Cerebral Plasticity Induced by Abacus-based Mental Calculation Training in Children

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Introduction

Through long-term training, experts of abacus-based mental calculation (AMC) demonstrate extraordinary calculation ability and superior digit working memory capacity (Stigler 1984; Hu, et al. 2010), and exhibit quite different activation pattern when compared to untrained peers in numerical fMRI experiments (Hanakawa, et al. 2003; Chen, et al. 2006). Recently, the AMC training-induced brain structural plasticity was explored using diffusion tensor imaging (Hu, et al. 2010). The effects and mechanism of AMC training, however, are still far from clear. The aim of the present study was to further examine the effects of AMC training on brain structure using voxel-based morphometric method.

Methods and materials

Seventeen right-handed healthy abacus children (age mean = 10.39 years, AMC training over three years) and seventeen controls (age mean = 10.06 years) participated with informed consent of themselves and their parents. In the digit memory span (DMS) test, subjects were required to recall the digits in order after audio presentation of digit sequences. Their brain structure data were collected by a Philips 3.0 Tesla scanner using a sagittal T1-weighted sequence (TR/TR 30/5 ms; FOV 230 mm; phase/frequency encoding steps 322/256; 168 slices without gap; voxel size 0.41 x 0.41 x 1mm^3). The DARTEL toolbox released with SPM8 (http://www.fil.ion.ucl.ac.uk/spm/) was employed in the data preprocessing steps including 1) gray matter (GM) and white matter (WM) segmentation, 2) custom templates iteration, 3) normalization to MNI space and modulation, and 4) smooth with a Gaussian blurring kernel of 12mm FWHM.

Statistical Analysis and Results

Structural difference was examined using a two-sample *t*-test factorial design with age and gender as covariates, and with an absolute threshold of 0.1 for the explicit mask in SPM8. GM comparison revealed increased volume in rolandic operculum and supplementary motor area (SMA) in the AMC group. Moreover, WM comparison indicated that AMC children showed larger structural volume in three regions including right SMA, left cerebellum tonsil, and right putamen-caudate regions (uncorrected p < 0.005, cluster > 50 voxels). Further analysis revealed significant correlation between structural measures and individual digital memory spans. Structural comparison and correlation results were presented in Figure 1.

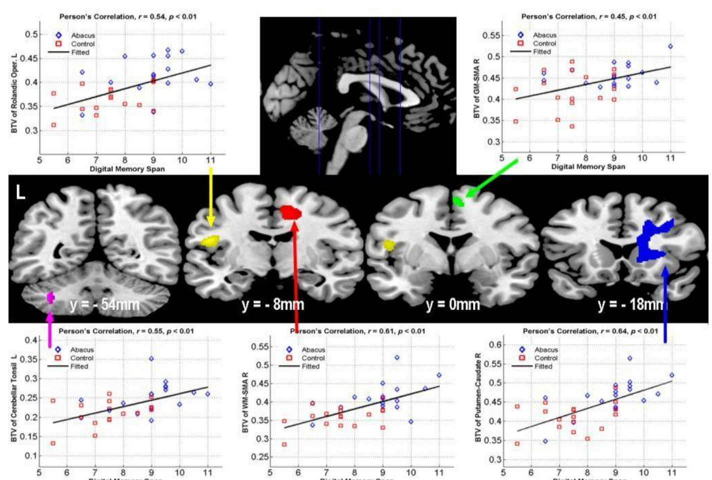

Figure 1. Compared with controls, AMC group showed increased cerebral volume in both gray and white matter in some motor-related regions, which also demonstrated significant correlation with digital memory span. MIN coordinates were used. L: left.

Discussion

Many studies have reported the effect of training on behavioral performance, but it has not been definitively established how training affects behavioral performance and the underlying neuro-structure. Investigation of training-induced structural plasticity could enrich our understanding to this issue. As in the case of abacus training, previous studies reported that it helps greatly in improving calculation skills and digital working memory. In early behavioral studies, visuospatial strategy was supposed to be utilized in the AMC (Stigler 1984), and the frontal-parietal network was found to be engaged in by later fMRI experiments (Hanakawa, et al. 2003; Chen, et al. 2006). As the AMC training was consistently reported to improve digital working memory span, the positive correlation between digital memory span and cerebral volume in this study indicated that some brain regions related to visuospatial functions might be influenced by long-term AMC training.

Reference

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