EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 2
Issue: 7
91-95
Year: 2015

BRAIN VISUAL CORTEX BEHAVIOR DURING RESTING STATE AND COGNITIVE TASK

Ibrahim E. Hassan*

Department of Physics, Faculty of Science, Helwan University, Cairo,Egypt.

***Author for Correspondence: Ibrahim E. Hassan**
Department of Physics, Faculty of Science, Helwan University, Cairo,Egypt.

Article Received on 15/10/2015 **Article Revised on 03/11/2015** **Article Accepted on 26/11/2015**

ABSTRACT
The aim of this study was to explore the visual cortex behavior during resting state and cognitive task. Fourteen subjects were imaged during rest and working memory task. For five visual cortex seeds, the correlation maps were generated for resting state and cognitive task data. The multi-subject analysis level was performed to determine the change in the spatial extent and magnitude of positive correlations within the visual cortex area. Our results show that, the strength and connection between visual cortex voxels during resting state greater than in cognitive task. The results reveal significant blood oxygen level dependent (BOLD) effects on the visual cortex during resting state greater than in cognitive task. The visual cortex exhibits correlated activity at rest and has shown decreased activation during performance of cognitive tasks.

KEYWORDS: visual cortex, resting state, cognitive task, fMRI, BOLD.

1. INTRODUCTION
Much of what is currently known about brain function comes from studies in which a task or stimulus is administered and the resulting changes in neuronal activity and behavior are measured. Modulation of the functional magnetic resonance imaging (fMRI) blood oxygen level dependent (BOLD) signal attributable to the experimental paradigm can be observed in distinct brain regions, such as the visual cortex, allowing one to relate brain topography to function.[1, 2]

Many fields of investigation, spanning medicine, science, and humanities, have an interest in the spatially localized measurements of human brain activity provided by functional magnetic resonance imaging (fMRI). In recent years, there has been an increase in interest in the application of the technique at rest, termed resting-state fMRI or functional connectivity MR imaging.[3] The first human fMRI experiments measured cortical responses to visual stimuli that covered a large part of the visual field. These stimuli elicited responses in a broad swath of occipital cortex.[4, 5]

This study uses resting state fMRI and working memory task to evaluate the visual area behavior. Resting-state functional connectivity MRI (fc-MRI) uses task-free BOLD time courses [6] to measure the temporal correlation between different regions of the brain. Application of this technique has allowed the identification of various resting state networks, or spatially distinct areas of the brain that demonstrate synchronous BOLD fluctuations at rest. Several resting state networks have been identified. The visual network is highly consistent across various studies and spans much of the occipital cortex. [2, 7, 8, 9, 10] Many studies proved that working memory plays an important role in learning, calculating, reasoning and verb comprehension of cognitive processing. Working memory processing of audiospatial information activated areas in the superior, middle and inferior frontal gyri, and in the posterior parietal and middle temporal cortices. [11, 12, 13]

The human brain can be conceptualized as a complex, hierarchical network, in which billions of neurons are precisely organized into circuits, columns, and functional areas. The whole human cortex occupies a surface area equal to ≈ 1000 cm^2 and ranges between 2 and 4 mm in thickness. Each cubic millimeter of cortex contains approximately 50000 neurons so that neocortex in the two hemispheres contains quite 30 billion neurons.[14]

Visual cortex represents approximately 20% of the surface area of the total neocortex. Human visual cortex includes the entire occipital lobe and extends significantly into the temporal and parietal lobes. Visual cortex contains ≈ 4-6 billion neurons. Over the first two decades of functional magnetic resonance imaging, steady progress in measuring

visual cortex led to the identification of more than twenty retinotopically mapped cortical areas.
The visual cortex can be involved in primary visual cortex (V1), and extrastriate visual cortical areas (V2, V3, V4, and V5). The primary visual area, which receives primary visual stimulation, also forms numerous connections with the secondary visual cortex.[15] The images from the two eyes are combined in the primary visual cortex. The left cortex codes images seen on ones right side (by both eyes). By comparing these two images, depth is computed. From the primary visual cortex information is sent to V2 and then to V3.

