Analysis of Brain Activity for Given Auditory Stimulus Using Functional MRI

H. N. Suma and H. N. Champa

***Abstract*—Functional Magnetic Resonance Imaging (fMRI) is one of the most recent (and most advanced) techniques to record brain activity. fMRI Technique can be used to produce activation maps showing which parts of the brain are involved in a particular physical / mental process. It measures brain function indirectly, i.e., not through the direct computation or calculation of neuronal activity, but through a mapping of blood perfusion levels in the brain. This method uses perfusion as a substitute or proxy for brain activity. This is because of the demonstrated fact that neuronal activation in any region of the brain increases the flow of blood to that region. A trial to understand and study the brain activity patterns for a given auditory stimulus. The auditory cortex of the brain is expected to show activity on either hemisphere in a healthy subject. A study done over different age groups or patients with abnormalities is useful to identify reasons of reduced or abnormal (diseased) activities of human body.**

***Index Terms*—Auditory cortex, auditory stimulus, blood oxygenation, brain activity, functional magnetic resonance imaging.**

I. Introduction

Image intensity observed in MR images is determined by various tissue contrast mechanisms: proton density, T1 and T2 relaxation rates, diffusive processes of proton spin dephasing, loss of proton phase coherence due to tissue magnetic susceptibility variations and in-flow of blood plasma protons. Two dominant tissue contrast mechanisms have functional sensitivity in MR imaging and are produced via hemodynamic responses [1][2]. Precise changes in brain activation or metabolism are not directly observed, but the effects of local increases in blood flow and micro vascular oxygenation on one or more of the above mentioned MR mechanisms can be mapped as a change in raw image intensity.

One mechanism depends upon the fact that the micro vascular MR signal on T2 and T2* weighted images is strongly influenced by the oxygenation state of the blood. The rate of loss of proton spin phase coherence is a measure of T2 and local magnetic field homogeneity (T2*); this can be modulated by the presence of intravoxel deoxyhaemoglobin. Recent data shows that the observed T2* is dependent on the presence of blood deoxygenation and that deoxygenated hemoglobin is a "blood oxygenation level dependent" or "BOLD" effect that can be observed by noninvasive MR imaging at high magnetic fields.

The BOLD imaging technique does not measure tissue perfusion or flow directly, however, because over 70% of the brain's blood lies within the micro vascular capillaries and venules, the measurement of the magnetic susceptibility-induced T2* signal loss is thought to most reflect the regional deoxyenation state of the venous system. In addition, proton perfusion and diffusion through changing local gradients modulated by changing oxy-/deoxyhaemoglobin levels has a direct impact on the observed T2 relaxation times, which is another mechanism of tissue contrast generation. Amongst these various mechanisms, the T2* effect is larger by factors of 3 to 10 and is the dominant and most widely-studied mechanism employed in fMRI [3], [4].

Various parametric methods have been developed to analyze such data sets. An early method, called subtraction technique, simply performs a t-test, subtracting the mean of all images from each one. In other words, the signal time course for each individual voxel is examined with the goal of identifying voxels in which the signal shows a significant change between the stimulus and control periods. This method is very sensitive towards voluntary and involuntary motion of the subject in the MR scanner, which leads to gross artifacts. Another method is correlation analysis. This method already takes into account that an estimate of the hemodynamic response can be modeled and included in the analysis, since the BOLD effect lags behind the stimulus. The correlation of this model function with the measured voxel time course is calculated for each voxel.

Voxels whose correlation coefficient exceeds a certain threshold are designated as activated. The general linear model used in SPM99 is a generalization of these two early methods and supervene in including the hemodynamic response function model, removing confounding effects, handling serial autocorrelation of the fMRI time series and so on [5][6]. The end result of the statistical analysis is a decision for each voxel of whether or not there is a significantly detectable activation, based on whether a calculated statistic (e.g., t statistic, correlation coefficient), passes a chosen threshold, yielding a statistical parametric map.

SPM was written to organize and interpret functional neuro imaging data. Some of the main features (Fig. 1) of the software are: realignment of image sequences, automated non-linear spatial normalization, image segmentation, coregistration, spatial smoothing, formation of statistic images assessment of statistic images, interrogation of results, global adjustment and image averaging and image calculator. SPM is not a biomedical imaging package [7][8][9]. Access

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to a dedicated biomedical imaging package such as Analyze system greatly enhances SPM. SPM uses the Analyze file format.

