Journal of
Neurophysiology and Neurological Disorders

Research Open Access

How Human Brain Reacts to Active Thinking: A Conjunction Analysis Using fMRI

C. Girija Navaneedhan*

Department of Management studies Indian Institute of Technology Madras

***Corresponding author:** C. Girija Navaneedhan, Department of Management studies Indian Institute of Technology Madras; Tel: +919840945592; E-mail: girija.navaneedhan@gmail.com

Received Date: August 04, 2019 **Accepted Date:** September 02, 2019 **Published Date:** September 04, 2019

Citation: C. Girija Navaneedhan (2019) How Human Brain Reacts to Active Thinking: A Conjunction Analysis Using fMRI. J Neurophysiol Neurol Disord 5: 1-17.

Abstract

The human brain is the most complex biological organ in the creation of more than 100 billion neurons responsible for mind-blowing activities we witness on a day to day basis in our lifetimes. These activities are the result of both active and passive thinking. The distinction between active and passive thinking is extremely narrow comparable to a single strand of human hair. The aim of the present research work is to find the difference in brain activation on exposure to active thinking state, passive thinking state compared to baseline task using fMRI. The experiment targets to analyze brain activity when the teacher subjects are exposed to visuals to differentiate visual cognitive tasks associated with metaphorical thinking (active thinking) as well as non-metaphorical thinking (passive thinking). The aim is to establish the implementation of metaphorical thinking in enhancing the information processing ability among learners.

Keywords: Active thinking; Passive thinking; Metaphorical thinking; non-metaphorical thinking; and information processing ability.

Introduction

Functional Magnetic imaging fMRI is a technique measuring brain activity by detecting the associated changes in blood flow. This technique, which is similar to MRI, uses the change in magnetization between oxygen-rich and oxygen-poor blood happening in the brain areas as the basic feature of measurement Cheryl et al [1]. The idea for foundations of magnetic resonance imaging was almost started in 1946 by Felix Bloch (1905-1983) who was at Stanford University studying liquids, and Edward Purcell (1912-1997) working on solids at Harvard University. Although they could have won Nobel Prizes for these discoveries, it was not until 1973, that successful nuclear magnetic resonance (NMR) was used to produce images. Finally, in the 1990s they discovered showing changes in blood oxygenation level could be considered with the use of MRI as a window opening a new generation of functional brain imaging techniques.

Blood Oxygenation Level-Dependent fMRI (BOLD fMRI) is a technique detecting the brain and neural activity indirectly, based on magnetic properties of hemoglobin Scott et al [2], It means that when Hbo and dHbo are placed in a magnetic field, dHbo will act as a contrast agent. Seong-Gi Kim and Kamil Ugurbil [3] discussed the mechanisms underlying the effects of deoxyhemoglobin concentration and the cerebral blood flow. Stephen C Strother, Saman Sarraf, and Cheryl Grady [4] investigated using fMRI whether there is a specific reduction in the selectivity of brain activity during associative encoding in older adults, but not during item encoding, and whether this reduction predicts associative memory performance. Healthy young and older adults were scanned while performing an incidental-encoding task for pictures of objects and houses under item or associative instructions. An old/new recognition test was administered outside the scanner. They used agnostic canonical

©2019 The Authors. Published by the JScholar under the terms of the Creative Commons Attribution License http://creativecommons.org/licenses/by/3.0/, which permits unrestricted use, provided the original author and source are credited.

variates analysis and split-half resampling to detect whole-brain patterns of activation that predicted item vs. associative encoding for stimuli that were later correctly recognized. Older adults had poorer memory for associations than did younger adults, whereas item memory was comparable across groups. Associative encoding trials, but not item encoding trials, were predicted less successfully in older compared to young adults, indicating less distinct patterns of associative-related activity in the older group. Importantly, higher probability of predicting associative encoding trials was related to better associative memory after accounting for age and performance on a battery of neuropsychological tests. These results provide evidence that neural distinctiveness at encoding supports associative memory and that a specific reduction of selectivity in neural recruitment underlies age differences in associative memory. Price CJ, Friston KJ [5] used cognitive conjunction method. They designed the study such that a pair of tasks differ only by the processing component(s) of interest, the neural correlates of the process of interest are then associated with the common areas of activation for each task pair. There are two main advantages of cognitive conjunction relative to cognitive subtraction. The first is that it provides greater latitude for selecting baseline tasks because it is not necessary to control for all but the component of interest. Caplan D, Moo L [6] suggested that the cognitive conjunctions identify the areas in which differences between several pairs of tasks do not differ significantly. These are regions in which subtractive contrasts across a set of experimental – baseline task pairs yield differential vascular responses of equal magnitude and in which interactions of pairs of tasks do not occur. For example, in the present experiment the teacher participants are shown the baseline task followed by metaphorical thinking statements followed by baseline, then non metaphorical statements, baseline, metaphorical images, baseline then non-metaphorical images. Thus, the conjunction method involves single cognitive operation comparing the experimental and the baseline task associated with different vascular activity in the brain regions.

In the BOLD fMRI, the change in the concentration of deoxy Hemoglobin (dHbo) is dynamically monitored. Changes and correlations between tasks (stimulation) and concentration of oxyhemoglobin (Hbo) will be considered. As a general fact, the more neural activities there are, the more tissue needs energy. This will increase the consumption of Glucose and O2, increasing the blood flow and volume, while the local concentration of dHbo is decreasing which will produce the BOLD fMRI signals. This process will be repeated to the end and it should mention that BOLD fMRI signals are relevant to these three physiological concepts: Glucose and O2consumption, blood flow and volume, and concentration of dHbo, respectively. Since the fMRI provides vast information which could be difficult to interpret, a variety of statistical approaches are used in the analysis of the fMRI data. The present research is mainly focused on studying the BOLD signals while the subjects are engaged in active thinking and passive thinking with respect to a baseline state. As there are several methods of analysis available in the literature, the method chosen for fMRI data in the present scenario is General Linear Model (GLM) applied to estimate unknown regression parameters using CONN software first-level analysis. In this experiment, the subjects are exposed to four different experimental conditions 1. Metaphorical thinking statements, non-metaphorical thinking statements, 3.Metaphorical images, and 4. Non- metaphorical images. The aim of conjunction analysis is the conjoint testing for multiple effects in one subject or the conjoint testing for the same effect in different subjects. With propositional logic in combination with Bayesian statistics, the probability of a logical expression over different effects or over effects in different subjects can be determined. A very first implementation of conjunction analysis is the concept of cognitive conjunction introduced. The idea of cognitive conjunction is to detect areas where there is a significant main effect (sum of all effects) and no significant differences (interactions) between the single effects. These voxels are assumed to be significantly activated for all effects. The cognitive conjunction approach uses classical test-statistics.

Methodology

The experiment was designed using E-prime 2 software which synchronizes with 3T Siemens Skyra mode l for studying fMRI images of the subjects. fMRI block design model was adopted to design the experiment. The main objective of the experiment is to find out the effect of rest vs task on performing subjects. All the subjects included in this study are teachers teaching Science subjects in Govt or Govt aided as well as private schools. It is well known fact that the teacher formulates the learning objectives of the content based on Bloom's taxonomy as well as plans to instruct the content based on conscious practice of Metaphorical thinking statements would result in the enhancement of the information processing ability of the learners. Based on this objective in mind, the experiment is designed to display a resting state followed by a task state. The task state comprises four conditions arranged randomly. The four conditions are 1. The metaphorical statement, 2. The non-metaphorical statement, 3. Metaphorical images and 4. Non- metaphorical images. The slides showing the four conditions are randomly arranged. the duration of the slides shown to the subject is fixed at 3 seconds.

To begin with, the experiment starts with a blank slide with a "#" symbol displayed at the center displayed for three seconds which is followed by the display of five slides depicting the above four conditions arranged randomly. The duration of each slide is fixed at 3 seconds. Standard techniques are used in acquiring images. The following instructions as specified Siemens Skyra 3 TMRI scanner were adopted.

• True Inversion Recovery to obtain strong T1-weighted contrast

• Dark Blood inversion recovery technique that nulls fluid blood signal

• Saturation Recovery for 2D Turbo FLASH, gradient echo, and T1-weighted 3D Turbo FLASH with short scan time (e.g. MPRAGE).

• Freely adjustable receiver bandwidth, permitting studies with increased signal-to-noise ratio • Freely adjustable flip angle. Optimized RF pulses for image contrast enhancement and increased signal-to-noise ratio

• MTC (Magnetization Transfer Contrast). Off-resonance RF pulses to suppress signal from certain tissues, thus enhancing the contrast. Used e.g. in MRA

• Argusviewerforreviewingcinestudies•ReportViewerforDICOMstructuredreports including report editing

• Dynamic Analysis for addition, subtraction, division, standard deviation, calculations of ADC maps, T1 and T2 values, TTP, t-Test, etc.

• Data storage of images and cine AVI files on CD / DVD with DICOM viewer as the viewing tool

• Selectable centric elliptical phase reordering via the user interface •Inversion Recovery to nullify the signal of fat, fluid or any other tissue.

Analysis of the data

Analysis of fMRI data was carried out using CONN toolbox supported by SPM and MATLAB. Conn is a MATLAB based cross-platform software used for computation, display, and analysis of functional connectivity for resting as well as task-based analysis. It involves connectivity measures which include seed to voxel, ROI to ROI connectivity matrices, graph properties of connectivity networks, generalized psychophysiological interaction models (gPPI), intrinsic connectivity, local correlation and another voxel -to-voxel measures, independent component analysis(ICA) and dynamic component analysis (Dyn-ICA).

