The Alpha Network Changes Elicited by Working Memory Training

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Abstract In the current study, we utilized EEG coherence and complex brain network to study the changes of working memory (WM) and constructed differential statistical networks under alpha rhythms before and after training. The results showed that the long-range frontoparietal and frontooccipital interactions during WM retention involved in the alpha frequency network. The findings revealed that the connections between neurons varied to complete the efficient transmission and processing of information, indicating the neural plasticity before and after WM training from the network level.

1 Introduction

Visual working memory (WM) involved neuronal activity in the various cortical regions including frontal, parietal, occipital, and temporal areas based on functional magnetic resonance imaging (fMRI). Brain oscillations at different frequencies are associated with cognitive processes such as emotion and memory (Jay & René, 2004). And the oscillation synchronization could be used to define interactions between different brain regions at relatively high temporal resolutions (Li et al., 2015). Moreover, the alpha synchronization prevents external input from interfering with ongoing working memory tasks (Ole & Tesche, 2010), implying neural synchronization activation of alpha oscillations could suppress information processing independent of WM (Li-Yu et al., 2013). The continuous activity of the brain is strong evidence, which reflected WM characterization during the delayed period of WM. Many brain areas of the cortex and subcortex also exhibited similar sustained activity and formed a brain networks for memory information interaction to support the processing and delivery of WM retention information (Curtis et al., 2005). EEG coherence

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was primarily a measure of phase consistency, reflecting the functional connection between paired brain regions (Nolte et al., 2004). Strong coherence reflected the simultaneous oscillation of neurons, while weak coherence indicated that the activity between these neural clusters was independent of each other. In brain science research, graphical theory analysis was widely used in brain network to provide a theoretical basis for understanding the brain network topology. Studies have shown that the human brain was a highly interconnected complex network (Langer et al., 2013). Therefore, we utilized the graph theory analysis method based on EEG coherence to construct a coherence network before and after WM training, and difference network relied on statistical analysis under different brain oscillations. We hope that the current study could reveal the plasticity of WM training from the brain network perspective based on EEG coherence.

2 Materials and Methods

Twenty right-handed normal male subjects (21 years old) participated in the experiment. All subjects did not have any cognitive impairment, history of mental and neurological diseases. The experiment was approved by the Ethics Committee of Chongqing University of Posts and Telecommunications. All subjects who participated in this experiment read the informed consent form in advance and signed it. After the experiment, subjects will receive corresponding compensation for their time and efforts. The experiment was similar to our previous design on working memory (Yin et al., 2017). Subjects were asked to remain relaxed throughout the experiment and to suppress as much as possible the wide range of motion. Subjects needed to perform three task difficulty levels (2, 4, and 8 items) delayed WM tasks consisting of two sessions. The experimental content of the two sessions was the same. The only difference was that the subject completed the first session tasks without training, and completed the task of the second session after receiving the short memory training. A 64-channel NeuroScan system was used to record subjects' EEG data during doing the WM experiment. The offline processing of EEG data mainly included: re-reference, data segmentation, artifact removal, filtering, and baseline correction. The coherence of EEG signals reflected the correlation of the time domain signals of the two brain regions in alpha frequency band. The coherence function between the two signals as shown in the previous literature (Curtis et al., 2005). The graph analysis method was used to construct the brain networks before and after WM training, and the network topological properties were measured by the optimal path length (Lp), clustering coefficient (CC), local efficiency (Eloc), global efficiency (Eg), degree (Deg) and small-world properties of the network (Palva et al., 2010).

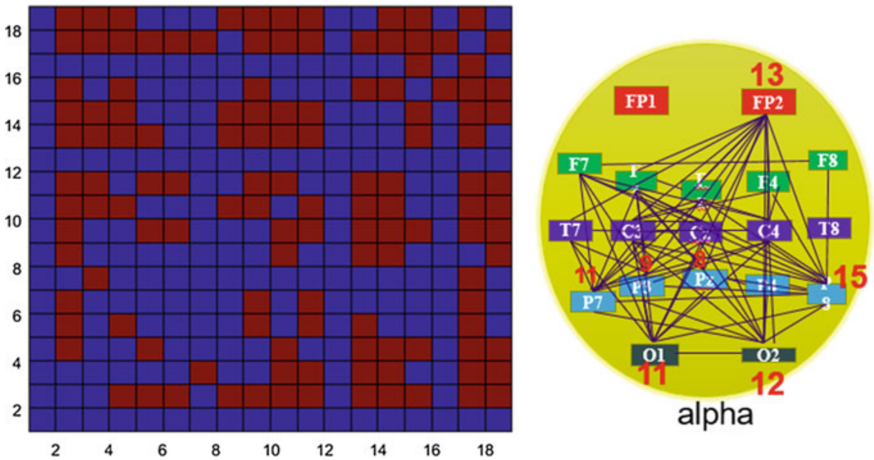

Fig. 1 Coherence statistical matrix and statistics network

3 Results and Discussion

For the coherence matrix in alpha brain oscillation, the paired t-test was utilized to statistically obtain the corresponding elements of the coherence statistical matrix before and after the training. That is, if there was a significant difference on the coherence values of WM network between the two nodes before and after WM training ($p < 0.05$, FDR correction), the corresponding elements of the statistical matrix was set to 1. Otherwise, the element of the statistical matrix was set to 0. Finally, statistical matrix before and after WM training (binary matrix) was obtained, and thus the difference statistical network of alpha rhythms was acquired. Figure 1 showed the statistical matrix and difference statistical networks of alpha rhythms before and after the WM training.

For the difference statistical network of alpha band, the node degrees at the FP2, P7, P3, Pz, P8, O1, and O2 electrode positions was significantly different before and after memory training, indicating that the increased coherence between paired nodes in fronto-occipital network under alpha rhythm after WM training. Moreover, it involved the long-range integration of the "top-down" information processing between the frontoparietal, fronto-occipital brain regions, similar to previous study (Palva et al., 2010).

Conflict of Interest There is no conflict of interest.

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