2. MATERIALS AND METHOD

2.1 Participants and Protocol

Fourteen healthy right handed subjects participated in this study after giving informed consent in accordance with S. Lucia Foundation Institutional Review Board. Ages ranged from 23 to 39 years (30 ± 5, mean ± SD). Participants with a history of psychiatric or neurological illness or under medication were excluded from the study. All participants have been trained 30 minutes outside the scanner before their first experimental session, to ensure that subjects had a clear understanding of the task.

Two sessions fMRI data were acquired continuously during a continuous acquisition"rest-task" paradigm: during the resting stage (duration: 5 mins) participants laid quietly in the scanner with eyes open; during the task stage (duration: 5 mins) participants were presented with a continuous 2-back auditory working memory test. During each n-back task, for each subject, working memory performance was assessed as the average percentage of correct responses.

All subjects in our study performed the task successfully (performance scores > 75%) and none fell asleep during the resting state period. Two subjects were excluded from the analysis for widespread movement reasons (z-axis translation > 2mm).

2.2 Scanning Parameters

All subjects were scanned using a 3T Siemens Allegra system (Erlangen, Germany) (http://www.medical.siemens.com/). Subjects' heads were well stabilized using pillows. Functional data were collected by using a 2D gradient echo planar sequence, sensitive to BOLD contrast (TR/TE=2100/30 ms, Flip Angle= 70◦, 3x3x2.5 mm^3 voxels). Whole brain coverage was obtained with 33 slices (1.25-mm skip) parallel to the anterior commissure posterior commissure plane.

Structural data were also acquired and included a high resolution (1.33x1.33x1 mm^3) sagittal, T1 weighted magnetisation prepared rapid gradient echo scan (TR/TE = 2000/4.38 ms, Flip Angle= 8◦). During the experiments, respiration and cardiac signals were recorded using a pneumatic belt and a pulse oxymeter, respectively.

2.3 Images Preprocessing

The preprocessing steps are illustrated as follows. After converting DICOM files to NIFTI images. Data were then preprocessed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/) and homemade developed software coded in MATLAB. The physiological noise fluctuations were corrected using RETROICOR[16], while low frequency respiratory and heart rate effects were removed by using RVHRCOR.[17] Images of the first four scans were discarded before further processing to make sure that the MR signal had reached steady state.

The preprocessing steps included: compensation of systematic slice dependent time shifts and rigid body correction for inter frame head motion within and across runs. Non linear transform connecting T1 weighted images with MNI atlas was estimated. Several processing steps were used to optimize the voxelwise analysis. Sources of spurious variance were removed from data by means of linear regression of six parameters (three translations and three rotations) obtained by rigid body correction of head motion. Data were normalised to the MNI space and spatially smoothed (8-mm full width at half maximum Gaussian blur).

2.4 Histological Visual Areas

Five different visual cortex masks were obtained by the Juelich histological atlas (FSL www.fmrib.ox.ac.uk/fsl).[18, 19] The atlas is based on the microscopic and quantitative histological examination of ten human post-mortem brains. These masks show that the primary visual cortex (V1) is anatomically equivalent to BA17 and that the extrastriate cortical areas (V2:V5) includ BA18 and BA19. Specifically, V1 is located in and around the calcarine sulcus, which can be found on the medial surface of both hemispheres.

The V2 area surrounds V1. One section of V2 is located on the cuneus and the other section falls on the lingual gyrus. The V2 area is surrounded by a third area, V3. The V4 area is located anterior to V2 and posterior to posterior inferotemporal area (PIT).Visual area V5, also defined as visual area MT (middle temporal), is often described as a 'motion center'. Its inputs include the visual cortical areas V1, V2, and dorsal V3.

2.5 Seed-Based Correlation Analysis

Seed-based correlation analysis was undertaken on resting state and cognitive task data.[20] Five seeds (V1, V2, V3, V4, and V5) were selected from Juelich histological atlas. The intersection between the seed voxels and gray matter mask was calculated to exclude unwanted signals.

For each seed, the correlation maps were generated for resting state and cognitive task data. Correlation maps were produced by extracting the average time series of each seed then computing the correlation coefficient between that time series and time series from every voxel in the visual area. The resulting correlation maps for each individual seed were then converted to z-scores using the Fisher transform.