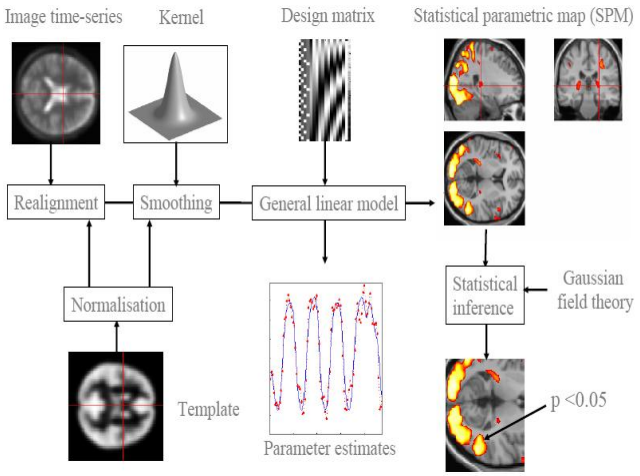

Fig. 1. Main features of SPM processing.

This experiment was conducted by Geraint Rees under the direction of Karl Friston and the FIL methods group. 96 acquisitions were made (RT=7s), in blocks of 6, giving 16 42s blocks. The condition for successive blocks alternated between rest and auditory stimulation, starting with rest. Auditory stimulation was with bi-syllabic words presented binaurally at a rate of 60 per minute. The functional data starts at acquisition 4, image fM00223_004. Due to T1 effects it is advisable to discard the first few scans (there were no "dummy" lead-in scans). These whole brain BOLD/EPI images were acquired on a modified 2T Siemens MAGNETOM Vision system. Each acquisition consisted of 64 contiguous slices (64x64x64 3mm x 3mm x 3mm voxels). Acquisition took 6.05s, with the scan to scan repeat time (RT) set arbitrarily to 7s.

II. Methodology

The experiment was conducted to study the brain activity patterns for a given auditory stimulus. It was done on a single subject in one session. The auditory cortex of the brain is expected to show activity on either hemisphere in a healthy subject. Scans obtained during the response time showed motor activity alongside the auditory activity, which was a result of the action performed by the subject (pressing a button on hearing the auditory stimulus). Theoretically we propose to observe the sensory cortex of the brain getting activated after the above task owing to the sense of touch felt on pressing the button.

This is evidently supported by the scans which when analyzed showed activity in the sensory cortex. The secondary activities of motor and sensory are less prominent and time subsequent (occur after the auditory cortex activation). A study done as mentioned above, over different age groups or patients with abnormalities is useful to identify reasons of reduced or abnormal (diseased) activities of human body. Figs and tables.

