TMS-related evolution of brain functional networks emerging during motor imagery

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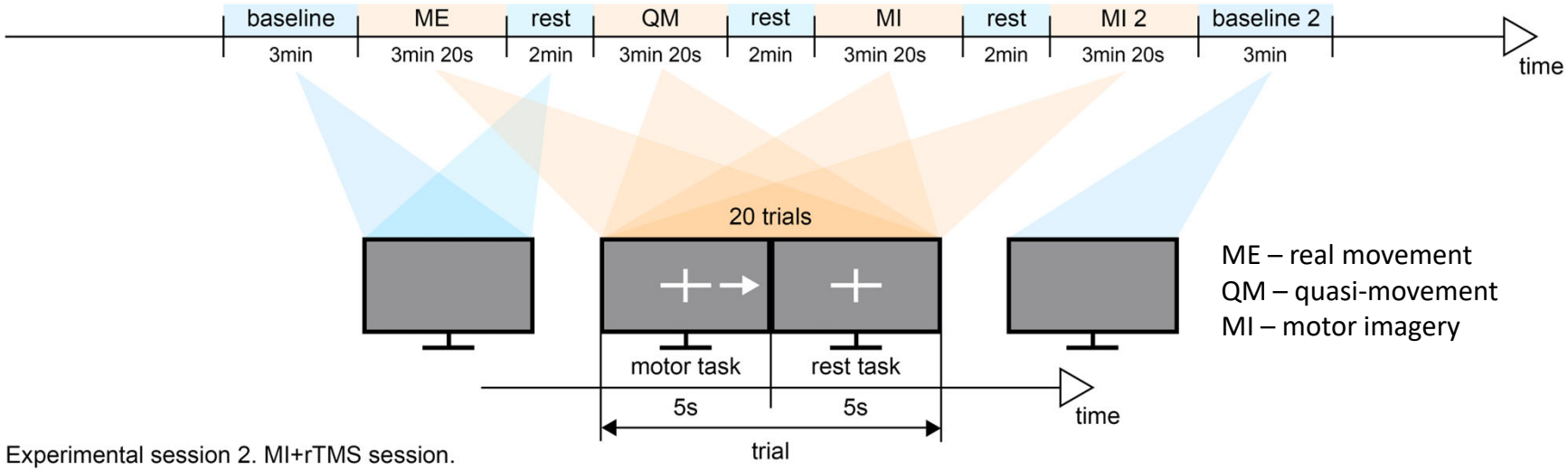
Experiment design.

Day 1: training of kinesthetic motor imagery (MI) with the right hand; determination of the cortical area for subsequent transcranial magnetic stimulation (TMS).

Day 2: investigation of the effect of TMS on the performance of MI.

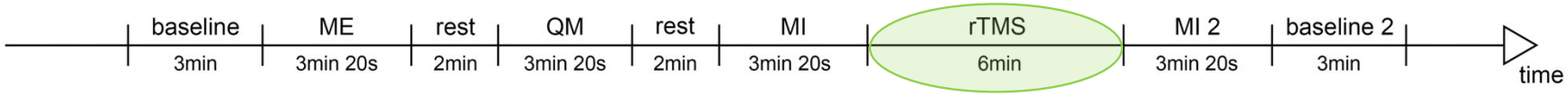
1 trial – making several successive squeezes of the right hand into a fist.

Experimental session 1. MI training session.

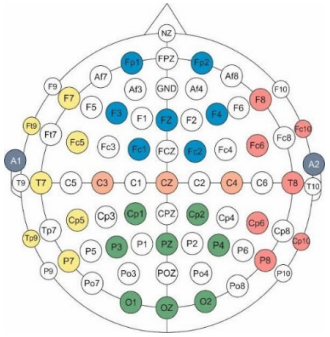


ME – real movement
QM – quasi-movement
MI – motor imagery

Experimental session 2. MI+rTMS session.



