger, 2001). The chronic stress of perceived discrimination has recently emerged

as one potential pathway linking racism, health disparities, and negative health outcomes (e.g., Hicken et al., 2014; Himmelstein et al., 2015; Williams & Mohammed, 2009). However, very few neuroimaging studies have sought to determine how or whether perceived racial discrimination might differ from more commonly studied forms of social stress such as negative evaluation or ostracism. Akdeniz and colleagues (2014) examined autonomic and neuroendocrine responses to a social stress task in a sample of ethnic majority (German) and minority (Turkish) participants. Ethnic minority participants showed a significant increase in functional connectivity between the dorsal ACC (dACC) and the perigenual ACC (pgACC) – a region implicated in perceptions of lower social standing (Gianaros et al., 2014) – which may suggest disrupted ability to regulate pgACC stress reactivity. The Turkish group reported higher levels of chronic stress, and chronic stress mediated the association between perceived discrimination and pgACC-dACC connectivity. This suggests that adverse social environments interact with psychological mechanisms such as perceived discrimination to alter social stress processing (Akendiz et al., 2014). In the sole published neuroimaging study of perceived discrimination to date, Masten and colleagues (2011) examined the impact of attributing social exclusion to racial discrimination. Black participants completed the Cyberball exclusion task with ostensibly White partners. Observer-rated distress during a videotaped post-task interview was associated with decreased activity in the dorsomedial prefrontal cortex (dmPFC) and increased subgenual anterior cingulate (sgACC) activity. Similar patterns have been observed in major depressive disorder (e.g., Mayberg et al., 1999); a recent study found that clinically depressed adolescents exhibited heightened sgACC response to peer rejection, relative to controls (Silk, Siegle, Lee, Nelson, Stroud, & Dahl, 2013). Participants who attributed their exclusion to racial discrimination showed greater activation in the dACC and less activation in

the anterior insula, a region consistently implicated in the affective component of both social and physical pain (e.g., Eisenberger, 2015): categorizing one's treatment as discrimination may serve a regulatory function (Masten et al., 2011). This is consistent with theories that during intergroup interactions involving a degree of attributional ambiguity – or uncertainty as to the motivations underlying others' behavior – ascribing rejection to one's group, rather than one's individual identity, can preserve self-esteem by reducing self-blame (e.g., Major, Quinton, & Schmader, 2003) and inhibit cardiovascular responses to threat (Mendes, Major, McCoy & Blascovich, 2008). On the other hand, attributing rejection to discrimination can also lead to externalized anger and other negative emotions (e.g., Major, Quinton, & McCoy, 2002) or vigilance for subsequent discrimination (e.g., Mendes et al., 2008; Mendoza-Denton, Downey, Purdie, Davis, & Pietrzak, 2002), which can increase the chronic stress and allostatic load of discrimination through heightened reactivity and prolonged mental representations (e.g., Hicken et al., 2014). High levels of perceived discrimination also appear to negate the putatively adaptive nature of some forms of emotion regulation (e.g., Perez & Soto, 2011; Yoo & Lee, 2005), potentially further depleting physical and psychological resources for coping with stressors.

Based on the results of these two neuroimaging studies (Akendiz et al., 2014; Masten et al., 2011), the neural correlates of social stress processing in the context of perceived discrimination appear to be congruent with other accounts of social stress – yet these findings also emphasize the importance of other factors (such as adverse social environment, attributions, prior experiences of discrimination, chronicity, and many others) that can substantively impact how people respond in the face of rejection or unfair treatment. Racial discrimination represents a multidimensional social stressor that may interact with generic sources of stress (i.e., "daily hassles"; Kanner, Coyne, Schaefer, & Lazarus, 1981) to produce significant decrements in health

and well-being of minority individuals (Harrell, 2000; see the systematic review and meta-analysis by Paradies et al., 2015). For these reasons, nomothetic tasks such as the Cyberball exclusion paradigm or the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993) may not allow investigators to capture phenomena such as autobiographical recall and other forms of self-referential processing that may contribute to the deleterious impact of perceived discrimination on one's physical and psychological health (e.g., Brosschot, Gerin & Thayer, 2006; Hicken et al., 2014).

The present study

The present pilot study uses archival data collected by Dr. Mary-Frances O'Connor and Dr. Arpana Gupta as part of a larger study of social stress processing in South Asian women conducted at the University of California Los Angeles (UCLA). No studies to date have explored social stress processing in South Asian women, even as the United States South Asian community increased by 81% between 2000 and 2010 to reach 3.4 million individuals by 2012 (Asian American Federation/South Asian Americans Leading Together, 2012[3]). Although South Asians in the US may encounter some positive stereotypes (such as being a "model minority" group), they are also subject to discriminatory treatment, particularly after the events of 9/11. According to a 2003 report by the New York City Commission on Human Rights ("Survey of Discrimination against Muslims, Arabs and South Asians in New York City Since 9/11")[4], 69% of those surveyed reported at least one incident of perceived discrimination. Further, 79% of those surveyed reported that their lives were negatively affected by 9/11, "regardless of whether they believed they had directly experienced any discrimination. They felt more afraid and minimized their contact with the general public or made their religion and ethnicity less evident"

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[3] http://saalt.org/wp-content/uploads/2012/09/Demographic-Snapshot-Asian-American-Foundation-2012.pdf
[4] http://home2.nyc.gov/html/cchr/html/report.html

(NYC Commission on Human Rights, 2003; p.ii). More recently, a 2016 report using official government data found that anti-Muslim hate crimes increased 78.2% from 2014 to 2015, while anti-Arab hate crimes increased 219% during that time (Center for the Study of Hate and Extremism, 2016). Despite these concerning trends, the experiences of South Asian individuals in the US have rarely been studied (Gee, Ro, Shariff-Marco, & Chae, 2009; Gupta, Szymanski, & Leong, 2011). The National Institute of Health has emphasized the importance of conducting studies with diverse samples in order to improve external validity. Investigating basic social-affective processes in more heterogeneous samples will allow the psychological research community to better respond to the critical question of "*What is a representative brain?*" (Falk et al., 2013).

Aims

By comparing neural responses to grief and perceived discrimination, this study aims to explore whether and how the brain response to socially-oriented, negative emotional imagery differs as a function of association with either a specific loved one or the larger social group. My first aim was to replicate (separate) findings regarding neural correlates of grief and perceived discrimination, building on the extant work by using an idiographic script-driven imagery task in an underrepresented sample. My second aim was to extend these separate findings through direct comparison between grief and perceived discrimination, in order to identify shared and unique neural correlates that may characterize the two hypothesized types of social stressors distinguished by their relational context – i.e., the "interpersonal" versus "social" distinction suggested by Landa and colleagues (2013). I predicted that both emotions should elicit activation in cortical midline structures involved in social distress, autobiographical memory, self-referential processing, and emotion regulation (e.g., Eisenberger, 2015; Fletcher et al., 1995;

Northoff et al., 2006), including the dACC, anterior insula, PFC, and precuneus. Compared to discrimination, I predicted that grief would elicit greater activation in regions associated with attachment and separation/loss (e.g., Panksepp, 1998; 2010), such as the dorsal striatum (i.e., caudate, putamen), posterior cingulate cortex (PCC), and periaqueductal gray (PAG). Given that perceived discrimination entails "the capacity to have thoughts about experiences, especially about how external events relate to internal events" (Panksepp, 2005, p.32) in conjunction with prior findings that individuals of lower social status show increased neural activity in the mentalizing network, I predicted that perceived discrimination should elicit greater activation in regions associated with threat, social cognition, and social status (e.g., Fox et al., 2015; Gianaros et al., 2014; Muscatell et al., 2012; Van Overwalle, 2009), including the amygdala (AMY), superior temporal gyrus (STG), bilateral temporal poles, and pgACC.

