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Regional gray matter volume is associated with trait modesty: Evidence from voxel-based morphometry

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Modesty when defined as a personality trait, is highly beneficial to interpersonal relationship, group performance, and mental health. However, the potential neural underpinnings of trait modesty remain poorly understood. In the current study, we used voxel-based morphometry (VBM) to investigate the structural neural basis of trait modesty in Chinese college students. VBM results showed that higher trait modesty score was associated with lager regional gray matter volume in the dorsomedial prefrontal cortex, right dorsolateral prefrontal cortex, left superior temporal gyrus/left temporal pole, and right posterior insular cortex. These results suggest that individual differences in trait modesty are linked to brain regions associated with self-evaluation, self-regulation, and social cognition. The results remained robust after controlling the confounding factor of global self-esteem, suggesting unique structural correlates of trait modesty. These findings provide evidence for the structural neural basis of individual differences in trait modesty.

Modesty, often defined as the "public under-representation of one's favorable traits and abilities (p. 473)[1]", has recently garnered the attention of psychologists, particularly with the resurgence of interest in positive psychology and character virtues[2,3]. Some researchers have considered modesty as a behavioral self-presentation, used in order to obtain positive social images and results[4,5]. While, other researchers have argued that modesty can also be defined as a personality disposition, a trait that remains consistent across time and situations[6]. As an attribute of personality, modesty or trait modesty has been increasingly recognized as an important component in personality structures such as the Big Five[1] and the HEXACO model[7] (which includes six basic factors: Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience). Trait modesty reflects personal thoughts, feelings and actions about themselves in comparison to other people[6], indicating how an individual appraises himself/herself. People with high trait modesty scores tend to be unassuming and view themselves as ordinary people without any claim to special treatment, whereas low scorers tend to be self-enhancing and consider themselves as superior and entitled to special privileges[8]. Previous studies have indicated that trait modesty is a reliable predictor of individual differences in diverse self-reported criteria and behaviors[9]. Trait modesty has been associated with positive life outcomes, such as stable interpersonal relationship[10], positive social evaluation[11], and better group performance[12]. Furthermore, evidence indicates that trait modesty is beneficial to adaptive psychological functioning. For example, people with high trait modesty scores are less angry, hostile, and aggressive towards others and show better social adjustments[13,14]. Trait modesty is also related to a greater sense of psychological well-being[2], and entails serving a valuable social function by reducing conflict and resentment[15]. These studies suggest that trait modesty is a valuable disposition with significant practical functions in crucial domains such as the workplace, interpersonal and social function, and mental health. Despite the numerous studies focused on modesty and its beneficial effects for multiple life outcomes, the neural correlates of trait modesty remain unclear.

By explaining the psychological processes involved in trait modesty, it is beneficial in further understanding the neural mechanisms of trait modesty. Personality and social psychological research has suggested that

[1]S P a a C S , P U , B , C a. [2]M G I B a R a , P U , B , C a. [3]B K La a B a a M a H a , P U , B , C a. C a a a a a Y.W. (a : @ . .)

trait modesty involves a cognitive, self-regulatory and social component[14], which are formed by self-evaluation, self-regulation and social cognition, respectively. When considering the cognitive component of trait modesty, trait modesty has been regarded as a form of psychological self-evaluation, with Sedikides *et al.*[14] defining it as "*a moderate self-view* [italics in original]". It involves the perception of one's ability or achievement and is linked to self-reflection and cognitive evaluation process. Moreover, trait modesty provides modest individuals with accurate perceptions of their abilities and ample self-esteem, which facilitates self-regulatory abilities to resist self-enhancing tendencies and to generate adaptive consequences[14]. Previous research has indicated that modest individuals are able to regulate egotism in socially appropriate ways[14], so they may achieve social acceptance and maintain interpersonal harmony, especially in collectivist cultures[16,17]. Compared to self-enhancing people, modest people are more prudent risk-takers[18] and are more focused on long-term objectives rather than fulfilling short-term emotional needs (e.g., feeling good about themselves)[19]. In addition, modesty is often manifested in social interactions, involving a comparison between the self and others[16]. Trait modesty delineates an individual's tendency to care for others and concern about relationships with others in social comparison. For example, downplaying personal achievements after one's success, in order to reduce the threat to others' self-esteem, while also elevating others through expressions of gratitude and appreciation[17]. Trait modesty is associated with prosociality and relational harmony[14,17], and has also been characterized by traits such as solicitousness, plainness, helpfulness, empathy, agreeableness, gratitude, and forgiveness[20,21]. These aspects reflect a social component of trait modesty, involving in the perception of other's needs and feelings and the social situations. In summary, these studies suggest that trait modesty is linked to psychological processes such as self-evaluation, self-regulation, and social cognition.

