Applying Resting-State Functional MRI to Study Impact of Attention Training on Healthy Highly Educated Subjects

B. L. Hou[1], A. Smith[2], J. Chong[2], J. Brefczynski-Lewis[1], and M. Haut[2]
[1]Radiology, West Virginia University, Morgantown, WV, United States, [2]Behavioral Medicine & Psychiatry, West Virginia University, Morgantown, WV, United States

Introduction: Resting-state functional MRI (rfMRI) has been used to investigate intrinsic, dynamic connections among brain regions of healthy subjects and patients with a variety of brain diseases (1-3). Recently research has focused on applying the information on the strength of the connectivity to study the effects of treatments (4), visual perceptual learning (5), and drug addiction (6). Here we present our study applying rfMRI data to examine the impact of attention training on healthy highly educated subjects. Our hypotheses were that brain attention function is linked with the resting-state brain attention network, and the improvement of attention due to "training" results from an increase in the strength of the network connectivity. **Materials and Methods:** 8 normal subjects (3 females; age range 21-26, years with mean of 23.3±1.9 years, mean IQ 115.8±7.8 and mean years of education 16.6±1.5) were recruited for attention training in which they were asked to practice N-back tasks for 20 minutes a day for two weeks. Among them 6 showed improvement on the training and are reported in this abstract. The 6 subjects were scanned twice: one was prior to the training, and the second at the completion of training. The MRI scans were performed on two 3.0 T MRI scanners (GE or Siemens) with a standard birdcage head coil. After a T1-weighted high spatial resolution imaging using either a SPGR or a MPRAGE pulse sequence (TR/TE: 450/3.81ms, slice thickness: 1.5 mm and 124 axial slices for covering whole brains), rfMRI imaging was performed by using a multi slice 2D EPI(TR/TE: 4000/30ms, field of view (FOV): 240 mm, image matrix:128*128, slice thickness: 4 mm, 32 slices) for total 64 volumes in 4:32 minutes. The subjects were asked to close their eyes, and "rest" during the rfMRI scans. rfMRI analyses were performed offline by using both FSL(7) and AFNI(8). Individual and group independent component analyses (ICA) were performed by FSL, and the "attention" component was found from the ICs, then the attention component map for each individual subject was exported to AFNI to get the mean Z score values. A two tail, equal variance, t-test was applied to the data before and after attention training in order to get P values. If a P is less than 0.05, the compared two groups are significantly different. **Results:** The images of the resting state attention network from the group analyses of the 6 subjects before and after attention training were presented in Figure 1. The attention network determined from the rfMRI analyses includes that the intraparietal sulci, areas at the intersection of precentral and superior frontal sulcus, ventral precentral, and middle frontal gyrus. In Figure 2 the strength of attention network (i.e., mean Z score) versus the total number correct on the N-back for each subject were plotted (the left is before and the right is after training). After the data were fitted by linear lines, the P values based on the R values of the fittings suggest that only after the training the connectivity strength linearly increases with the N-back score (R^2=0.37, $P<0.05$). The mean values and standard deviations of the attention score and the network strength (i.e., Z score) for before and after training groups were listed in the Table 1. P values of t-testes obtained from comparing before with after training in the N-back and Z- score groups were also calculated and were listed in the table. The P values imply that after the training, the attention scores and the strength of the network connectivity were significantly higher.

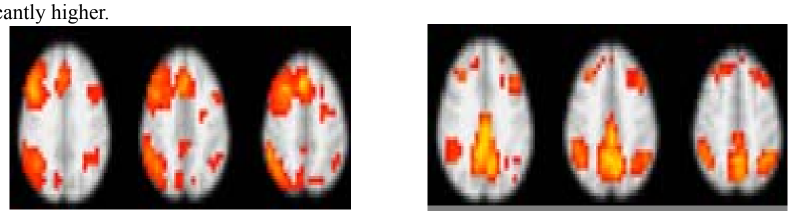

Figure 1 Images with resting state attention network from group analyses of the 6 subjects for before (the left) and after (the right) attention training.

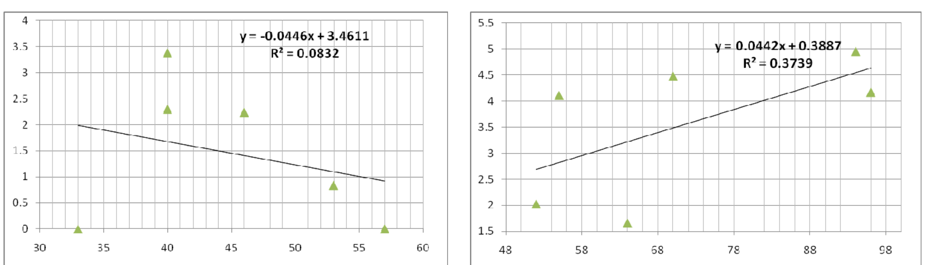

Figure 2 The strength of attention network (i.e., mean Z-score) versus the score of N-back for each subject before (the left) and after (the right) attention training.

	N-back Score	Z score of network
Before	**44.80±8.98**	**1.46±1.39**
After	**71.83±19.00**	**3.57±1.38**
Pvalues	**0.01**	**0.03**

Table 1 The mean scores and standard deviations of the attention (N-back) score, the Z score, and the P values of the groups of N-back and Z scores.

Discussions: The images (Figure 1) from the rfMRI group analyses demonstrate a bilateral dorsal attention system which is very similar to the one exposed by task-related attention studies, and the system involves with perception, action, language, and memory (9). The similarity of the attention networks suggests that the attention function is not only related to a high energy level (task-related) neuron activity, but also linked to a low energy level (resting-state) intrinsic, dynamic connectivity in the eloquent cortices associated with attention. A study of juggle learning (10) and the visual learning case (5) demonstrated that a healthy brain has plasticity. The N-back data in Table 1 reveals that attention ability was improved in two weeks (P=0.01). Meanwhile, the improvement correlates with the strength of the attention network (the right plot of Figure 2, R^2=0.37, $P<0.05$). Without the training, the attention function (the left plot of Figure 2) appears to be independent with the strength of the network connectivity (R^2=0.08, and $P>0.05$). This implies that the training effect enhances the intrinsic, dynamical linkage among the attention eloquent cortices and is further evidenced (Table 1) by the significantly increased N-back performance score (P=0.01) and significantly increased Z score for the strength of the attention network (P=0.03). **References:** [1] Biswal, B., et al. MRM, 1995, 537-541. [2] Greicius MD., et al. PNAS, 2004,4637-42.[3] Li SJ., et. al. 2002, Radiology, 253–259. [4] Rajan S., et al. Brain Imaging and Behavior, 2007,1682-1689. [5] Lewis, CM., et al. PNAS, 2009, 17558-17563. [6] Gu,H., et al. NeuroImage, 2010,10.1016. [7]Smith, SM., et al. NeuroImage, 2004, 208-219. [8]Cox, RW.,Comput. Biomed. Res., 1996, 162–173. [9] Wager, T., Neuroimage,2004,1679-93. [10]. Draganski, B., Nature, 2004, 311-312.