Method

Participants

Participants were 10 South Asian females between 18 and 42 years old ($M = 26.10$, $SD = 8.43$) who were right-handed and fluent in English. Five were first-generation US citizens (i.e., born in the US to parents who were born abroad) and five were born abroad. The latter group had lived in the US between 5 and 36 years ($M = 16.80$, $SD = 13.92$). Other sample characteristics are presented in Table 1.

To reduce the documented effects of gender and ethnic variation in the experience and processing of discrimination (Krieger, 1990), the larger study from which the current data was drawn focused on one gender (women) and a specific ethnic group (South Asians), whose ancestry included India, Pakistan, Bangladesh, Bhutan, Nepal, Sri Lanka, and others. Electronic

recruitment announcements were sent to Los Angeles County agencies serving South Asian communities, and to the student body of the University of California Los Angeles (UCLA). Participants were screened for exclusionary criteria by interview, including a structured clinical interview (SCID-I/R; First et al., 2010). Participants were deemed ineligible for the imaging portion of the study if they reported standard MRI contraindications (e.g., ferromagnetic implants, claustrophobia), current DSM-IV-TR psychiatric disorders (American Psychiatric Association, 2000), neurological disorders, or other serious medical conditions.

Procedure

The UCLA Institutional Review Board approved all procedures. Participants gave written informed consent in accordance with the guidelines of the Committee for Protection of Human Subjects, and were compensated for their time.

Clinical interview

As part of a larger study, participants were interviewed approximately one month prior to the neuroimaging session by a female clinical psychologist of South Asian descent (AG). During the interview, participants identified specific experiences associated with grief and discrimination that had most affected them during their life. They were asked to describe the experience in detail (e.g., when, where, who was involved, what led up to it, what happened, how it ended, thoughts and feelings associated with the incident) for five minutes. Reported experiences of discrimination included the following incidents: being threatened, ridiculed, and chased at a gas station, being denied housing, being laid off after the September 11th terror attacks, or being treated unfairly at a restaurant by not being served. Reported experiences of grief included the loss of close family members to suicide, age, or illness. Participants for the

fMRI component of the larger study were not selected specifically for either their discrimination or grief experiences.

To serve as a control condition for the grief and discrimination narratives, the women also were asked to talk for five minutes about a specific neutral incident – brushing their teeth that morning – in detail (when, where, what led up to it, method of teeth brushing, type of toothbrush, type of toothpaste, any other procedures, how it ended, thoughts and feelings associated with the incident). Similar prompts have been used previously (e.g., Rathschlag & Memmert, 2013) to elicit narratives that are neutral in valence yet which involve episodic memory. Tooth-brushing was selected because it occurs daily, so a specific memory can be recalled, as well as its non-social nature (versus another mundane but social task such as grocery shopping, which may not be emotionally neutral for individuals who face discrimination). All three narratives (grief, discrimination, and neutral) were audio-recorded and reviewed by AG. Narratives were selected for each woman based on the highest subjective distress ratings. Three 30-second excerpts from the participant's own narrative were extracted from the full audio recordings for the emotional imagery task. Participants also completed a number of demographic and self-report measures, including the measures described below.

Emotional imagery task

The fMRI task was designed to replicate script-driven tasks from prior studies, which found that re-imagining stressful events elicited a greater hemodynamic response and more subjective distress compared to hearing the narratives played back (Frewen et al., 2008; Frewen et al., 2011; Lanius et al., 2007; Lanius et al., 2002; Lanius et al., 2001). The fMRI task consisted of a 3 x 3 x 3 block design with three conditions: Neutral, Grief, and Discrimination (Figure 1). Participants first listened to one of the three 30-second audio excerpts from their interview

('Listen'). They were then instructed to imagine themselves back in that specific scenario in the most vivid and immediate detail as possible ('Imagine'), followed by instructions to breathe and let go of the memory ('Breathe'). This sequence was repeated three times within each condition. Participants were provided with task instructions prior to the MRI session.

Self-report measures

Experiences of discrimination. The Everyday Discrimination Scale (EDS; Williams, Jackson, & Anderson, 1997) is a nine-item measure of self-reported daily unfair treatment. Sample items include being treated with less respect than others; receiving poorer service in stores or restaurants; being threatened, harassed, or insulted; or others acting as if they are afraid of you, think you are dishonest, or think you are not as smart as they are. Participants are asked for their primary attribution of these experiences (e.g., ethnicity; gender; race; age; physical characteristics such as skin color or weight; sexual orientation; income or educational level). In the present study, participants indicated whether they experienced these occurrences almost every day, at least once a week, a few times a month, a few times a year, less than once a year, or never. Higher scores indicate lower frequency (1 = almost every day, 6 = never). The EDS was found to reflect a unidimensional construct of discrimination in a diverse sample, with good psychometric properties (Krieger et al., 2005). Cronbach's alpha in the present sample was .91. Participants also provided single-item ratings for the following questions: "How often do people dislike you because you are [own words]?" "How often do people treat you unfairly because you are [own words]?" "How often have you seen friends treated unfairly because they are [own words]?" and "How much did [discrimination event] bother you?"

Depressive symptoms. The Center for Epidemiological Studies – Depressed Mood Scale (CES-D; Radloff, 1997) is a 20-item screening measure used widely to assess past-week

depressive symptoms. Possible scores range from 0-60, with higher scores indicating greater likelihood of major depressive disorder. Although the factor structure of the CES-D appears to vary in different racial and ethnic groups (e.g., Kim, DeCoster, Huang, & Chiriboga, 2011), few if any studies have specifically examined the measure's performance among South Asian women. Cronbach's alpha in the present sample was .94.

Physical health and somatic symptoms. Participants were asked to rate their overall physical health on a scale of 0 to 5 (0 = poor, 5 = excellent). They were also asked to rate their physical health compared to others of the same age (1 = worse than age group, 3 = better than age group) and to list any specific health problems they had been diagnosed with (e.g., hypertension, asthma, cardiovascular disease, diabetes, cancer, arthritis, chronic pain). They were also asked to report the frequency (0 = not at all, 2 = a lot) with which they had been bothered by various somatic symptoms – such as heart palpitations, stomach pain, headaches, or dizziness – during the past 4 weeks (Kroenke, Spitzer, & Williams, 2002).

fMRI Data Acquisition and Processing

fMRI data acquisition was performed on a Siemens Trio 3-Tesla MRI scanner. For each participant, a high-resolution structural T1-weighted anatomical image (MPRAGE, TR = 2200ms, TE = 3.4ms, TI = 900ms, flip angle = 10°, matrix size 256°— 256, FOV = 256mm, 176 continuous 1mm slices, 1.0 x 1.0 x 1.0 mm) was acquired for anatomical reference. Participants completed the emotional imagery task during an 18-minute functional sequence (echo-planar T2*- weighted gradient-echo, TR = 2500ms, TE = 28ms, flip angle = 90°, matrix size 64°— 64, FOV = 200 mm; 36 3mm axial slices, 3.1 x 3.1 x 3.0 mm).

Image processing and analyses were conducted in Statistical Parametric Mapping software (SPM12; Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK, http://www.fil.ion.ucl.ac.uk/spm). Raw functional images were manually reoriented to set the origin to the anterior commissure, then realigned, unwarped, and coregistered to the participant's individual anatomical image, using the default SPM12 algorithms. Functional images were normalized to MNI space and spatially smoothed with a 6mm full-width at half-maximum Gaussian kernel before being resliced to 2 x 2 x 2mm voxels. Artifact Detection Tools (ART; http://www.nitrc.org/projects/artifact_detect/) were used to identify outlier images based on global intensity >3 standard deviations and scan-to-scan motion >1mm. The percent of outliers per participant ranged from 2.7 and 12% of scans (M = 5.88%, SD = 2.96%). In the first-level analyses for each participant, the eight experimental conditions were modeled as regressors in the general linear model and convolved with the canonical hemodynamic response function. Outlier scans from ART were included as nuisance regressors in the design matrix, which was corrected for serial autocorrelations and low-frequency signal drift using a first-order autoregressive model and 128Hz high-pass filter.