Although there has been no direct evidence of neural correlates of modesty, previous neuroimaging studies have provided insights into the potential brain mechanisms underlying trait modesty. Previous research has consistently revealed the involvement of the cortical midline structures (CMS) in self-referential processing[22–24]. The CMS consists of the dorsomedial prefrontal cortex (DMPFC), ventromedial prefrontal cortex, anterior cingulate cortex and posterior cingulate cortex[22]. The DMPFC is activated during self-evaluation and general self-reflection[24–26]. Other studies have revealed that several areas of the prefrontal cortex (PFC), such as the dorsolateral prefrontal cortex (DLPFC), the ventrolateral prefrontal cortex, and the ventromedial prefrontal cortex, play a role in cognitive control[27], emotion regulation[28], self-control[29] and self-regulation[30]. Furthermore, alterations in these regions were found to lead to dysregulation of social behavior, abnormal emotional expression, and cognitive deficits[31,32]. Given that trait modesty has been suggested as a cognitive self-evaluation and self-regulatory process, we speculated that certain regions of the PFC, especially the DMPFC and the DLPFC may be associated with trait modesty.

In addition, trait modesty has been linked to the tendency to focus on the concerns of other people, which involves in the process of dealing with social information (e.g., perceiving, thinking about, and making sense of oneself and others in the social world)[33,34]. This process is associated with brain structures related to the social cognition network. Previous research has shown that the involvement of the superior temporal gyrus (STG), temporo-parietal junction (TPJ), temporal pole (TP), posterior cingulate cortex (PCC)/precuneus, medial and lateral frontal regions are important in guiding social behaviors in this social network[33–35]. Moreover, recent structural magnetic resonance imaging (MRI) studies have demonstrated that regional variation in brain morphometry (e.g., gray matter volume and cortical thickness) is correlated with individual differences in behavior, cognition, and more importantly, personality traits[36–40]. For example, DeYoung *et al.*[41] found that the different dimensions of Big Five personality traits were associated with regional differences in gray matter volume (GMV) in specific brain regions. Agreeableness, which is closely and positively associated with trait modesty[6,42], was also associated with reduced volume in the posterior left superior temporal sulcus and with increased volume in the PCC, both being areas that are involved in the processing of social information[43]. These findings suggest that the social cognition network may be engaged in the formation of trait modesty.

Based on previous behavioral and brain imaging studies, we hypothesized that individual differences in trait modesty would be associated with regional GMV (rGMV) in regions involving in self-evaluation, self-regulation, and social cognition, including the PFC (e.g., DMPFC, DLPFC) and social cognition network (e.g., STG, TPJ). In this study, structural magnetic resonance images were acquired from Chinese college students, and trait modesty was measured by the Honesty-Humility Modesty facet scale of the Chinese version of HEXACO Personality Inventory-Revised (HEXACO-PI-R)[44]. To test our hypotheses, we used voxel-based morphometry (VBM)[45] to examine the associations between individual differences in trait modesty and brain structure differences in rGMV.

Results

Trait modesty score. Table 1 showed the means, standard deviation (SD), skewness, and kurtosis for trait modesty and self-esteem score. The kurtosis and skewness of trait modesty and self-esteem score were within range between −1 and +1, confirming the normality of the data[46]. One sample *t*-test comparing the midpoint of the trait modesty scale revealed that the current sample had a high level of trait modesty [$t(49) = 5.07, p < 0.001$], which is in line with the results of previous studies that modesty is highly valued in Chinese culture[17,47]. In

addition, the trait modesty score was not significantly correlated with age ($r = -0.03$, $p = 0.842$), global GMV ($r = -0.04$, $p = 0.793$), and self-esteem ($r = -0.04$, $p = 0.793$). No significant gender difference in trait modesty [$t(48) = -0.54$, $p = 0.594$] was found.

Correlation between rGMV and trait modesty score. We investigated rGMV associated with individual differences in trait modesty. VBM results showed a significant positive correlation between the trait modesty score and rGMV in the left STG/left TP (peak voxel of MNI: x = −59, y = −1, z = 0, $Z = 4.53$, $p_{FWE} < 0.001$ at cluster level), left DMPFC (peak voxel of MNI: x = −8, y = 51, z = 36, $Z = 4.04$, $p_{FWE} = 0.008$ at cluster level), right posterior insular cortex (PIC) (peak voxel of MNI: x = 41, y = −18, z = 19, $Z = 3.90$, $p_{FWE} = 0.016$ at cluster level), and a (marginal) positive association with right DLPFC (peak voxel of MNI: x = 21, y = 27, z = 46, $Z = 4.50$, $p_{FWE} = 0.077$ at cluster level) after controlling for age, gender and global GMV (See Fig. 1, Table 2). No negative correlations between trait modesty and rGMV were observed.

correlations remained significant after age, gender, global GMV, and global self-esteem had been controlled (left STG/left TP: peak voxel of MNI: x = −56, y = 11, z = −12, $Z = 4.45$, $p_{FWE} = 0.001$ at cluster level; left DMPFC: peak voxel of MNI: x = −8, y = 51, z = 36, $Z = 4.01$, $p_{FWE} = 0.013$ at cluster level; right PIC: peak voxel of MNI: x = 41, y = −18, z = 19, $Z = 3.82$, $p_{FWE} = 0.029$ at cluster level), and a (marginal) positive association with right DLPFC (peak voxel of MNI: x = 21, y = 27, z = 46, $Z = 4.41$, $p_{FWE} = 0.099$ at cluster level).

