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Social status modulates neural activity in the mentalizing network

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ABSTRACT

The current research explored the neural mechanisms linking social status to perceptions of the social world. Two fMRI studies provide converging evidence that individuals lower in social status are more likely to engage neural circuitry often involved in 'mentalizing' or thinking about others' thoughts and feelings. Study 1 found that college students' perception of their social status in the university community was related to neural activity in the mentalizing network (e.g., DMPFC, MPFC, precuneus/PCC) while encoding social information, with lower social status predicting greater neural activity in this network. Study 2 demonstrated that socioeconomic status, an objective indicator of global standing, predicted adolescents' neural activity during the processing of threatening faces, with individuals lower in social status displaying greater activity in the DMPFC, previously associated with mentalizing, and the amygdala, previously associated with emotion/salience processing. These studies demonstrate that social status is fundamentally and neurocognitively linked to how people process and navigate their social worlds.

Social hierarchies are a ubiquitous feature of social groups, from adolescent cliques to the stratification of wealth across societies. Decades of research now suggest that social status, or an individual's place in a social hierarchy, is predictive of a variety of important outcomes, such as physical and mental health (Adler et al., 1994; Gianaros and Manuck, 2010) as well as neurocognitive functioning (e.g., working memory, language processing; Noble et al., 2007). Where one stands in a social hierarchy is a critical determinant of their psychological and biological outcomes.

Social status also seems to affect how people navigate their social worlds. A growing body of research has begun to document status-based differences in social behavior. For example, during interpersonal interactions, individuals who are relatively lower in social status exhibit cues that they are closely attending to an interaction partner (more eye contact, head nodding, laughing; Kraus and Keltner, 2009). By contrast, higher-status individuals' are more likely to behave in ways suggesting *less* engagement in the interaction (relatively more self-grooming, fidgeting, doodling). Furthermore, relative to higher-status individuals, low-status individuals are more likely to give to others during economic bargaining games, and they donate a greater percentage of their income to charity (Piff et al., 2010; Rucker et al., 2011). Together, these data converge on the idea that social status moderates the extent to which individuals are focused on others.

A related line of research suggests that social status not only guides social behavior, it also influences social cognitive processes. In particular, social status affects performance on tasks that involve thinking about the thoughts and feelings of others. For example, individuals who are lower-status are more accurate at inferring the emotional states of others, relative to their higher-status counterparts (Kraus et al., 2010). When people are experimentally manipulated to feel low status, they are more accurate at reading the emotions of others, compared to when they are made to feel high status (Kraus et al., 2010). Finally, participants who are asked to recall a time in which they had low power (a characteristic similar to status) are more likely to adopt the perspective of another person than individuals who recall a time in which they had high power (Galinsky et al., 2006). Together with the literature on social status-based differences in social behavior, these data provide support for the hypothesis that lower-status individuals are more likely to engage in social cognitive processes that aid in understanding how others think, feel, and behave.

Although past research suggests that social status affects the tendency to try and understand how others think and feel, much of this research has explicitly asked participants to take the perspective of another (e.g., "identify the emotion the person in this photo is

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feeling"; cf. Galinsky et al., 2006). Thus, it remains relatively unclear whether individuals who are lower in social status spontaneously think about the thoughts and feelings of others when they encounter social situations, or if they are simply better at inferring others' beliefs and emotions when directed to do so. Neuroimaging methods offer an opportunity to examine the extent to which people may be engaging social cognitive processes even when they are not explicitly asked to perform such tasks. Although some neuroimaging studies have examined how people process cues of social status in others (Chiao, 2010; Chiao et al., 2009; Marsh et al., 2009), and the role of social status in the context of performance-based feedback (Zink et al., 2008), no known studies have examined the relationship between an individual's own social status and their neural activity during tasks that involve understanding others.

As it turns out, the neural processes that are engaged when thinking about the thoughts and feelings of others are well documented. Specifically, a network of brain regions, including the dorsomedial prefrontal cortex (DMPFC), medial prefrontal cortex (MPFC), precuneus/posterior cingulate cortex (PCC), temporoparietal junction (TPJ), and posterior superior temporal sulcus (pSTS) is consistently activated during tasks that require understanding the mental states of others, or mentalizing (Frith and Frith, 2006; Lieberman, 2010; Mitchell, 2009).