Results

Self-Reports

Participants completed measures of daily experiences of discrimination (EDS; M = 31.10, SD = 10.44), and somatic symptoms (M = 8.6, SD = 2.72). The mean CES-D score in the sample was 20.80 (SD = 13.46). A score of 16 is considered to indicate significant, mild depressive symptoms (Radloff, 1997). Sixty percent of the sample (n = 6) scored a 20 or higher (minimum score = 7, maximum score = 51). On average, participants rated their overall health as

neither poor nor excellent (M = 2.4, SD = 1.35). They rated their comparative health as being about the same as others their age (M = 2.20, SD = 0.79).

In response to the question items, the majority of participants reported that others disliked them either "often" (n = 1) or "sometimes" (n = 6), and that others treated them unfairly either "often" (n = 3) or "sometimes" (n = 6), due to their racial/ethnic background. All participants reported seeing friends either "often" (n = 6) or "sometimes" (n = 4) treated unfairly due to their racial/ethnic background. 80% (n = 8) indicated that the discrimination event described in their narrative bothered them "a lot," with the other two participants endorsing "a little" and "somewhat/slightly" bothered.

fMRI Analysis

Listen, Imagine, and Breathe blocks were compared to each other across conditions using one-way t tests. This yielded a total of 12 contrasts, six for the Discrimination condition: 'discrimination-listen' > 'neutral-listen' (DL > NL), 'discrimination-listen' > 'grief-listen' (DL > GL), 'discrimination-imagine' > 'neutral-imagine' (DI > NI), 'discrimination-imagine' > 'grief-imagine' (DI > GI), 'discrimination-breathe' > 'neutral-breathe' (DB > NB), and 'discrimination-breathe' > 'grief-breathe' (DB > GB). Similarly, the Grief condition contained six contrasts: 'grief-listen' > 'neutral-listen' (GL > NL), 'grief-listen'> 'discrimination-listen' (GL > DL), 'grief-imagine' > 'neutral-imagine' (GI > NI), 'grief-imagine' > 'discrimination-imagine' (GI > DI), 'grief-breathe' > 'neutral-breathe' (GB > NB), and 'grief-breathe' > 'discrimination-breathe' (GB > DB). The resulting individual within-subjects contrasts were aggregated for whole-brain analyses at the second level, with the intensity threshold set at an uncorrected p = .001, and extent cluster threshold of 20 contiguous voxels (t = 4.297, df = 9). The Breathe blocks in the design matrix were modeled only in order to ensure a correct error

variance estimate. However, Listen and Imagine blocks were the only focus for group-level contrasts, as the Breathe segments were simply intended to serve as a chance for the participants to "reset" before the next emotion elicitation block.

Discrimination > Neutral

Compared to the neutral narrative, listening to the discrimination narrative produced significant activation in a small cluster in the left superior frontal gyrus (MNI -10 40 44; $k = 26$ voxels, peak voxel z-value= 3.41, $p < .001$) (Figure 2). No suprathreshold clusters were found when the Discrimination-Imagine condition was compared to Neutral-Imagine.

Discrimination > Grief

No suprathreshold clusters were found when comparing discrimination to grief conditions, either during Listen or Imagine blocks.

Grief > Neutral

Listening to the grief-related narrative vs. the neutral narrative elicited greater activity in numerous clusters, including left caudate, cerebellum, brainstem and midbrain, bilateral temporal poles, hippocampus, fusiform gyrus (FFG), supplementary motor area (SMA), mid-cingulate cortex (MCC), and calcarine regions (Table 2; Figure 3).

When asked to re-imagine the events of the grief narrative vs. the neutral, the participants showed significant activations in a number of regions. Though much of the observed activation overlapped with that found during the Grief-Listen condition, participants also showed putamen and precuneus activation (Table 3; Figure 4).

Grief > Discrimination

Compared to the discrimination narrative, listening to the grief narrative resulted in activation in several small clusters in the middle occipital gyrus, dACC, cerebellum, and

hippocampus (Table 4; Figure 5). No regions showed significantly greater activity during Grief-Imagine compared to Discrimination-Imagine.

Region of interest analyses

I conducted region of interest (ROI) analyses on *a priori* structural regions of interest using the Marsbar toolbox for SPM12 (http://marsbar.sourceforge.net). Because an ROI analysis constrains the search to a hypothesized region rather than all possible voxels in the brain, (or several regions), the correction is less conservative compared to the whole-brain analysis due to the much larger number of voxels in the latter. The discrimination-related analyses were based on regions previously implicated in social processing and response to threat (e.g., Britton et al., 2006; Fox et al., 2015; Gianaros et al., 2014; Van Overwalle, 2009) – namely, AMY, ACC, superior temporal gyrus (STG), and temporal poles. For the grief-related analyses, I focused on regions implicated in attachment-type love and separation/loss – the dorsal striatum (caudate and putamen), periaqueductal gray (PAG), and posterior cingulate cortex (PCC). With the exception of the PAG, all ROI masks were taken from the Automated Anatomical Labeling (AAL) atlas in Marsbar. Because the AAL does not contain a structural mask for the PAG, two 10mm spheres (at 0 -28 -12 and 6 -17 -6) for the central and right PAG were created based on previous neuroimaging studies of attachment-type love (Noriuchi, Kikuchi, & Senoo, 2008; Beauregard et al., 2009).

Discrimination > Neutral

Two regions of the left temporal pole showed significantly greater activation during Discrimination-Listen versus Neutral-Listen. However, neither survived the correction for testing multiple regions (L mid temporal pole contrast value = .30, $t = 2.68$, uncorrected $p = .013$, corrected $p = .119$; L superior temporal pole contrast value = .45, $t = 2.65$, uncorrected $p = .013$,

corrected p = .124). None of the hypothesized ROIs showed significant activation when the Imagine blocks were compared.

Discrimination > Grief

None of the hypothesized ROIs showed significant activation during Discrimination versus Grief, during either Listen or Imagine blocks.

Grief > Neutral

There was significantly greater activation in the PAG region at 0 28 -12 during Grief-Listen, contrast value = .35, t = 3.61, uncorrected p = .003, corrected p = .022. I also observed activation in the R PAG, and bilateral PCC, caudate, and putamen (Table 5). Similarly, during Grief-Imagine, ROI analyses found activation in all of the hypothesized regions, with the exception of the R PAG (Table 5). However, none of these regions remained significant after correction.

Grief > Discrimination

None of the hypothesized ROIs showed significant activation during Grief versus Discrimination, during either the Listen or Imagine blocks.

ROI analyses: Relationship to self-report

After the group-level ROI analyses, we extracted the parameter estimates at each region for each individual during each of the eight contrasts. We used bivariate correlations to examined relationships between these parameter estimates as an index of neural activity, and self-report measures of perceived discrimination, depressive symptoms, somatic symptoms, and physical health (rated both overall, and as compared to others of the same age) for the four contrasts comparing discrimination or grief to neutral (DL > NL, DI > NI, GL > NL, GI > NI). We did not examine correlations between self-reports and neural activity for the four contrasts comparing

grief and discrimination (DL > GL, DI > GI, GL > DL, GI > DI) due to the difficulty in drawing meaningful conclusions from any observed findings.

Discrimination > Neutral

Tables 6 and 7 show significant correlations between parameter estimates for discrimination-related ROIs and self-report measures.

Listen. Those who rated their physical health as being worse than others of their age showed greater amygdala activation in response to hearing the discrimination narrative (Figure 6). Those who rated their overall physical health more poorly showed greater activity in the L mid temporal pole. L mid temporal pole activity was also associated with higher CES-D scores, as well as greater frequency of observing friends being treated unfairly due to their race/ethnicity. Greater activity in the R mid temporal pole, as well as the R STG, was associated with higher ratings on the "How often do people dislike you because you are [own words]?" item. Greater activity in the L STG was associated with lower ratings for overall health, both overall and as compared to others of the same age. None of the measures correlated significantly with parameter estimates in the ACC or R superior temporal pole. In addition, none of the following self-report measures were significantly associated with parameter estimates in any of the ROIs: EDS, somatic symptoms, or item ratings for "How often do people treat you unfairly because you are [own words]?" and "How much did [event] bother you?" (Table 6).

