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Fiber connectivity between the striatum and cortical and subcortical regions is associated with temperaments in Chinese males

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ABSTRACT

The seven-factor biopsychosocial model of personality distinguished four biologically based temperaments and three psychosocially based characters. Previous studies have suggested that the four temperaments—novelty seeking (NS), reward dependence (RD), harm avoidance (HA), and persistence (P)—have their respective neurobiological correlates, especially in the striatum-connected subcortical and cortical networks. However, few studies have investigated their neurobiological basis in the form of fiber connectivity between brain regions. This study correlated temperaments with fiber connectivity between the striatum and subcortical and cortical hub regions in a sample of 50 Chinese adult males. Generally consistent with our hypotheses, results showed that: (1) NS was positively correlated with fiber connectivity from the medial and lateral orbitofrontal cortex (mOFC, lOFC) and amygdala to the striatum; (2) RD was positively correlated with fiber connectivity from the mOFC, posterior cingulate cortex/retrosplenial cortex (PCC), hippocampus, and amygdala to the striatum; (3) HA was positively linked to fiber connectivity from the dorsolateral prefrontal cortex (dlPFC) and PCC to the striatum; and (4) P was positively linked to fiber connectivity from the mOFC to the striatum. These results extended the research on the neurobiological basis of temperaments by identifying their anatomical fiber connectivity correlates within the subcortical–cortical neural networks.

Introduction

In the seven-factor biopsychosocial model of personality, Robert Cloninger distinguished four temperaments (novelty seeking, reward dependence, persistence, and harm avoidance) and three characters (cooperativeness, self-directedness, and self-transcendence) (Cloninger, 1987, 1994b; Cloninger et al., 1993). Temperaments represent individuals' congenital and automatic behavioral responses to the environmental stimuli of novelty, reward and danger, whereas characters represent individuals' adaptation to complex social contexts (Cloninger, 1994a,b). Consequently, the four temperaments are proposed to be more dependent on biological (genetic and neural) factors, whereas characters depend more on socio-cultural factors. Extreme/abnormal personality traits (especially temperaments) are common characteristics of a wide spectrum of prevalent personality and psychiatric disorders (Richter and Brandstrom, 2009; Svrakic et al., 1993), such as depression (Celikel et al., 2009; Farmer et al., 2003; Sandi and Richter-Levin, 2009), bipolar disorder (Olvera et al., 2009), borderline personality disorder (Barnow et al., 2007), obsessive–compulsive disorder (Ettelt et al., 2008), and schizophrenia (Hori et al., 2008; Smith et al., 2008). These disorders have been found to be accompanied by abnormal/pathological neurobiological changes in the brain (Hazlett et al., 2005; Nakamura et al., 2005). In order to have a better understanding of the neurobiological basis of temperaments and a deeper insight into the pathogenesis of the temperament-related neuropsychiatric disorders, the current study investigated the associations between temperaments and fiber connectivity from the cortical and subcortical regions to the striatum.

Several lines of research have reported that extensive subcortical and cortical regions are involved in temperaments. In the following paragraphs, we briefly introduce the four temperaments as identified by Cloninger and summarize previous neuroimaging results (see

Abbreviations: NS, novelty seeking; RD, reward dependence; P, persistence; HA, harm avoidance; TCI, the Temperament and Character Inventory; DTI, diffusion tensor imaging; mOFC, the medial orbitofrontal cortex; lOFC, the lateral orbitofrontal cortex; lPFC, the lateral prefrontal cortex; dlPFC, the dorsolateral prefrontal cortex; PCC, the posterior cingulate cortex/retrosplenial cortex; dACC, the dorsal anterior cingulate cortex; ACC, the anterior cingulate cortex.

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Table 1). Novelty seeking (NS) is linked to the behavioral activation system and refers to one's tendency to initiate an exploratory behavior towards novelty as well as one's excessive response to cues of rewards. A recent diffusion tensor imaging (DTI) study (Cohen et al., 2009) reported that fiber connectivity between the striatum, hippocampus, and amygdala could predict individual differences in NS. Two brain anatomical studies also found that NS was correlated with white matter volume in the frontal cortex and gray matter volume in the frontal cortex and PCC (Gardini et al., 2009; Van Schuerbeek et al., 2011). Consistent with the structural data, functional brain studies reported that the striatum, substantia nigra and ventral tegmental regions (Krebs et al., 2009), and prefrontal cortical regions (Bermpohl et al., 2008) were involved in NS.

Reward dependence (RD) refers to the behavioral dependence system and reflects one's tendency to stimulate and maintain reward behavior. As shown in Table 1, the mesolimbic-dopamine-centered network, especially the striatum and frontal cortex (Berridge and Robinson, 2003; Schultz, 2000, 2002), plays a key role in RD. Cohen et al., 2009 found that fiber connectivity between the striatum and frontal cortex was associated with individual differences in RD. RD has also been correlated with gray matter volumes of the frontal and temporal regions and caudate nucleus (Gardini et al., 2009; Van Schuerbeek et al., 2011), and gray matter densities of the medial orbitofrontal cortex, ventral striatum, and putamen (Lebreton et al., 2009). Functional brain imaging studies confirmed the key role of the striatum and orbitofrontal cortex in RD and reward processing (Krebs et al., 2009).