To examine if social status modulates neural activity in the mentalizing network, we conducted two functional magnetic resonance imaging (fMRI) studies. In Study 1, we examined how a subjective measure of social status related to neural activity when encoding information about another individual. Given that subjective perceptions of social status have been shown to predict certain health outcomes even better than more objective measures of status (i.e., socioeconomic status [SES]; Singh-Manoux et al., 2005), we focused on subjective social status in this study. We employed a task that involved encoding information about another individual, given that this type of task has been shown in prior work to reliably engage the mentalizing network (for a review, see Mitchell, 2009). We predicted that individuals lower in social status would show greater activity in brain regions typically engaged during mentalizing, compared to high status individuals. In a second study, we used a new subject population – adolescents – and examined whether a more objective measure of social status, SES, would modulate neural activity during a threat-processing task. Responses to a threat-processing task may be particularly illuminating of status-based differences in mentalizing, as interpretations of whether another's intentions are threatening – which requires mentalizing – has been shown to be moderated by SES (Chen et al., 2004). We predicted that adolescents from lower SES households would show greater neural activity in brain regions involved in mentalizing during this task compared to high SES adolescents. Across the two studies, we predicted that regardless of subject population and whether the stimuli were threatening or non-threatening, those lower in social status would show greater neural activity in mentalizing-related neural regions.

Study 1

Method

Participants

Participants were 16 undergraduate students (8 males) who were between the ages of 18 and 24 (M age = 19.81 years, SD = 1.8). All participants were Caucasian, right-handed, and reported no history of neurological disorder.

Procedure

Participants underwent an fMRI scan while they viewed pictures and read social and non-social passages describing people and objects. Following the scan, participants completed a measure of subjective social status.

Measures

Social status measure. To measure social status, participants completed a modified version of the MacArthur Subjective Social Status Scale (Adler et al., 2000). Participants were shown a picture of a ladder with ten rungs: at the top of the ladder are the people who are the best off (most money, most education, best jobs); at the bottom of the ladder are the people who are the worst off (least money, least education, worst jobs). They were asked to indicate on which rung they thought they were, in reference to the rest of the UCLA community, given that this was likely to be the group in which status was most salient for a college-student sample. Scores ranged from 2 to 8 (out of a possible 10; M = 6.16, SD = 1.91), indicating that participants varied in their perceptions of their social status within the UCLA community.

Neuroimaging task. Participants were scanned using BOLD fMRI while they were presented with a series of images (described below), each accompanied by a descriptive text passage (see Supplementary Fig. 1; designed by S. Morelli). First, participants viewed a fixation crosshair for 4 s. Then, they completed a self-paced task. Participants were asked to look at a photo, read a passage, and press a button to advance to the next screen when they were finished reading, which yielded a measure of reaction time. Participants completed a total of four trials, alternating between two social-information trials, and two object-information trials (presented in counterbalanced order). After making a button press to indicate they had finished reading the passage, the passage disappeared, and a fixation crosshair was presented for 15 s.

During the "social information" trials of the task, participants viewed an image of a UCLA student that matched the participant's gender and ethnicity, and read two passages the person supposedly wrote. The passages were written from a first-person perspective, using the pronoun "I". Importantly, participants were not explicitly instructed to take the perspective of the person in the photo. One passage described the pictured individual's thoughts and feelings at the beginning of a new quarter of school; the other described his/her thoughts and feelings about going to lunch with a friend.

During the "object information" trials of the task, participants viewed an image of an inanimate object (e.g., pedometer, flash drive) and read a passage describing the object in an objective, unemotional way. These trials were designed as a comparison task for the social task: They did not involve any social information, but still required participants to view an image and read a description of that image.

fMRI data acquisition

Images were collected using a Siemens Trio 3-T MRI scanner. Participants were instructed to hold as still as possible during the scan; foam padding around the head was provided to restrict motion. A high-resolution structural scan coplanar with the functional scans was obtained for functional image registration during preprocessing (echo planar fast T2-weighted segmented spin echo, TR = 5000 ms, TE = 34 ms, FOV = 220 mm, 33 slices, 4.0 mm slice thickness). Task stimuli were presented on a computer screen through MR-compatible goggles. Both the social-information and object-information tasks were presented during a functional scan lasting approximately 5 min (parameters for functional scan: echo-planar T2*weighted gradient-echo, TR = 2000 ms, TE = 30 ms, flip angle = 75, 33 slices, FOV = 220 mm, 4.0 mm slice thickness).

fMRI data analysis

Data analysis was performed using SPM5 (Wellcome Department of Imaging Neuroscience, London). Images were realigned, coregistered, normalized into Montreal Neurological Institute (MNI) space, resliced into voxels of 3 mm cubed and smoothed with an 8 mm Gaussian kernel. First-level effects were estimated using the general linear model and employed a canonical hemodynamic response function convolved with the experimental design. Low-frequency noise was removed using a