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Gray matter correlates of dispositional optimism: A voxel-based morphometry study

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HIGHLIGHTS

- Voxel-based morphometry was used to determine differences in dispositional optimism.
- Individual optimism was linked to larger gray matter volume (GMV) in specific areas.
- Optimists with larger GMV in thalamus/pulvinar may be better at regulating emotion.
- Larger GMV in parahippocampal gyrus may reflect positivity and good emotion encoding.

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ABSTRACT

Dispositional optimism is an important product of human evolution. This individual difference variable plays a core role in human experience. Dispositional optimism is beneficial to physical and psychological wellbeing. Previous task-related neuroimaging studies on dispositional optimism were limited by small sample sizes, and did not examine individual differences in dispositional optimism related to brain structure. Thus, the current study used voxel-based morphometry and the revised Life Orientation Test to investigate individual dispositional optimism and its association with brain structure in 361 healthy participants. The results showed that individual dispositional optimism was associated with larger gray matter volume of a cluster of areas that included the left thalamus/left pulvinar that extended to the left parahippocampal gyrus. These findings suggest a biological basis for individual dispositional optimism, distributed across different gray matter regions of the brain.

Introduction

Dispositional optimism is an important product of human evolution. This individual difference variable plays a core role in human experience [3,6,42]. Dispositional optimism is related to positive expectations regarding possible outcomes such that optimistic individuals are confident that they will attain their goals successfully [5,34,38]. Many previous studies have shown that dispositional optimism is beneficial to physical and psychological wellbeing [1,39,40]. For example, optimists tend to have lower depression symptoms at initial assessment [14], whereas pessimism has been associated with: depression in all age groups, self-reported depression, a number of depressive symptoms and negative expectations about the future [24,31,32]. In addition, subjects with higher levels of optimism (compared with pessimists) are reported to have a lower risk of future cardiovascular disease [3,14,44]. Furthermore, one study has suggested that the lower incidence rate and better recovery shown for optimists, may in part be a result of their constant positive emotional state and perception [45]. Optimists are also likely to benefit in the social domain [13]. For example, researchers have found an association between expecting positive outcomes in the future and having broader social networks [28]. People with optimistic dispositions are curious and open to new experiences, and have high positive emotionality [13]; optimists expect good outcomes, even when times are hard, which results in a relatively positive outlook. It is therefore meaningful to investigate the brain mechanisms of the dispositional optimism.

There have been numerous task-related neuroimaging studies on dispositional optimism. Most of these have indicated that dispositional optimism is related to emotion processing and specific emotion-related brain regions. For example, a reduction in the blood oxygenation level-dependent signal was observed in the amygdala and rostral anterior cingulate cortex (rACC), which are involved in emotion processing, during the imagination of negative future events relative to positive future events. These findings

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suggest that optimism may be related to a reduction in future negative thought. In addition, optimistic individuals showed relatively greater rACC activation when imagining positive vs. negative future events compared with less optimistic individuals [39,42]. Another study found that lower levels of optimism were associated with reduced regional cerebral blood flow in the right and left amygdala [12]. Sharot et al. (2011) suggest that optimism is tied to a selective update (reappraisal; an emotion regulation strategy) failure and diminished neural coding of undesirable information regarding the future [18,42]. Researchers have observed that the thalamus plays an important role in emotion regulation; for instance, it is activated when a person views films or recalls personal experiences that evoke happiness or sadness [26,36], and shows greater activity when a person imitates emotional expressions [8]. Studies have also revealed that the hippocampus and parahippocampal gyrus play a role in emotion memory, and the left posterior parahippocampus plays a role in emotional memory encoding [32].

To our knowledge, no studies have yet examined the individual differences in brain structure related to dispositional optimism. The use of magnetic resonance imaging (MRI) allows us to examine these differences with voxel-based morphometry analysis [33], which provides a structural measure of gray matter. Potential correlates of regional gray matter volume (rGMV) may include the number and size of neurons and glia, the level of synaptic bulk, and the extent of neuritis [10]. In this study, we focused on rGMV, which is an appropriate means to investigate individual differences in dispositional optimism. This study used the revised Life Orientation Test (LOT-R) to assess participants' level of dispositional optimism [41]. Based on previous neuroimaging studies on dispositional optimism, we predicted that individual dispositional optimism would be associated with reduced negative thought and negative emotion, corresponding with significant structural differences in the hippocampus, parahippocampal gyrus, thalamus, rACC and amygdala.

