Sci. Bull. (2015) 60(21):1824–1832
DOI 10.1007/s11434-015-0910-0

www.scibull.com
www.springer.com/scp

Article

Life & Medical Sciences

Examining brain structures associated with attention networks in a large sample of young adults: a voxel-based morphometry study

Lei Hao · Na Sang · Xue Du · Jiang Qiu · Dongtao Wei · Xu Chen

Received: 2 June 2015 / Accepted: 11 September 2015 / Published online: 16 October 2015

Abstract Attention networks have three principal components supported by separate subprocesses, which include alerting, orienting, and executive control (EC) networks. Efficiently and accurately extracting useful information from the environment as the function of attention is pivotal to our survival. Previous brain imaging studies have examined activation patterns underlying the different attention networks in different cortical regions, yet focal differences in brain structures related to attention network components were not well understood. Therefore, in this study, voxel-based morphometry was used to investigate the relationship between gray matter volume (GMV) and different attention networks in a large young adult sample ($n = 156$). As a result, multiple regression analysis revealed that higher alerting scores (stronger alerting ability) were negatively significantly correlated with region gray matter volume (rGMV) in the PCC/PreCu (posterior cingulate cortex/precuneus), which might be associated with continuous maintenance of a vigilant state. Then, lower EC scores (stronger conflict resolution ability) were associated with larger rGMV in the dorsal anterior cingulate cortex, which might be related to high-efficiency executive control processing. Together, findings of the present study provided a unique structural basis of GMV for individual differences in alerting and EC networks.

Keywords Alerting · Orienting · Executive control · Attention network test · Gray matter volume

1 Introduction

Attention has three complex networks supported by separate network subprocesses, which include alerting, orienting, and executive control (EC) networks [1]. One of the abilities such as efficiently and accurately extracting the useful information of the environment is the core function of attention, which is essential to our survival. Specifically, the alerting network was defined as acquiring and maintaining an vigilant state [2–4], the orienting network was defined as movement of attention through space to orienting toward sensory information [5–7], and the EC network was defined as resolving conflict that arises between potential responses [8, 9]. Many previous brain imaging studies have examined the activation patterns and resting-state networks underlying the attention networks in different cortical regions via using functional magnetic resonance imaging (fMRI) [10–12]. However, until now, there was no study that directly used a large young adults sample to investigate the relationship between individual attention network components and brain anatomical structure differences.

To some extent, the attention network test (ANT) provides a measure that quantizes the efficiency of attention networks including the alerting, orienting, and executive control functions of attention in a single task [1]. The ANT has been widely used in different categorized and individual researches, including genetic [13–15], behavioral

Lei Hao and Na Sang contributed equally to this work.

L. Hao · N. Sang · X. Du · J. Qiu (✉) · D. Wei · X. Chen (✉)
Key Laboratory of Cognition and Personality (SWU), Ministry of Education, Chongqing 400715, China
e-mail: qiuj318@swu.edu.cn

X. Chen
e-mail: chenxu@swu.edu.cn

L. Hao · N. Sang · X. Du · J. Qiu · D. Wei · X. Chen
Department of Psychology, Southwest University, Chongqing 400715, China

[1], electrophysiological [16, 17], and functional neuroimaging studies [4, 18], and in different individuals such as children with disorders [19, 20], adults with borderline personality disorders [21], patients with Alzheimer's disease [22], and schizophrenia [23]. For example, previous patient studies had found that lesions of the frontal and parietal lobe, especially in the right hemisphere, had strong deficit on sustained attention and these patients were very difficult to maintain the alert state in the absence of a warning signal [4, 24, 25]. In addition, an fMRI study of attending to visual stimuli showed that distinct right temporoparietal junction (TPJ) mediated the attentional processes of voluntary orienting [5]. Moreover, some fMRI studies of the executive control networks had consistently found activated areas of the anterior cingulate cortex (ACC) in general cognitive conflict monitoring and the dorsolateral prefrontal cortex (DLPFC) in resolution of the perceived conflict [9, 10, 26]. Previous functional neuroimaging and lesion studies indicated that there might be some key brain regions with the different attention networks in function activation. However, whether the performances of different attention networks had the neuroanatomical differences in healthy volunteers might be worth exploring, such as testing the correlates between structural regions and different attention subprocesses, via testing the correlative relationship between GMV and scores on alerting, orienting, and EC networks.

Therefore, in this study, voxel-based morphometry (VBM) was employed to investigate the neural bases of individual differences in attention networks, including attention alerting, orienting, and EC networks. Generally, VBM is a fast and straight forward method to quantify the amount of gray matter existing in a voxel [27–30]. GMV is conceptualized as the amount of gray matter lying between the gray–white interface and the diameter [31]. Compared to functional imaging studies, structural imaging studies are particularly suitable for investigating the anatomical correlations of stable personal characteristics including a series of behaviors and ideas occurring outside the laboratory [32]. Therefore, based on previous findings [10, 11, 33, 34] that a specific involvement of frontoparietal areas of right hemisphere in the alerting network. Consequently, we hypothesized that individual differences in alerting would be associated with differences in the volume of the frontal and/or parietal areas of the right hemisphere when examining the correlation between structural brain images data and alerting scores, which might be related to sustain attention or maintain the alert state [4, 24, 25]. Previous fMRI studies showed that distinct right temporoparietal junction (TPJ) mediated the attentional processes of voluntary orienting when attending the visual stimuli. So, we hypothesized that orienting would be associated with differences in the volume of the temporal parietal junction, which might be involved in voluntary orienting to the detected target [5], and EC would be associated with differences in the volume of ACC or/and DLPFC in the general cognitive conflict monitoring and the resolution of the perceived conflict [9, 10, 26]. The hypothesis was based on the previous fMRI studies that showed the importance of anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC) in executive control network. This study might be the first to investigate the regional variations in GMV underlying individual differences on attention network levels using VBM and to provide a direct neuroanatomical evidence for understanding and improving individuals' attention ability.

2 Experimental procedures

2.1 Participants

One hundred and fifty-six subjects (62 men, aged 18–25 years, mean 20.06 ± 1.24 years; 94 women, aged 17–22 years, mean 19.59 ± 0.96 years) were included in this study for investigating the neural mechanism of cognition, emotion, and personality. All of the subjects were right-handed, had no obstacle in vision, and had no disorders on the aspects of neurology or psychiatry. All subjects came from Southwest University as graduates or undergraduates. Informed written consent was obtained from every participant even from the guardian who took charge of the participants aged 17 years. The procedures of consent and experiment were approved by local ethics which were in accordance with the standards of the Declaration of Helsinki.

2.2 The attention network test

A version of the ANT [1] was used with four cue conditions and two target conditions proposed by Dr. Jin Fan [1]. This version used in our study consisted of one practice run of 24 trials, with feedback on accuracy and speed of response. The practice run was consisted of 96 trials per run following three experimental runs, with no feedback. For each trial, the participants pressed the mouse left key or right key indicating the direction of the centrally presented arrows. All trials presented a target stimulus, either above or below the fixation cross in the screen center. The centrally presented arrow was flankered by one of the three different types of arrows: (1) pairs of congruent arrows, (2) pairs of incongruent arrows, or (3) pairs of neutral lines. Target stimuli were preceded by one of the four cue conditions: (1) no-cue condition, (2) center-cue condition, (3) spatial-cue condition, or (4) double-cue condition. At the beginning of a trial, a fixation cross was presented for 400, 800, 1,200, or 1,600 ms, and a cue was presented for