Harm avoidance (HA) is similar to the behavioral inhibition system and refers to one's tendency to inhibit behavior to avoid punishment, loss, and non-reward. The amygdala, anterior cingulate cortex, and medial orbitofrontal cortex had been found to contribute significantly to HA in several previous studies (Buckholtz et al., 2008; Iidaka et al., 2006; Pezawas et al., 2005; Pujol et al., 2002; Yamasue et al., 2008a; Yang et al., 2009, see Table 1). Recent studies also found that HA was associated with local structural integrity indexed by fractional anisotropy as well as mean and radial diffusivity within most main white matter fibers in the brain (Kim and Whalen, 2009; Westlye et al., 2011). There appears to be a widely distributed, interconnected neural network of HA, including the limbic system and the higher-function cortical regions.

Table 1
Previous brain imaging studies showing neural correlates of temperaments.[a]

Temperaments	Studies	Frontal cortex	Temporal cortex	Parietal/occipital cortex	Subcortical nucleus
NS	Sugiura et al. (2000)	ACC,SFG, anterior insula	STG		
	Turner et al. (2003)		ITG & MTG	PCC	
	Suhara et al. (2001)	Right insula			
	Youn et al. (2002)	Right MFG	MTG		
	Hakamata et al. (2006)		Left STG	IPG & PCC	
	Cohen et al. (2009)				Striatum, hippocampus, amygdala
	Iidaka et al. (2006)	Left MFC			
	Gardini et al. (2009)	PFC		PCC	
	Van Schuerbeek et al. (2011)	IFC		PCC	
	Bermpohl et al.(2008)	MFG, pregenual ACC			
	Krebs et al. (2009)				SN/VTA
RD	Sugiura et al. (2000)	ACC,SFG, anterior insula	STG		
	Turner et al. (2003)		ITG & MTG	MOG & SOG	
	Youn et al. (2002)	Left OFC	ITG & MTG		
	Hakamata et al. (2006)	Left insula	MTG	Right IOG	Caudate head
	Cohen et al. (2009)	OFC, lateral and dorsal PFC			Striatum
	Iidaka et al. (2006)				Right caudate nucleus
	Gardini et al. (2009)	Rectal PFC			Caudate nucleus
	Lebreton et al. (2009)	Medial OFC			Ventral striatum, left putamen
	Van Schuerbeek et al. (2011)	Left MFG, right IFG		PCC	Thalamus, putamen
	Krebs et al. (2009)				SN/VTA
HA	Sugiura et al. (2000)	Right orbito-insular junction, SFG	Left ITG		
	Turner et al. (2003)		ITG & MTG	MOG & SOG	
	Youn et al. (2002)	Right ACC	Left MTG, ITG		
	Hakamata et al. (2006)	Left MFG	Left MTG	Right PCC	Right thalamus
	Inada et al. (2009)	Right SFG & MFG in females			
	Cohen et al. (2009)				Striatum & hippocampus
	Pujol et al. (2002)	Right ACC			
	Iidaka et al. (2006)	OFC			Left amygdala
	Yamasue et al. (2008b)	Left anterior PFC			Right hippocampus
	Gardini et al. (2009)	Orbito-frontal regions		Occipital cortex	
	Van Schuerbeek et al. (2011)	Left SFG & IFG, ACC			
	Pezawas et al. (2005)	ACC			Amygdala
	Most et al.(2006)	Subgenual ACC			Amygdala
	Yang et al. (2009)	Subgenual ACC			
	Westlye et al. (2011)	Subgenual ACC, OFC			Amygdala
P	Turner et al. (2003)		ITG & STG		
	Hakamata et al. (2006)	Right MFG & insula	Left MTG	PCC	
	Cohen et al. (2009)	mOFC			Striatum
	Gardini et al. (2009)			PCC	
	Van Schuerbeek et al. (2011)	Right ACC	ITG	PCC	
	Gusnard et al.(2003)	OFC			Ventral striatum

Abbreviation: ACC, the anterior cingulate cortex; OFC, the orbitofrontal cortex; SFG, the superior frontal gyrus; MFG, the middle frontal gyrus; IFG, the inferior frontal gyrus; PFC, the prefrontal cortex; STG, the superior temporal gyrus; MTG, the middle temporal gyrus; ITG, the inferior temporal cortex; PCC, the posterior cingulate cortex/precuneus; SPG, the superior parietal gyrus; MPG, the middle parietal gyrus; IPG, the inferior parietal gyrus; SOG, the superior occipital cortex; MOG, the middle occipital cortex; IOG, the inferior occipital cortex; SN/VTA, the substantia nigra/ventral tegmental area; NS, novelty seeking; RD, reward dependence; HA, harm avoidance; P, persistence.

[a] This table includes all PET/SPECT studies and functional and structural MRI studies of TCI (Temperament and Character Inventory) or TPQ (Tridimensional Personality Questionnaire) in healthy and normal samples that were published between 2000 and 2011. Excluded were studies that did not use the original TCI or TPQ scales or subscales (e.g., Schweinhardt et al. (2009), who used principal component analysis to extract a main component from NS, HA, and subscales of the Behavioral Appetitive System Scale [Carver and White, 1994]).