Materials and methods

Participants

In total, 374 university students from Southwest University, China, participated in the study, which is a part of ongoing project to examine the associations between brain imaging, creativity and mental health. All participants were healthy, right-handed individuals, with no history of neurological or psychiatric illness. Participants completed the psychological tests and questionnaires prior to scanning. The study was approved by Southwest University Brain Imaging Center Institutional Review Board, and was carried out in accordance with the Declaration of Helsinki [27]. Written informed consent was obtained from all participants.

The data of five participants were excluded from analysis due to excessive motion artifacts or gross anatomical abnormalities (e.g., unusually large ventricles). Data from another eight participants were excluded as a result of missing questionnaire items or for failing to correctly understand the questionnaire. Thus, only the data for 361 participants (158 men and 203 women; mean age 19.96 ± 1.29 years) were analyzed.

Assessment of dispositional optimism

The current study used the LOT-R [41] to assess participants' levels of dispositional optimism [31,42]. Substantial research supports the reliability and validity of the LOT-R instrument, which also has a high degree of internal consistency ($\alpha = 0.80$) [17]. The LOT-R includes 10 items that evaluate generalized expectancies for either positive or negative outcomes. Ratings are made on a 5-point Likert-type scale from 1 (I disagree a lot) to 5 (I agree a lot). Only 6 of the 10 LOT-R items are used to derive an optimism score. Four of the items are filler items and are not used in the scoring. Respondents were advised to be as accurate and honest as possible throughout, and to avoid letting their answers to one question influence their answers to other questions. They were told explicitly that there was no right or wrong answers. Negatively worded items (i.e., items 3, 7, and 9) are reverse-scored. All scores are then added together to compute an overall optimism score [41]. Thus, total scores range from 6 to 30, with higher scores indicating increased levels of dispositional optimism.

MRI data acquisition and preprocessing

MRI images were acquired on a 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany). High-resolution T1-weighted anatomical images were acquired using a magnetization-prepared rapid gradient echo (MPRAGE) sequence (repetition time (TR) = 1900 ms; echo time (TE) = 2.52 ms; inversion time (TI) = 900 ms; flip angle = 9 degrees; resolution matrix = 256 × 256; slices = 176; thickness = 1.0 mm; voxel size = 1 mm × 1 mm × 1 mm).

The MRI images were processed using SPM8 software (Welcome Department of Cognitive Neurology, London, UK; www.fil.ion.ucl.ac/spm) implemented in Matlab 7.8 (MathWorks Inc., Natick, MA, USA). Each MRI image was first displayed in SPM8 to screen for artifacts and gross anatomical abnormalities. For better image registration, the reorientation of the images was manually set to the anterior commissure. The images were then segmented into gray matter and white matter using the new segmentation feature in SPM8. Subsequently, we performed diffeomorphic anatomical registration through exponentiated lie (DARTEL) algebra in SPM8 for registration, normalization and modulation [2]. To ensure that regional differences in the absolute amount of gray matter were conserved, the image intensity of each voxel was modulated by the Jacobian determinants. Then, registered images were transformed to Montreal Neurological Institute (MNI) space. Finally, the normalized, modulated images (gray matter and white matter images) were smoothed with an 8-mm full-width at half-maximum Gaussian kernel to increase the signal to noise ratio.

