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Brain Network Analysis using fMRI Features

*Aparupa Ghosh, #Indrajit De

*,#Department of Information Technology, MCKV Institute of Engineering, Kolkata, India.

*indrajitde2003@yahoo.co.in

Abstract functional Magnetic Resonance Imaging (fMRI) is a technique that provides the opportunity to study brain function non-invasively and is a powerful tool utilized in both research and clinical arenas since the early 90s[1]. This paper is based on the identification of brain activation regions of a group of healthy subjects which performed the Visual Search Task (Camouflage Detection) in a task-based fMRI. The primary identification of such Brain Activation Regions by using Independent Component Analysis (ICA) helps in further development of Algorithms based of Mathematical modeling of Camouflage detection by human being.

Keywords —: fMRI, GIFT, Camouflage detection, GIC, Brain Network.

I. INTRODUCTION

The main aim of this work is to find out the brain activation regions and thereby the brain networks that are involved in performing the given Cognitive task (CAMOUFLAGE DETECTION). Camouflage Detection is basically a 'visual search task'. A paradigm was designed to obtain neural correlates of camouflage detection, with real life photograph using functional Magnetic Resonance Imaging (fMRI)[2]. The experimentation results are based on the data acquired during the task based fMRI performed in the labs of NMR Research Centre, INMAS, DRDO (Delhi).

It primarily deals with the **G**roup **I**ndependent **C**omponent **A**nalysis (GICA) of a task based functional Magnetic Resonance Imaging (fMRI) study. The data for this research work are acquired from the fMRI images of the subjects where the subjects had to perform camouflage detection task. The database was created having the NIFTY (Neuroimaging Informatics Technology Initiative) images of a group of subjects and then GICA was performed until satisfactory Independent Components (ICs) were obtained. The ICs were then analyzed to obtain the ICs of interest, which were used to recognize and identify the brain network it corresponds to.

II. REVIEW OF EXISTING WORK

A. Block Paradigm Design

Block Paradigm was the first and the most widely used fMRI paradigm. The block paradigm consists of several discrete epochs of task and baseline periods. The design is based on maintaining cognitive engagement in a task by presenting stimuli sequentially within a condition [3].

The alteration of two conditions is known as an 'AB block' design, in which a 'cycle' corresponds to two epochs of each condition. The duration of blocks may range from 16secs-1minute or more.

The figure1 below shows a typical block paradigm with two experimental conditions: picture (red blocks) and words (green blocks), along with their resulting hemodynamic response. Same paradigm has been used in the given task as well.

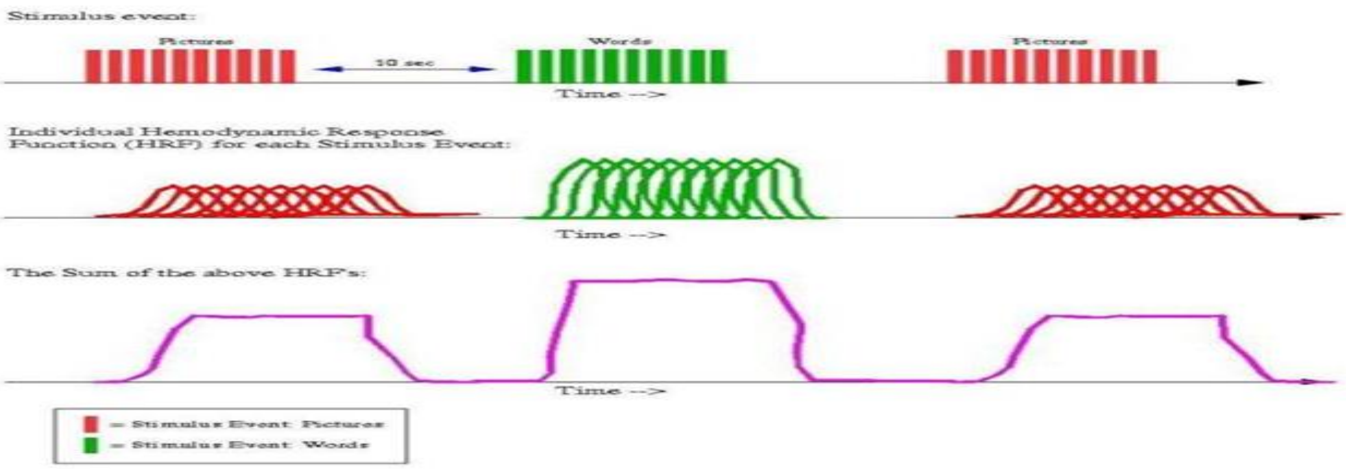

Figure 1:- Block Paradigm Design

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B. About Camouflage Detection Task

Detecting camouflage has been considered a 'visual search task' in which the perceiver has to identify target objects among the 'distracters' [4]. A recent study suggests that this type of search involves perceptual strategy, apart from edge detection, motion perception and shape recovery and texture segregation. It is not clearly known as to why some people identify camouflaged objects with ease compared with others.

