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Research Report

Individual differences in local gray and white matter volumes reflect differences in temperament and character: A voxel-based morphometry study in healthy young females

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ABSTRACT

The psychobiological personality model of Cloninger distinguishes four heritable temperament traits (harm avoidance (HA), novelty seeking (NS), reward dependence (RD) and persistence (P)) and three character traits (self-directedness (SD), cooperativeness (CO) and self-transcendence (ST)) which develop during lifetime. Prior research already showed that individual differences in temperament are reflected in structural variances in specific brain areas. In this study, we used voxel-based morphometry (VBM) to correlate the different temperament and character traits with local gray and white matter volumes (GMV and WMV) in young healthy female volunteers. We found correlations between the temperament traits and GMV and WMV in the frontal, temporal and limbic regions involved in controlling and generating the corresponding behavior as proposed in Cloninger's theory: anxious for HA, impulsive for NS, reward-directed for RD and goal-directed for P. The character traits correlated with GMV and WMV in the frontal, temporal and limbic regions involved in the corresponding cognitive tasks: self-reflection for SD, mentalizing and empathizing with others for CO and religious belief for ST. This study shows that individual variations in brain morphology can be related to the temperament and character dimensions, and lends support to the hypothesis of a neurobiological basis of personality traits.

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Abbreviations: WMV, white matter volume; GMV, gray matter volume; HA, harm avoidance; NS, novelty seeking; RD, reward dependence; P, persistence; SD, self-directedness; CO, cooperativeness; ST, self-transcendence; PD, personality disorder; MD, mood disorder; ACC, anterior cingulate cortex; PCC, posterior cingulate cortex; MFC, medial frontal cortex; PFC, prefrontal cortex; OFC, orbitofrontal cortex; DTI, Diffusion tensor imaging; MTR, Magnetic transfer ratio

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1. Introduction

Biopsychosocial theories propose that personality traits are related to genetic and neurobiological markers. In the late 1980s and early 1990s, Robert Cloninger presented his psychobiological model of personality to account for normal and abnormal variations in temperament and character between individuals (Cloninger, 1986, 1987; Cloninger et al., 1993). This model focused on the structure of learning abilities within the person, based on the neurobiology of functional brain systems to account for the evolution and function of the brain. He distinguished four temperament dimensions (harm avoidance (HA), novelty seeking (NS), reward dependence (RD) and persistence (P)) and three character dimensions (self-directedness (SD), cooperativeness (CO) and self-transcendence (ST)). HA, NS, RD and P respectively reflect one's tendency to inhibit behavior to avoid punishment, to initiate a behavior towards novelty, to generate a reward related behavior and to maintain an ongoing behavior despite an absence of reward. SD, CO and ST respectively describes one's view on the self as an autonomous individual, as an integral part of human society and as a part of a broader universe including its tendency towards spiritualism.

Both major components of personality, temperament and character, are differentiated by their biologic and social determinants. The temperament traits are found to be genetically determined, heritable and relatively stable during lifetime. It is postulated that they determine one's disposition to the early emotions of fear, anger and attachment and one's automatic behavioral responses to the environmental stimuli of danger, novelty and reward. The character traits are the complex result of learning, maturation and socio-cultural factors and evolve during the entire life. They were added to the model to account for individual differences in the modulation of automatic behavioral responses, regulated by temperament, by changes in the significance and salience of stimuli due to the individual concepts of identity. It is postulated that the character traits are involved in higher cognitive processes.

In this two component model, character adapts one's heritable personality traits and behavioral patterns to one's own socio-cultural environment and experiences which may prevent the maladaptive impact of the temperament traits.

To measure all personality dimensions for clinical and research purpose, the Temperament and Character Inventory (TCI) questionnaire was developed (Cloninger et al., 1993).

The Cloninger personality model has been introduced to distinguish normal from abnormal personality. In general, patients suffering from a personality disorder (PD) are found to be characterized by immature character traits and extreme temperament traits. In clinical practice, the temperament as well as the character dimensions were found to be of interest in the assessment and the differential diagnosis of PDs (Cloninger et al., 1993; Richter and Brändström, 2009; Svrakic et al., 2002). Furthermore, all seven personality dimensions have proven to be useful in understanding the epidemiology, co-morbidity and treatment of mental illnesses such as mood disorders (MD) (Cloninger et al., 1998, 2006; Farmer and Seeley, 2009).

In addition to changes in mood and personality, local brain morphology and functional alterations in PD and MD patients were revealed in several brain imaging studies (Drevets et al., 2008; Goodman et al., 2007; McCloskey et al., 2005). To investigate a possible link between structural abnormalities and personality traits, Iidaka et al. (2006) and Gardini et al. (2009) conducted a voxel-based morphometry (VBM) study on healthy young adults, not suffering from a major mental illness. Both studies showed evidence for a correlation between individual structural variances in specific brain regions and the temperament dimensions. They hypothesized that the structural variances of interest, related to personality, are genetically determined so the character dimensions were not taken into account.

Kaasinen et al. (2005) conducted a similar VBM study in older adults to investigate a possible correlation between morphologic alterations in the brain and personality changes due to aging. In this study all personality traits were taken into account but only a correlation between ST and local gray matter volume (GMV) in the temporal cortex was found.

To correlate brain function to personality, Sugiura et al. (2000) used the SPECT imaging technique to voxel-wise correlate the temperament traits to cerebral blood flow. In a replication of this study, but with all seven personality dimensions included, Turner et al. (2003) found that individual differences in brain function in some regions may not only reflect differences in temperament but also differences in character.

These studies suggest that meaningful associations exist between neurobiology and personality variance. However, the findings of Kaasinen et al. (2005) and Turner et al. (2003) suggest that the expression of personality traits may be related to neurodevelopmental variability, and the work of Iidaka et al. (2006) and Gardini et al. (2009) took only into account the temperament traits that are genetic determined and believed to be rather stable. Therefore, our aim was to go beyond these studies, extending our analysis to the character dimensions that develop over the first decades of life. We hypothesized that a correlate of one's temperament and character, as described by Cloninger's model, can be found in local brain morphology. To exclude confounding variations of age and gender in brain morphology and personality scores (Good et al., 2001; Miettunen et al., 2007; Yamasue et al., 2008a,b), only females in a narrow age range were included. Due to the fact that the character traits develop during maturation and maturation in the brain is shown to influence local GMV as well as white matter volumes (WMV) (Lenroot and Giedd, 2006), we performed our analysis on both GMV and WMV maps.

2. Results

In our final cohort of 68 subjects, the mean TCI scores were 13±6 for HA, 22±6 for NS, 19±3 for RD, 5±2 for P, 35±5 for SD, 36±4 for CO, and 8±6 for ST.

In Tables 1 and 2 the correlations found for the temperament and character traits respectively were summarized. The results from the GMV and WMV analyses are indicated by GMV and WMV, respectively. The coordinates reported in the tables are Talairach coordinates.