TASK-INDUCED DEACTIVATION DOES NOT DISRUPT FUNCTIONAL COUPLING OF THE DEFAULT MODE NETWORK DURING THE MOVEMENT

Oleksii Omelchenko[1] and Zinayida Rozhkova[2]

[1]*Human and Animal Physiology, Taras Shevchenko National University of Kyiv, Kyiv, Kyiv, Ukraine,* [2]*Radiology, Medical Clinic BORIS, Kyiv, Ukraine*

Target audience: Scientists interested in default mode network and task-related deactivation research.

Purpose: To analyze the connectivity pattern of the default mode network during the complex motor task execution and to study its coupling with the task-induced deactivation (TID).

Introduction: The default mode network (DMN) has gained considerable attention in the fMRI research, particularly due to its possible role of resting brain activity regulation, and the evidence of functional connectivity disruption in different diseases like autism, schizophrenia and Alzheimer's[1]. Early studies were devoted to the pattern of the deactivation of the regions which were later considered as distinct nodes of DMN[2]. Thus, it is widely accepted that the DMN is task-negative network, which is more active during the wakeful rest. DMN consists of such anatomical regions: posterior cingulate cortex (PCC), precuneus (pC), medial prefrontal cortex (MPFC), left and right inferior parietal lobuli (IPL_L, IPL_R), left and right posterior medial temporal gyri (MTG_L, MTG_R)[2]. It was shown that sensorimotor network (SMN) activation by movements is accompanied by the deactivation of several regions of the DMN[3]. Also it was shown that performance of motion is accompanied by the activation of DMN at the stage of task preparation, but the stage of task execution evokes deactivation of the DMN[4], which might mean that task relevant attentional resources are allocated due to the task demands. Different modes of DMN deactivation associated with more or less effort[5]. PCC and pC were shown to be the key regions in the DMN and have potential role to be the central 'hub'[6]. CBF decrease inhomogeneity in the pC adds evidence for its functional heterogeneity[7]. Some DMN regions might function as part of a certain network in one task, while the same region might function as part of a different network under a different one[8]. From the task-based studies of movement activation we have concluded that deactivation occurs only in the limited regions of DMN locales. We hypothesized that some regions of DMN could remain active and functionally connected during the task execution. We propose TID and functional connectivity analysis under the execution of motor tasks with various complexities for DMN heterogeneity study.

Methods: Two groups of subjects were studied by fMRI with 1.5T SIGNA EXCITE (GE, USA). Group 1 consisted of 7 healthy subjects (3F, 20-39 y.o.), Group 2 consisted of 10 healthy subjects (5F, 24-48 y.o.). For the Group 1 paradigm of activation comprised complex motor task consisted of three stages: 1 - index finger to thumb tapping, 2 - sequential II-IV fingers to thumb tapping, 3 - hand gripping. Group 2 underwent simple finger tapping motor task. The scanning session time was 6 min, 5 blocks of activation were acquired. Because paradigm execution supposed predictable signal oscillation, estimated frequencies for BOLD fluctuation for Group 1 were f_1=1.1x10^{-2} Hz, f_2=3.6x10^{-2} Hz and for Group 2 was f_3=1.67x10^{-2} Hz. The single shot EPI sequence was used for BOLD images acquisition (TR/TE=3000/71 ms, voxel size=4x4x5 mm). Anatomical images were acquired with FSPGR sequence (TR/TE=11.6/5.2 ms, TI=450 ms, voxel size=1x1x1.5 mm). FMRI data processing was carried out using GLM (FEAT) and ICA (MELODIC) based software from FSL (Oxford, GB). Standard FSL pre-processing was done. Single subject and group GLM and ICA analyses were done. ICA correlation analysis with GLM data was done using a built-in F-test. The frequency spectrum of BOLD signal fluctuations was analyzed for ICA components which corresponded to the anatomical regions of SMN and DMN.