Discussion

The present study provides direct evidence regarding the brain structures underlying individual differences in trait modesty. The results of our analysis revealed that trait modesty score was positively correlated with rGMV in the left DMPFC, right DLPFC, left STG/TP, and right PIC, suggesting that neural pathways underlying self-evaluation, self-regulation, and social cognition are associated with trait modesty.

First, we found a positive association between rGMV in the DMPFC and trait modesty, which is consistent with the results of previous research documenting the role of the DMPFC in the processes of reappraisal and evaluation of self-relevant information[22,48]. For example, Kelley *et al.*[23] and Johnson *et al.*[26] found an increased DMPFC activation in the processes of self-referential evaluation regarding personal traits and abilities, while Fossati *et al.*[25] confirmed that the DMPFC is important for the self-referential processing irrespective of the valence of processed personality traits. Moreover, Wu *et al.*[49] observed that positive self-evaluation was associated with increased resting-state function activity in the DMPFC (including the DLPFC), indicating that these brain regions play a key role in maintaining spontaneous positive self-evaluative tendencies. Consequently, we can speculate that being modest may function as a strategy for maintaining positive self-evaluations among the Chinese. Modest Chinese participants will manifest lower explicit self-evaluation while manifesting higher implicit self-evaluation[48]. In other words, trait modesty can be perceived through outward self-effacing presentations such as not bragging or downplaying personal achievements, but not necessarily a lack of self-confidence or self-esteem[6,17] This is consistent with previous research, which demonstrated that Chinese modesty is not just a form of self-effacing presentations but also functions as self-enhancement as well[16,47]. Furthermore, the DMPFC is also critical to social interactions, such as s comparing oneself to others[24]. As modesty is often manifested in social comparison, this result may indicate that modest individuals process information about the self in relation to others rather than context-independent self-views.

Additionally, the DLPFC is considered to play a critical role in the cognitive control[27] and emotion regulation processes[28]. This region is also found to be involved in self-regulation, such as regulating goal-directed interpersonal behavior to adapt to social norms (e.g., altruism and fairness norms)[50–52]. Based on this, even though there was only marginal significance, increased rGMV in the DLPFC linked to trait modesty is consistent with more modest individuals having increased self-regulatory abilities[14,18,19]. Increased self-regulation might enable a modest person to regulate his/her behaviors in social interactions[14,19], which is important for promoting better social adjus.29990038(t).5(b)001(io)12(n6s)]TJ 0 0 1 4.90000018s intiesc-9(ci)-3(a)4(er)1d
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collectivist culture or hold interdependent self-construal. Future research should examine participants influenced by individualistic cultures to explore the neural basis underlying individual differences in trait modesty. Finally, previous studies suggested that there were two elements of trait modesty, intrapersonal (e.g., self-evaluation) and interpersonal (e.g., social orientation)[14,20]. However, this study is only an exploratory structure analysis and did not examined these two elements of trait modesty separately due to the lack of an established measure. In the future, as the next step to further analysis, we hope to develop a highly reliable measure that assesses these two dimensions of trait modesty and to explore whether the different dimensions of trait modesty are associated with gray matter differences.

In conclusion, the present study successfully identified potential neural correlates of trait modesty using VBM approach. We found that individual differences in trait modesty are linked to brain regions associated with self-evaluation processing, self-regulation, and social cognition. Moreover, these findings were maintained after controlling for individual differences in global self-esteem, suggesting a unique structural basis for individual differences in trait modesty. The results of the present study are the first step in exploring the neural correlates of trait modesty and will begin the advancement of our understanding of the nature and function of modesty.

Method

Participants. 50 healthy adult volunteers (25 males, and 25 females, mean age ± standard deviation = 22.22 ± 2.37 years, age range: 18–29 years) were recruited from Peking University. All participants were right-hand (except for one participant) and none of them reported a history of neurological or psychiatry disease, or substance abuse. Written informed consent was obtained from each participant. This study was approved by and conducted in accordance with the Human Subjects Review Committee of Peking University.

Assessment of trait modesty. The current study used the Honesty-Humility Modesty facet scale of the Chinese 200-item version of the HEXACO Personality Inventory-Revised (HEXACO-PI-R)[44] to assess participants' levels of trait modesty. The HEXACO trait modesty scale consists of eight items measuring individual differences in their tendency towards being modest and unassuming; for example, "I am an ordinary person who is no better than others", "I would not want people to treat me as though I were superior to them", "I am special and superior in many ways" (reverse coded), and "I think that I am entitled to more respect than the average person is" (reverse coded). High scores suggest that peop.404.8000002(d tT1000002(io)12.1999998(r t)6.1999998(o t)-5.800000

Statistical Analysis. Statistical analyses of GMV data was performed using SPM8. Individual smoothed

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