The Z-maps were analyzed at single and multi-subject level. The multisubject analysis level was performed to determine the change in the spatial extent and magnitude of positive correlations within the visual cortex area. One sample t-tests provided qualitative comparisons between all data sets for each seed.

3. RESULTS AND DISCUSSION

The sub-regions of visual cortex are shown in figure 1. The colour code of the visual cortex regions is V1-red, V2- blue, V3- green, V4- violet, and V5-yellow. The present study was used each visual cortex region as region of interest (seed) to estimate the correlation maps.

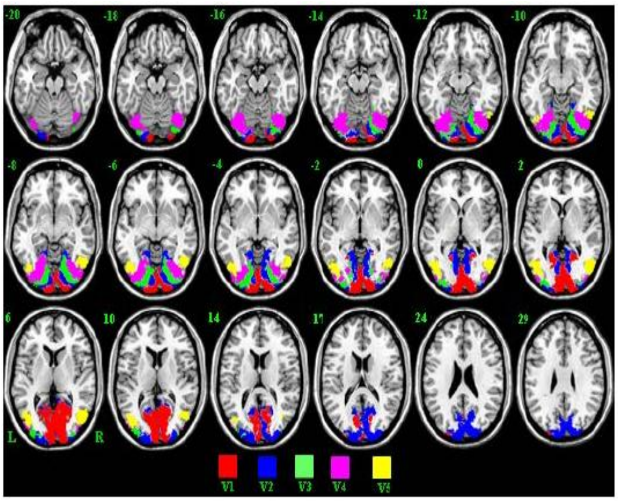


Fig. 1- The sub-regions of visual cortex for the human brain.

The group level analysis of visual cortex voxels having positive ($p<0.05$, FWE) correlations with V1 seed is shown in figure 2, which reports results for resting state (a), and cognitive task (b). It is worth to notice that, the resting state spatial extent of positively correlated voexls with V1 seed larger than cognitive task spatial extent of positively correlated voexls.

The magnitude of the BOLD change due to elevated neuronal activity is determined by the local susceptibility changes. These changes originate from the variations of deoxyhemoglobin content in blood and spread both in the intravascular and extravascular tissue compartments. Neuronal activity induces both metabolic and hemodynamic changes in focal areas.[21, 22]

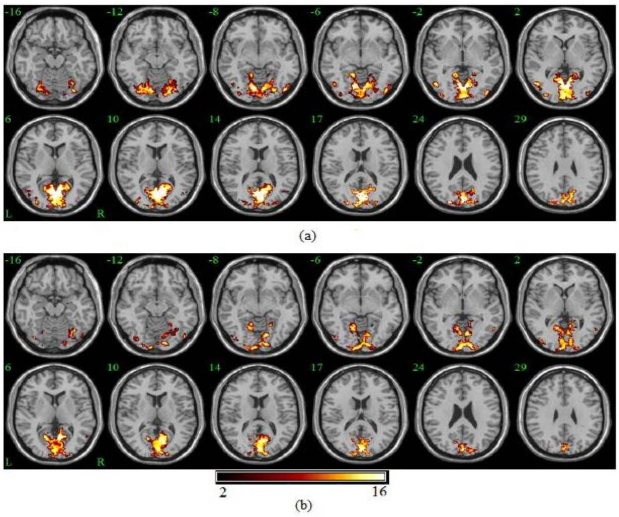


Fig. 2- Group analysis (N=12) of visual cortex regions having positive ($p<0.05$ FWE) correlations with the V1 during resting state (a) and cognitive task (b).

For the second seed V2, group level analysis across the subjects is shown in figure 3 for resting state (a) and cognitive task (b). The visual cortex activated voxels during resting state greater than the number of activated voxels during cognitive task. It is worth to notice that, there are high correlation between V2 seed and the all the voxels of primary visual cortex V1 region. These results prove the information change between primary visual cortex V1 and V2.