Preprocessing of the data

Pre-processing of the raw data involves the following steps

The DICOM files are imported using SPM 12 software supported by MATLAB version 18b and all the files were converted to NIFTI image files suitable to further processed using conn Functional connectivity SPM toolbox 18. Conn is a Graphic User Interface (GUI based)which is supported by SPM as well as MATLAB. Structural data obtained for each subject is used to derive grey/white/CSF masks used in the Confound removal method. Region of Interest termed as ROI which includes seed areas useful for resting state as well as task-based connectivity regions characterizing dorsal attention network, executive control network as well as a complete brain region which include 91 cortical areas and 15 subcortical areas from the FSL, Harvard-Oxford Atlas and also 26 cerebellar areas from the AAL atlas. CONN's default MNI options involve functional realignment and unwrapping, slice timing correction, structural segmentation, and normalization. The present research works are mainly focused on volume-based analysis on MNI -space for voxel-level analyses which is subject-specific as well as condition-specific. Similarly, subject as well as condition-specific analyses for ROIs for ROI - level analyses were carried out by co- registering the functional files to structural files both normalized in MNI-space.

Post-processing the data

Post-processing of the fMRI data acquired for each subject is tested based on the following hypotheses

Is there a significant difference in BOLD signals between resting vs task 1 (Processing Metaphorical thinking -statements)?

Is there a significant difference in BOLD signals between resting vs task 2 (Processing non- Metaphorical thinking -statements)?

Is there a significant difference in BOLD signals between resting vs task 3 (Processing Metaphorical thinking images)?

Is there a significant difference in BOLD signals between resting vs task 4 (Processing non- Metaphorical thinking - images)?

In order to explain the variation of BOLD signals in the above-mentioned tasks, CONN uses Deionizing step. This step applies linear regression and band-pass filtering to remove unwanted motion, physiological and other artefactual effects from the BOLD signal before computing connectivity measures. By default, the software performs three different sources of possible cofounders: 1. BOLD signal from the white matter and CSF masks (5dimensionseach), 2. Any previously defined within-subject covariate (realignment and scrubbing parameters. 3) the main condition effects. This would give the direct BOLD signal changes associated with the presence/absence of the task. For the first subject after deionization, the BOLD variance was shown with reference to the frontal pole left. Analyses is restricted to showing BOLD variance in the white matter of the brain, Cerebrospinal fluid (CSF), realignment and scrubbing for the above-mentioned conditions. The results are shown for 5 subjects though 20 teachers participated in the study. All the figures from1to 20 represents % variance of BOLD signals among 5 subjects in white matter, CSF, realignment and scrubbing for the baseline vs 4 conditions namely metaphorical thinking, non-metaphorical thinking, metaphorical images, and non-metaphorical images. The first level analyses indicate that there is voxel to voxel connectivity for all the four conditions vs baseline which in turn represented by the Bayesian statistics. The basic idea of conjunctional analyses is if there are two simultaneous tasks A and B, one could find the connectivity between voxel to a voxel is greater in A than B or vice versa by random sampling of t value distribution. The above figures1to20 represents conjunction analysis showing the effect of metaphorical thinking statement, non-metaphorical statement, metaphorical images and non-metaphorical images vs baseline. In all cases, there is activation in voxel to a voxel in the prefrontal cortex as well as the hippocampus regions of the brain. With the application of conjunctional analysis, it is possible to test the null hypothesis whether voxel to voxel connectivity is large in any of the above conditions or small, if in one case it is large and in another case it is smaller in terms relativity, the smaller effect is rejected by interaction masking of the voxel.