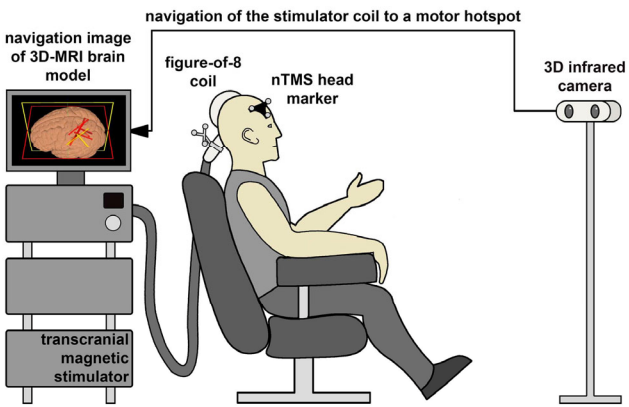
EEG Registration



32 channels with NVX-52 amplifier (MKS, Zelenograd, Russia), 10-10 arrangement scheme

TMS Experiment

rTMS parameters:
Neuro MS/D magnetic stimulator (Neurosoft, Ivanovo, Russia)
Duration – 6 minutes
Frequency – 5 Hz (excitatory effect)
Number of impulses – 1800
Intensity – 90% of individual resting motor threshold (RMT)
Navigation - Localite TMS Navigator system (Localite, Germany)



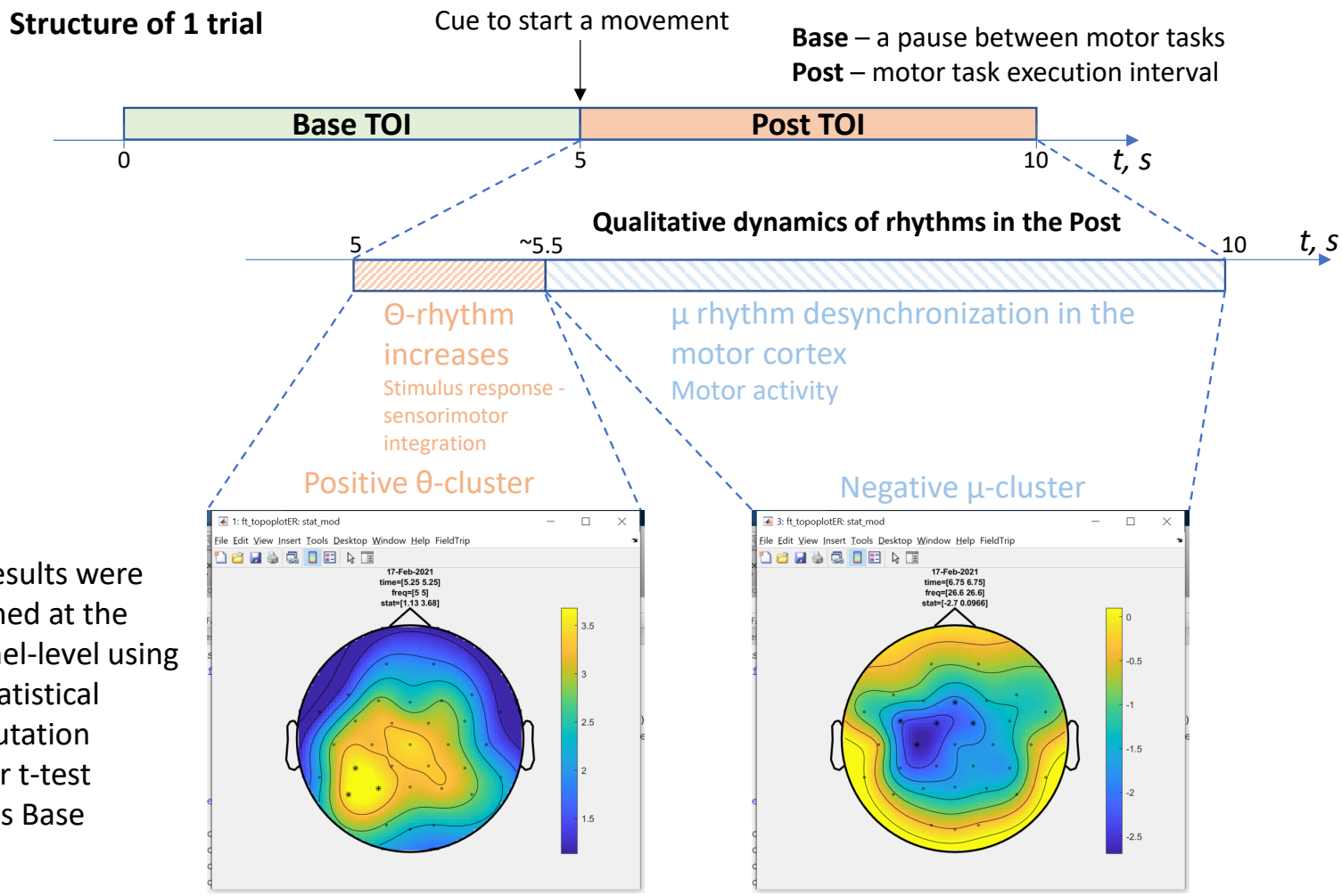
Experiment in the Brain-Machine Interfaces Laboratory of Lobachevsky State University of Nizhny Novgorod