Cognitive styles such as Field Dependency and Field Independency have been extensively studied wherein embedded objects need to be isolated. The construct of Field Dependence/Independence (FD/FI), as one of the cognitive style dimensions [5], was defined by HA Witkin in the mid-1940s, based on the effects of external influences on individual perception and judgment. Although there exists extensive literature on the perceptual differences in FD/FI (Canelos et al. 1980[6]; Frank and Davis 1982[7]; Lu and Suen 1995[8]), little attempt has been made to substantiate this viewpoint using a biological model. It is pertinent to examine the activation patterns in the brain of FDs as compared to FIs during a search task involving camouflaged objects. A fMRI experiment was carried out to obtain neural correlates of camouflage detection, with real-life photographs, using functional magnetic resonance imaging.

III. Experimental Procedures

A. The experiment carried out for obtaining the fMRI Data

Twenty-NINE right-handed healthy individuals (12 males and 17 female, age range 18–31years) were chosen for the study. Group Embedded Figure test was employed to stratify the subjects into FD and FI individuals [9]. The fMRI was carried out using 3-tesla whole-body MRI systems (Magnetom Skyra, Siemens, Germany). Functional images were acquired using echo-planar T2*-weighted sequence. Each brain volume consisted of 36 interleaved 3 mm thick slices and parallel to AC-PC axis (TE=36 ms; TR=3000 ms; FOV=220 mm; flip angle=90°; voxel size= 3.3 × 3.3 × 3 mm). Paradigm (BABABABABAB) with alternating phases of activation (A) and baseline (B) was chosen.177 sequential image volumes (belonging to seven cycles + one baseline for eliminating T1 saturation effects and acclimatization of the patient to the gradient noise) were taken. Each block in the active phase consisted of 6 photographs with camouflage displayed for 7 seconds each with a blank screen for 500 msec between any two photographs. The subject's task was to identify the location of the camouflaged object (left/ right visual field) in the photograph using the left/ right buttons of the response grip. Baseline consisted of 6 non-camouflaged photographs (i.e. an obvious object in the image) in every block presented for 4 sec with a blank screen for 500 msec between any two photographs. The subject's task was to locate the obvious object (left/ right visual field) in the image using the left/ right buttons of the response grip. Stimuli were presented using fMRI hardware from NordicNeuroLab[10].

B. Dataset description

- The final dataset consisted of fMRI results of 29 subjects where each of the subjects performed the same camouflage detection task.
- There were a set of total 168 swraf [**s**= smoothing, **w**= normalization, **r**=realignment, **a**=slice timing **f**=functional]images(processed and smoothened data) which is done using SPM (**S**tatistical **P**arametric **M**apping Software) for each of the 29 subjects.

C. Info Max Algorithm:

Info Max algorithm proposed by Amari et al [16] has been used to find out the Independent Components. The algorithm is described as:

1. Initialize $w(0)$, eg. Random.
2. $w(t+1) = w(t) + \eta(t)(I - f(Y)Y^T)w(t)$
3. If not converged, go back to step 2.

Where w is the un mixing Matrix, t represents a given approximation step, $\eta(t)$ a general function that specifies the size of the steps for the unmixing matrix updates (usually an exponential function or a constant), $f(Y)$ a nonlinear function usually chosen according to the type of distribution (super or sub Gaussian), I the identity matrix of dimensions $m \times m$ and T *is* the transpose operator.

D. Software Used For Obtaining The ICs

In this work Group ICA of fMRI Toolbox (GIFT) software module has been used for obtaining the ICs. GIFT [11] is an application developed in MATLAB that enables group inferences from fMRI data using Independent Component Analysis (ICA). GIFT is used to run both single subject session analysis as well as group analysis. Toolbox is thoroughly tested and works on MATLAB R2008a and higher.

E. ICA on fMRI data

ICA [12]has found a fruitful application in the analysis of fMRI data. A principal advantage of this approach is its ability to cognitive paradigms for which a detailed *apriori* models of brain activity is not available [13].ICA is a method of blind source signal separation i.e., ICA allows one to extract or "unmix" unknown source signals which are linearly mixed together. For fMRI data, temporal and spatial ICA are possible, but spatial ICA is by far the most common approach.

