Comparing functional connectivity in default mode of brain between adult and children during mental calculation

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Introduction

Recently, there have been increased interests in the default mode of brain function and the presence of spontaneous low-frequency BOLD signal fluctuations in default regions during resting state and cognitive processing (such as working memory) state in the neuroscience community [1-4]. While all these studies focused on the default mode of adult, there are scarcely researches based on children. Then, questions are coming that whether this default mode can be extended to children, and whether the spontaneous signal fluctuations in default regions will reorganize in response to changes of cognitive tasks such as mental calculation. In this study, we want to explore these questions by detect the default mode of children and adult during performing continuous mental calculating task using a ROI-based functional connectivity analysis.

Methods

Subjects 11 right-handed healthy children (aged between 10 and 14 years) and 12 right-hand healthy adult (age between 21 and 28 years) volunteered to participate in this study with informal written consent by themselves or by their parents (to child subjects). The fMRI experiment was performed with the approval of the local ethics committee of Zhejiang University. All subjects underwent 4 scans (250 sec each scan) when they performed a sequential random 2-digit addition task through visual stimuli during MRI scanning sessions.

Data acquisition Imaging data were collected with a 1.5 T MR scanner (Siemens, Sonata, Germany) with a standard circularly polarized head coil. Anatomical imaging included a transverse 2D gradient echo T1-weighted sequence (500/14 ms [TR/TE], flip angle 90^{o}, FOV 24×24 cm, matrix 256×256, slice thickness/gap 5/1 mm, number of slices 23). For fMRI, a whole brain T2*-weighted, echo-planar imaging (EPI) sequence (2000/40 ms [TR/TE], flip angle 90^{o}, FOV 24×24 cm, matrix 64×64, slice thickness/gap 5/1 mm, number of slices 23) was used.

Data analysis The first 5 points of each session were discarded because of the instability of the initial MRI signal leaving 120 time points. The data analysis was performed with SPM2 [available via www.fil.ion.ucl.ac.uk/spm/spm99.html]. After realignment, the images were normalized into standardize coordinate space approximated to the MNI space and then smoothed spatially using a Gaussian kernel of 8 mm FWHM. Additionally, the mean global brain signal was subtracted. A ROI-based functional connectivity analysis was used. Firstly, the posterior cingulate cortex (PCC)/precuneus area [0, -53, 30] was choose as a seed point (a single spherical ROI (radius 10 mm)) for correlation analysis. Then the mean signal intensity time course from the voxels inside the ROI was extracted from scans in all subjects. The ROI signal time course was inserted as a regressor in a general linear model and statistical parametrical contrast images were calculated at the subject level. Subsequently, these contrast images constituting subject-specific positive correlation with the selected seed were entered into a second level analysis, one sample t-test for each contrast ($p<0.05$ corrected, cluster>50 voxels). Next, two sample t-test analysis was used to compare the contrast images between two groups ($p<0.001$, uncorrected, clusters>50 voxels).

Results and Discussion

Positive correlations with the PCC/precunues were found in the regions of default mode network, such as medial prefrontal cortex (MPFC), angular gyurs/supramarginal gyurs, middle/inferior temporal cortex and temporal pole, as well as in the left inferior frontal gyurs, cerebellum and parahippocampal gyrus in both groups (Fig.1). These results are consist with previous studies [1-4]. Additionally, significant correlations were also detected in the bilateral precentral gyrus in adult. Then, a direct comparison of correlations in default regions between two groups showed relatively stronger correlation in MPFC, temporal pole, precunues in adult, while relatively increases in angular gyurs in children (Fig. 2). One probable explanation of the discrepancy is that the prefrontal cortex is not completely mature in children, and it is the slowest region of the brain to development, with detectable changes still occurring into the teenage years [5]. To sustain the self-referential or introspectively oriented mental activity, as well as to integrate internal and internal environment [1-4], It more depended on angular gyurs, the posterior part of default network in children. Another probable interpretation is that there are dynamic changes in the default mode network during development of the brain. The patterns of functional connectivity shift or reorganiz with development of the brain. These changes are relevant with experiences, knowledge and so on. In conclusion, during mental calculation state, almost similar default mode network were observed in children and adult groups, but the intensities of connectivity in default mode network were different. MPFC and temporal pole had stronger correlation with PCC in adult, while angular gyurs had much greater connectivity with PCC in children. Our findings have demonstrated that the default mode network may dynamic change with functional development and maturation of the brain.

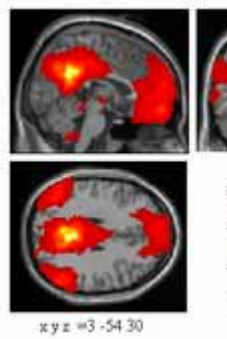

Fig. 1. Correlation between a ROI seed region and all other voxels in the brain during mental calculation in adult.

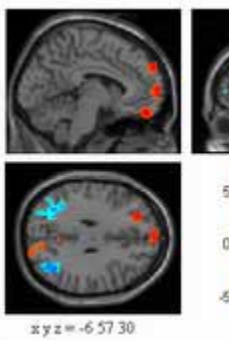

Fig. 2. A direct comparison of correlation activity in the default mode network between both groups. Red color: adult>children; blue color: children>adult

Reference

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