Choosing the rTMS parameters:

The zone of stimulation is the left dorsolateral prefrontal cortex (DLPFC). This zone is unique for MI [Hardwick R. M. et al. Neural correlates of action: Comparing meta-analyses of imagery, observation, and execution //Neuroscience & Biobehavioral Reviews. - 2018. - V. 94]. Confirmation of the zone – the 1st day of the experiment.

The stimulation frequency is 5 Hz, which corresponds to the θ-range [Scheeringa R. et al. // Int. j. of psychophysiology. 67 (3), 2008].

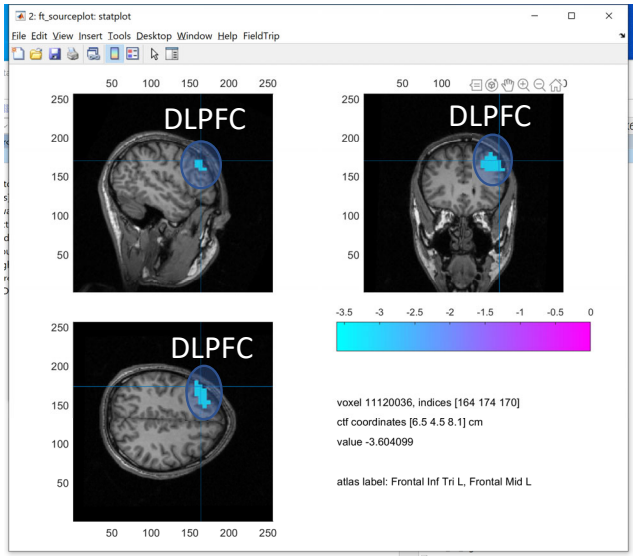
Dynamics of rhythms in the process of motor activity. Choosing times of interest (TOIs)



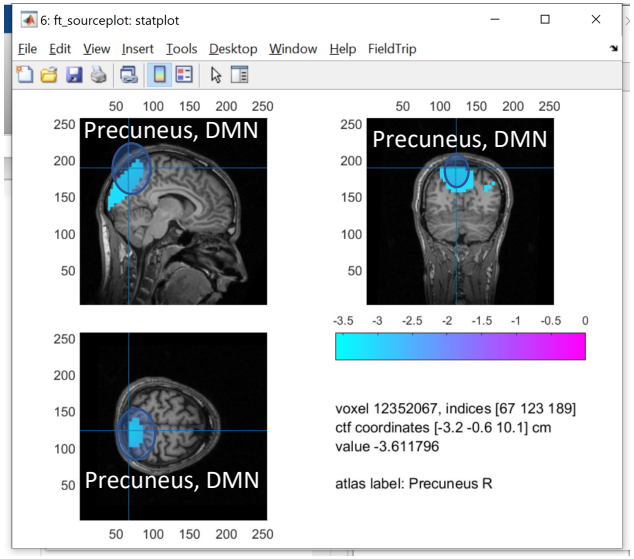
The results were obtained at the channel-level using the statistical permutation cluster t-test Post vs Base