Imagine. Greater bilateral ACC activity in response to re-imagining the discrimination event compared to the neutral event was significantly correlated with lower ratings for frequency of unfair treatment. Activity in the L mid temporal pole was associated with lower self-reported overall health, and greater frequency of observing friends being treated unfairly due to their

race/ethnicity, while activity in the R mid temporal pole was associated with perceiving oneself to be more frequently disliked by others (Table 7).

Grief > Neutral

For the grief conditions, I examined only physical health ratings, somatic symptoms, and depressive symptoms, due to the difficulty of interpreting correlations between grief-related neural activity and discrimination-related measures.

Listen. None of the self-report measures were significantly associated with activity in any of the grief-related ROIs (PAG, PCC, and dorsal striatum [caudate and putamen]).

Imagine. Left putamen activity was significantly correlated with higher CES-D scores, $r = .648$, $p = .043$.

Discussion

The present pilot study examined social stress processing related to two experiences (grief and perceived discrimination) in a sample of South Asian women. Our aim was to clarify how the neural representation of these experiences might differ as well as what they might have in common, as a hypothesized function of their association with either a specific loved one or their larger social context.

Summary

Grief > Neutral

As the women listened to their own grief narrative, we observed activity in numerous regions associated with memory (hippocampus), visual processing (occipital cortex, fusiform gyrus), attachment (caudate), language (temporal cortex/BA21) and social cognition (temporal poles), as well as regions previously observed in social stress processing (e.g., cingulate cortex, SMA; Eisenberger, 2015) and grief neuroimaging studies (e.g., anterior cerebellum and

cerebellar vermis; Gündel et al., 2003). The regions observed were also quite similar to those associated with social vs. non-social emotional processing in the study using a script driven imagery task by Frewen and colleagues (2011). Although the cerebellum has traditionally been associated primarily with motor activity, it has recently been implicated more often in non-motor, higher order cognitive processes, including language and executive function as well as viewing affective images and facial displays of emotion (Bucker, 2013; Chen, Ho, & Desmond, 2014). We also found several clusters in the midbrain and brainstem. The dorsal raphe nucleus is located in the mid-brainstem region, and features dopaminergic and serotonergic projections to the forebrain, including striatal and limbic regions (Waselus, Valentin, & Von Bockstaele, 2011). Recent animal research points to a role for dorsal raphe dopamine neurons in the experience of social isolation and loneliness, suggesting that neuronal activity in this region may underlie the aversive nature of social isolation as well as the drive to seek out social connection (Matthews, Nieh, Vander Weele, Halbert, Pradhan, Yosafat... & Wildes, 2016). The raphe nucleus is also implicated in pair-bond formation among both newlyweds and long-term partners, in which the serotonergic system is implicated in the sense of "felt security" while the dopaminergic system is implicated in proximity-seeking and reward processes in attachment relationships (Acevedo, 2015). The temporal pole activation was unexpected – this was one of our hypothesized regions for the perceived discrimination conditions given its role in social cognition and particularly automatic or reflexive processing in social cognition, in conjunction with the dACC, amygdala, and ventromedial PFC (Liberman, 2007). However, upon listening to the interview excerpts, it became clear that some participants' grief memories centered around their empathy and sadness at witnessing the grief of others they were close to (for example, a younger participant discussed how painful it was for her to see her mother mourning the death of her own mother). Thus, the

Grief condition may have involved greater theory of mind than anticipated. Temporal pole activation has also been shown in prior grief studies (O'Connor, Irwin, & Wellisch, 2009).

Unlike prior studies, the present study did not find activity in either the precuneus or PCC in the whole brain analyses for the Grief-Listen condition, although PCC activity emerged in the ROI analysis. Both PCC and precuneus are implicated in memory and self-referential processing (Northoff et al., 2006). The task used in the present study differed from previous grief neuroimaging studies in that the control condition for the present study was designed to evoke episodic memory related to the self in order isolate mental functions specifically related to grief or discrimination experiences versus self-referential thought and memory more broadly. In previous studies, the control condition featured images of a stranger (versus images of the deceased in the experimental condition). However, we did observe activation in a small cluster in the precuneus (Brodmann Area 31) when Grief-Imagine and Neutral-Imagine conditions were compared. When participants were instructed to re-imagine themselves back in the situation described in their grief narrative, we observed additional activity in regions including the mid-cingulate cortex, putamen, pallidum, and thalamus. Several studies suggest that connectivity in the thalamocingulate division, which encompasses a number of these areas, facilitates mammalian attachment behavior, both romantic and maternal (e.g., Acevedo, 2015; Lorberbaum, Newman, Horwitz, Dubno, Lydiard, Hamner... & George, 2002).

Grief > Discrimination

Compared to discrimination, when women listened to their grief narrative they showed greater activation in several small clusters associated with memory, attention, and visual processing. There were no significant differences between grief-imagine and discrimination-imagine conditions.

Discrimination > Grief

No areas showed significantly greater activity during discrimination versus grief, for either listen or imagine segments. However, this does not necessarily imply that there are no differences in how perceived discrimination and grief are processed in the brain. Woo, Koban, Kross, Lindquist, Banich, Ruzic, Andrews-Hanna, & Wager (2014) argue that overlapping fMRI activity does not necessarily indicate identical neural representations. For example, an anatomical region such as the dACC, which is implicated in numerous cognitive and affective functions, contains "multiple, functionally specific subpopulations of neurons" encoding for distinct types of affect. In this instance, multivariate pattern classification of resting state data showed that neural representations for pain and rejection that are "encoded in the same set of dACC voxels have distinct functional connectivity patterns with the rest of the brain" (Woo et al., 2014). Thus it may be important to examine neural representations of grief and perceived discrimination at different levels of analysis beyond simply their shared neuroanatomy, using more advanced methods than in the present study.

Discrimination > Neutral

Listening to the discrimination narrative produced significant activation in a small cluster in the left dmPFC, a prefrontal region that has been widely implicated in top-down processes including socioemotional processing, behavioral inhibition and emotion regulation (e.g., Ochsner, Silvers, & Buhle, 2012). Recalling experiences of discrimination, which should involve considering one's relationship to the larger social context may draw on one or several of these processes. Muscatell and colleagues (2012) found that individuals who perceived themselves to be of lower social status in their community showed greater neural activity in the mentalizing network, including the mPFC, precuneus, and PCC. Additionally, they found that lower

socioeconomic status predicted greater activity in the dmPFC and amygdala in response to threatening faces.

Contrary to the hypothesis that Imagine segments should elicit greater activity compared to Listen segments, and that re-imagining the discrimination experience should be more emotionally evocative than imagining oneself brushing one's teeth, there was no significant difference between Discrimination-Imagine and Neutral-Imagine. During Discrimination-Listen, we observed activity in only one small cluster in the mPFC. This was unexpected, and inconsistent with both previous literature as well as participants' observed and stated affect as evidenced in their recordings. There are several possible explanations for this discrepancy. After looking back at the single-subject analyses, I identified one participant (RD017) for whom either listening to or imagining her discrimination experience elicited no activation relative to grief or neutral. The discrimination incident that she chose to relay occurred when she was a very young child, unlike other participants who described events from their adult life. She stated in the interview that she "didn't take [being discriminated against] personally," knowing that the perpetrator was wrong to treat her unfairly. I re-ran the Discrimination-Listen > Neutral-Listen contrast after excluding this participant, in order to explore her potential impact on these findings. Results of this analysis ($n = 9$) identified two additional suprathreshold clusters, one near the right hippocampus (30, -28, -2), $t = 8.11$, $Z = 4.11$ and the other in the supplementary motor area (-8, 8, 62), $t = 7.91$, $Z = 4.07$, $p = .001$, $k = 20$. Both of these clusters would be reasonable to expect given the nature of the emotional imagery task in drawing upon memory and social exclusion-related processes. SMA activity appears consistently in fMRI studies of social exclusion and rejection (e.g., Eisenberger, 2015), including the racial discrimination study

by Masten and colleagues (2011). However, these findings should be considered purely exploratory, particularly without the subjective distress and manipulation check data.

