



Extraversion mediates the relationship between structural variations in the dorsolateral prefrontal cortex and social well-being



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ABSTRACT

Social well-being reflects the appraisal of one's circumstance and functioning in society, which is crucial for individuals' mental and physical health. However, little is known about the neural processes associated with social well-being. In this study, we used voxel-based morphometry (VBM) to identify the brain regions underlying individual differences in social well-being, as measured by the Social Well-being Scale (SWBS), in a large sample of young healthy adults. We found that social well-being was negatively correlated with gray matter volume in left mid-dorsolateral prefrontal cortex (mid-DLPFC) that is implicated in executive functioning, emotional regulation and social reasoning. The results remained significant even after controlling for the effect of socioeconomic status. Furthermore, although basic personality factors such as neuroticism, extraversion, and conscientiousness (as measured by the NEO Personality Inventory) all contributed to social well-being, only extraversion acted as a mediational mechanism underlying the association between the left mid-DLPFC volume and social well-being. Together, our findings provide the first evidence for the structural basis of individual differences in social well-being, and suggest that the personality trait of extraversion might play an important role in the acquisition and process of social well-being.

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Introduction

Most studies on well-being focus on quality of life and personal functioning such as emotional or psychological well-being, relatively little attention has been given to social functioning in public and social life. Social well-being is conceptualized as the appraisal of one's circumstance and functioning in society (Keyes, 1998), which is important for individuals' mental and physical health (Keyes, 1998; Zhang et al., 2011). It involves in the perception of one's social integration, of one's acceptance of others, of one's contribution to society, of the coherence of society and of the potential and trajectory of society (Keyes, 1998). Previous studies have shown that social well-being is moderately correlated with well-being in private life (i.e., individual well-being) including positive affect, life satisfaction, happiness and psychological well-being (Keyes, 1998; Lamers et al., 2011; M. Li et al., 2014; Wilt et al., 2010), which suggests that both social and individual well-being are related but distinct constructs. Recently, researchers have paid a lot of attention to how individuals increase their well-being, which to a certain extent relies on their individual differences or personality dispositions (Steel et al., 2008). Several behavioral studies demonstrating the

importance of personality characteristics, especially the Five-Factor Model of personality (FFM; McCrae and Costa, 1991) in social well-being have found that all five basic personality traits such as neuroticism, extraversion, openness, agreeableness and conscientiousness are correlated with social well-being (Hill et al., 2012; Joshanloo et al., 2012; Wilt et al., 2010). In this study, we used structural magnetic resonance imaging (sMRI) to investigate the brain structures underlying individual differences in social well-being and the role of personality in these associations.

To the best of our knowledge, no study has directly explored the neural correlates of social well-being, but recently, neuroscientists have begun to investigate the association between the brain and individual well-being. Evidence from an electroencephalography study has revealed that greater left than right superior frontal activation is associated with individual well-being including life satisfaction, positive affect and psychological well-being (Urry et al., 2004). Furthermore, two functional MRI (fMRI) studies reported that psychological well-being was associated with activities of the ventromedial (VMPFC) in response to negative stimuli (van Reekum et al., 2007) and dorsolateral prefrontal cortex (DLPFC) in response to positive stimuli (Heller et al., 2013). Recently, using voxel-based morphometry (VBM), Takeuchi et al. (2014) found significant negative relationships between regional gray matter volume (rGMV) in specific regions of the PFC including left dorsomedial and rostralateral regions and individuals' total life

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satisfaction (as measured by the self-report WHOQOL questionnaire). These findings consistently indicate that the PFC, which is known to be involved in cognitive–emotional functions such as executive functioning (Alvarez and Emory, 2006; Blumenfeld and Ranganath, 2006), emotional regulation (Kalisch, 2009; Ochsner and Gross, 2005; Pessoa, 2008) and social cognition (Barbey et al., 2009; Forbes and Grafman, 2010; Rilling and Sanfey, 2011), may play an important role in individual well-being. Nevertheless, it is not clear whether these relationships with the PFC regions (e.g., DLPFC, VMPFC) would be seen in social well-being.

The PFC has been also thought to contribute to development of personality traits, particularly neuroticism and extraversion, which are of particular interest because they are closely related to mood and anxiety disorders (Bienvenu et al., 2004; Clark et al., 1994; Khan et al., 2005). Previous functional imaging studies have shown that extraversion and neuroticism measures are associated with the activities of specific PFC regions including the DLPFC and orbitofrontal cortex in the resting state (Adelstein et al., 2011; Johnson et al., 1999; Kunisato et al., 2011; Wei et al., 2011, 2014) or in response to some specific activation procedures (Brühl et al., 2011; Canli et al., 2001; Canli, 2004; Gioia et al., 2009; Gray et al., 2005; Harenski et al., 2009; Kumari et al., 2004). This is in accordance with previous VBM studies that reported the associations between regions of the PFC and extraversion and neuroticism (Coutinho et al., 2013; DeYoung et al., 2010; Forbes et al., 2014; Iidaka et al., 2006; Lu et al., 2014; Rauch et al., 2005; Wright et al., 2007). In contrast to extraversion and neuroticism, limited studies have identified the role of the PFC regions in conscientiousness (DeYoung et al., 2010; Forbes et al., 2014; Kunisato et al., 2011) and openness (DeYoung et al., 2005; Koelsch et al., 2013). In light of the importance of personality in social well-being (Hill et al., 2012; Joshanloo et al., 2012; Wilt et al., 2010) and the fact that personality traits are more robust psychological constructs with a more solid biological basis when compared with social well-being, personality traits might mediate the effects of structural differences in the PFC, particularly the DLPFC on social well-being.

