A Comparison of Joint ICA and Parallel ICA Multimodal Fusion Methods in Schizophrenia

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ABSTRACT
Schizophrenia is still considered unknown disease that needs more study and analysis. In this case Multimodal fusion is a good way to make analysis on the joint information found on the different imaging modalities related to this disease. This paper discusses Schizophrenia analysis using two approaches of the common Brian Imaging multimodal fusion approaches (Joint ICA and Parallel ICA). The aim of this study is to investigate these two approaches for more understanding showing their strengths, limitations, and analysis strategies.

General Terms
Medical image fusion

Keywords
Image fusion, Joint ICA, Parallel ICA, Schizophrenia, fMRI image

1. INTRODUCTION
Schizophrenia is a chronic disease that impairs a lot of cognitive domains such as memory, attention, and executive functions [1]. A hypothesis stating that, a misconnection of neural circuitry in some networks of the brain regions (or dysfunctional integration between them) would be one of the causes of the schizophrenia [1]. Due to brain data can be collected from a various imaging techniques, which are varying from each other. For example; Functional Magnetic Resonance Imaging (fMRI) shows the hemodynamic response related to the neural activity in the brain. Structural Magnetic Resonance Imaging (sMRI) gives information about the brain tissue type in a definite position [2]. Diffusion tensor imaging (DTI) provides information about the brain networks connections [3]. Electroencephalography (EEG) measures the brain electrical activity with a high temporal resolution (higher than fMRI) and low spatial resolution [4]. These imaging techniques provide a unique and very important characteristic of the brain, and all of them together can provide a good amount of information about the brain. So a lot of studies had been published trying to reveal the neural mechanisms of schizophrenia using these different brain imaging modalities (fMRI [5, 6], sMRI [7, 8], DTI [9, 10], and genetics [11, 12]).

Unfortunately, Schizophrenia is one of the most mental disorders that cause human suffering. In Schizophrenic it was noticed that hallucinations in the auditory and visual modalities are the most frequent experiences [13, 14]. With imaging the brain activity of those patients it was noticed that the brain activity in speech production is increased [15]. In spite of knowing that there is a relation between (functional, structural, and genetic abnormalities in the brain) and this disease, but till now there is not enough information that can help in making a clinical decision. All the diagnosis applied on the brain in this case is just done for symptom assessment [1]. One of the solutions to overcome this problem and having more information about the disease is to analyze the different imaging modalities together, by combining them using the multimodal fusion techniques.

The following sections of the paper show two methods of the multimodal fusion methods (Joint Independent Component Analysis, and Parallel Independent Component Analysis). The two methods enable us to analyze the schizophrenia (brain functional, structural, genetic aspects) for more understanding about it. The paper also will discuss their strengths, limitations and their analysis strategies.

2. JOINT INDEPENDENT COMPONENT ANALYSIS (Joint ICA)
The need of the joint analysis methods became important to enable examining and analyzing the shared information between the features found in the different imaging modalities to be fused. One of these methods is the Joint ICA.

Joint ICA is applied on two different imaging modalities and extracts the spatially independent maps for each modality of them. Usually these maps are coupled together by a shared loading parameter. Joint ICA have been used in fusing couples of the modalities (fMRI-sMRI (GM) [16-18], fMRI-EEG [19-22], fMRI-DTI (FA) [23, 24], GM-WM [25]). In this paper Joint ICA was applied on two modalities fMRI and EEG of both healthy and Schizophrenia patients to jointly compare the features of each of them together to find some features that can describe the nature of the Schizophrenia.

Joint ICA assumes that the two or more modalities have the same mixing matrix [26].

The basic steps of the Joint ICA (as it was implemented in the Fusion ICA Toolbox (FIT)) can be showed in Fig.1, and summarized as following [27]:

- The features of each imaging modality are computed and collected.
- For each task a normalization process is done on the collected features.
- Principal Component Analysis (PCA) is used in reducing the dimensions of the normalized features.
- The spatially independent Components are extracted from the reduced data obtained by PCA, and as noted each component will share a common loading or mixing parameter between the tasks.

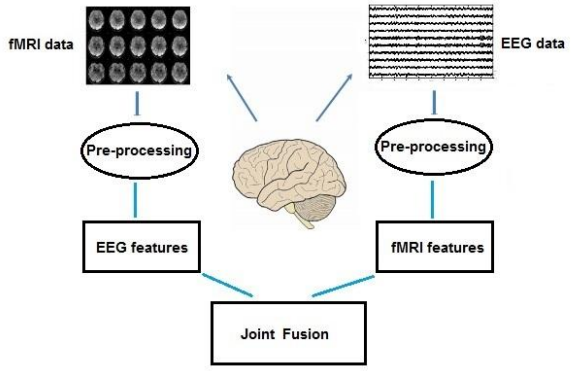

Fig 1: fMRI-EEG fusion steps using Joint ICA.