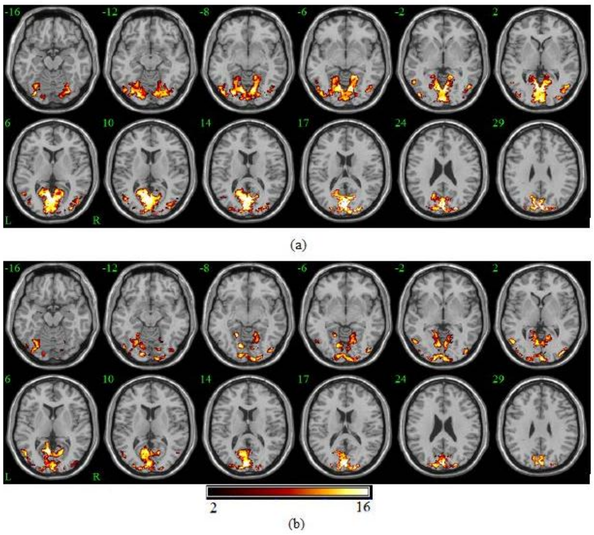


Fig. 3- Group analysis (N=12) of visual cortex regions having positive ($p<0.05$ FWE) correlations with the V2 during resting state (a) and cognitive task (b).

Figure 4 shows the group analysis for the visual cortex during resting state (a) and during cognitive task (b) with seed V3. The spatial extent of positively correlated visual cortex voexls with V3 seed for resting state larger than cognitive task results.

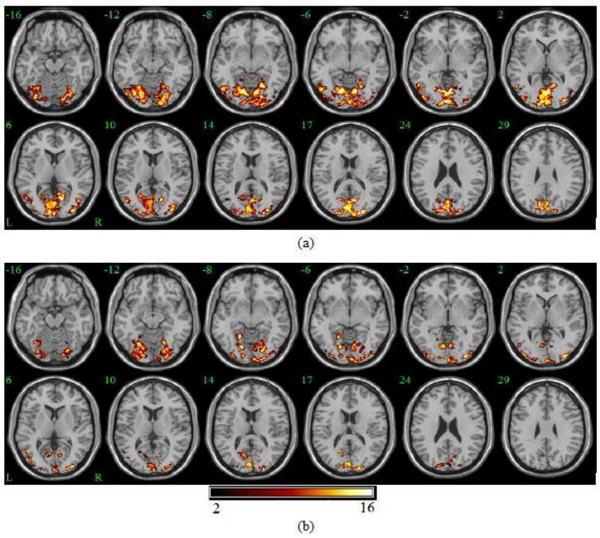


Fig. 4- Group analysis (N=12) of visual cortex regions having positive (p<0.05 FWE) correlations with the V3 during resting state (a) and cognitive task (b).

Figure 5 illustrates the group analysis of visual cortex regions having positive (p<0.05 FWE) correlations with the V4 during resting state (a) and cognitive task (b). There are significant different in the spatial extent between resting state and cognitive task results. For the least seed V5, the results of group level anylsis are show in figure 6 for resting state (a) and cognitive task (b). The spatial extent of positively correlated voexls with V5 seed is diminished for cognitive task results.

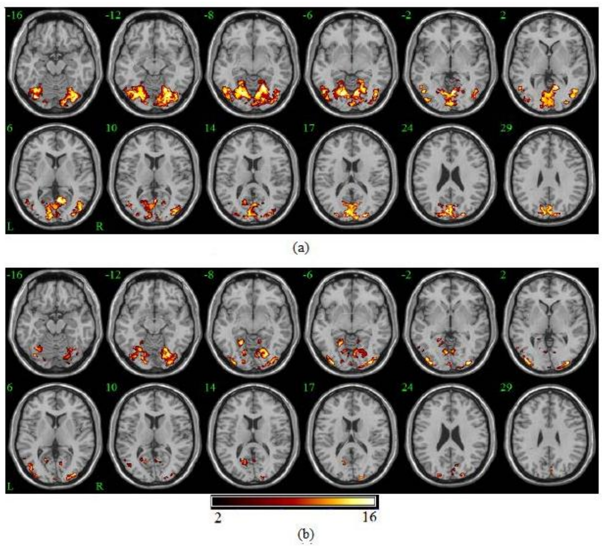


Fig. 5- Group analysis (N=12) of visual cortex regions having positive (p<0.05 FWE) correlations with the V4 during resting state (a) and cognitive task (b).

The percentage of activated visual cortex voxels for each seed were shown in figure 7, for the resting state and cognitive task. It is worth to notice that, the number activated visual cortex voxels for restating state dataset is always larger than the number activated visual cortex voxels for cognitive task for all seeds V1, V2, V3, V4, and V5. The different in the spatial extent between resting state and cognitive task is significant for V3, V4 and V5. In general, The difference between the spatial extent between resting state and cognitive task is approximately 25% of visual cortex voxels.