Statistical analysis

Statistical analyses of gray matter volume (GMV) data were performed using SPM8. In the whole-brain analyses, we used a multiple linear regression to identify regions where rGMV was associated with individual differences in dispositional optimism as measured by the LOT-R. The LOT-R scores were used as the variable of interest in these analyses. Previous studies had indicated that some aspects of brain asymmetries interact with gender [21,25]. Although the participants' age only ranges from 17 to 27 years old in present study, we included age as covariates in the analysis since age has an appreciable effect on brain morphology [16]. Thus, to control for possible confounding variables, age, sex and global volumes of gray matter were entered as covariates into the regression model. We also applied explicit masking using the population-specific masking toolbox in SPM8 in order to restrict the search volume within gray matter and white matter (http://www.cs.ucl.ac.uk/staff/g.ridgway/masking/). This Approach was used instead of absolute or relative threshold masking in order to reduce the risk of false negatives caused by overly restrictive masking, in which potentially interesting voxels are excluded from the statistical analysis [37]. For all analyses, the cluster-level statistical threshold was set at $P < 0.05$, and corrected

Table 1
Demographic data of the study participants ($N = 361$; men = 158, women = 203).

Measure	Mean	SD	Range
Age	19.96	1.29	17–27
LOT-R scale	21.24	3.17	10–29

Demographic variables of the study participants ($N = 361$; men = 158, women = 203).

using non-stationary cluster correction [20] with an underlying voxel level of $P < 0.001$.

Results

Behavioral data

Participants' LOT-R scores were used as a measure of their dispositional optimism, with higher scores indicating more optimistic. Kurtosis (0.131) and skewness (−0.257) of LOT-R scores were within the range between −1 and +1, indicating the normality of the data [29]. Table 1 shows the mean, range and the standard deviation of age and LOT-R scores, and Table 2 shows the distribution of the LOT-R scale scores. In this study, the LOT-R scale scores were not significantly correlated with age ($P = 0.627$, $r = -0.026$), total brain gray matter volume ($P = 0.220$ $r = 0.065$) or sex ($t = 0.757$, $P = 0.450$).

Correlation between GMV and LOT-R scale scores

After entered age, sex and global volumes of gray matter as covariates into the regression model, a multiple regression analysis revealed that LOT-R score (i.e., individual dispositional optimism) were significantly and positively correlated with GMV in a cluster that mainly included areas in the left thalamus/left pulvinar, which extended to the left parahippocampal gyrus ($x = -14$, $y = -39$, $z = -1$, cluster size = 748 voxels, $t = 4.61$, $P < 0.05$ (corrected); see Fig. 1). Then we examined the individual differences in brain structure related to dispositional optimism when didn't enter age and sex as covariate into the regression model. The results are the same as the previous (control for sex and age), but the corrected brain cluster size was smaller. The similar result might be caused by a small range of age and nearly balanced sex of the sample.

Discussion

To our knowledge, this is the first study to investigate the associations between brain structures and individual dispositional optimism in a voxel-wise manner. Our results showed that individual dispositional optimism was significantly and positively correlated with GMV in a cluster that mainly included areas in the left thalamus/left pulvinar, which extended to the left parahippocampal gyrus.

In the current study, higher levels of optimism were associated with larger GMV in the thalamus/pulvinar. Many previous studies have shown the importance of the thalamus in emotion regulation [9,15,46]. This is not due to the thalamus itself, but to its connections with other limbic system structures (amygdala, hippocampus, anterior cingulate cortex, insular cortex, ventral striatum) [4,9]. Emotion regulation involves processes that amplify, attenuate, or maintain an emotion [9]. Optimistic individuals are more positive in their attitude in daily life. They make an active effort to rectify bad moods and have higher self-esteem than less optimistic individuals [18,34]. When faced with undesirable information, more optimistic individuals use reappraisal as an emotional regulation strategy and so are more likely to report better moods than lower optimistic individuals [18,42]. Psychiatric disorders such as anxiety disorder represent a failure to either elect an adaptive response or to inhibit a maladaptive response in a given situation; in other words, those affected by such disorders have poorer emotion regulation abilities [7]. Furthermore, studies have found that individuals with psychiatric disorders show a reduced thalamic size compared with individuals that have no psychiatric or neurological disorders [24,35]. Together, these studies indicate that thalamus might play an important role in emotion regulation. In sum, the finding of increased GMV in this area in subjects with higher dispositional optimism indicates that these individuals might have better emotion regulation abilities.

