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Neural correlates of envy: Regional homogeneity of resting-state brain activity predicts dispositional envy

Yanhui Xiang [a,b,c], Feng Kong [d,e], Xue Wen [a,b,c], Qihan Wu [a,b,c], Lei Mo [a,b,c,*]

[a] Center for Study of Applied Psychology, South China Normal University, Guangzhou, Guangdong, China
[b] School of Psychology, South China Normal University, Guangzhou, Guangdong, China
[c] Center for Studies of Psychological Application, South China University, Guangzhou, Guangdong, China
[d] School of Psychology, Shaanxi Normal University, Xi'an, Shaanxi, China
[e] State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China

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ABSTRACT

Envy differs from common negative emotions across cultures. Although previous studies have explored the neural basis of episodic envy via functional magnetic resonance imaging (fMRI), little is known about the neural processes associated with dispositional envy. In the present study, we used regional homogeneity (ReHo) as an index in resting-state fMRI (rs-fMRI) to identify brain regions involved in individual differences in dispositional envy, as measured by the Dispositional Envy Scale (DES). Results showed that ReHo in the inferior/middle frontal gyrus (IFG/MFG) and dorsomedial prefrontal cortex (DMPFC) positively predicted dispositional envy. Moreover, of all the personality traits measured by the Revised NEO Personality Inventory (NEO-PI-R), only neuroticism was significantly associated with dispositional envy. Furthermore, neuroticism mediated the underlying association between the ReHo of the IFG/MFG and dispositional envy. Hence, to the best of our knowledge, this study provides the first evidence that spontaneous brain activity in multiple regions related to self-evaluation, social perception, and social emotion contributes to dispositional envy. In addition, our findings reveal that neuroticism may play an important role in the cognitive processing of dispositional envy.

Introduction

Envy is a powerful emotion that "arises when a person lacks another's superior quality, achievement, or possessions and either desires it or wishes that the other lacked it" (Parrott and Smith, 1993). Envy is a "painful emotion" associated with inferiority, anxiety, or resentment (Aristotle, 1981). Envy has widespread effects on an individual's mental health (Smith et al., 2008), life satisfaction (Smith et al., 1999), and moral behavior (Polman and Ruttan, 2012; Gino and Pierce, 2009). Therefore, envy has always been a hot topic of intense study in multiple fields. Simultaneously, theoretical studies have shown that personality is closely related to envy (Habimana and Massé, 2000; Smith et al., 1999). Although the concept of dispositional envy has garnered significant attention, the precise neural correlates of dispositional envy remain unclear. Therefore, in this study, we explored the neural correlates underlying individual differences in dispositional envy and the role of personality in these associations.

Several researchers have explored the neural correlates of episodic envy via task-based functional magnetic resonance imaging (fMRI). For example, using a face emotion task, Shamay-Tsoory et al. (2007) found that, compared to a normal group, the individual with ventromedial prefrontal cortex (VMPFC) impairment was unable to distinguish the emotion of envy. Takahashi et al. (2009) adopted a scenario method to elicit envy, and the results showed that the degree of envy elicited was positively correlated with activity in the dorsal medial prefrontal cortex (DMPFC), which has been implicated in the execution of social emotion (Singer et al., 2004; Kerns et al., 2004). These findings indicate that the medial prefrontal cortex (MPFC) may be important for episodic envy in a particular task. However, fMRI based tasks have an obvious drawback: a particular task only activates particular regions. According to the definition of envy provided by Parrott and Smith (1993), envy involves the complex synthesis of various negative emotions. Therefore, the cognitive process of envy may be related to several brain regions. Additionally, the display of envy is not permitted in society, as it is considered a negative emotion. Individuals with stronger feelings of envy need to allocate a significant amount of psychological resources to control their emotions. Thus, brain regions involved in emotion regulation and cognitive control are likely to be activated during recruitment of these psychological resources. Previous neuroimaging studies have indicated that the lateral prefrontal cortex (LPFC) plays a crucial role in regulating or processing negative emotion. For example, Kühn et al. (2013) found

* Corresponding author at: Center for Study of Applied Psychology, South China Normal University, Guangzhou, Guangdong 510631, China.
E-mail address: molei_edu@163.com (L. Mo).

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that unwanted thoughts were negatively associated with the dorsolateral prefrontal cortex (DLPFC), which is associated with the control of negative emotions; this finding was consistent with those of several other studies (Papousek et al., 2012; Cacioppo and Gardner, 1999; Davidson, 1998; Kemp et al., 2010; Lopez-Duran et al., 2012). In addition, Wang et al. (2014) further explored the relationship between the LPFC (including the DLPFC and ventrolateral prefrontal cortex [VLPFC]) and conflict adaptation, and found that both the DLPFC and VLPFC are positively associated with the ability to adapt to conflict. According to one concept of envy, envy is elicited by social comparison of oneself to others (Parrott and Smith, 1993; Smith et al., 1999; Smith and Kim, 2007). Therefore, envy often reflects self-conflict or a threat to an individual's concept of self (Tesser and Collins, 1988; Takahashi et al., 2009). That is, from the perspective of conflict control, the LPFC (including the DLPFC and VLPFC), which is associated with cognitive conflict or cognitive adaptation, may be a crucial region for envy processing. Therefore, we assume that the LPFC may also be associated with dispositional envy. Based on previous findings, in the present study, a standard measure of regional homogeneity (ReHo) was used to explore the neural basis of dispositional envy. ReHo explores regional brain activity at rest by examining the degree of regional coherence in a resting-state fMRI (rs-fMRI) time course. Previous research has defined ReHo as an index reflecting the synchronization of activity in different brain regions (Zang et al., 2004), and increased ReHo reflects neural hyperactivity in a specific brain area, indicating increased blood supply to cope with chronic hypoxia (Yan et al., 2010). Furthermore, many previous studies have demonstrated that ReHo is associated with different psychological traits, such as intelligence (Wang et al., 2011), personality (Hahn et al., 2013), and psychological resilience (Kong et al., 2015a). Therefore, ReHo may be an effective index reflecting the neural basis of dispositional envy. Based on a review of the neural basis of episodic envy, we predicted that ReHo in the prefrontal cortex (PFC), including the MPFC and LPFC, would be significantly related to dispositional envy.