Analysis at the source-level

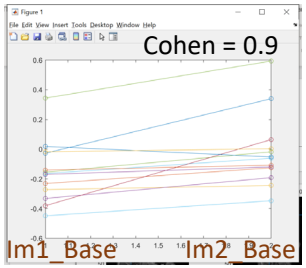
Day 1. Distribution of neuronal activity power – results of statistical within-subject test **Post vs Base** for Im1; f: 12-14Hz; Post: 6.5-8.5s; Base: 4-s rest interval before the cue. The negative cluster is shown where $P_{post} < P_{base}$



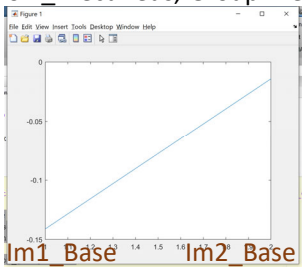
Day 2. Distribution of neuronal activity power – results of statistical within-subject test **Im1_Base vs Im2_Base**; f: 4-8 Hz; Base: rest interval before the cue. The negative cluster is shown where $P_{base2} > P_{base1}$



Pow_Precuneus, individuals



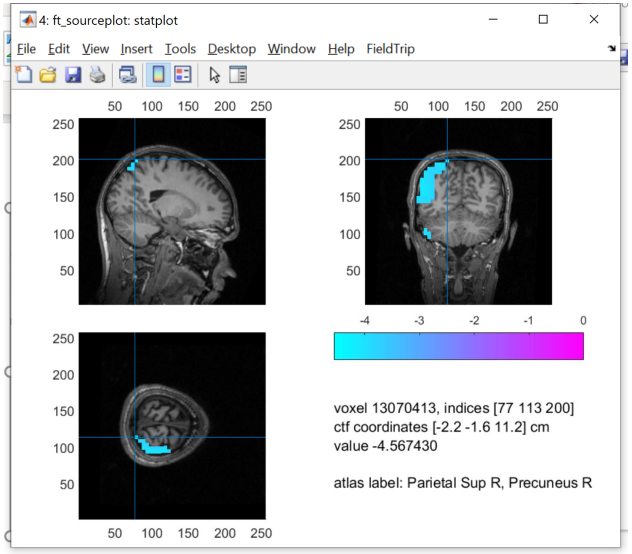
Pow_Precuneus, Group Mean



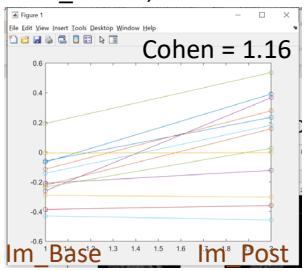
Thus, TMS of DLPFC zone increased the power in the θ-band in the Base interval in the Precuneus R zone, which is an element of the default-mode network (DMN).

TMS preactivates the zone to perform MI

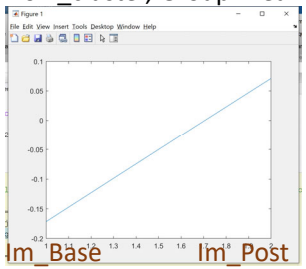
Distribution of neuronal activity power – results of statistical within-subject test **Im_Base vs Im_Post**; f: 4-8 Hz; Post: 5-5.5s; Base: 4-s rest interval before the cue. The negative cluster is shown where $P_{post} > P_{base}$