Figure 1: Shows BOLD % variation in the white matter of the brain for subject 1

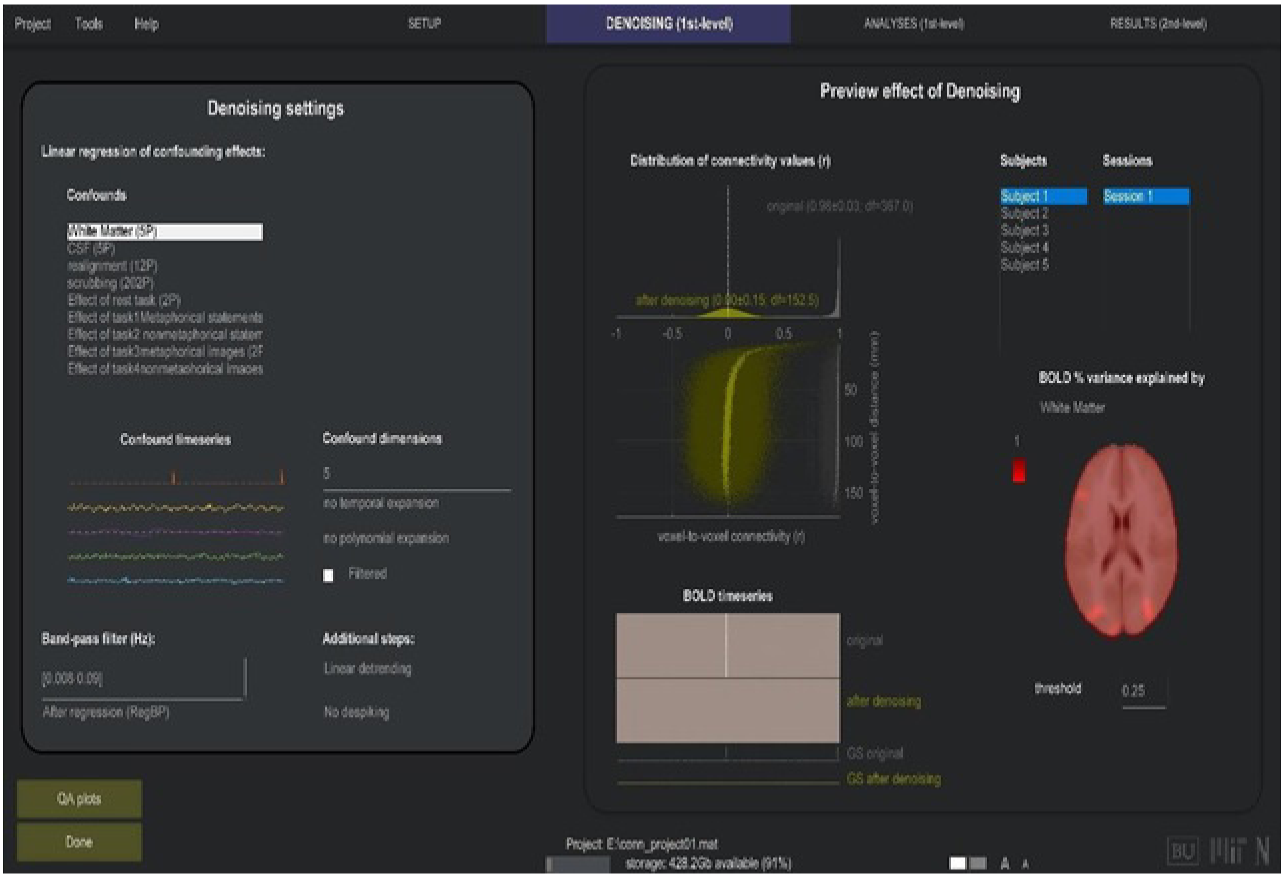


Figure 2: BOLD % variation in the white matter of the brain for subject 2

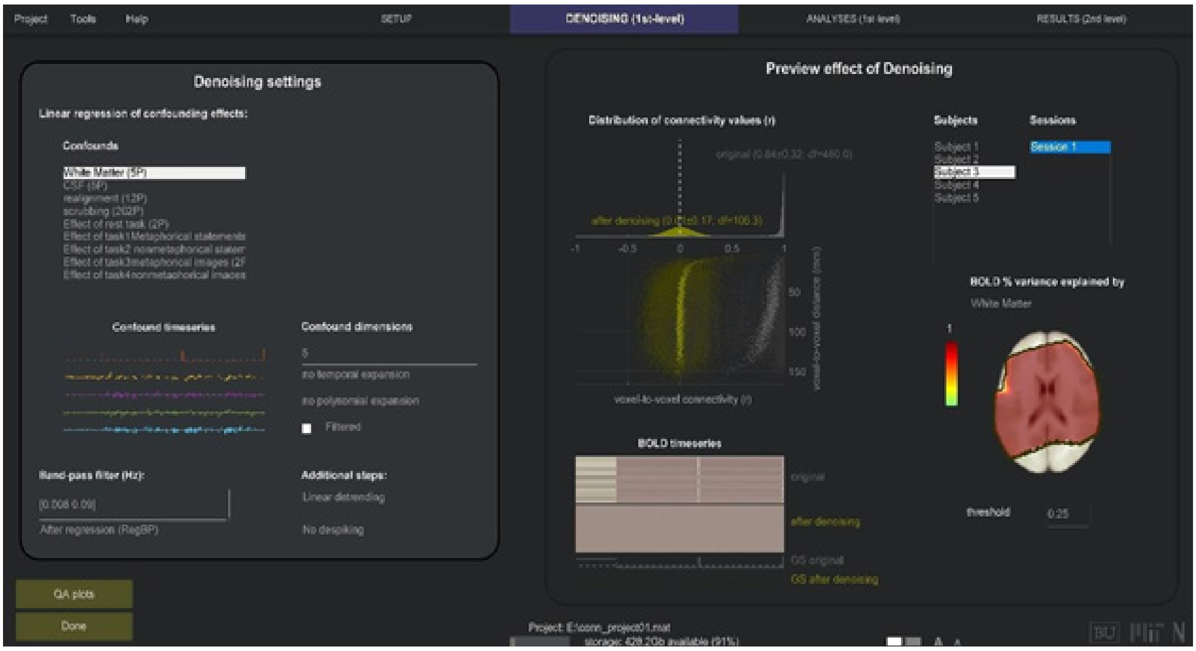


Figure 3: BOLD % variation in the white matter of the brain for subject3

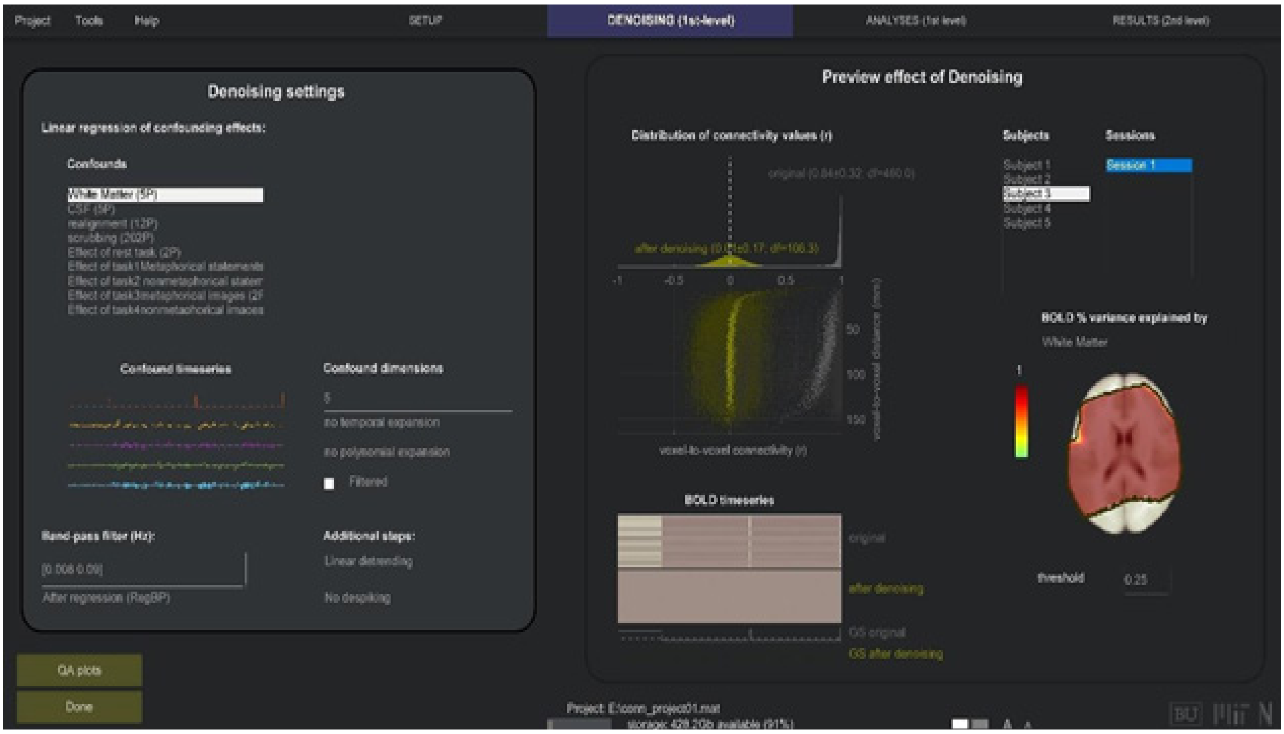


Figure 4: BOLD % variation in the white matter of the brain for subject4

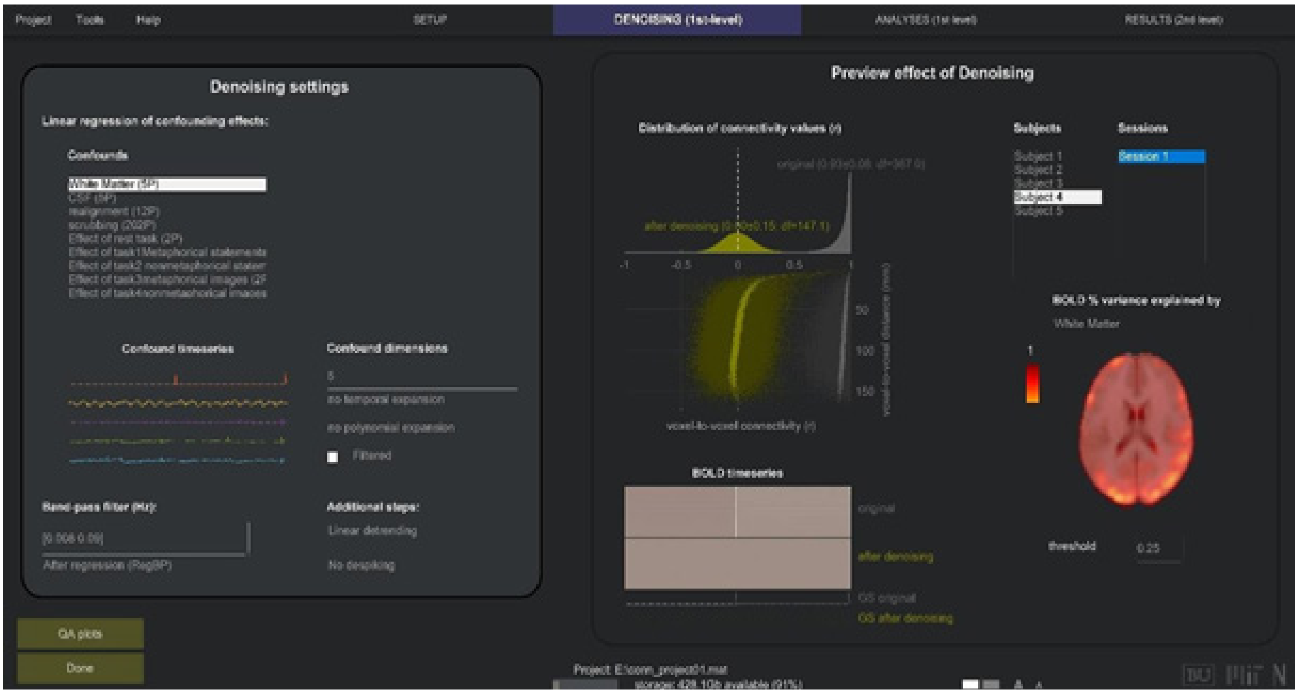


Figure 5: BOLD % variation in the white matter of the brain for subject5

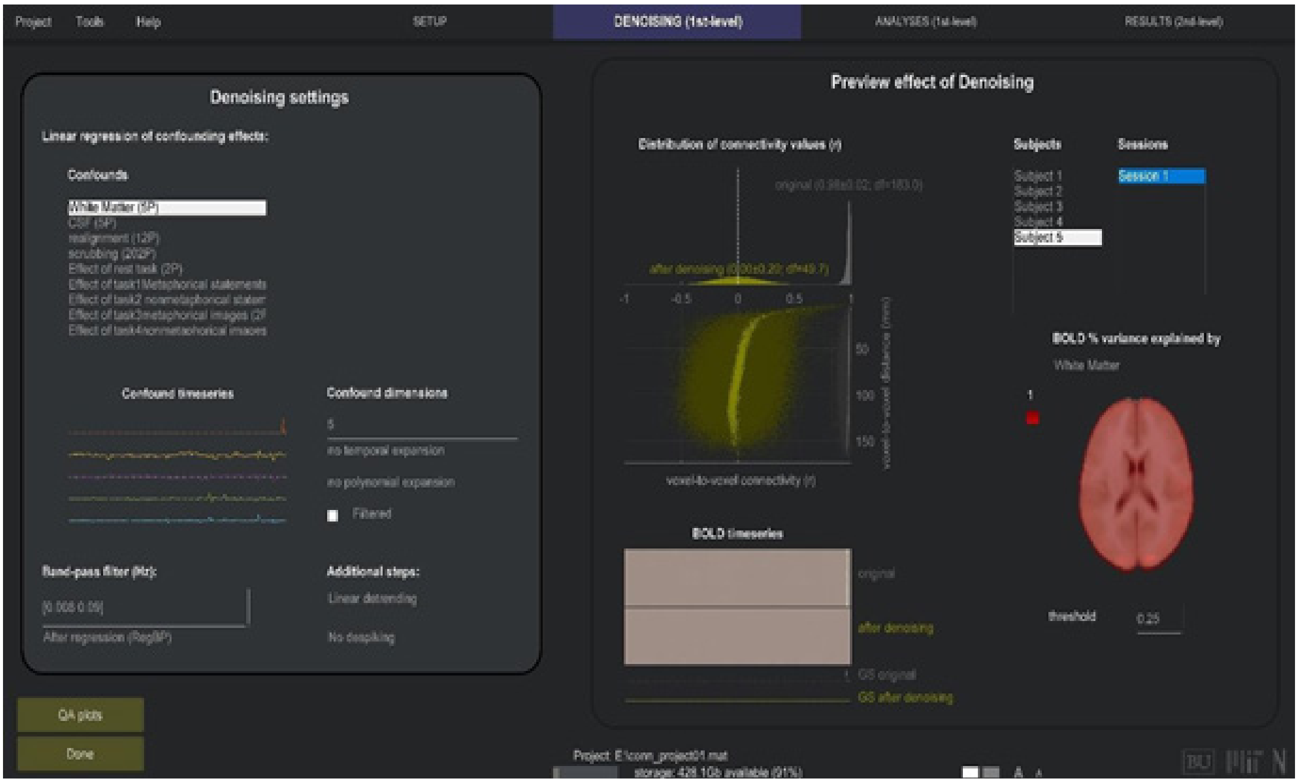


Figure 6: BOLD % variation in CSF for subject1

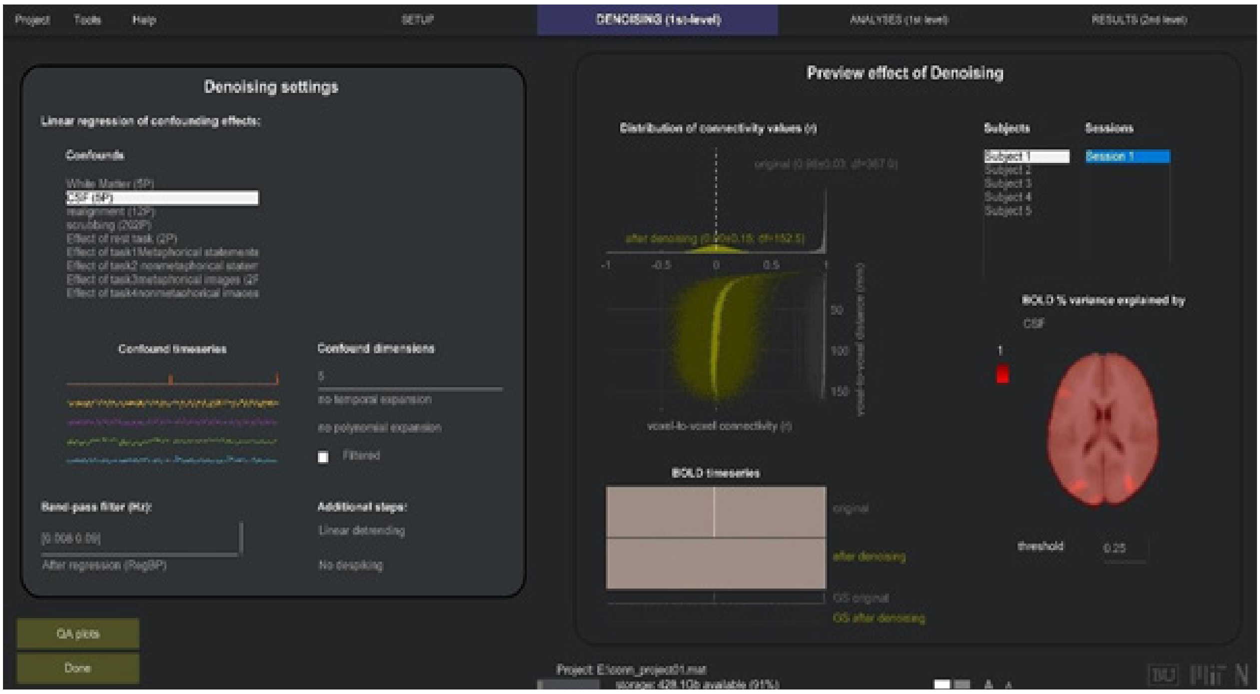


Figure 7: BOLD % variation in CSF for subject2

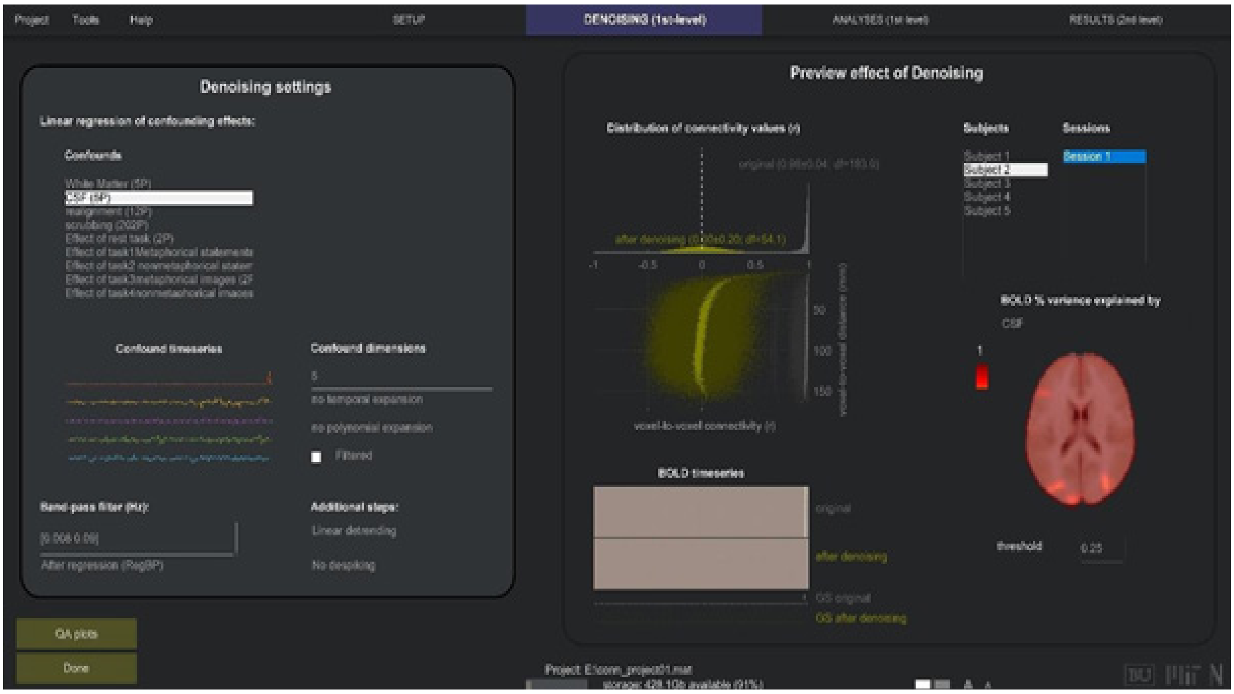


Figure 8: BOLD % variation in CSF for subject3

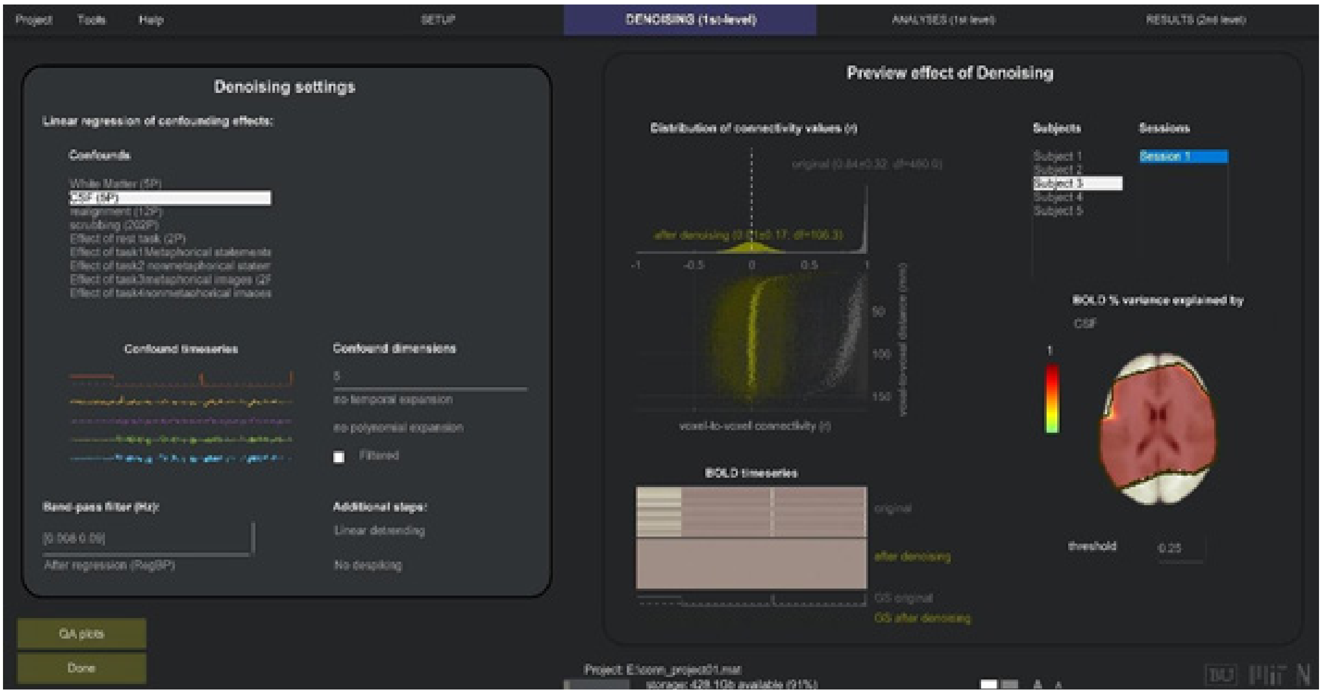


Figure 9: BOLD % variation in CSF for subject4

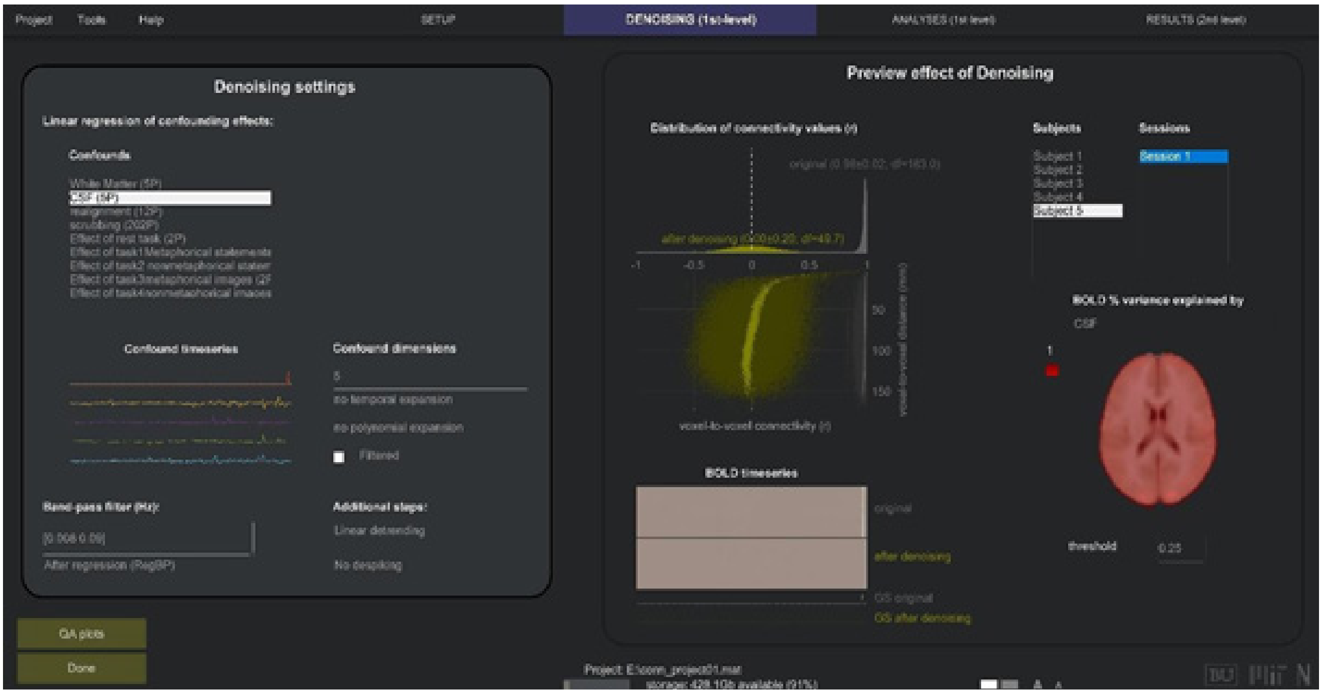


Figure 10: BOLD % variation in CSF for subject 5

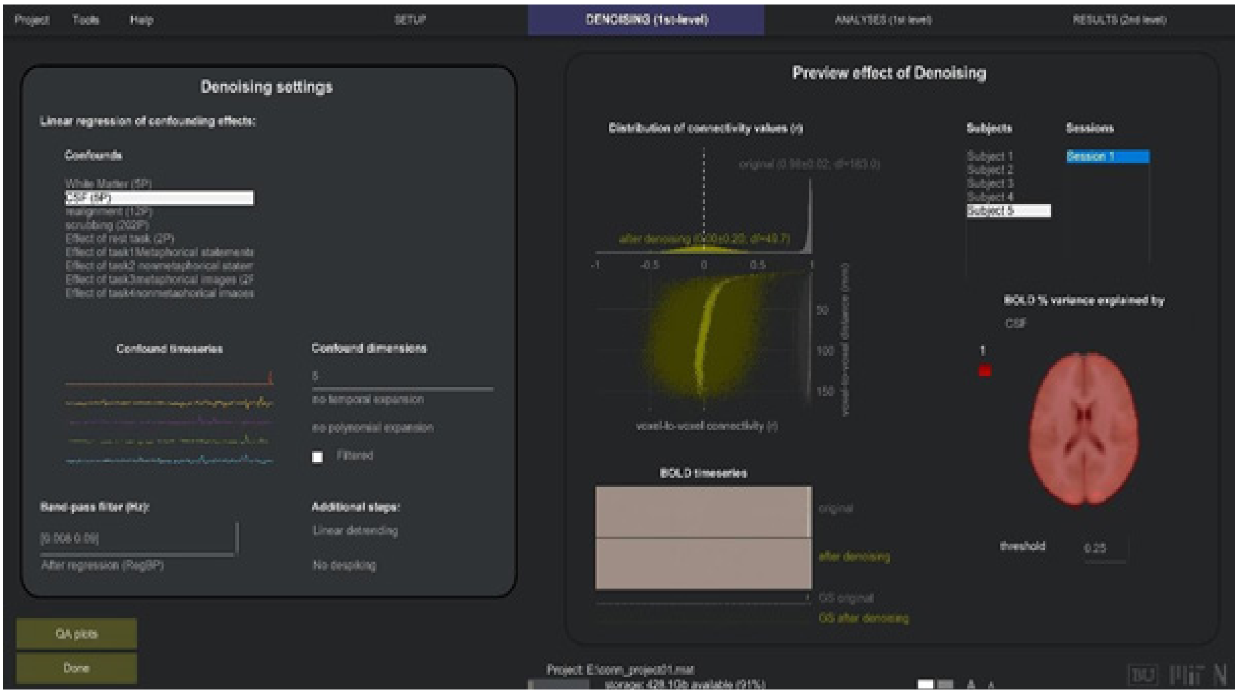


Figure 11: BOLD % variation by realignment for subject 1

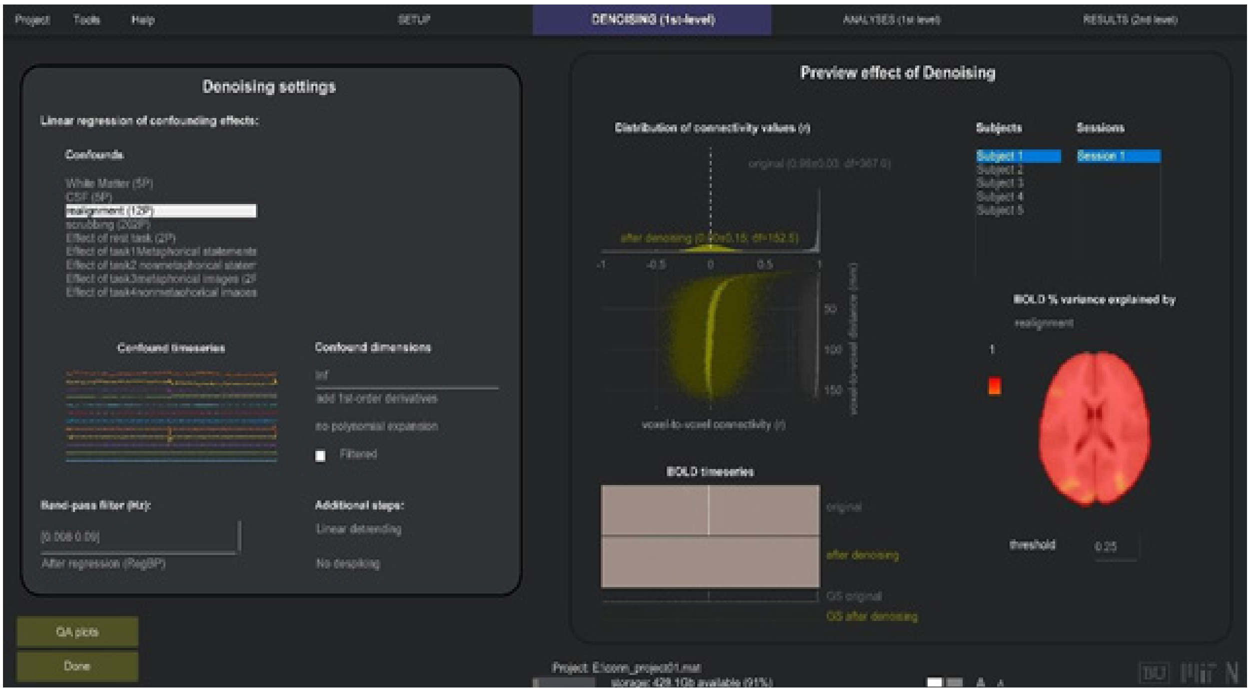