In the same exploratory vein, I also examined the full group-level analysis ($n = 10$) for Discrimination-Listen > Neutral-Listen using a more liberal threshold for significance, as I was interested in seeing if there was any discrimination-related activation in areas consistent with the existing literature, even if not strong enough to pass the original threshold of $p_{uncorrected} = .001$. At the more liberal threshold of $p = .005_{uncorrected}$, $k = 20$, I observed additional clusters in several additional regions, including the superior temporal gyrus/temporal pole, supramarginal gyrus, dorsolateral PFC (BA 9), pars triangularis (BA 45), occipital (BA 19), cerebellar uvula, and brainstem. This suggests that listening to personal experiences of discrimination did involve different brain activation compared to neutral, at least for the majority of participants, but that our sample may have been underpowered to detect these differences given the small number of participants and the heterogeneity of discrimination experiences described.

The observed prefrontal activity during discrimination may suggest that the women could have engaged more top-down control over the emotions evoked by recalling perceived discrimination experiences, relative to grief. For example, increased activity in the vlPFC has been associated with greater tolerance for unfair treatment in the context of monetary offers and decreased negative affect-related neural activity (Tabibnia, Satpute, & Lieberman, 2007). Consistent with the view that attributing unfair treatment to group, rather than personal characteristics may be protective (e.g., Major et al., 2003), African-American participants who attributed their exclusion during the Cyberball task to discrimination showed greater, hypothetically emotion regulation-related activation in the dACC and lesser activity among in affective regions such as the anterior insula. Additionally, lower dmPFC activation was

associated with greater post-task distress (Masten et al., 2011). Individuals may have greater motivation to down-regulate their responses in the context of repeated exposure to chronic discriminatory treatment, as a protective measure. Inman et al. (2015) suggest that emotional suppression or avoidance may be an adaptive response in this context, and may in fact confer resilience as a culturally-congruent form of coping for Asian Indian individuals, whereas confrontation or overt emotional expressivity would conflict with cultural values. In coping with discrimination, prior research suggests that South Asian women have tended to disengage or distance themselves from perceived discrimination incidents, depersonalizing or diffusing the emotional impact of the events in their narrative through phrasing events as hypothetical or focusing on cognitive, rather than emotional, details of the incident (Inman et al., 2015; Liang et al., 2010). Many of the women in the present study recounted incidents that were representative of numerous lifetime experiences as a South Asian in the US, so many of the discrimination narratives were less crystallized in time compared to their grief narratives. Rather than a specific incident, a woman might relate her impression of cumulative lifetime experiences along a theme – for example, a young woman whose family was always subjected to extra scrutiny at the airport every time they traveled, or a woman who described how hurt she felt when the people in her life invoked stereotypes about Indians. An additional element in the discrimination experiences was that the majority of incidents centered around post-9/11 Islamophobia, even though only two of the ten women were Muslim (six identified as Hindu; the other two were Sikh or agnostic). Effects of discrimination are often moderated by group identification, so future research should seek to disentangle how being marginalized based on misperception of one's identity might shape emotional responses. For example, one Hindu woman described how upsetting it was for her to be a target of Islamophobia based solely on her name and physical

appearance: "*I have nothing against the race or anything but for them to say, like, to base me on that – just, it tore me up. You know? It was not right.*"

Moderate-to-strong correlations among parameter estimates in selected discrimination-related regions of interest and self-report measures suggest that the tendency to give more thought to others' actions and motivations may confer greater susceptibility to experienced discrimination, as temporal pole activation was positively correlated with depressive symptoms and greater perceived discrimination for both self and others. Greater bilateral amygdala activation was associated with poorer self-reported physical health compared to others of the same age (Figure 6). During the Discrimination-Imagine condition, activity in the mid temporal pole was associated with lower ratings for physical health and more frequent perception of friends receiving discriminatory treatment. Although the ACC ROIs were not associated with any self-reports during the Listen condition, bilateral ACC signal during Imagine correlated negatively with perceived frequency of discriminatory treatment. This is consistent with prior accounts showing positive relationships between ACC activity and duration of exclusion – studies that employed longer periods of exclusion found greater ACC activation relative to studies that featured shorter exclusion conditions – as well as positive relationships with self-reported distress (Rotge et al., 2015). However, none of these areas emerged as significant in the ROI analysis, and these associations should therefore be interpreted with caution.

Limitations

The present study has several limitations that should be noted. First, sample size meant that we were likely underpowered to detect effects (as reflected in the whole brain analyses, which did not pass familywise error correction), and that results may have been heavily influenced by a single individual, as described above with regard to the participant RD017, or

another participant who seemed particularly upset as she recounted intense regret, isolation and sadness in response to the death of her parents. Another limitation of the small sample was that we were unable to conduct subgroup analyses. Age and first- or second-generational status may be important factors to consider (e.g, Inman et al., 2015; Kaduvettor-Davidson & Inman, 2012). The intersection of race and gender along with other aspects of identity and environment, such as socioeconomic status and education (e.g., Cole, 2009; Ruiz & Brondolo, 2016) are also important considerations that we were unable to explore given the sample size. Secondly, the design of the emotional imagery task was not counterbalanced: participants always completed the grief condition first (after one sequence of neutral to acclimate to the scanner), followed by neutral, with discrimination last. This could have contributed to the differential neural activity that we observed during grief conditions relative to discrimination. Third, subjective distress and manipulation check ratings (intensity of reliving experience, vividness of sensations) administered at time of the scan were unavailable, so it is impossible to know whether the participants were able to engage in the task as intended. Available ratings from the time of the interview indicated that on average, grief experiences (mean distress = 8.44; $n = 9$) and discrimination experiences (mean distress = 8.57, $n = 7$) were substantially more distressing than the neutral condition (mean distress = 1.83; $n = 6$). However, it is possible that participants may have rated how bothered they were *at the time of the event*, rather than how bothered they were in the moment of recollection, due to the ambiguous wording of the probes ("how much did [event] bother you?") Finally, it is important to note that racism occurs at multiple levels; the current study focused primarily on perceived discrimination at the individual level, rather than discrimination occurring at cultural or institutional levels. Experiences of racism among South Asian groups have been shown to span multiple levels (Inman et al., 2015).

Strengths

Despite these limitations, the study also features several strengths. South Asian women represent a group that is critically underrepresented in the neuroimaging literature, which has tended to feature samples comprised predominantly of Western, Educated, Industrialized, Rich, and Democratic (WEIRD) individuals (Heinrich, Heine, & Norenzayan, 2010). Even among the discrimination literature, few studies have focused specifically on the South Asian experience in the US. Though we would not necessarily expect neural functioning to be fundamentally unique among South Asian women (i.e., "invidious comparisons"; see Cole & Stewart, 2001), a more comprehensive and representative body of scientific knowledge requires that research be conducted with diverse samples, given that our social and cultural environment shapes the way in which we experience and perceive the world (e.g., Bronfenbrenner, 1989; 2004), and this is likely reflected in our neural activity. For example, a recent EEG source-localization study showed that although default mode network activity is present cross-culturally, alpha activity is most prevalent in the anterior hub in a Taiwanese sample – versus the posterior hub in a Russian sample (Knyazev, Savostyanov, Volf, Liou, & Bocharov, 2012). The authors link their findings to cultural differences in attentional focus, affect, personality, and cultural dimensions (e.g., collectivism versus individualism). Another strength of the present study is that few studies have explored 'sociality' as a potential third dimension of emotion, and fewer still if any have explored whether there are varying degrees to the sociality dimension – for example, distinguishing between "interpersonal" versus more broadly "social" emotions (Britton et al., 2006; Landa et al., 2013) or at different levels of participants' social networks (Wlodarsk & Dunbar, 2016). Though the results presented here should be considered preliminary, and thus interpreted with caution, the current study fills a gap in the literature and addresses the

intersection of several underexplored areas, potentially stimulating further work in this area.