Moreover, many studies have revealed some core emotional characteristics of envy, such as feelings of injustice, inferiority, depression, and anxiety (Aristotle, 1981; Parrott and Smith, 1993; Smith et al., 1999). Of all these emotions, inferiority is very typical for envy. Smith et al. (1999) proposed that a sense of inferiority was a typical characteristic of neuroticism. Furthermore, using measures of neuroticism from different personality scales, including the NEO Personality Inventory, Big Five Personality Test, and the Eysenck Personality Inventory, they demonstrated a positive association between dispositional envy and neuroticism with correlations ranging from 0.41 to 0.56. This finding is consistent with other studies that have shown positive associations between neuroticism and other complex negative emotions such as anxiety, self-consciousness, and irritability (Watson et al., 2008; Costa and McCrate, 1992). In addition, envy has also been demonstrated to be a blended synthesis of multiple negative emotions (Lazarus, 1991; Parrott, 1991; Smith, 1991). Based on these findings, we hypothesized that several personality traits, especially neuroticism, may mediate the relationship between brain activity and dispositional envy.

Thus, the present study explored the neural basis of dispositional envy and how personality mediated the effect of the PFC, particularly the MPFC or LPFC, on dispositional envy. Firstly, we computed the correlation between envy and ReHo across the whole brain. We hypothesized that individual differences in dispositional envy would be significantly correlated with ReHo in some regions of the PFC (e.g., MPFC and LPFC), which have been linked to self-evaluation and negative emotion processing. Secondly, we explored which personality traits were significantly associated with dispositional envy. According to previous studies (Watson et al., 2008; Costa and McCrate, 1992; Smith et al., 1999), we predicted that neuroticism would be significantly correlated with dispositional envy. Thirdly, after identifying the dimension most closely associated with dispositional envy and the neural basis of dispositional envy, we explored how specific personality traits would affect regions of the PFC in envy.

Methods

Participants

Forty-one healthy students from South China Normal University participated in this study (17 men; mean age = 21.37 years; standard deviation [SD] = 1.99). All participants were Chinese and right-handed with normal or corrected-to-normal vision. No participants had a history of mental or neurological illness. This study was approved by the Imaging Center Institutional Review Board of South China Normal University. All participants were asked to provide written informed consent before engagement in this research.

Behavioral assessments

Dispositional envy

The dispositional envy scale (DES), which was proposed by Smith et al. (1999) and consists of 8 items, was used to assess the degree of envy. Examples of statements include, "I feel envy every day," and "Feelings of envy constantly torment me." Each item was scored on a 5-point Likert-type scale, in which 1 = strongly disagree, 2 = moderately disagree, 3 = neither agree nor disagree, 4 = moderately agree, and 5 = strongly agree. Previous studies have demonstrated that the DES has high reliability and has been used widely to assess envy (McCullough et al., 2002; Froh et al., 2011). To ensure the reliability and validity of the Chinese translation of the scale in the present study, we implemented the following procedure: first, two English major specialists translated the DES to Chinese; second, 10 students evaluated the semantic clarity, cultural appropriateness, and grammatical aspects of the items; and third, the translated version was discussed within the group of researchers and the final version was derived. A total score was calculated, of which higher scores represented greater degrees of envy. In this study, the scale showed adequate internal reliability ($\alpha = 0.79$).

NEO Personality Inventory

We adopted the Revised NEO Personality Inventory (NEO-PI-R) with five dimensions: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness (Costa and McCrate, 1992). Each dimension is measured by 24 items, and the scale includes 120 items in total. The NEO-PI-R was scored using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Some items were reversely coded before further analysis. Several studies have demonstrated the high reliability and validity of the scale in Chinese culture (Kong et al., 2015b; Li et al., 2014; Yang et al., 1999). In this study, Cronbach's alphas ranged from 0.79 to 0.89.

MRI data acquisition

The rs-fMRI scan was executed by a 3.0-T scanner (Siemens Magnetom Trio, A Tim System) equipped with a 12-channel phased-array head coil at South China Normal University. Resting-state scanning consisted of 240 contiguous echo-planar imaging (EPI) images (TR = 2000 ms; TE = 30 ms; flip angle = 90°; slices = 32; matrix = 64 × 64; FOV = 220 × 220 mm^2; thickness/gap = 3.5/0.8 mm). Simultaneously, high-resolution T1-weighted structural images were collected using a MPRAGE sequence (TR/TE = 1900/2.52 ms; flip angle = 9; matrix = 256 × 256; slice thickness = 1.0 mm; sagittal slices = 176). During resting-state fMRI, all participants were asked to relax, keep their eyes closed, and stay awake.

Data preprocessing

EPI data was preprocessed by DPARSF (Data Processing Assistant for Resting-State fMRI software; http://www.restfmri.net/forum/DPARSF) (Yan and Zang, 2010), using Statistical Parametric Mapping 8 (SPM8)