Figure 12: BOLD % variation by realignment for subject2

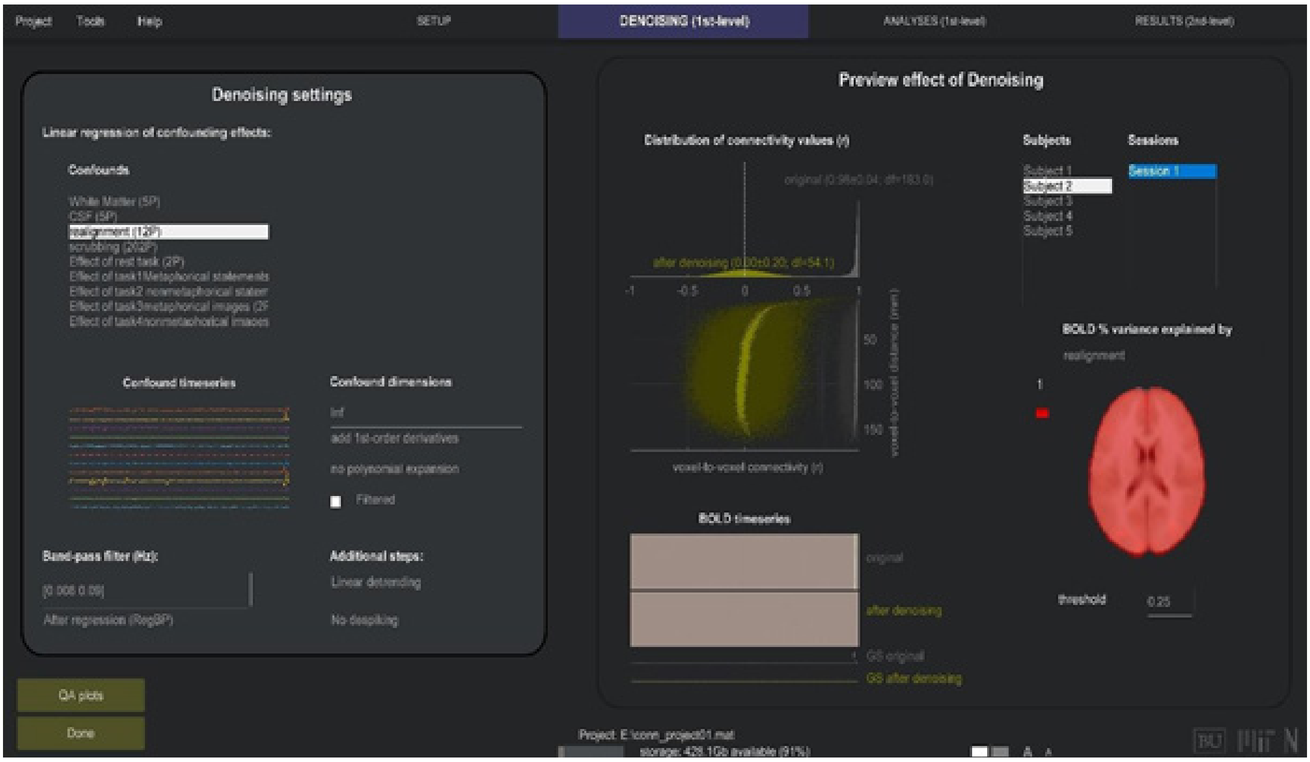


Figure 13: BOLD % variation by realignment for subject3

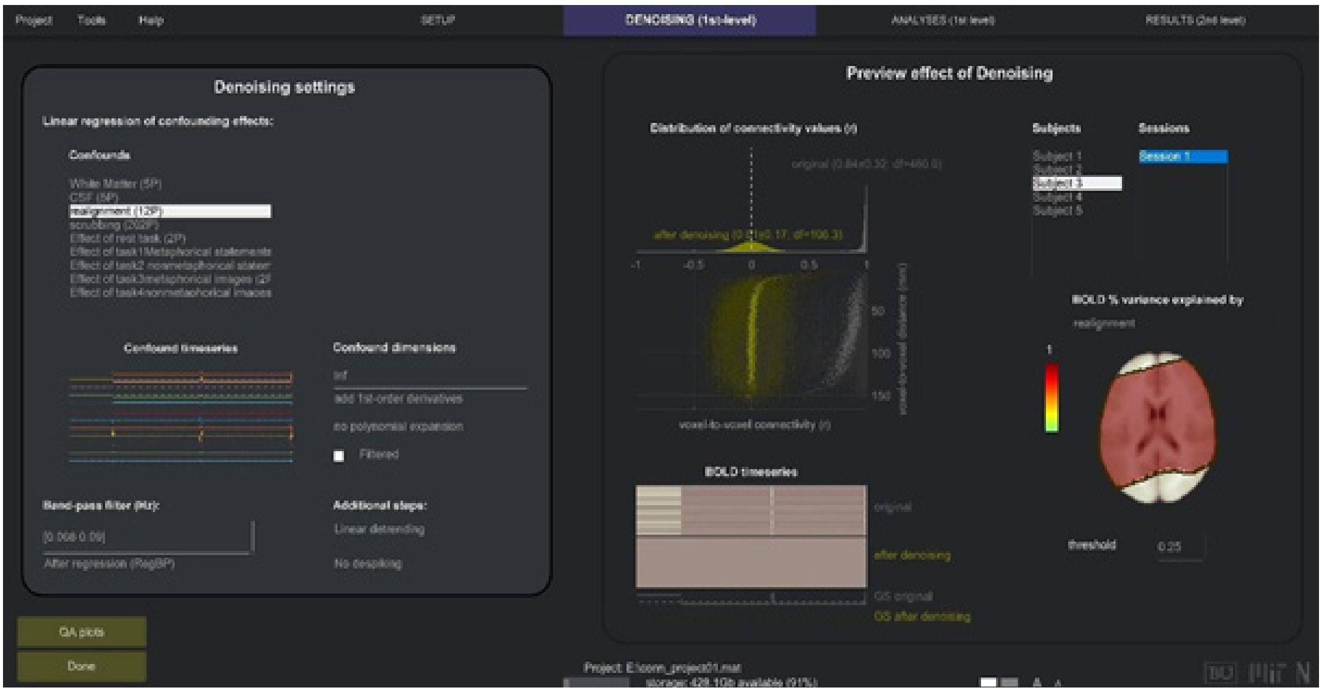


Figure 14: BOLD % variation by realignment for subject4

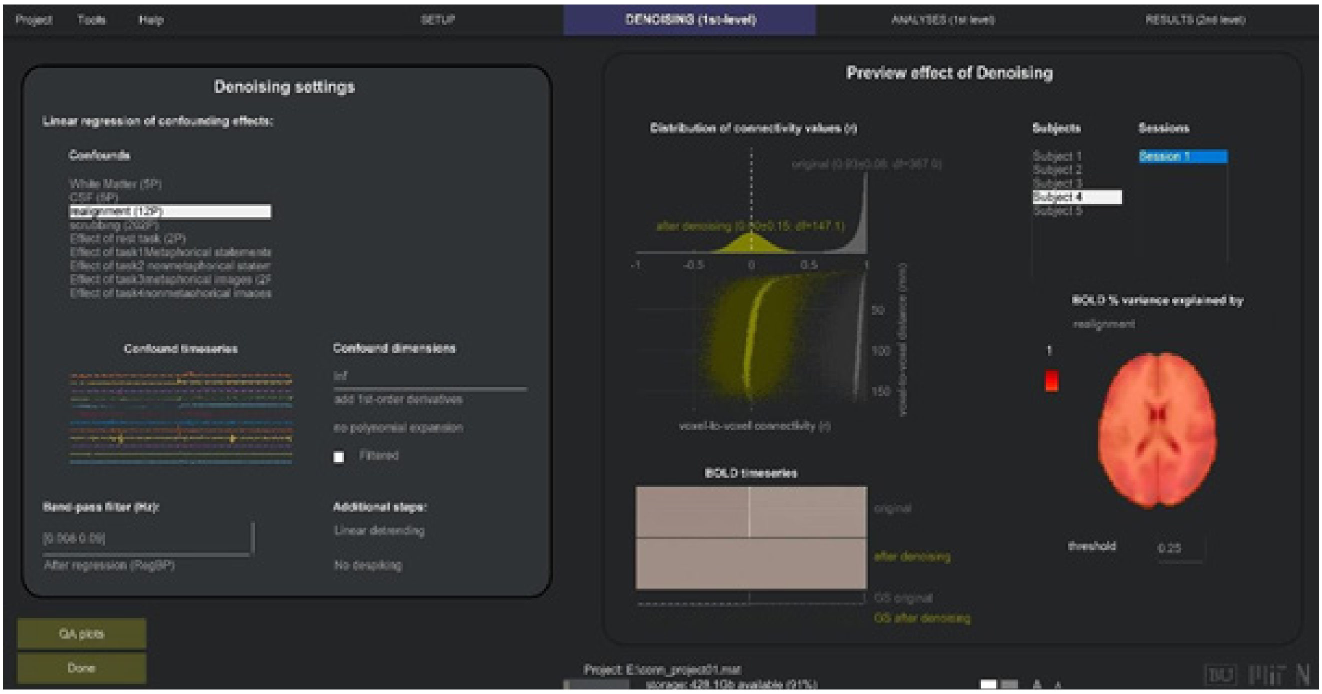


Figure 15: BOLD % variation by realignment for subject5

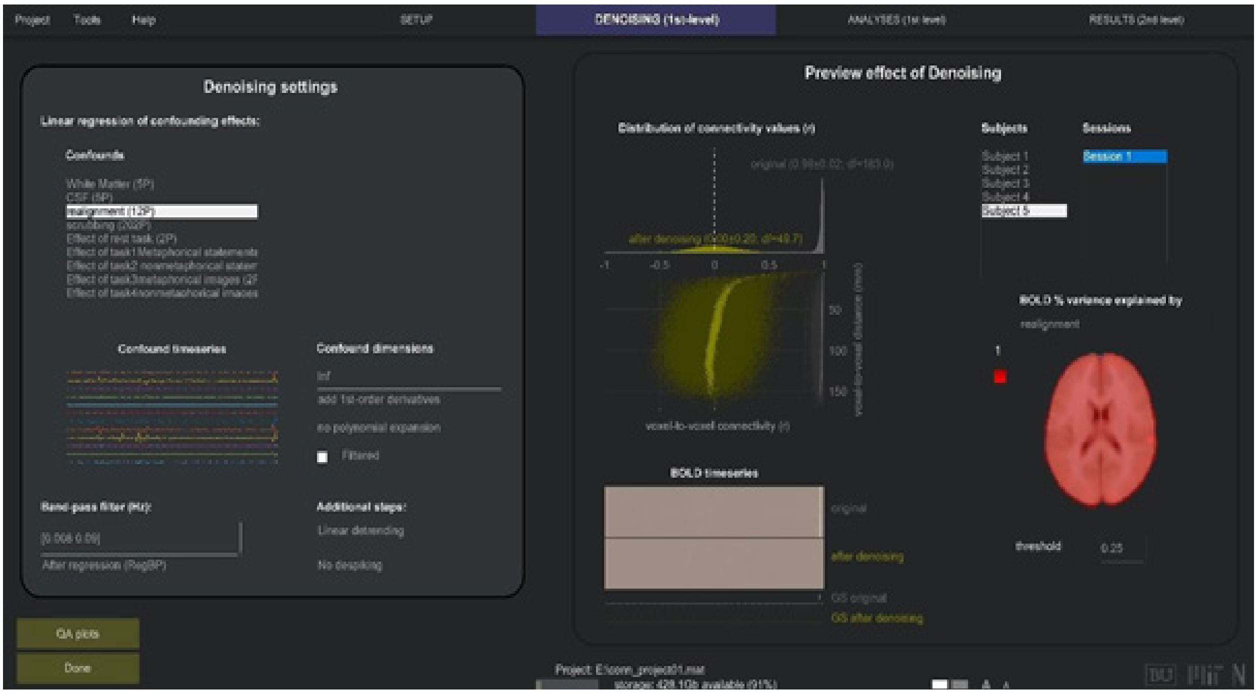


Figure 16: BOLD % variation by Scrubbing for subject1

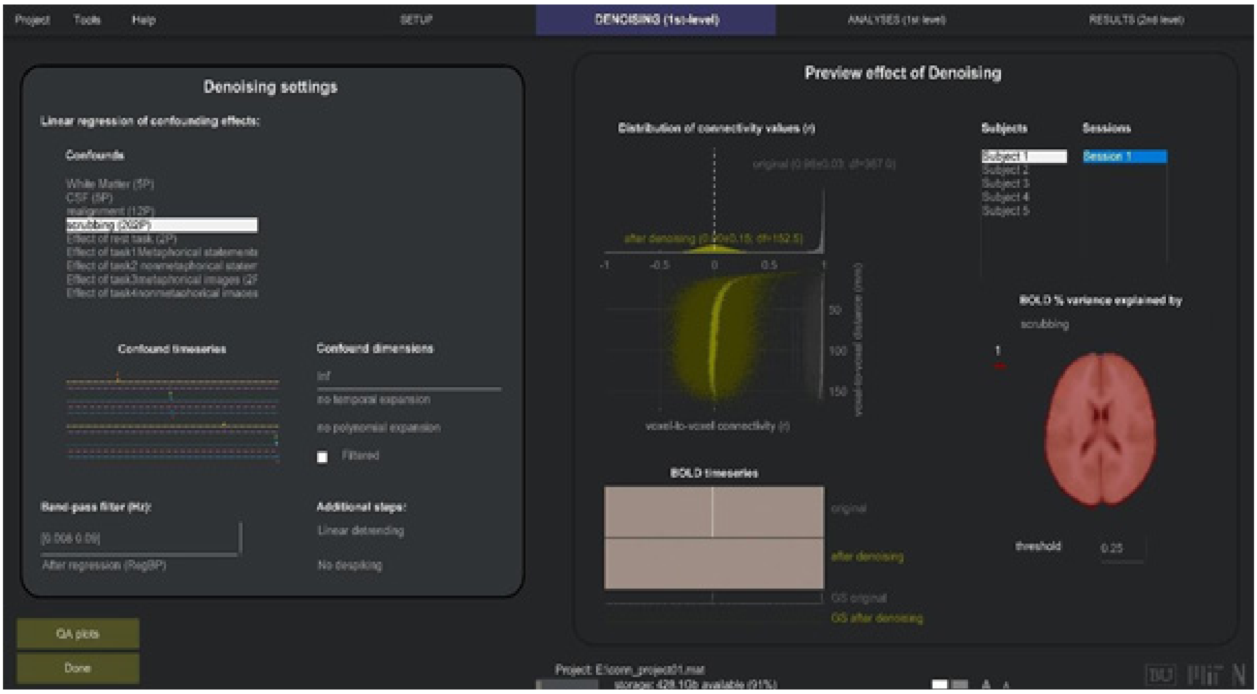


Figure 17: BOLD % variation by Scrubbing for subject2

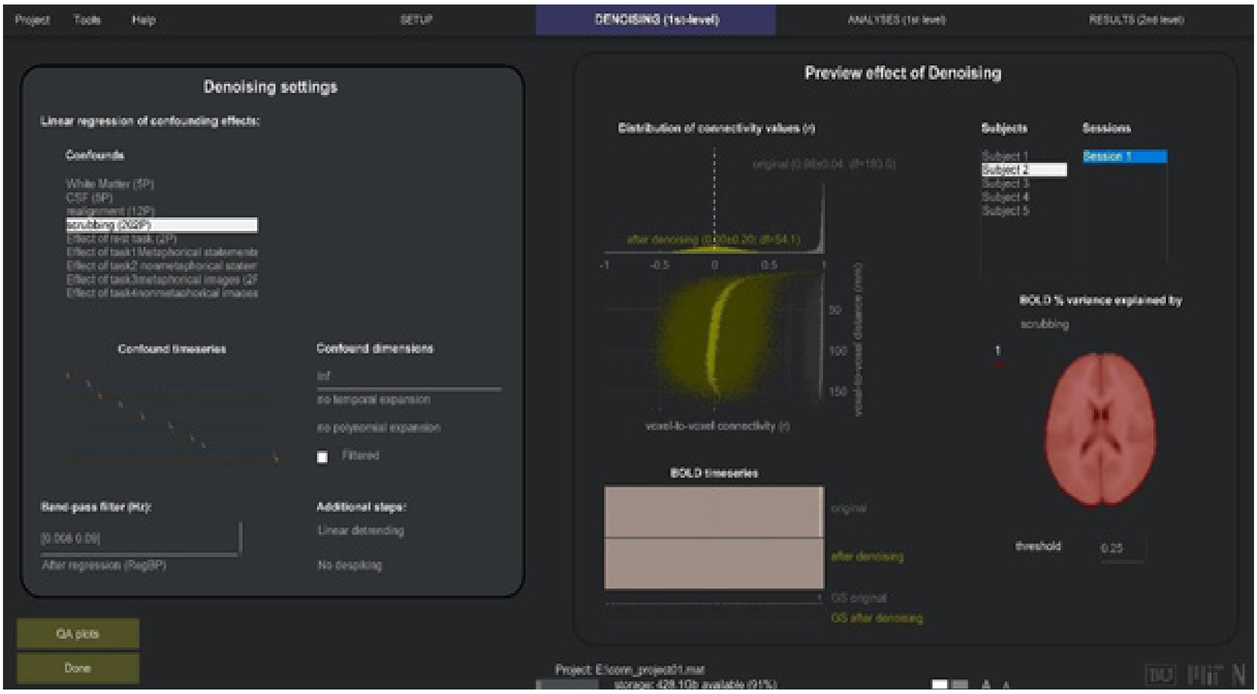


Figure18: BOLD % variation by Scrubbing for subject 3

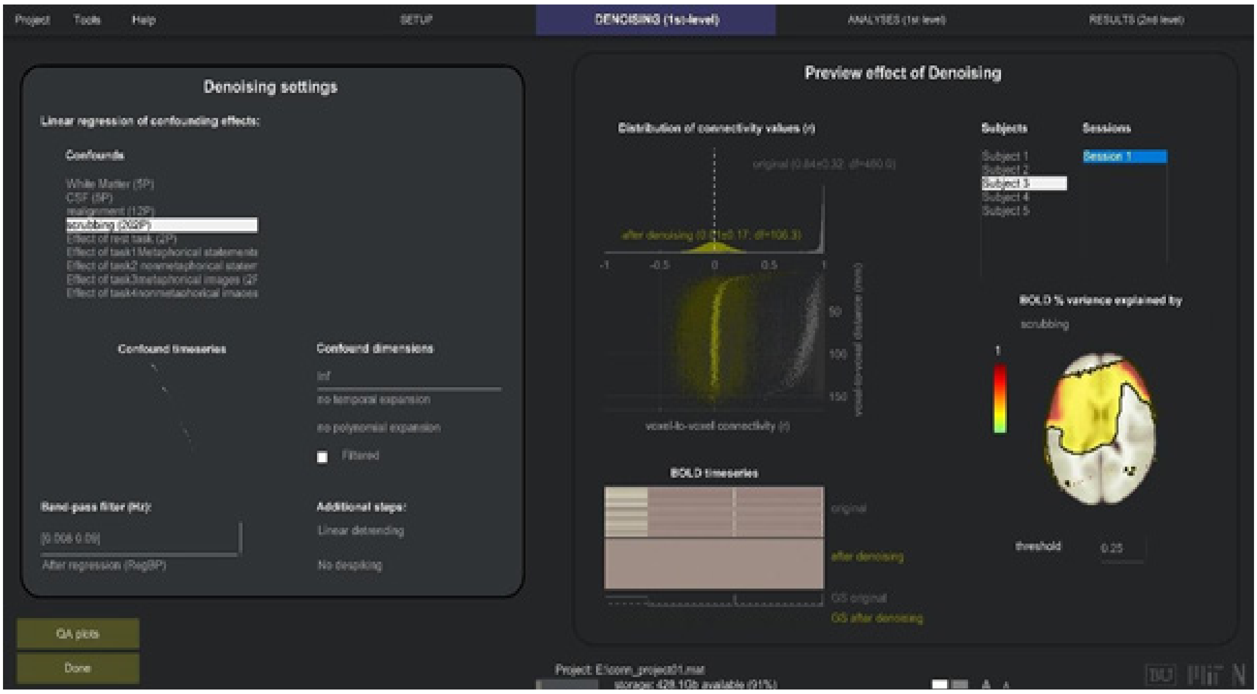


Figure 19: BOLD % variation by Scrubbing for subject 4

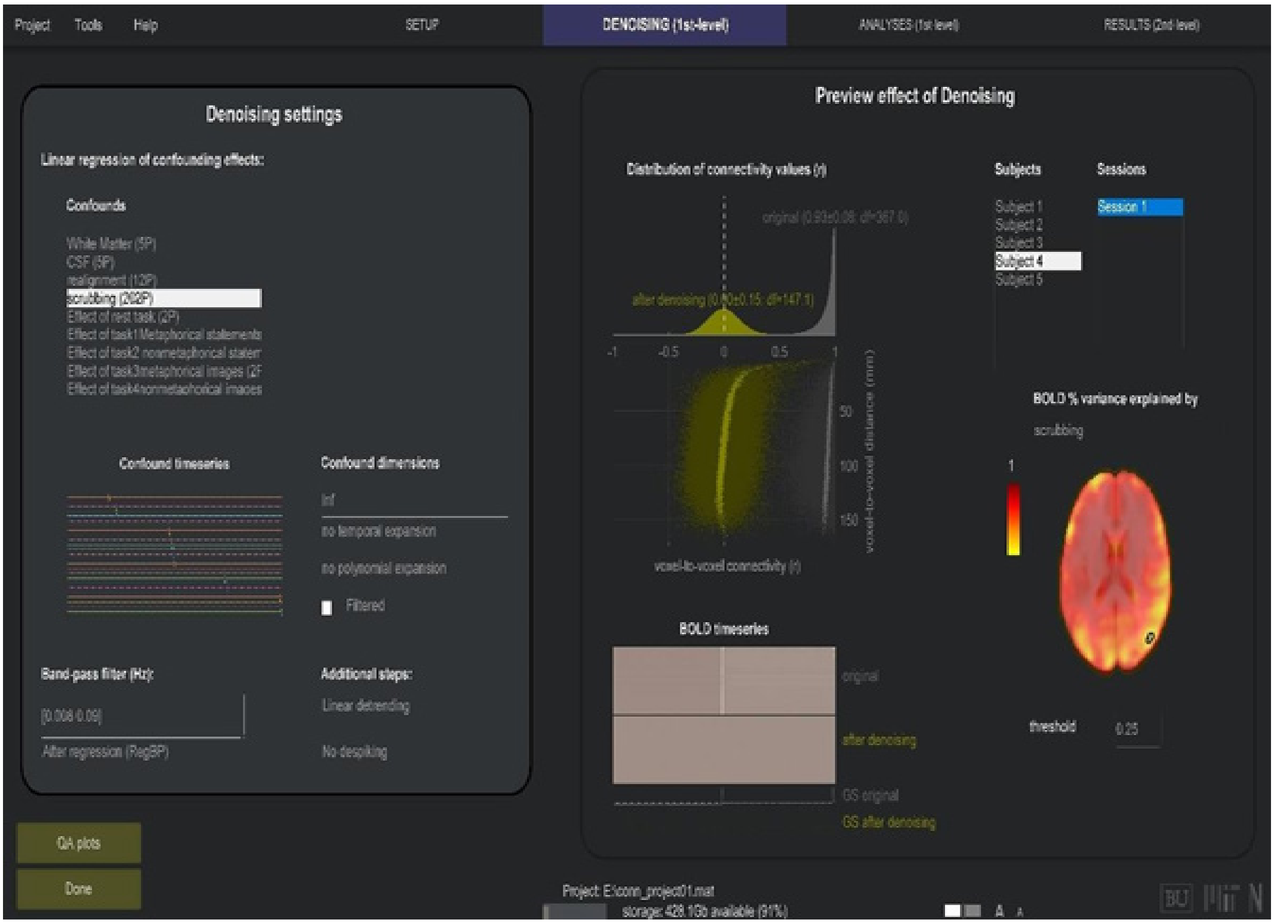
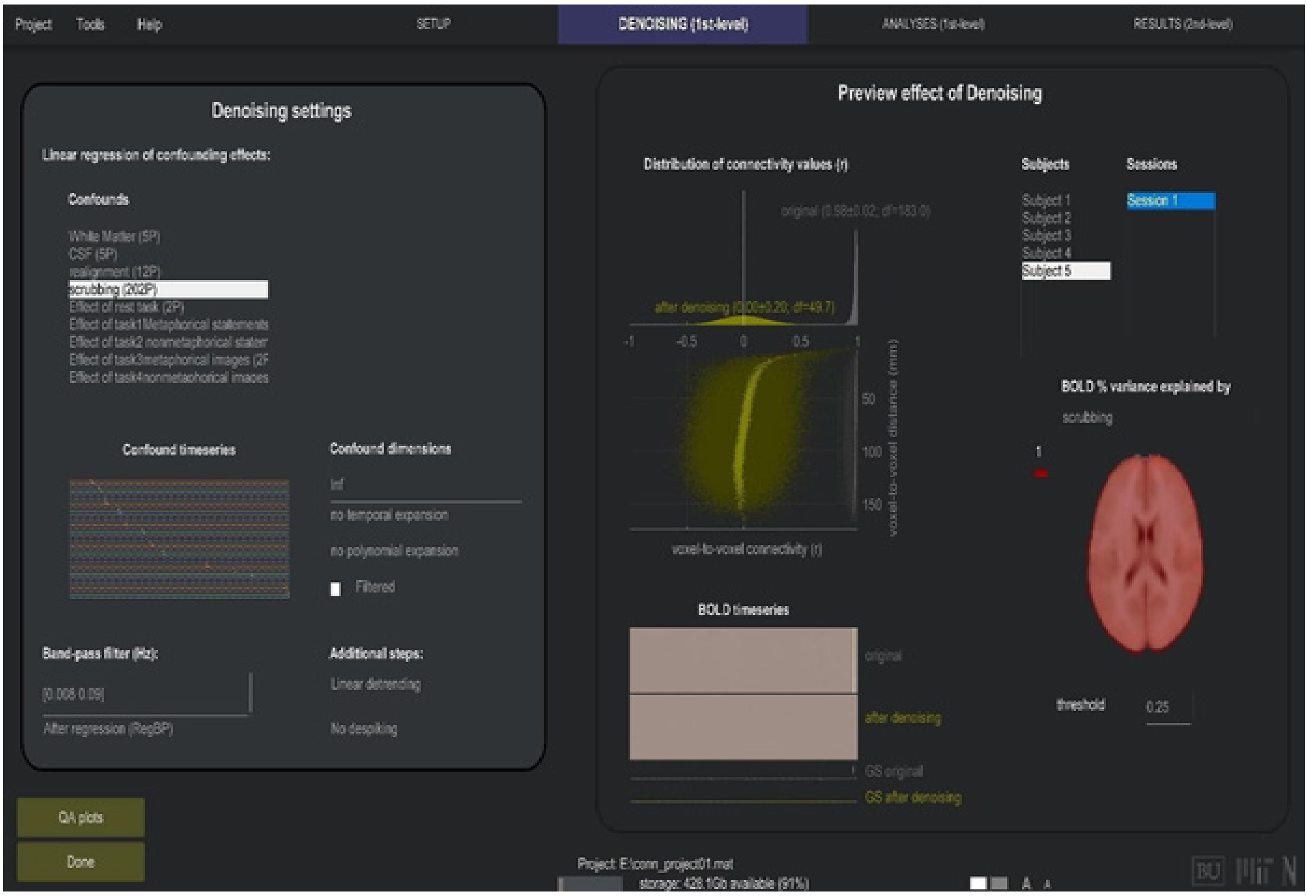


Figure 20: BOLD % variation by Scrubbing for subject 5



Discussion

Friston & Price [8] suggested that a valid conjunction analysis can be viewed in a brain map of activations as follows: 1) each voxel is significantly activated by two or more tasks, 2) each voxel is not