Results and Discussion: GLM based analysis of Group 1 and Group 2 motor tasks steadily revealed activation of SMN. GLM based deactivation analysis revealed ipsilateral primary sensorymotor cortex, PCC and pC to be involved in the process. Fig. 1A shows ICA based patterns of DMN functioning under motor task execution, in the way of TID (Fig. 1B, C), and in task-independent manner (Fig. 1D, E). Thus, during the motor task execution some regions of DMN function in the regime of TID (DMN_{deact}). DMN_{deact} structure for Group 1 – PCC, pC_R, IPL_L, IPL_R, $DLPFC_R$, MTG_L, M_1S_{1ips}, for Group 2 – PCC, pC_R, pC_L, MTG_R, MTG_L. Simultaneously, some regions of DMN function without correlation with task execution (DMN_{ind}). DMN_{ind} structure for Group 1 – PCC, pC_R, pC_L, MPFC, IPL_L, IPL_R, $DLPFC_R$, MTG_R, MTG_L, M_1S_{1cont}, for Group 2 - PCC, MPFC, IPL_L, IPL_R. For Group 1 regions of the SMN frequency spectrum of the BOLD signal fluctuation comprised two main frequencies ν_1=0.01Hz and ν_2=0.032 Hz. It was the same as the estimated frequencies of the activation paradigm f_1 and f_2. The last supports the correspondence of the ICA component to the motor activity not only in the terms of topography, but also in terms of frequency of BOLD fluctuation. Also ICA revealed two different components which topographically corresponded to the regions of the DMN. The frequency spectrum of the one component DMN_{deact} was the same as for SMN ν_3=0.01Hz and ν_4=0.032Hz, but another component had a different frequency spectrum DMN_{ind} had ν_5=0.018Hz и ν_6=0.034Hz. For Group 1 the topography of the DMN_{deact} included regions of the PCC and precuneus (pC_R) primarily at the ipsilateral to the executed movement side, but the DMN_{ind} comprised PCC and precuneus (pC_R, pC_L) bilaterally and was much more pronounced in all the nodes of classical DMN. For Group 2 the GLM and ICA also revealed deactivation of the DMN regions. Strong correlation (P<0.000) between motor paradigm execution and SMN was shown, with frequencies of BOLD fluctuation measurably close to the f_3, ν_1=0.0153Hz, ν_2=0.0204Hz, and DMN_{deac} P<0.000 ν_3=0.0204Hz, ν_4=0.0357Hz. Also DMN_{ind} was shown to function during simple motor task execution, with low correlation to the movements (P<0.420). The frequency spectrum of DMN_{ind} was different from f_3, ν_5=0.0306Hz, ν_6=0.0459Hz. Thus, we have found out topography differences of DMN_{deac} and DMN_{ind}. Particulary DMN_{deac} PCC/pC node involved mainly PCC, and pC was implicated only partially and primarily ipsilateral, whereas DMN_{ind} showed functional connectivity of all the pC and PCC regions. Despite the almost unified pattern of brain activation across different motor tasks, deactivation pattern might differ depending on the complexity of the movements and their cognitive demand. Nodes of DMN may function simultaneously in the TID and task independent regimes during the simple or complex movement execution. The last evidence suppose that different loops of DMN functioning quasi autonomously. Obligatory PCC involvement in TID and task independent patterns of DMN functioning supports its possible 'hub' function.

Conclusion: Functional analysis of the DMN connectivity under motor task execution supports the hypothesis of DMN heterogeneous structure, different regions of which might simultaneously desynchronize and act autonomously. The data supports PCC role of 'hub' in DMN.

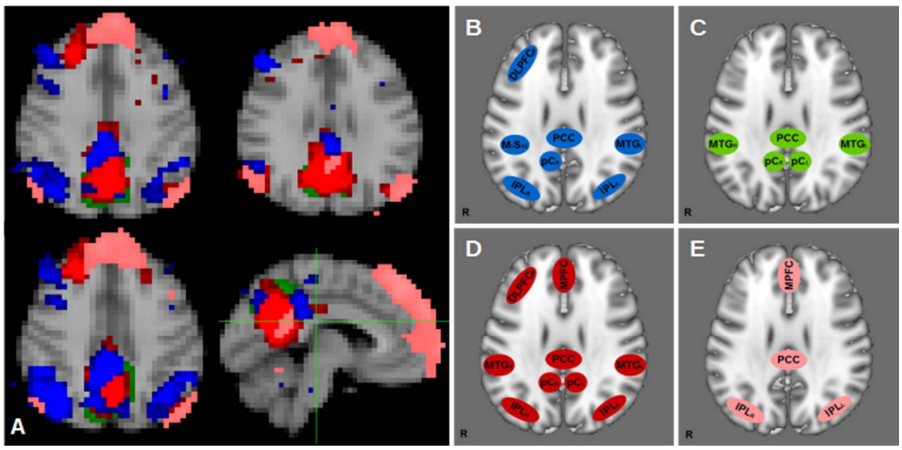

Figure 1. Two different regimes of DMN functioning under motor task execution for Group 1 and Group 2. ***A*** – ICA results Group 1 DMN_{deac} – blue, DMN_{ind} – red, Group 2 DMN_{deac} – green, DMN_{ind} – pink. B - DMN_{deac} pattern for Group 1, C - DMN_{deac} pattern for Group 2, D - DMN_{ind} pattern for Group 1, E - DMN_{ind} pattern for Group 2.

References: [1]Broyd et al. 2009. *Neuroscience & Biobehavioral Reviews.* [2]Raichle and Snyder 2007. *NeuroImage.* [3]Allison et al. 2000. *Nerology*. [4]Koshino et al. 2014. *Sci Rep*. [5]Zhang and Li 2012. *Front Psychol*. [6]Laird et al. 2009. *J. Neurosci.* [7]Pfefferbaum et al. 2009. *Cereb Cortex*. [8]Koshino et al. 2013. *Jap J Phys Psych Psychophys.*