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Research paper

The role of ventromedial prefrontal cortex volume in the association of expressive suppression and externally oriented thinking

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ABSTRACT

Background: Studies have suggested that expressive suppression (ES) is linked to externally oriented thinking (EOT) through the ventromedial prefrontal cortex (vmPFC), and there are gender differences in their association. The present structural magnetic resonance imaging study was to investigate the neural bases of ES and EOT and their association in females versus males in a Chinese college sample.

Methods: A total of 142 participants (83 females) were enrolled, and they completed the ES subscale of the Emotion Regulation Questionnaire, 20-item Toronto Alexithymia Scale, and anatomical scanning. Voxel-based morphometry, region of interest, and whole brain analyses with peak-level significance (family-wise error corrected at $p < .05$) were conducted to investigate the association of gray matter volume (GMV) variations with ES and EOT. A bootstrapping analysis was conducted to examine the role of vmPFC volume in the ES-EOT association.

Results: The ES scores were positively linked to the GMV of the vmPFC in females and negatively related to right dorsolateral PFC volume in males. The EOT scores were positively correlated with the GMV of the vmPFC in females and supplementary motor area in males. Furthermore, vmPFC volume mediated the relationship between ES and EOT

Limitations: The cross-sectional design limited causal conclusions.

Conclusions: The vmPFC may be the only neural base of ES and EOT and their association. In addition, these results were sex-specific.

1. Introduction

1.1. The characteristics of externally oriented thinking (EOT)

Alexithymia, which means an absence of words for feelings, consists of three key components: difficulty identifying feelings (DIF), difficulty describing feelings (DDF), and EOT (Parker et al., 2008). The 20-item Toronto Alexithymia Scale (TAS-20) is a widely used tool that contains subscales for these three factors (Bagby et al., 1994). Although a variety of cross-cultural studies have confirmed the three-factor structure of alexithymia and significant associations among the three factors (Taylor et al., 2003; Zhu et al., 2007). EOT has weaker relationships with DIF and DDF compared with the association between DIF and DDF (Zhu et al., 2007), which are collapsed into a single factor in some studies (e.g., Chen et al., 2011). Furthermore, in contrast to the other two components, EOT, which is assessed as a set of values and preferences for emotions (Taylor et al., 2003), is thought to be less associated with emotional deficits and more associated with expressive style variations that depend on the importance that a culture places on emotional expression (Grabe et al., 2000; Kirmayer, 1987).

1.2. The relationship between expressive suppression (ES) and EOT

ES is considered a form of emotional regulation that involves the tendency to hide, inhibit, and reduce ongoing emotion-expressing behaviors (Gross and John, 2003). Individuals with a high degree of ES tend to inhibit or mask any outward signs of emotion (e.g., deliberately inhibiting their facial expressions in social interactions). EOT refers to the way that emotions are thought about, with more emphasis placed on external concrete stimuli than on inner emotions (Taylor et al., 2003). Individuals with high levels of EOT do not focus on their inner emotional experiences and are characterized by a concrete and poorly

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introspective thinking style (e.g., preferring to talk about daily activities rather than their feelings). Empirical observations have suggested a close relationship between ES and EOT. For example, Chen et al. (2011) conducted a cluster analysis and found three subject subgroups for alexithymia characteristics: general-high alexithymia (high scores on the TAS-20 for all three factors), extrovert-high alexithymia (high scores for EOT and normal scores for the other factors), and introvert-high alexithymia (high scores for DIF and DDF and low scores for EOT). The general-high alexithymia group demonstrated higher ES scores compared with a nonalexithymia group (having low scores for all three factors), which was consistent with findings that ES scores are positively associated with individual differences for alexithymia (e.g., Swart et al., 2009). For ES, the extrovert-high alexithymia group also showed higher scores compared with the nonalexithymia group, whereas the group differences between the introvert-high alexithymia and nonalexithymia groups were not significant (Chen et al., 2011). Taken together, these findings suggested that ES may have a positive association with EOT.

1.3. The mediating role of the ventromedial prefrontal contex (vmPFC)

Welborn et al. (2009) reported larger volumes in the vmPFC, right lateral orbitofrontal cortex (OFC), cerebellum, and basal ganglia in females reporting less frequent use of ES. Using a region of interest (ROI) approach, Hermann et al. (2014) showed a positive association between ES and the gray matter volume (GMV) of the vmPFC, dorsomedial PFC, and anterior cingulate cortex (ACC). Furthermore, Diekhof et al. (2011) performed a coordinate-based meta-analysis with activation-likelihood estimations and demonstrated that the vmPFC is the only neural substrate that shows a concordant hyperactivation during in the control of negative affective responses. Although these conclusions are controversial, the results of these neuroimaging studies suggest that the vmPFC is related to individual differences in ES.