Joint ICA fusion method has the following advantages; first, it can be used in identifying some diseases such as Schizophrenia (SZ), and that is due to the activation patterns that can be obtained from different brains images that are SZ patients will be similar in multiple tasks. Second, Joint ICA shows a good spatial and temporal resolution in case of fusing fMRI, and EEG modalities together, and that is because fMRI has a good spatial resolution and EEG has a good temporal resolution.

As shown in Fig.2. The figure is divided to three parts. Part A shows the loading parameters of each control, patient and the component. Part B shows fMRI image for the temporal and frontal lobe regions of the brain. Part C shows another example of applying the Joint ICA on GM/WM to have more joint features about the brain [28].

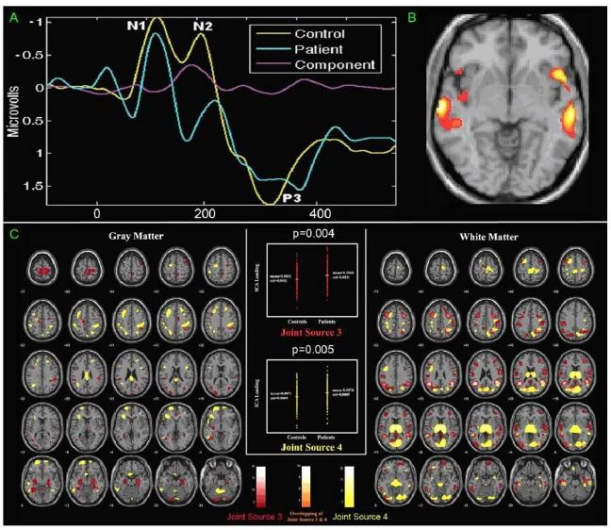

Fig 2: Fusion of the fMRI and EEG modalities using Joint ICA.

3. PARALLEL INDEPENDENT COMPONENT ANALYSIS (Parallel ICA)

Parallel ICA is an extension of the ICA that is used in analyzing multiple modalities. As it was mentioned previously Joint ICA takes into consideration the whole inter effects between the two modalities to be fused. Parallel ICA finds the hidden factors from both modalities and the connections between them by finding the independent components of both the modalities and their connections [29]. Parallel ICA had been used in fusing multiple modalities such as fMRI-EEG [30, 31], fMRI-Gene (SNP) [32, 33], GM-Gene (SNP) [34, 35].

Both Joint ICA and Parallel ICA are depending on the shared mixing matrix, but Parallel ICA assumes that the two data sets are mixed in a similar pattern but not identical one such as Joint ICA. Parallel ICA is more interested and focusing on the individual linked components and their connections [36].

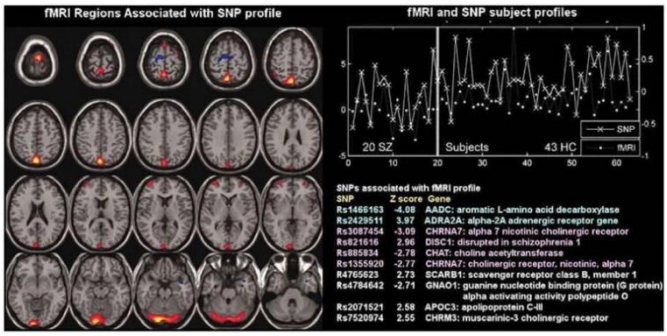

Fig 3: Fusion of the fMRI and SNP modalities using Parallel ICA.

Fig.3 shows using the parallel ICA fusion method in the analysis of fMRI data and 367 SNPs from 20 SZ patients and 43 healthy controls [29]. As shown Parallel ICA divides the output to three regions, the left one represent the fMRI part, the lower right part represent the SNP detailed part, and the upper right part which represent subject profiles obtained from fusing fMRI and SNP parts together.

4. SUMMARY

Finally it can be concluded that, Joint analysis is very important issue in case of the need of analyzing the shared information between the features found in different modalities.

Joint ICA and Parallel ICA are two of the most common Joint analysis techniques, which can be used in fusing two imaging modalities to analyze the shared information and features between them. According to previous studies Joint ICA is very efficient in case of analyzing fMRI and EEG modalities together; in this case it assumes sharing the same mixing matrix between the features of the two modalities.

Parallel ICA also can be used between any two modalities, but it was widely used in analyzing fMRI and Genetic data by fusing them together.

Analyzing of medical images using one of the last methods can help in understanding and knowing more about Schizophrenia features, which may help in early prediction of it by comparing any new features of any suspected case with the previous known features of Schizophrenia which can help clinical decision makers in taking the appropriate action towards this disease.

5. ACKNOWLEDGMENTS

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