SMRI COMPLEX FRAMEWORK FOR EVALUATING RELATIVE GRAY AND WHITE MATTER GROUP DIFFERENCES

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Introduction

Source based morphometry (SBM) [1] (the deep purple part in figure 1) is an ICA-based approach aiming to detect sources in structural magnetic resonance imaging (sMRI) images showing group differences. Here, the "source" comprises several regions which together exhibit intersubject covariance. In the SBM applications, following tissue segmentation, the gray and white matter sources have been detected separately. In order to efficiently summarize the relationship that exists between the gray and white matter showing group differences and take over the merits of SBM without increasing the dimensionality of the problem, we built a SBM based sMRI complex framework to jointly evaluate the gray and white matter. In this framework, sMRI complex image generator (the light purple part in figure 1) is plugged into SBM process and the sources showing gray and white matter relative changes are detected.

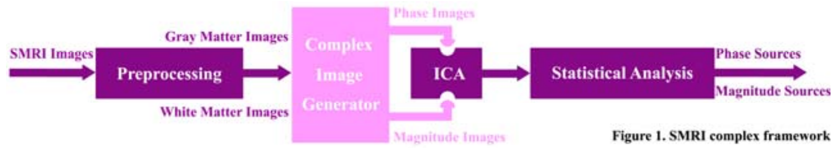


Figure 1. SMRI complex framework

Methods

Preprocessing:

One hundred and twenty structural MRI images from schizophrenia patients and 120 images of healthy controls were scanned at Johns Hopkins University. The images were preprocessed using the preprocessing steps used for VBM [2] employing the Matlab program SPM5. Images were first spatially normalized to the T_1 MNI template, then interpolated to voxel dimensions of 1.5x1.5x1.5 mm and segmented into gray, white and cerebrospinal fluid (CSF) compartments. The gray matter images and white matter images were then smoothed with 12-mm full width at half-maximum (FWHM) Gaussian kernel and masked by 0.1.

SMRI complex image generation:

Our sMRI complex image generation approach is presented in Figure 2. Let's assume the gray matter concentration within each voxel in the gray matter image is g_i and the white matter concentration within each voxel in the corresponding white matter image is w_i. Then a complex variable g_i+jw_i was generated by putting the gray matter concentration g_i into the real part and the white matter concentration w_i into the imaginary part. The phase part of the complex variable is $\varphi_i(g_i,w_i)=arctan(w_i/g_i)$ and the magnitude part of the complex variable is $M_i(g_i,w_i)=sqrt(g_i^2+w_i^2)$. By replacing the concentration value with the phase value throughout the whole brain sMRI image, we obtain an sMRI phase image which is proportional to the gray and white matter ratio changes. By replacing the concentration value with the magnitude value throughout the whole brain sMRI image, we obtain an sMRI magnitude image which is the power mean of the gray matter and white matter tissue concentrations, representing the average concentration within each voxel. The sMRI complex image is represented by overlapping the colored magnitude image on the textured phase image. An example of complex images is shown in Figure 3.

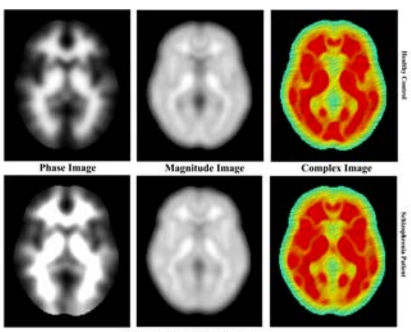


Figure 2. SMRI Complex Image

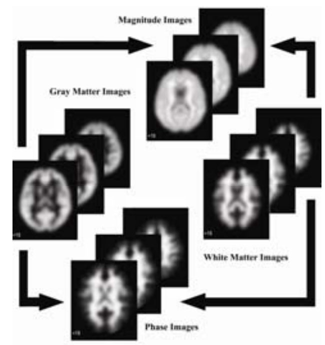


Figure 3. Phase and magnitude images generation

Independent Component Analysis:

ICA was performed on the phase images and magnitude images separately. Here we took phase images as our example. Every phase images was converted to a one-dimensional vector. The 120 phase image vectors of healthy controls and 120 phase image vectors of schizophrenia patients were then arrayed into one 240 row subject-by-phase matrix. Akaike's information criterion (AIC) modified to improve the estimation performance for medical images was used to estimate the number of sources *k*. Next, the subject-by-phase matrix was decomposed into a subject-by-source *phase mixing matrix* and source-by-phase *phase source matrix* using spatial ICA [3]. The phase mixing matrix expresses the relationship between 240 subjects and *k* phase sources. In contrast, the phase source matrix expresses the relationship between the *k* phase sources and the voxels within the brain. The same process was done to the 240 magnitude images to get the magnitude mixing matrix and magnitude source matrix.

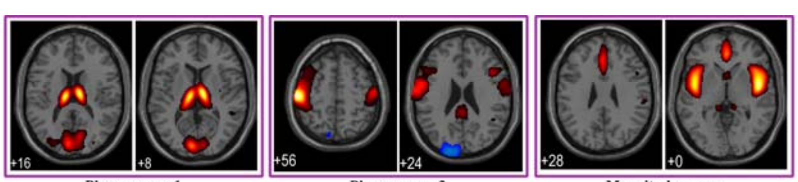
Statistical Analysis:

The two sample t-test was performed to the phase mixing matrix and magnitude mixing matrix separately to test which source shows a significant group difference. The effects of age and sex on the sources can also be determined by regressing the columns of the mixing matrix separately on age and sex.

Results and Discussion

The number of phase sources was estimated to be 37 and the number of magnitude sources was estimated to be 25. The mixing matrix and source matrix were determined using Infomax ICA. Six phase sources and one magnitude source whose loading scores differed significantly between groups were identified. Here we list the two most interesting phase sources and the magnitude source.

Phase Source 1: The source areas included thalamus and cuneus. The partition of white matter increased while the partition of gray matter decreased in the schizophrenia. Although most of the studies have been focused on the gray matter in thalamus [4], our study suggested the thalamic white matter might also play an important role in receiving and projecting information between the thalamus and particular cortical fields.



Phase source 1 **Phase source 2** **Magnitude source**

Figure 4. Results

Phase Source 2: This source consisted of precentral gyrus, postcentral gyrus, frontal gyri and cuneus. The healthy controls had more gray matter partition and less white matter partition than patients. The regions identified were primarily within visual and motor cortex. Interestingly, the source pattern looked similar to a functional MRI image which suggested that structural brain information underlying functional areas might be identified with our framework.

Magnitude Source: The average concentration of gray and white matter was less in the schizophrenia patients. The source areas included the superior temporal gyrus and media frontal gyrus. The region is consistent with previous reports of selective reductions in the bilateral superior temporal gyrus [5]. This most significant symbol in schizophrenia might be caused by average concentration change of the gray matter and white matter, not ratio change.

References

[1] L. Xu, et al., Hum Brain Mapp. Epub ahead of print. 2008; [2] J. Ashburner and K.J. Friston, Neuroimage. 11(6 Pt 1): p. 805-21. 2000; [3] V.D. Calhoun, et al., Hum Brain Mapp. 14(3): p. 140-51. 2001; [4] W. Byne, et al., Acta Neuropathol. 2008; [5] G.D. Pearlson, Progress in Neuro-Psychopharmacology & Biological Psychiatry. 21(8): p. 1203-29. 1997