Although an increasing number of structural imaging studies have investigated the neuroanatomical bases of alexithymia (Borsci et al., 2009; van der Velde et al., 2014; Goerlich-Dobre et al., 2014, 2015a, 2015b; Grabe et al., 2014; Ihme et al., 2013), and the ACC, insula, amygdala, vmPFC, and middle temporal gyrus (MTG) have been reported as key regions for alexithymia. The neural bases of EOT are still unclear. A hypothesis that vmPFC volume might be a neural correlate of EOT is reasonable because the vmPFC is thought to be engaged in emotional regulation and intentional inhibition (Kühn et al., 2009; Quirk and Beer, 2006) and EOT refers to the tendency to focus one's attention externally and not on inner emotional experiences (Taylor et al., 2003). Furthermore, the fantasizing factor of alexithymia that can be indirectly assessed by the EOT factor of the TAS-20 (Bagby et al., 1994; Taylor and Bagby, 2013), is associated with vmPFC volume (van der Velde et al., 2014).

Taken together, these findings suggest that the vmPFC is involved in both ES and EOT and that ES is associated with EOT through the vmPFC.

1.4. Gender differences

Females are often considered more emotional because they experience and express their emotions more intensely than males do, whereas males are thought to suppress or avoid their emotional experiences and expression (Barrett and Blissmoreau, 2009; Fabes and Martin, 1991; Fujita et al., 1991). The use of ES reveals a gender difference. Specifically, males use ES more than females do both in Western cultural contexts (Gross and John, 2003; Welborn et al., 2009), and in Chinese contexts (Chen et al., 2005; Wang et al., 2017). Although no gender differences in the total alexithymia scale and the 3 factors are found among Chinese individuals (Yi et al., 2003; Zhu et al., 2007), males tend to exhibit an EOT style more than females do in the general population of Finland (Salminen et al., 1999), and in large, Japanese community and clinical samples (Moriguchi et al., 2007).

Similarly, gender-related variations in the structure of the brain regions involved in ES and EOT have been identified. Welborn et al. (2009) have demonstrated that the volumes of the right lateral OFC and vmPFC (Brodmann area 11) are relatively larger in females, which supports previous reports of gender differences in the OFC, including the vmPFC (Gur et al., 2002). Interestingly, sex-related structural variations in the volume of the vmPFC, but not the right lateral OFC, are associated with self-reported individual differences in ES (Welborn et al., 2009). Wang et al. (2017) investigated the neural correlates of gender difference in ES among the Chinese; results showed a significant gender effect of ES on cortical thickness in the superior frontal gyrus and on functional connectivity between the superior frontal gyrus and medial PFC. In addition, structural imaging studies have investigated GMV differences between female (Borsci et al., 2009), and male (Heinzel et al., 2012) subjects with high and low alexithymia. Borsci et al. (2009) demonstrated decreased GMV in the left ACC and MTG of subjects with high alexithymia, whereas Heinzel et al. (2012) failed to find any significant morphological differences between subjects with high and low alexithymia. These gender-related differences may explain the contradictory findings in these two alexithymia studies.

Although several neuroimaging studies on alexithymia have been conducted, little or no research has investigated the neural correlates of EOT among Chinese samples. EOT, as a particular component of alexithymia, was found to be higher among Chinese than among English-speaking samples (Dere et al., 2012), which may due to cultural variations in the importance placed on emotional experience and expression (Dere et al., 2012, 2013). Hence, the main aim of the present voxel-based morphometry study was to investigate the neural underpinnings of ES and EOT and their association separately for females and males in a Chinese college sample. Specifically, we hypothesized that ES is positively related to EOT, both ES and EOT are correlated with the GMV of the vmPFC, and this region mediates the ES-EOT association. To examine the hypothesis that the vmPFC is the shared neural basis of ES and EOT, we conducted ROI-based and exploratory whole brain analyses. To examine the role of vmPFC volume in the ES-EOT association, we conducted the bootstrapping analysis proposed by Preacher and Hayes (2008). Furthermore, to investigate the putative gender differences, the study participants were divided into female and male groups, and the analyses were conducted separately for the groups.

2. Methods

2.1. Subjects

This study was part of an ongoing project examining the associations among brain imaging, creativity, and mental health. In total, 185 healthy right-handed college or postgraduate students (74 men and 111 women) were recruited from the local community of Southwest University (China). The mean age was 20.3 ± 1.2 years old (for men, 20.5 ± 1.2; for women, 20.2 ± 1.2). None of the subjects had a history of neurological or psychiatric disease, or substance abuse according to self-reports. This study was approved by the local ethics committee of Southwest China University and the Institutional Human Participants Review Board of the Southwest University Imaging Center for Brain Research. The methods were conducted in accordance with approved guidelines. All participants provided written informed consents prior to participating in the study. The subjects completed a battery of psychological instruments, including the ES subscale of the Emotion Regulation Questionnaire (ERQ; Gross and John, 2003), TAS-20 (Taylor et al., 2003), Beck Depression Inventory (BDI; Beck et al., 1988), state version of State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983), Combined Raven's Test (CRT; Raven, 2000)