Spatially independent component analysis for automatically delineating brain functional connectivity with resting-state fcMRI

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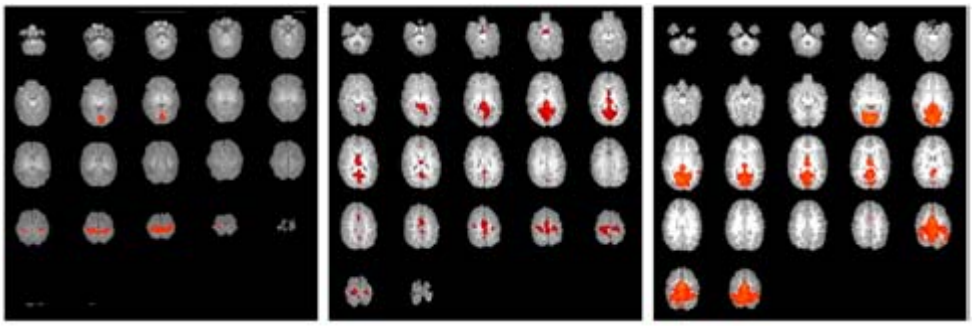
INTRODUCTION

Unlike the task-related fMRI, functional connectivity MRI (fcMRI) utilizing the synchronous low frequency fluctuation of BOLD signals, has been demonstrated to reveal brain functional connectivity during the resting state (1). Conventionally, a cross-correlation analysis (CCA) is applied between a low-pass-filtered 'seed' signal from one pre-defined voxel or a small region of interest (ROI) and the whole brain. However, one of the major limitations associated with this approach is the potential biases resulted from the choices of ROIs. Recently, spatial ICA (sICA) has been proposed as an effective alternative to circumvent the problems associated with the CCA approach (2,3). sICA requires no predefined seed signals or prior knowledge about spatial/temporal patterns of brain activity and performs a blind source separation based on the 2nd and higher order relations between voxels. By maximizing both the statistical independence and the non-Gaussianity of the source signals, sICA can decompose fcMRI signals into various sources consisting of a unique time course of activation and a corresponding 3D component map. Each brain function may be represented by one or more resulting spatially-independent sources. The sICA results are then visually examined to manually select the source(s) that may represent brain functional connectivity. As evident, this final step also requires user inputs, can introduce biases and is tedious. In this abstract, automatic procedures were developed to determine the components that most likely reflect fcMRI using sICA. The developed approaches were then utilized to depict cortical connectivity in neonates (2-4wks), one-year and two-year old children.

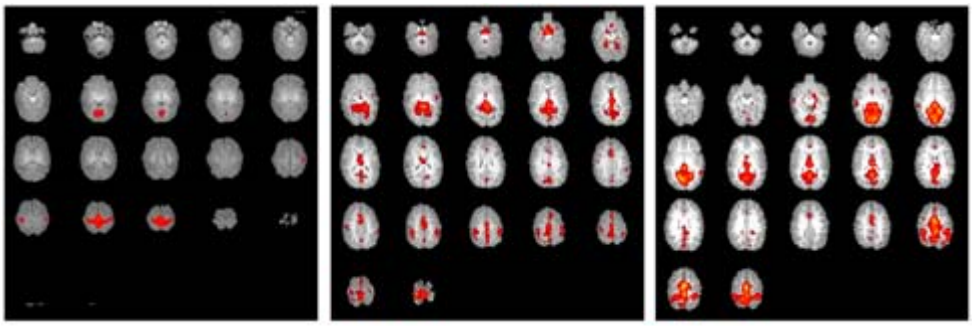
MATERIALS AND METHODS

All images were acquired on a 3T head-only MR scanner (Allegra, Siemens Medical Systems). Informed consent was obtained from the parents prior to imaging. A total of 77 children were recruited for this study and were divided into three sub-groups depending on age. All of the subjects were imaged during sleep (no sedation was employed). A T2*-weighted EPI sequence was used to acquired images. In addition, 3D MP-RAGE images were also acquired and used for co-registration among subjects. Those subjects who were offspring of patients with psychiatric disorders or have substantial motion during imaging were excluded from further analysis. For twins, only one of them was kept to ensure all subjects were independent with each other. In total, 12 neonates, 9 one-year and 7 two-year old subjects were included for the following data analysis. The pre-processing of the experimentally acquired images included a 3D Gaussian low pass filter to improve SNR, correcting time shift between different slice locations, and motion correction. After the preprocessing, spatial ICA was applied and the number of independent components (ICs) was obtained based on Bayesian information criterion (BIC). sICA sources that may represent the brain functional connectivity were automatically detected in the next two steps. First, boundary detector was used to exclude the motion-related sources that could be either low or high frequencies. Second, since the low-frequency synchronization (cutoff frequency ~0.08Hz) has been implicated to be responsible for brain connectivity, a spectrum analysis was performed and only sources showed low-frequency activations (<0.08Hz) were kept. The sICA maps of the chosen sources were converted to Z maps with a normal distribution using Z-test so as to allow group analysis. For comparison, CCA was also conducted using the same datasets. A board certified neuroradiologist manually drew 3 ROIs including the primary motor, somatosensory and visual cortice, respectively, for each subject.



(a) Neonates (b) 1 year old (c) 2 years old

Figure 1. Group average for brain functional connectivity using CCA in normal and healthy peadiatric



(a) Neonates (b) 1 year old (c) 2 years old

Figure 2. Group average for brain functional connectivity using sICA in normal and healthy peadiatric

RESULTS

The numbers of independent components estimated using BIC varied for different neonate datasets, but were quite consistent for one and two years old group. Explicitly, the number of independent sources ranges between 9 and 14 for neonates and the number was 14 in eight subjects and 13 in the remaining subject for one-year olds. All of the 2yrs old had 14 independent sources. The average Z maps for the neonate, one-year and two-year old groups are shown in Fig. 1 using CCA and Fig. 2 using sICA, respectively. Comparing Figs 1 and 2, it is evident that the functional connectivity maps are similar between CCA and sICA approaches, suggesting that the proposed automated approach is effective. Activations are observed in the primary sensorimotor and visual cortices through all three age groups. It is apparent that both the size and the strength of the activation areas increase as a function of age.

CONCLUSION

The proposed automated selection approach for independent components reflecting functional connectivity is feasible and results are similar between CCA and sICA. Nevertheless, it appears that sICA provides additional regions exhibiting functional connectivity which are not seen using CCA. Specifically, the results between CCA and sICA are extremely similar in the neonate group but discrepancies are observed for both 1 and 2 yrs old groups. One could speculate that sICA reveals additional regions exhibiting functional connectivity beyond the sensorimotor and visual cortices identified based on CCA. Further analysis will be required to determine the physiological underpinnings of these discrepancies between sICA and CCA.

1. Biswal BB, et al. NMR Biomed 1997;10:165-70. 2. Lowe MJ, et al. Neuroimage 1998;7:119-132. 3. van de Ven VG, et al. Human brain mapping 2004;22:165-178.