significantly modulated by an interaction effect between tasks, and 3) the estimated relationships between each voxel and each task are not significantly different. According to Nichols et al [7] random sampling of the t-value distribution is used to test null hypotheses stating task A has no effect on task B if there is significant effect null hypotheses could be rejected. t-values of a voxel identified in a conjunction analysis of two tasks should be more highly correlated across those tasks and within individuals than the correlation of t-values for voxels not identified in the conjunction analysis. Worsely [8] suggested that in a conjunction analysis, using a fixed-effect model, allows one to infer: (i) that every subject studied activated and (ii) that at least a certain proportion of the population would have shown this effect for the given conditions during the experiment. Recent neuro imaging evidence indicated that symbolic fractions experiment with fMRI by Ischebeck A, Schocke M, Delazer M [9] and non-symbolic proportions by Jacob SN, Nieder A [11] are processed within a frontoparietal network including the IPS. The results were in agreement with evidence obtained on whole number processing by (e.g., Dehaene S, Piazza M, Pinel P, Cohen L [13]. Arsalidou M, Taylor MJ [12]. Both these experiments suggest that both absolute and relative of magnitude information seem to be processed within this brain area.

Conclusions

fMRI experiment proved a concrete evidence showing activation in the frontal lobe left in all the subjects and in hippocampus regions of brain for the task baseline vs Metaphorical thinking though the experiment was conducted in all the subjects exposing them to visually process all the four different tasks with respect to the baseline. The idea of conjunctional analysis applied to this experiment might have simultaneously activated the voxel it was the relative activation was taken into account as it is impossible to ignore the activation caused by the other three tasks. Overall it could be concluded that the lesson plan implemented with metaphorical thinking statements influences the information processing ability of the learners.

References