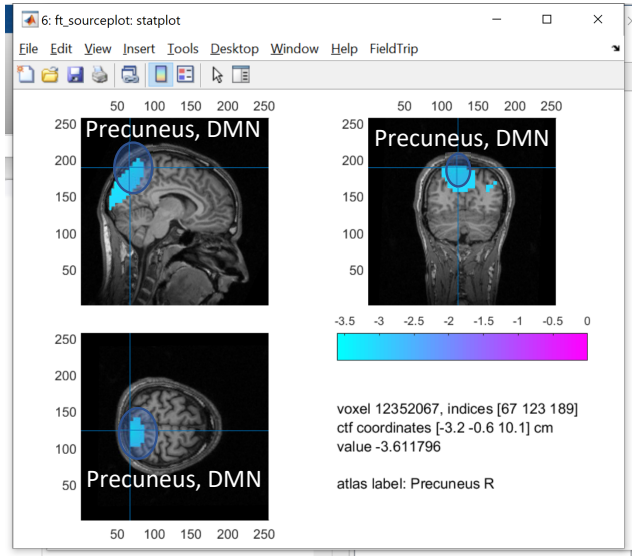
Pow_cluster, individuals



Pow_cluster, Group Mean



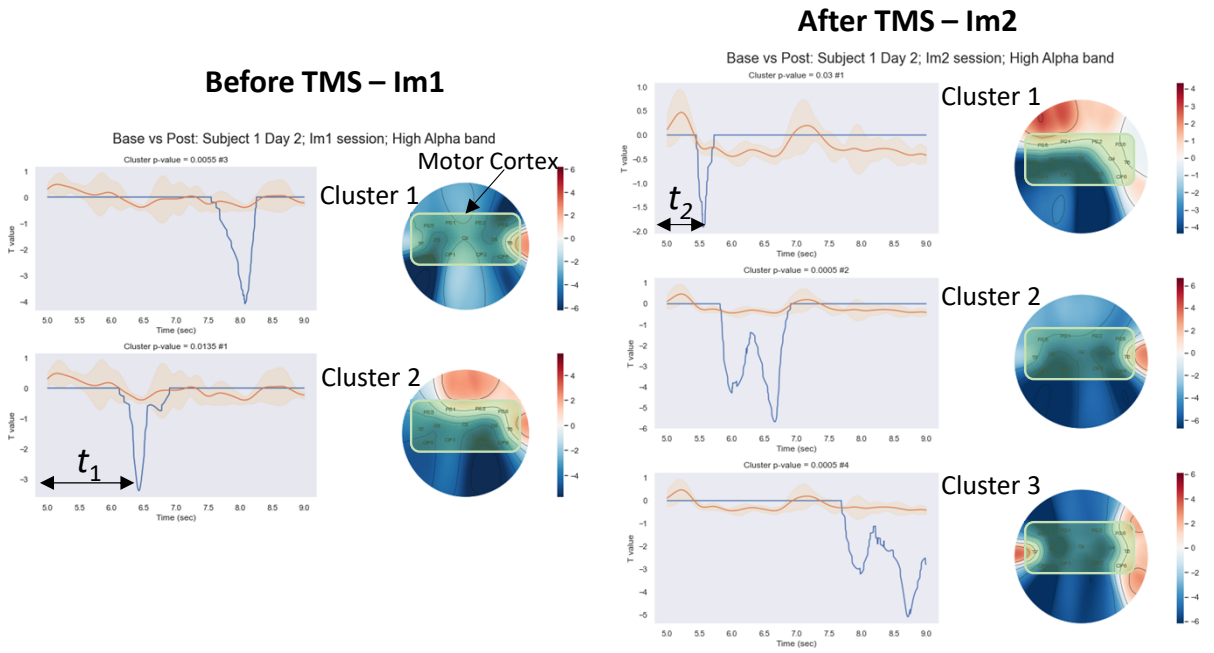
Day 2. Distribution of neuronal activity power – results of statistical within-subject test **Im1_Base vs Im2_Base**; f: 4-8 Hz; Base: rest interval before the cue. The negative cluster is shown where $P_{base2} > P_{base1}$

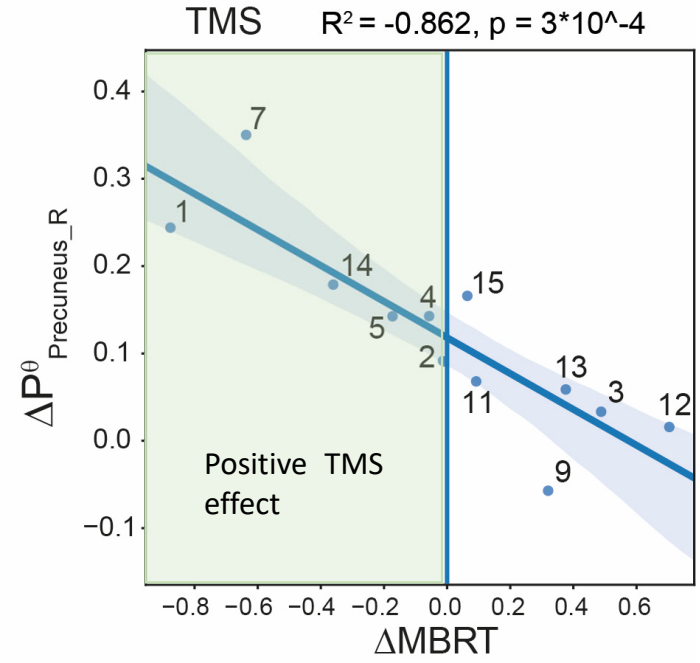


TMS preactivates the zone in the θ-band, similar to the one activated during sensorimotor integration after the command to make a movement; both include Precuneus R.