Future directions

Isolated incidents lend themselves more easily to laboratory study, but "real rejections occur within a complex system of other influences" (Smart Richman & Leary, 2009, p.2) and may carry different meaning for individuals embedded in different social ecological contexts. Future studies should consider how experimental design could capture higher-level forms of discrimination as well as instances of microaggression in addition to overt, individually-directed events. Cumulative subtle forms of discrimination may have greater power to negatively affect minority groups as a consequence of their attributional ambiguity (e.g., Sue et al., 2007). For example, the perseverative cognition hypothesis posits that prolonged activation of cognitive representations of threat elicits physiological dysregulation as a consequence of chronic anticipatory arousal (Brosschot et al., 2006), and the chronic social stress of racism-related vigilance has been linked to health disparities (e.g., Hicken et al., 2014; Himmelstein et al., 2015).

Conclusion

In sum, we observed patterns of neural activity in grief compared to neutral that were largely consistent with the few previous neuroimaging studies of grief (e.g., Gundel et al., 2003; O'Connor et al., 2008; 2009; Silva et al., 2014) despite the heterogeneity of grief experiences in a sample that was not selected specifically for bereavement. This suggests that grief-related activation is relatively consistent even when one's relationship with the deceased is not a prototypic attachment relationship. Discrimination-related neural activity was not as strong, although the regions that were observed using a more lenient threshold for significance are consistent with prior studies that used experimental manipulations such as the Cyberball task to

examine effects of discrimination (e.g., Masten et al., 2011). We also observed prefrontal activation during the perceived discrimination condition compared to neutral, which may suggest greater self-regulatory effort involved in coping with discrimination experiences. Though challenging to interpret this finding in isolation, these preliminary results suggest that there are observable differences in the brain response to these two types of social stressors, and indicate future directions for taking a more fine-grained view of the mechanisms through which the social environment impacts individuals.

Tables

Table 1.
Sample Characteristics

		n
Country of birth	United States	5
	India	4
	Saudi Arabia	1
	Years in the US: M = 16.80, *SD* = 13.92	
Religious affiliation	Hindu	6
	Muslim	2
	Sikh	1
	Agnostic	1
Employment	Student	1
	Part time	3
	Unemployed	3
	Declined to answer	3
Highest degree completed	High school diploma, GED, or vocational degree	5
	BA/BS	2
	Graduate degree	2
	Education (years): M = 16.4, *SD* = 3.53	

Table 2.

Regional Activation for Grief-Listen > Neutral-Listen

Anatomical Region	BA	T	Z-score[a]	Peak MNI coordinates			Voxels
				x	y	z	
L caudate		8.78	4.41	-20	6	22	222
R cerebellar vermis		8.63	4.38	4	-56	-20	765
L ITG/hippocampus/AMY	20/21	7.89	4.22	-44	-12	-22	757
R midbrain		7.83	4.2	12	-26	-10	286
L cerebellum		7.68	4.17	-12	-42	-46	292
R posterior cerebellum		7.62	4.15	16	-70	-36	82
L mid temporal pole	38/21	7.48	4.12	-50	6	-34	127
R fusiform gyrus		6.11	3.75	30	-74	-2	36
L anterior cerebellum		6.06	3.73	-24	-40	-28	51
R temporal pole	21	5.84	3.67	46	10	-38	29
L SMA	6	5.82	3.66	-10	-18	54	26
R calcarine	17	5.64	3.6	14	-94	-6	37
L MCC/medial SFG		5.51	3.56	-12	20	46	41
R temporal/sub-gyral		5.41	3.52	34	-2	-30	35
R midbrain		4.76	3.28	12	-16	-20	20

[a] $p < 0.001$, uncorrected; $k = 20$.

Note. AMY = amygdala, ITG = inferior temporal gyrus, MCC = mid cingulate cortex, MTG = middle temporal gyrus, SFG = superior frontal gyrus, SMA = supplementary motor area,.

Table 3.
Regional Activation for Grief-Imagine > Neutral-Imagine

Anatomical Region	BA	T	Z-score[a]	Peak MNI coordinates			Voxels
				x	y	z	
R IFG		13.48	5.13	28	12	-14	24
L caudate		9.62	4.57	-14	-8	20	167
L MCC/SMA	32	8.83	4.42	-12	14	38	123
L posterior cerebellum		7.84	4.21	-30	-56	-46	42
L hippocampus		7.64	4.16	-24	-10	-12	27
L inferior temporal lobe	20	7.51	4.13	-44	-14	-24	91
L cerebellar tonsil		7.36	4.09	-16	-50	-42	143
R thalamus		7.07	4.02	10	-14	16	31
L hippocampus/thalamus		6.75	3.93	-28	-24	-6	73
R inferior occipital	18	5.98	3.71	30	-92	-2	52
R cerebellum		5.94	3.7	8	-62	-28	88
L midbrain		5.84	3.67	-2	-34	-22	72
R putamen/pallidum		5.53	3.56	20	4	-2	35
R lingual gyrus	17	5.51	3.56	16	-88	-4	52
R precuneus	31	5.1	3.41	18	-48	38	50

[a] $p < 0.001$, uncorrected; $k = 20$.

Note. IFG = inferior frontal gyrus, MCC = mid cingulate cortex, SMA = supplementary motor area.

Table 4.

Regional Activation for Grief-Listen > Discrimination-Listen

Anatomical Region	BA	*T*	*Z*-score[a]	Peak MNI coordinates			Voxels
				X	*Y*	*z*	
Middle occipital gyrus		6.67	3.91	34	-78	-2	31
L dACC	32	6.43	3.85	-20	32	24	40
R cerebellar culmen		5.63	3.60	12	-44	-24	58
L hippocampus		5.58	3.58	-36	-30	-10	40

[a] *p* < 0.001, uncorrected; *k* = 20.

Note. dACC = dorsal anterior cingulate cortex,

Table 5.

Region of Interest Analyses: Grief > Neutral

Condition	ROI	Contrast value	*T*	*P*
Listen	PAG (0 -28 -12)*	.35	3.61	.003
	R PAG (6 -17 -6)	.25	2.71	.012
	L caudate	.35	2.82	.010
	R caudate	.32	2.01	.038
	L PCC	.63	2.50	.017
	R PCC	.71	2.83	.010
	L putamen	.41	2.17	.029
	R putamen	.41	2.66	.013
Imagine	PAG (0 -28 -12)	.32	1.86	.048
	R PAG (6 -17 -6)	.21	1.51	.083
	L caudate	.26	2.68	.013
	R caudate	.22	2.10	.033
	L PCC	.40	2.17	.029
	R PCC	.58	2.83	.010
	L putamen	.36	2.39	.020
	R putamen	.33	2.89	.010

Note. PAG = periaqueductal gray, PCC = posterior cingulate cortex.

*PAG survived correction for the number of ROIs (corrected *p* = .022).

Table 6.

Correlations Between Activity in Discrimination-Related Regions of Interest and Self-Report Measures During 'Listen'

	Measures				
	Physical Health (overall)	*Physical Health (compared to same-age others)*	*CES-D*	*How often do people dislike you because you are…?*	*How often do you observe friends treated unfairly because they are…?*
L AMY		-.638*			
R AMY		-.711*			
L ACC					
R ACC					
L mid TP	-.638*		.759*		.768**
R mid TP				.764*	
L sup. TP					
R sup. TP					
L STG	-.665*	-.737*			
R STG				.633*	

Note. Signs for the correlations with the question items (latter two measures) were switched in order to make them more interpretable: higher frequency ratings indicate greater frequency. AMY = amygdala, ACC = anterior cingulate cortex, TP = temporal pole, sup. TP = superior temporal pole, STG = superior temporal gyrus. Measures with no significant correlations are not shown. CES-D = Center for Epidemiological Studies – Depressed Mood Scale (Radloff, 1997). * p < .05, ** p < .01

Table 7.