Those with higher levels of optimism were also found to have larger GMV in the parahippocampal gyrus, particularly the posterior parahippocampal gurus. Kilpatrick and Cahill (2003) found that the parahippocampal gyrus correlated with long-term memory for emotional material [23]. In addition, the left posterior parahippocampus is reported to play a role in emotional memory encoding [32]. Previous studies have shown that the posterior parahippocampal gyrus may play a more domain-general role in emotion-driven learning [32], and might be linked to declarative memory [11]. Optimists expect good outcomes, even when times are hard. This yields relatively positive feelings. Those with lower levels of optimism expect bad outcomes, which results in more negative feelings—anxiety, anger, sadness, even despair [13]. In addition, a voxel-based morphometry study of healthy subjects showed that smaller left parahippocampal gyrus volume was associated with increased anxiety symptoms as measured by the

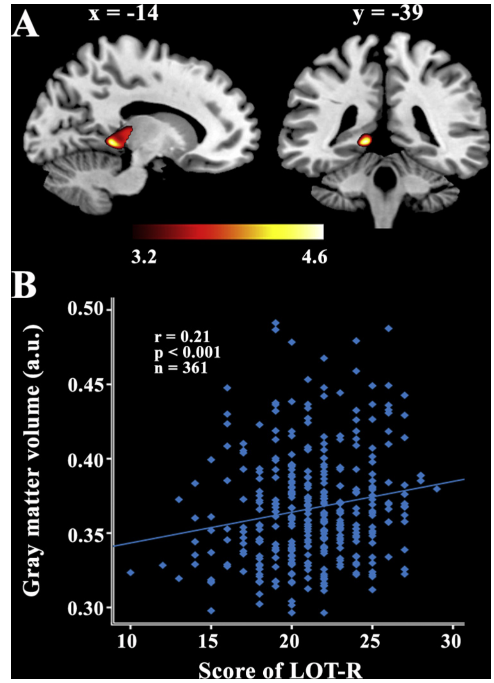

Fig. 1. The associations between regional gray matter volume (rGMV) and dispositional optimism. (A) A region showing a positive association between rGMV and revised Life Orientation Test (LOT-R) scores. Results are $P < 0.05$, corrected for multiple comparisons at the non-stationary adjusted cluster level, with an underlying voxel level of $P < 0.001$, uncorrected. The significant associations are primarily seen in the left thalamus/left pulvinar region, extending to the left parahippocampal gyrus. (B) Scatterplot of the correlation between LOT-R scores and mean rGMV within a significant cluster in the left thalamus/left pulvinar, extending to the left parahippocampal gyrus.

Table 2
Distribution of LOT-R scale scores of study participants.

	10–14	15–18	19–22	23–26	27–29
LOT-R scores	9	58	174	102	18

State Trait Anxiety Inventory [43]. Those with lower levels of optimism have been associated with: a greater risk of depression in all age groups, self-reported depression or a number of depressive symptoms, and negative expectations regarding the future [30]. Some neuroimaging studies have revealed reduced GMV in the hippocampus [19] and parahippocampal gyrus [20] in those in a depressive state. In sum, the finding of increased GMV in this area in subjects with higher dispositional optimism indicates that these individuals experience more positive emotions and feelings.

There are a few limitations in this study. First, we used young healthy subjects with high-level education. Thus, our interpretations have a certain limitation. Second, in present study, we only focus on Gray matter correlates of dispositional optimism, however, it is necessary to study the correlation between the GMV and brain activity in the future. Third, the differences in gray matter volume might reflect underlying synaptogenesis and dendritic arborization [22], but a direct link between microstructures and macrostructures has not been established in the human brain. In present study, we focus on the macroscopic volumetric difference, but we think it will be important to investigate how macroscopic volumetric measures are reflected in microstructures at the cellular level in the further study.

Conclusion

The present study found that individual dispositional optimism was significantly and positively correlated with GMV in a cluster that primarily included areas in left thalamus/left pulvinar, which extended to the left parahippocampal gyrus. Larger GMV in the thalamus/pulvinar in subjects with higher dispositional optimism may be indicative of better emotion regulation. Increased GMV in the left parahippocampal gyrus in subjects with higher dispositional optimism may reflect more positive emotions and feelings.

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