1. Cheryl Grady, Saman Sarraf, Cristina Saverino, and Karen Campbell (2016) Age differences in the functional interactions among the default, frontoparietal control, and dorsalattention networks. Neurobiology of Aging 41:159–172.

2. Scott A Huettel, Allen W Song, and Gregory McCarthy (2004) Functional magnetic resonance imaging, volume 1, Sinauer Associates Sunderland.

3. Seong-GiKim and Kamil Ugurbil, (1997) Functional magnetic resonance imaging of the human brain. Journal of neuroscience methods 74: 229–243.

4. Stephen C Strother, Saman Sarraf, and Cheryl Grady (2014) Ahierarchyof cognitive brain networks revealed by multivariate performance metrics. In Signals, Systems and Computers, 48th Asilomar Conference on 603–607.

5. Price CJ, Friston KJ (1997) Cognitive conjunction: a new approach to brain activation experiments. Neuroimage 5: 261–270.

6. Caplan D, Moo L (2004) Cognitive conjunction and cognitive functions. Neuroimage 21:751– 756.

7. Nichols T, Brett M, Andersson J, Wager T, Poline JB (2005) Valid conjunction inference with the minimum statistic. Neuroimage 25: 653–660.

8. Worsley KJ, Friston KJ (1995) Analysis of fMRI timeseries revisited—Again. Neuroimage 2: 173–181.

9. Ischebeck A, Schocke M, Delazer M (2009) The process sing and representation of fractions within the brain. An fMRI investigation, Neuroimage 47: 403–413.

10. Jacob SN, Nieder A (2009) Notation-independent representation of fractions in the human parietal cortex. J. Neuroscience 29: 4652–4657.

11. Jacob SN, Nieder A (2009) Tuning to non-symbolic proportions in the human frontoparietal cortex. Eur. J. Neuroscience 30: 1432–1442.

12. Arsalidou M, Taylor MJ (2011) Is 2+2=4? Meta-analyses of brain areas needed for numbers and calculations. Neuroimage 54: 2382–2393.

13. Dehaene S, Piazza M, Pinel P, Cohen L (2003) Three parietal circuits for number processing, Cognitive Neuropsychology 20: 487–506.

Submit your manuscript to a JScholar journal and benefit from:

¶ Convenient online submission
¶ Rigorous peer review
¶ Immediate publication on acceptance
¶ Open access: articles freely available online
¶ High visibility within the field
¶ Better discount for your subsequent articles

JScholar
Fostering Scholarly Communication

Submit your manuscript at
http://www.jscholaronline.org/submit-manuscript.php