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F. Group ICA Procedure

ICA has been successfully applied to single subject and single session analyses. Group analysis of fMRI is important to study specific conditions within or between groups of subjects. It is not clear how ICA can be applied on a group of subjects as different individuals in the group will have different time courses. A model was proposed to extend ICA to group studies [14].The GIFT contains an implementation of ICA for analyzing the fMRI data. Specifically, the GIFT implements both analysis and display tools, each using standard input and output file types (Analyze or Nifty format). There are three main stages to Group ICA; Data Compression, ICA, and Back Reconstruction. The outputs from these stages are multiple time courses. Each time course has an image map associated with it.

G. The Steps for Obtaining the ICs using GIFT

The software used in this work assignment is GIFT version 4.0b. It basically runs

on MATLAB version 2008 and higher. There are basically three big steps involved for running this software to get ICs. They are:

1. Setup ICA Analysis
2. Run Analysis
3. Report Summary.

The first two steps fall under the Analysis Functions section while the last step falls under the Postprocessing section.

- The very step prior to everything is that we need to download the GIFT software.
- Secondly we need to open MATLAB (version 8or higher).
- Add the path where the GIFT software is loaded with all its subfolders.
- Finally call the GIFT software by simply typing “GIFT” on the MATLAB command window.

Once the software opens we can see the button ‘Setup ICA Analysis’ under Analysis function, click on it.

- Now a window is going to open named “GIFT Setup ICA GUI” and we need to give the inputs accordingly.
- The next window that is going to appear is “Select Options for Infomax Algorithm” [that is to select the parameters for a particular algorithm].
- Once this step is done the software will automatically load the datasets, and if it is error-free then the command that is going to appear in the MATLAB command window is “run the parameter file” with name ‘abc’ (that is the same name which we have given earlier as the prefix name).

Now select the button ‘Run Analysis’ and the system will go through the step and finally it will open a GUI output prompt window for us, this step is quite time taking and depends on the size of the database.

Once this step is done properly, we will go to step ‘Report Summary’ in the Postprocessing part.

PARAMETER SETTINGS	PARAMETER VALUES
1. Number of Subjects	29
2. Number of Sessions	1
3. Number of Independent Components	33
4. ICA Algorithm	Infomax
5. Number Of Scans/Timepoints	168
6. Mask File	Default Mask Created From Functional Data
7. Data Pre-processing Type	Remove Mean Per Timepoint
8. PCA Type	Standard
9. Group PCA Type	Subject Specific
10. Group ICA Type	Spatial
11. Back Reconstruction Type	GICA
12. Scaling Components	Z-Scores
13. Stability analysis type	None
14. Group analysis mode	Serial
15. Anatomical file	(C:\Program Files\MATLAB\GroupICATv4.0b\icatb\icatb_templates\ch2bet.nii) path from where the data in fed
16. Slice Plane	Axial
17. Image values	Positive
18. Convert to Z-scores	Yes
19.Threshold	1

Table 1 : Parameter settings of GICA

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H. Condition

Although many trail runs were done using GIFT with different datasets using all sorts of possible parameter settings combination yet the best result were obtained in this case using all the default parameter settings.

The only thing that matters is that is needed to provide properly processed dataset.

IV. RESULTS

A. GICA parameter settings for the final study

The parameter setting for the final study is to obtain the ICs using GIFT is provided in Table1.

B. Component Number to Network Type Mapping.

The ICs of interest:-mapping to the brain networks:-

After the processing of the fMRI data using GIFT, out of the 33 obtained independent components the following 7 networks were of interest as presented in Table 2.

COMPONENT NUMBER	NETWORK TYPE
6	Medial Visual Network
13	Auditory Network
17	Left Executive Control Network
24	Right Executive Control Network
28	Lateral Visual Network
31	Default Mode Network
32	Visual Occipital Network

Table 2. Component Number-Type of Network Relationship

C. Resultant Images

The resultant images showing the activation region and peak coordinates are shown below.

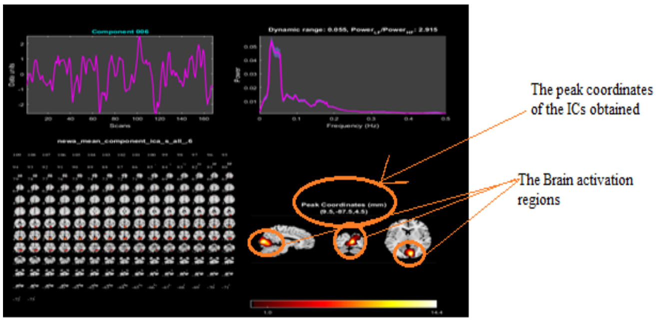

Figure 2:- Medial Visual Network as seen in the GIFT Software Output Interface.