Correlations Between Activity in Discrimination-Related Regions of Interest and Self-Report Measures During 'Imagine'

	Measures			
	Physical Health (overall)	*How often do people dislike you because you are…?*	*How often do people treat you unfairly because you are…?*	*How often do you observe friends treated unfairly because they are…?*
L AMY				
R AMY				
L ACC			-.701*	
R ACC			-.688*	
L mid TP	-.675*			.654*
R mid TP		-.644*		
L sup. TP				
R sup. TP				
L STG				
R STG				

Note. Signs for the correlations with the question items (latter three measures) were switched in order to make them more interpretable: higher frequency ratings indicate more dislike/greater frequency. AMY = amygdala, ACC = anterior cingulate cortex, TP = temporal pole, sup. TP = superior temporal pole, STG = superior temporal gyrus. Measures with no significant correlations are not shown. * *p* < .05, ** *p* < .01
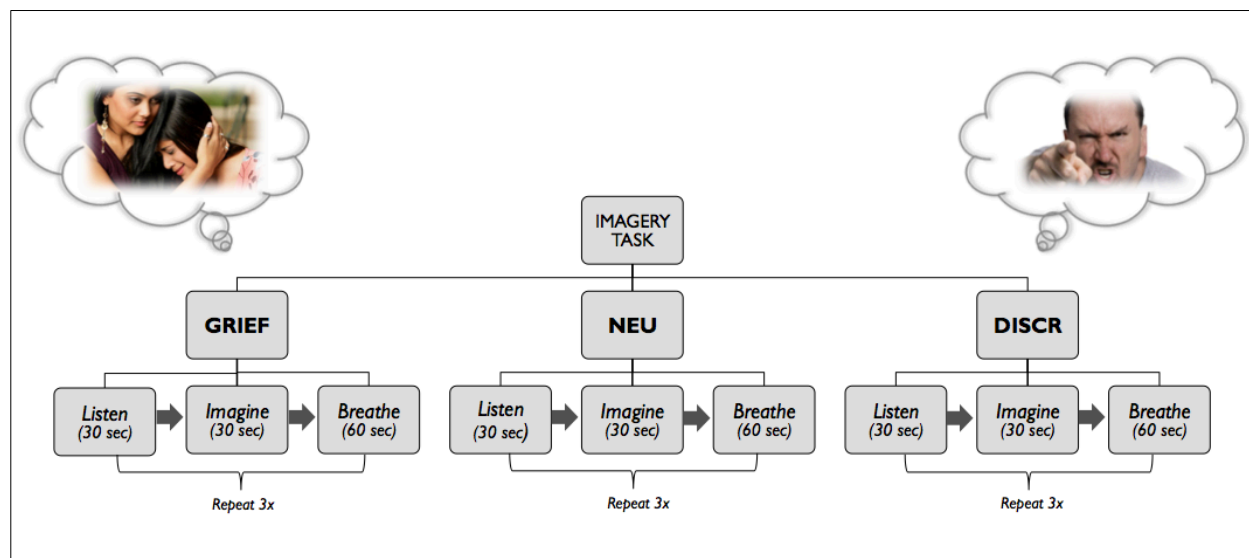
Figures

