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REGIONAL GRAY MATTER DENSITY ASSOCIATED WITH EMOTIONAL CONFLICT RESOLUTION: EVIDENCE FROM VOXEL-BASED MORPHOMETRY

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Abstract—Successful emotion regulation is a fundamental prerequisite for well-being and dysregulation may lead to psychopathology. The ability to inhibit spontaneous emotions while behaving in accordance with desired goals is an important dimension of emotion regulation and can be measured using emotional conflict resolution tasks. Few studies have investigated the gray matter correlates underlying successful emotional conflict resolution at the whole-brain level. We had 190 adults complete an emotional conflict resolution task (face-word task) and examined the brain regions significantly correlated with successful emotional conflict resolution using voxel-based morphometry. We found successful emotional conflict resolution was associated with increased regional gray matter density in widely distributed brain regions. These regions included the dorsal anterior cingulate/dorsal medial prefrontal cortex, ventral medial prefrontal cortex, supplementary motor area, amygdala, ventral striatum, precuneus, posterior cingulate cortex, inferior parietal lobule, superior temporal gyrus and fusiform face area. Together, our results indicate that individual differences in emotional conflict resolution ability may be attributed to regional structural differences across widely distributed brain regions.

Key words: emotion regulation, emotional conflict resolution, individual differences, gray matter density, voxel-based morphometry.

INTRODUCTION

As a Hindu proverb says, ''Conquer your mind and you conquer the world.'' Every day we tend to encounter all kinds of emotions. More often than not, emotions behave as obstacles when people are dealing with routine jobs in general and, in particular, jobs which demand a lot of attention. Therefore, the cognitive ability to control emotions is an essential aspect of social competence (Eisenberg and Fabes, 1992) and well-being (Charles and Carstensen, 2007).

Emotion regulation could conceptually be defined as including the (a) awareness and understanding of the relevant emotion, (b) acceptance of the emotion, (c) ability to inhibit impulsive behaviors and guide behavior in accordance with desired goals upon emotional arousal, (d) ability to flexibly recruit contextually appropriate emotion regulation strategies to modulate emotional arousal (Gratz and Roemer, 2004). In the present study, we chose to investigate the neural mechanisms underlying individual differences in the ability to control impulsivity and behave appropriately when experiencing emotions, which is one of the core dimensions of emotion regulation (Linehan et al., 1993; Melnick and Hinshaw, 2000) and could be measured by emotional conflict resolution-related paradigms (Gyurak et al., 2011). The face-word task, in which a positively or negatively valenced word is superimposed on a congruent or incongruent facial expression, has been used for investigating the neural mechanisms underlying emotional conflict resolution in both clinical (Chechko et al., 2009; Etkin and Schatzberg, 2011) and nonclinical studies (Etkin et al., 2006; Egner et al., 2008).We employed the face-word task and calculated the 'emotional interference effect' as our behavioral measure. The emotional interference effect is calculated as the difference between the mean reaction time (RT) of incongruent trials and that of congruent trials, which are associated with conflict resolution and emotion regulation (Etkin et al., 2006; Egner et al., 2008; Gyurak et al., 2011).

Early studies utilizing the face-word task found activations in the dorsal medial prefrontal cortex (DMPFC)/dorsal anterior cingulate (dACC) and rostral anterior cingulate cortex (rACC) as well as a deactivation of the amygdala during emotional conflict resolution (Etkin et al., 2006; Egner et al., 2008). Patients with general anxiety disorder showed reduced activations in the DMPFC and deficits in engaging the rACC to

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Abbreviations: BDI, Beck Depression Inventory; dACC, dorsal anterior cingulated; DMPFC, dorsal medial prefrontal cortex; DTI, diffusion tensor imaging; FFA, fusiform face area; IPL, inferior parietal lobule; MRI, magnetic resonance imaging; PCC, posterior cingulate cortex; rACC, rostral anterior cingulate; rGMD, regional gray matter density; RT, reaction time; SD, standard deviation; SMA, supplementary motor area; STG, superior temporal gyrus; VBM, voxel-based morphometry; VMPFC, ventral medial prefrontal cortex; VS, ventral striatum.

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regulate the activity of the amygdala (Etkin et al., 2010). Ochsner and his colleagues utilized an emotional flanker task and found emotional conflict selectively activated the DMPFC and posterior medial prefrontal cortex. Moreover, they found that the emotional interference effect positively predicted greater activity in the rACC/ventral medial prefrontal cortex (VMPFC) and suggested that a greater interference effect may require more involvement of the rACC/VMPFC to select goal-directed behaviors (Ochsner et al., 2009). Consistent with the notion that the ability to inhibit impulsivity and behave appropriately with respect to desired goals is an important dimension of efficient emotion regulation, emotion regulation-related research indicated that the DMPFC, VMPFC and amygdala are among the most consistent findings (Diekhof et al., 2011; Ochsner et al., 2012; Kohn et al., 2014).