To examine these two questions, this study used well-validated measures of personality and social well-being, and VBM methodology. Studies have shown that the VBM methodology can be used to investigate the neural basis of individual differences in behavioral performance (e.g., personality characteristics) (DeYoung et al., 2010; Kanai and Rees, 2011; Kong et al., 2014; Song et al., 2014; Takeuchi et al., 2014). Based on the previous neuroscience findings on individual well-being (Heller et al., 2013; Takeuchi et al., 2014; Urry et al., 2004; van Reekum et al., 2007), we hypothesized that individual differences in social well-being would be associated with rGMV in the PFC regions (e.g., DLPFC, DMPFC) that has been linked to cognitive–emotional functions (Alvarez and Emory, 2006; Curtis and D'Esposito, 2003; Ochsner and Gross, 2005). Here we hoped to identify which PFC regions are important for social well-being by examining the relationship between social well-being and brain structure across the whole brain in a large sample of participants ($N = 294$). Furthermore, given the association between personality and social well-being (Hill et al., 2012; Joshanloo et al., 2012; Wilt et al., 2010) and the crucial role of the PFC, particularly the DLPFC in personality (Coutinho et al., 2013; DeYoung et al., 2010; Lu et al., 2014; Rauch et al., 2005; Wright et al., 2007), we hypothesized that some specific personality traits (e.g., extraversion) would be able to mediate the relationship between the PFC, particularly the DLPFC and social well-being.

Methods

Participants

Two hundred and ninety-four healthy volunteers (157 females; mean age = 21.57 years, standard deviation (SD) = 1.01) from Beijing Normal University participated in this study as part of our ongoing project investigating associations among brain imaging, cognitive functions,

and genetics (Huang et al., 2014; Kong et al., 2014; W. Li et al., 2014; Song et al., 2014; Wang et al., 2014). Participants were instructed to undertake a series of computer-based cognitive ability tests, paper–pencil questionnaires, and MRI scans. Computer-based cognitive ability tests assess abilities mainly involved in reason, attention, memory, numerosity, object/face recognition ability, spatial ability, musical ability, theory of mind and language skills. Paper–pencil questionnaires mainly assess one's family environment (e.g., socioeconomic status, parental conflict and parenting styles), school environment (e.g., peer attachment and teaching styles), Big Five personality, positive character traits such as self-esteem, optimism and resilience, emotional and social competence, social support system, health outcomes such as loneliness, sleep quality, physical health and psychological health, and other outcomes such as aggression, internet addiction, and prosocial behavior. Data that are not relevant to the theme of this study were not reported here. Because the acquisition of MRI data was time-consuming for the large sample of participants, the questionnaires were measured at least a month after MRI data acquisition. Given that the questionnaires have been shown adequate long-term test–retest reliability (Costa and McCrae, 1992; Goodman et al., 2001; Yang et al., 1999), the time interval likely had little impact on the results in the present study. No participants had history of neurological or psychiatric disorders. The majority of the participants were right-handed ($n = 275$) based on a single-item handedness questionnaire (“Are you (a) right-handed, (b) left-handed, (c) mixed-handed?”). Written informed consent was obtained from all participants. The study was approved by the Institutional Review Board of Beijing Normal University.

Measures

Social well-being scale

Social well-being was assessed using a 15-item version of Keyes's (1998) social well-being scale (SWBS). It measures the five components of social well-being: social acceptance, social actualization, social coherence, social contribution, and social integration (three items each). It includes items such as, “I feel close to other people in my community.” (Social integration), “I believe that people are kind.” (Social acceptance), “I have nothing important to contribute to society.” (Social contribution), “Society has stopped making progress.” (Social actualization), and “The world is too complex for me.” (Social coherence). Each item required a respondent to answer on a 6-point scale the degree to which the item applies (1 = strongly disagree, 6 = strongly agree). Negatively worded items were reverse coded prior to all analyses. A higher score indicates higher levels of social well-being. Previous studies have shown that the scale has high reliability, construct validity and discriminant validity with other constructs such as life satisfaction, positive affect and negative affect in Chinese populations (M. Li et al., 2014). In the present study, the scale demonstrated adequate internal reliability ($\alpha = 0.81$).

NEO Personality Inventory

The Revised NEO Personality Inventory (NEO-PI-R, Costa and McCrae, 1992) is a 120-item self-report questionnaire based on the five-factor model of personality (Costa and McCrae, 1990, 1995). Each dimension was measured with 24 items and participants responded to each item using a 5-point Likert scale with response options ranging from strongly disagree to strongly agree. Negatively worded items were reverse coded prior to all analyses. This inventory provides summary scores for the five different dimensions of personality: neuroticism, extraversion, openness to experience, agreeableness and conscientiousness. Previous studies have shown that the scale has high reliability and validity in Chinese populations (Yang et al., 1999; W. Li et al., 2014). In the present study, Cronbach's α of the NEO-PI-R scales ranged from 0.71 and 0.88, indicating that these five personality dimensions of NEO-PI-R exhibited adequate internal reliability. Fifteen participants were excluded due to missing data.

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