Figure 1. Design of the emotional imagery task. The task consisted of a 3 x 3 x 3 block design with three conditions: Neutral, Grief, and Discrimination. Participants first listened to one of the three 30-second audio excerpts from their interview ('Listen'). They were then instructed to imagine themselves back in that specific scenario in the most vivid and immediate detail as possible ('Imagine'), followed by instructions to breathe and let go of the memory for 60 seconds ('Breathe'). This sequence was repeated three times within each condition.
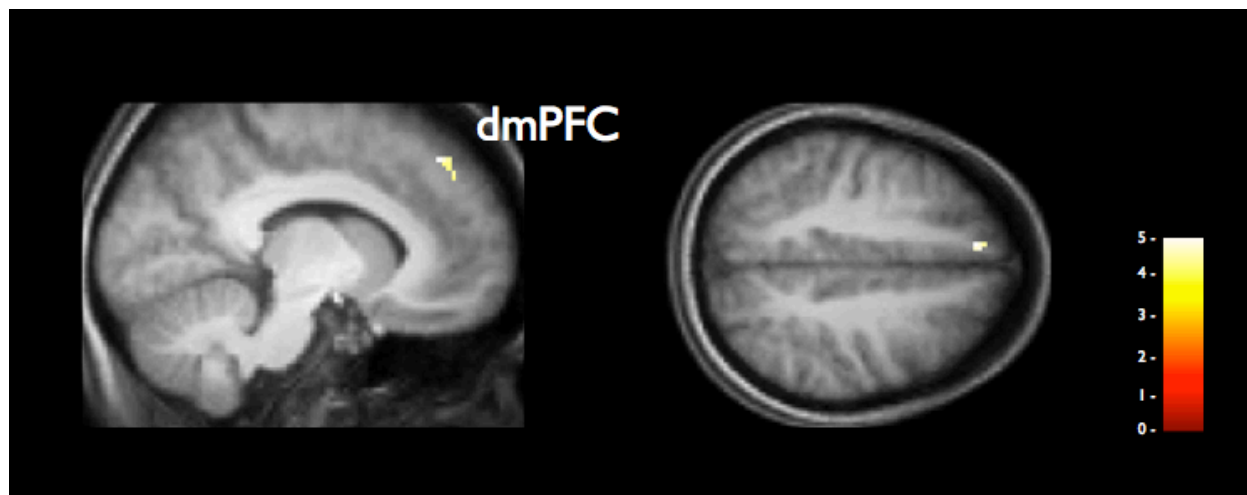
Figure 2. Discrimination (Listen) > Neutral (Listen). In response to hearing their discrimination narrative played back, participants showed activity in a small cluster in the left dorsomedial prefrontal cortex (dmPFC).
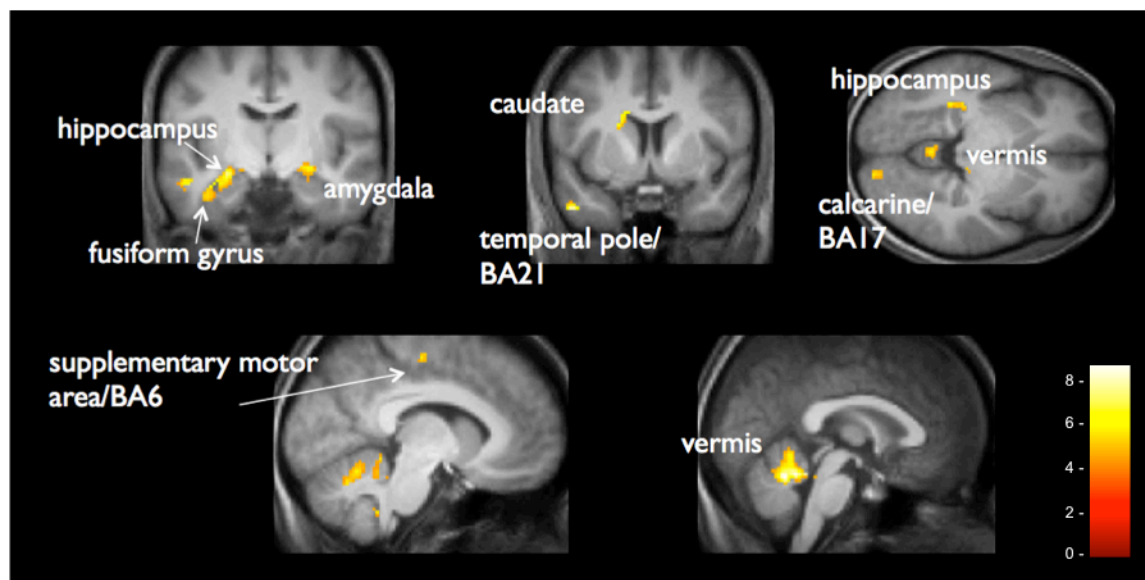
Figure 3. Grief (Listen) > Neutral (Listen). Hearing their own grief-related narrative elicited activation in the left hippocampus and fusiform gyrus, right amygdala, supplementary motor area, the calcarine area of the occipital cortex, and cerebellum. BA = Brodmann Area.
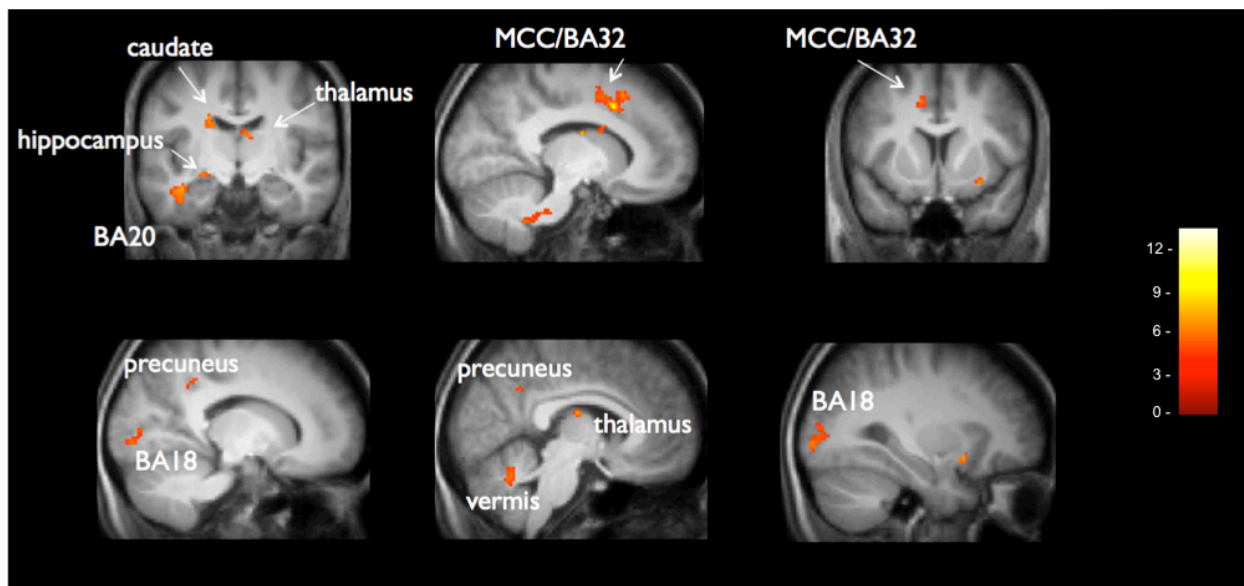
Figure 4. Grief (Imagine) > Neutral (Imagine). Re-imagining the events in the grief narrative evoked activity in hippocampal and thalamocingulate regions, as well as the right insula, precuneus, occipital cortex, and cerebellum. BA = Brodmann Area, MCC = mid cingulate cortex.
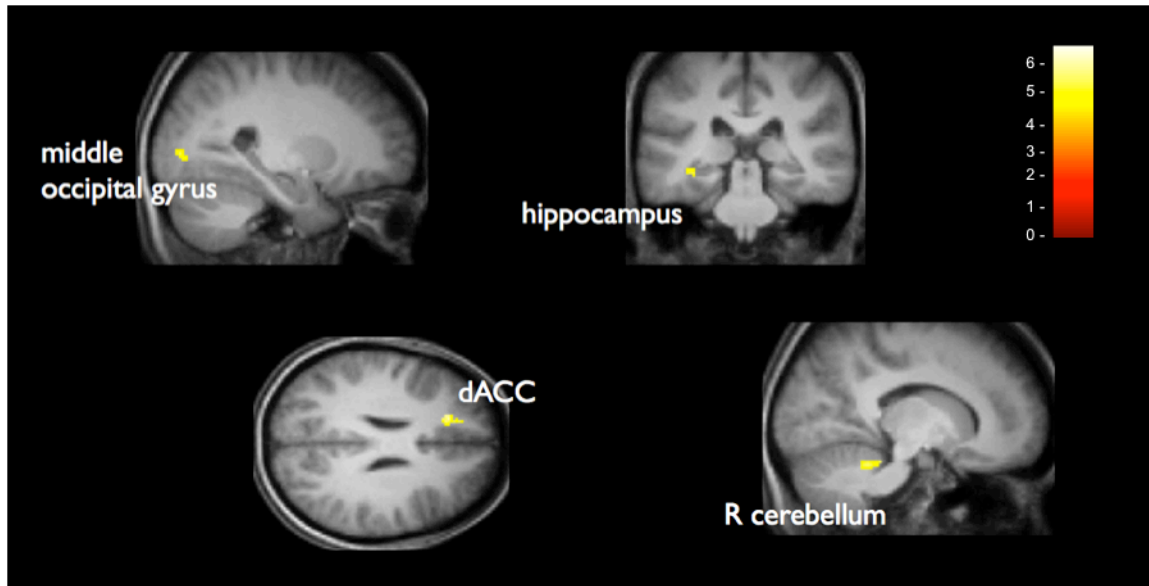
Figure 5. Grief (Listen) > Discrimination (Listen). Compared to the discrimination narrative, listening to the grief narrative elicited activity in the middle occipital gyrus, left hippocampus, dorsal anterior cingulate (dACC), and right anterior cerebellum.
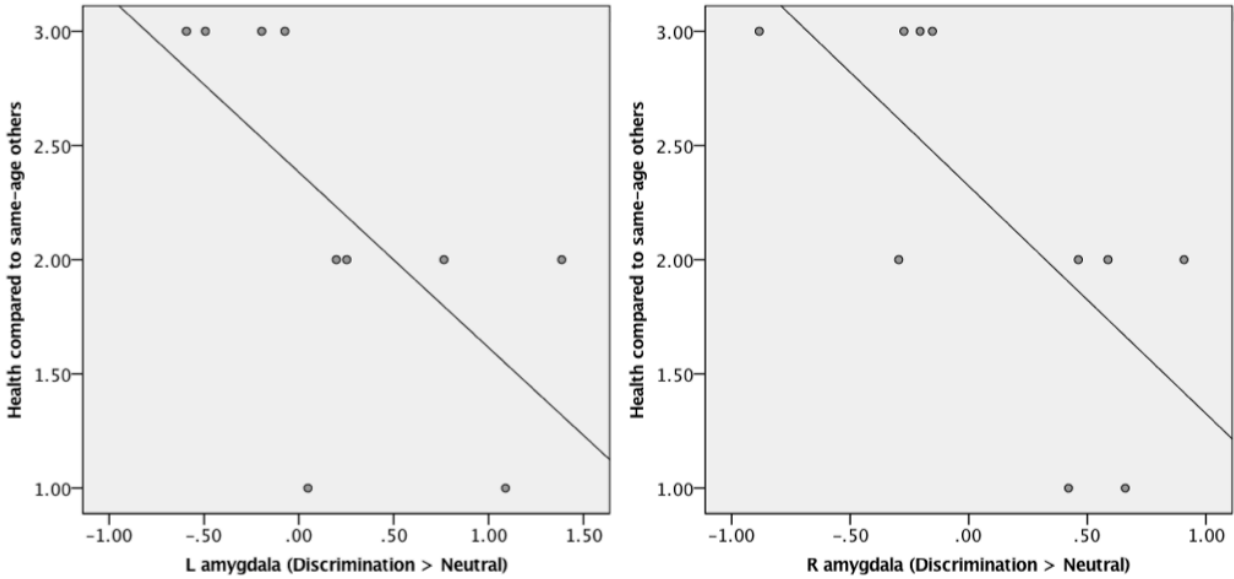
Figure 6. Poorer self-reported overall health correlates negatively with amygdala response to discrimination. Participants who rated their overall health as lower than others of the same age exhibited greater bilateral amygdala activation in response to listening to their discrimination narratives.

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