In the present study, we applied the voxel-based morphometry (VBM) method to probe the brain regions relevant for emotional conflict resolution from a purely structural perspective (Ashburner and Friston, 2000). Compared to functional neuroimaging studies, structural magnetic resonance imaging (MRI) studies share the following merits: (a) they allow the opportunity to observe the morphometric correlates underpinning individual differences (Gong et al., 2005; Takeuchi et al., 2011); (b) they allow the separation of behavioral assessment and MRI scanning, and thus behavioral assessments may be more ecologically valid (Kanai and Rees, 2011). We correlated the measured regional gray matter density (rGMD) with the magnitude of the emotional interference effect (as introduced above) to identify regions which are relevant for successful emotional conflict resolution. The current study also employed a large undergraduate cohort. The use of an ample sample size is of critical importance in probing individual difference effects, since studies with small samples share the common hazard of effect size inflation (Yarkoni et al., 2011).

Inspired by the aforementioned emotional conflict-related studies, we anticipated that the emotional interference effect might be associated with multiple cortical and subcortical regions. Specifically, we predicted that the medial prefrontal cortex might be negatively correlated with the emotional interference effect due to its role in the top-down control over spontaneous emotions (Ochsner et al., 2009; Etkin et al., 2010; Diekhof et al., 2011; Buhle et al., 2013). Furthermore, we predicted that the amygdala would be positively associated with the emotional interference effect through its involvement in emotional arousal (Egner et al., 2008; Etkin et al., 2010).

EXPERIMENTAL PROCEDURES

Subjects

In total, 300 healthy subjects participated in the current study as part of our progressive project examining the associations among mental health, creativity and brain imaging. All subjects had normal or corrected to normal vision. The subjects completed a self-report questionnaire before the scanning to exclude the possibility of neurological disorders, psychiatric disorders, drug abuse or pregnancy. Subjects with obvious mental clinical symptoms (depressive, nervous, etc.) were identified by psychiatrist Qinghua Luo and excluded from our database. In addition, the Edinburgh Handedness Inventory (Oldfield, 1971) was used and 40 left-handed subjects were excluded. Written informed consent was obtained and the project was approved by the ethics committee of the Southwest University Brain Imaging Center Institutional Review Board. Among the 260 right-handed subjects, 5 subjects were excluded from further analysis due to technical problems, whereas another 65 subjects completed the behavioral task, but did not take part in the MRI scanning. Therefore, 190 available subjects were incorporated for further analyses (85 males, mean age = 19.9 years, standard deviation (SD) = 1.27 years).

Assessment of general intelligence

General intelligence was assessed by Raven's Advanced Progressive Matrix (Raven and Lewis, 1962). An intelligence test was included to preclude the possible impact of general intelligence on the observed correlations between the emotional interference effect and brain structures (Shaw et al., 2006), as per previous emotion regulation-related VBM studies (Takeuchi et al., 2012b). Raven's Advanced Progressive Matrix proved to be the best measure for general intelligence and has been demonstrated to be culturally independent (Raven, 2000).

Assessment of depression

The 21 item Beck Depression Inventory (BDI) was used for assessing the severity of depressive symptoms. Each item is scored on a four-point scale (0–3). Higher scores indicate more severe symptomatology (Beck et al., 1996). The BDI is a valid and reliable questionnaire measuring the severity of depressive symptoms in clinical or non-clinical samples (Beck et al., 1988), including those in China (Chang, 2005). In the present sample, it had a satisfactory Cronbach's alpha of 0.78.

Face-word task and behavioral analysis

Stimuli. All facial pictures were selected from the new version of the Chinese Face Affective Picture System (Lu et al., 2005). Facial pictures were selected from five males and five females with either a happy or sad expression, and each facial picture was then superimposed with a Chinese adjective with a happy or sad meaning written in a red font. This resulted in two categories of trials in terms of word-expression valence compatibility: congruent and incongruent (see Fig. 1). For example, a happy meaning Chinese word in combination with a sad face constitutes an incongruent trial, while a happy meaning Chinese word in combination with a happy face constitutes a congruent trial. A total of 144 pictures were included in this task. Within the 144 pictures, 24 pictures were for practice use, and the remaining 120 pictures were used in the formal experiment.