Assessment of μ-rhythm desynchronization and correlation with TMS preactivation

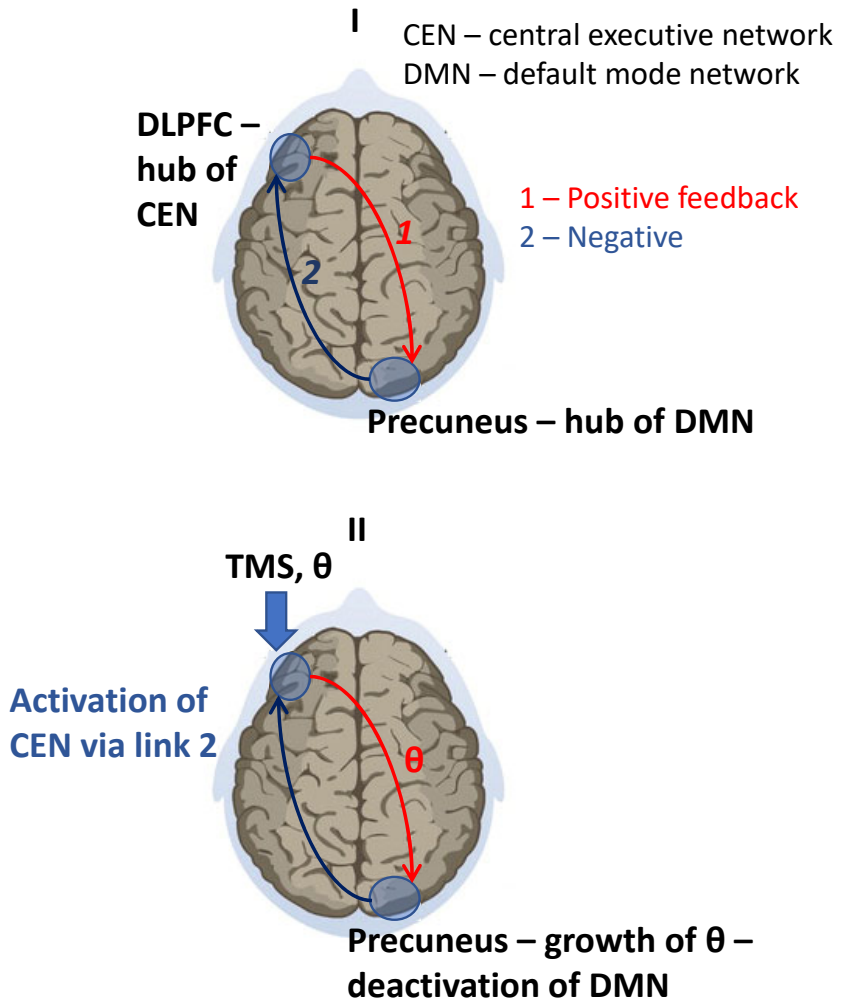
Example of channel-level power distribution for one subject – results of statistical (within-trial test **Post vs Base** in motor cortex for Im1 and Im2; f: 12-14 Hz; Post: 4-s interval after the cue; Base: 4-s rest interval before the cue.





Conclusions

- A strong correlation was found between Precuneus R θ-activation caused by TMS of left DLPFC and MI rate.
- This pattern of activity, i.e., CEN activation and DMN deactivation, is usually observed during task performance and indicates greater attention to external stimuli and tasks and less attention to internal feelings and thoughts [1].
- Thus, it is possible that for a part of the group TMS modulates these key brain networks by turning DMN off and turning CEN on, which provides a transition from an internally focused mental state to a state focused on an external task.



[1] Kumar J. et al. // European archives of psychiatry and clinical neuroscience. 270 (5), 2020, C. 567.

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