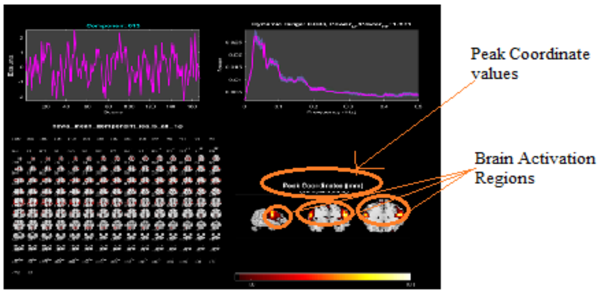

Figure 3:- Auditory Network as seen in the GIFT Software Output Interface

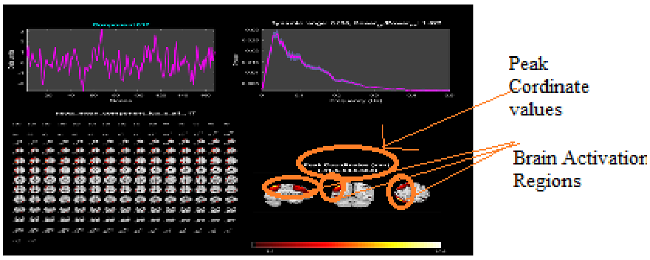

Figure 4:- Left Executive Control Network as seen in the GIFT Software Output Interface

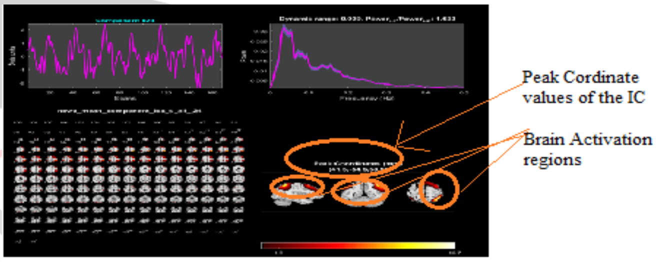

Figure 5:- Right Executive Control Network as seen in the GIFT Software Output Interface

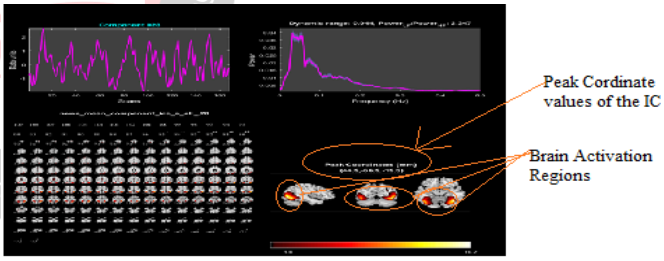

Figure 6:- Lateral Visual Network as seen in the GIFT Software Output Interface

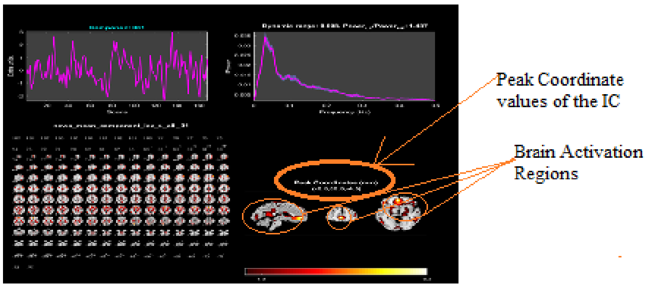

Figure 7:- Default Mode Network as seen in the GIFT Software Output Interface

D.Inference

The Brain Network Identification is done by mapping the peak coordinate values and activation regions (as shown in the figures) from the Brain Networks that are identified and established for resting state MRI [15]. It is considered that

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whether it is a resting state fMRI or a task-based fMRI the activations regions corresponding to a particular brain network will be similar. Thus, the basic Brain Network activated while performing the particular cognitive task (Camouflage Detection) was identified.

V. Conclusion

As camouflage detection is a visual search task requiring higher order visual and execution functions, all the visual and executive networks were activated while task performance. The data can further be used to analyze the difference in activated networks between field independent and field dependent subjects which will shed light on the underlying mechanisms for differential task performance (camouflage detection).

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