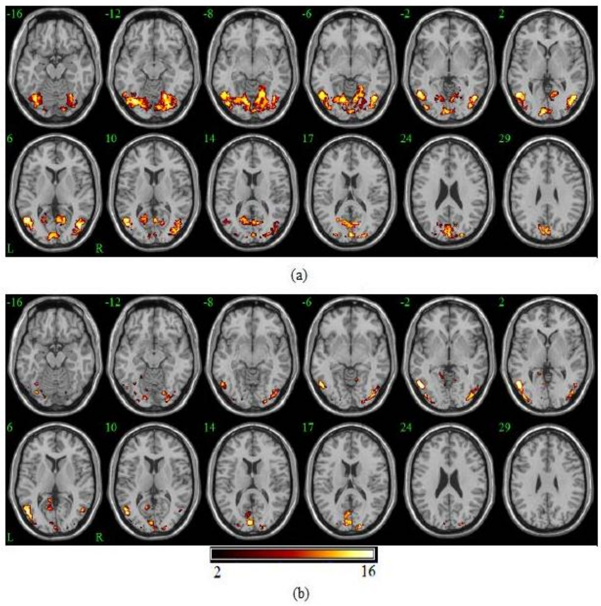
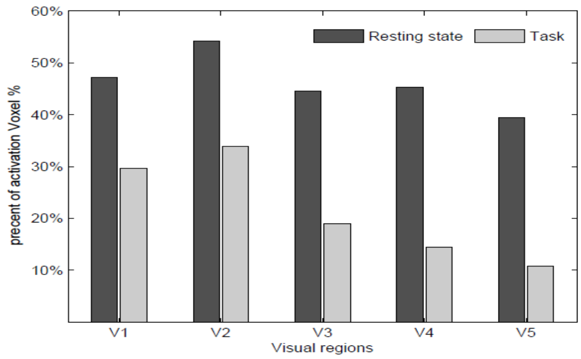


Fig. 6- Group analysis (N=12) of visual cortex regions having positive (p<0.05 FWE) correlations with the V5 during resting state (a) and cognitive task (b).

4. CONCLUSION

The main aim of the work described in this study was to provide more detailed and accurate information about the visual cortex behavior during resting state and cognitive task. Two sessions fMRI data were acquired continuously during a continuous acquisition ”rest-task” paradigm for fourteen healthy right handed subjects. The correlation maps for the visual area used the seeds V1, V2, V3, V4, and V5. The multi-subject analysis level was performed to determine the change in the spatial extent and magnitude of positive correlations within the visual cortex area.



(a)

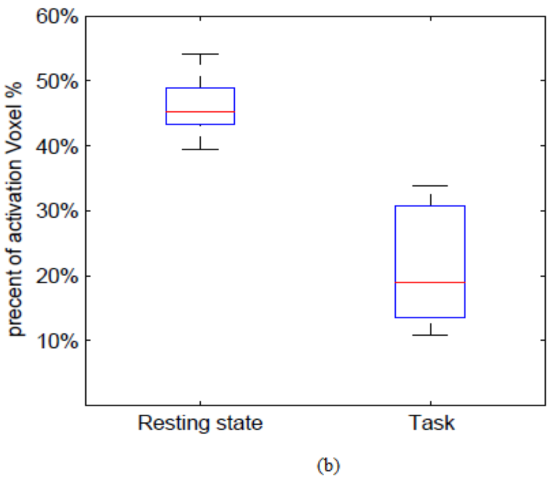


Fig. 7- The percentage number of activation voxels in visual cortex area for resting state and cognitive task data.

Our results show that, the strength and connection between visual cortex voxels during resting state greater than in cognitive task. Our results reveal significant BOLD effects on the visual cortex during resting state greater than in cognitive task. The visual cortex exhibits correlated activity at rest and has shown decreased activation during performance of cognitive tasks.

ACKNOWLEDGEMENTS
The author wishes to thank the La Sapienza Universty of Rome, especially the Department of Physics, for giving me the opportunity to acquisition dataset.

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