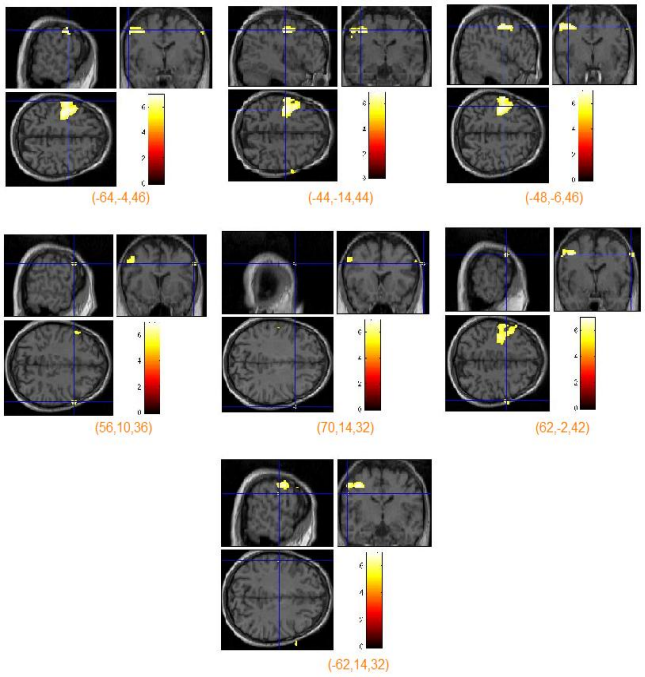

Fig. 2. Overlays of impaired subject's scans

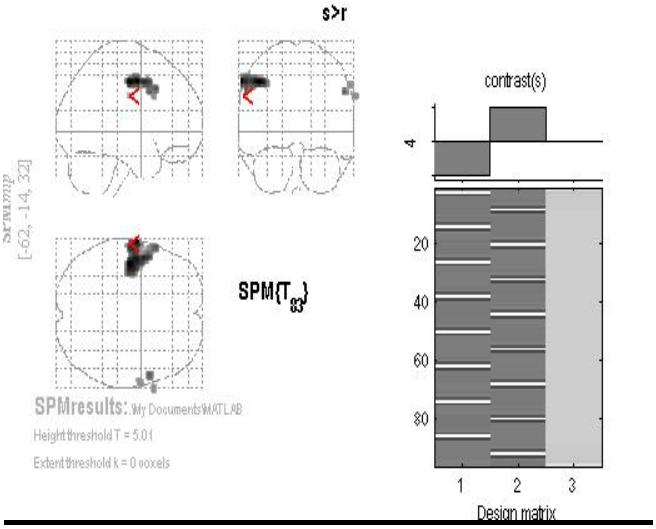

Fig. 3. 2D rendering of impaired subject's scans

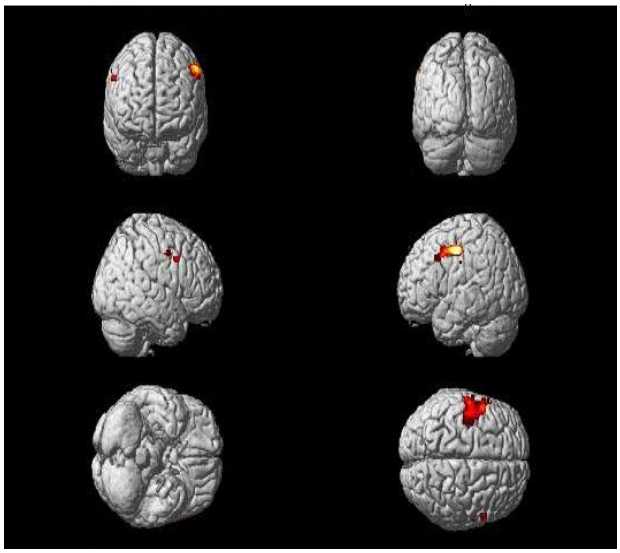

Fig. 4. 3D rendering of impaired subject's scans

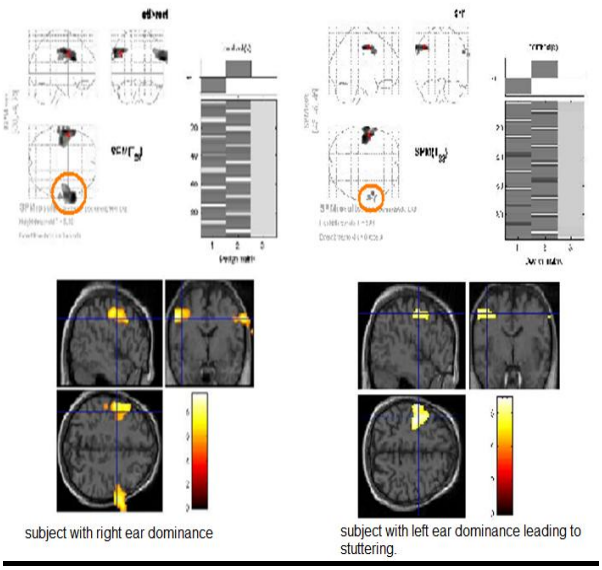

Fig. 5. Fmri maps representing auditory activity

III. Conclusion

It is proven that there exist a cross map for sound encoding and processing in the temporal lobe of the brain. Left temporal lobe is involved in majority of the processing. Comparison of the above two images prompt us to conclude the reason for stuttering. Image on the right side represents a subject with impairment in the form of stuttering because left ear response on right temporal lobe is less indicating left ear dominance. Stuttering is a result of the delay involved in relayed signaling from right temporal lobe to the left temporal lobe (encoding cortex) which results in delayed speech articulation. Because of the relayed signaling some activity is lost on the right temporal lobe.

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