THE IMPACT OF BIPOLAR TDCS ON CORTICAL NETWORKS CONNECTIVITY: A GRAPH THEORY STUDY

Miraglia F [1,2] Vecchio F [1], Di Iorio R [2], Granata G [2], Romanello R [2], Rossini PM [2]

fra.miraglia@gmail.com

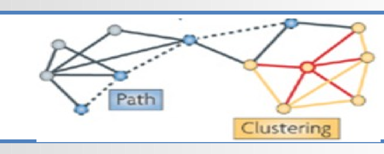
IRCCS San Raffaele Pisana

1) Brain Connectivity Laboratory, IRCCS San Raffaele Pisana, Rome, Italy
2) Institute of Neurology, Catholic University, Rome, Italy

UNIVERSITÀ CATTOLICA del Sacro Cuore

AIM

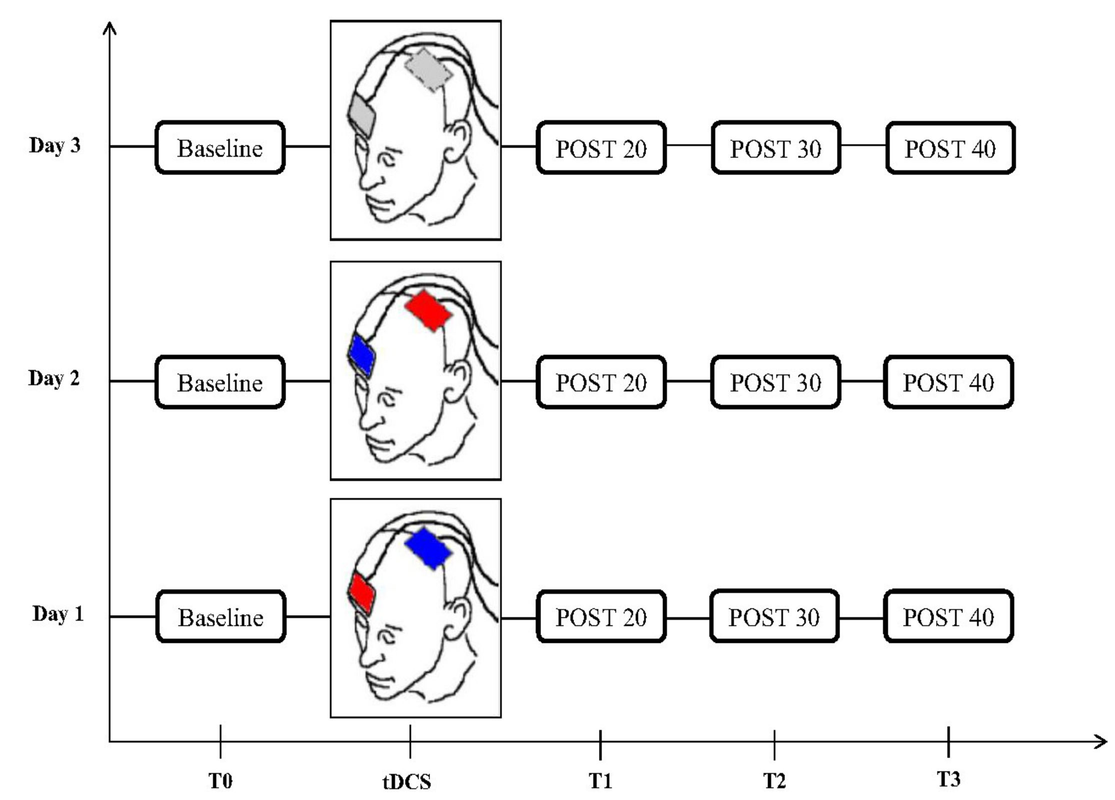
Aim of this study is to investigate -through graph theory analysis- how bipolar tDCS modulate cortical networks in healthy subjects.



PARTECIPANTS AND STIMULATION PROTOCOL

14 subject participated in three single blind, randomized experimental sessions of anodal, cathodal or sham tDCS. Each session was separated by at least 24 hours from the other.

Electroencephalographic signals were recorded from 57 electrodes (NEURO PRAX® EEG NeuroConn GmbH) in four blocks, each one lasting 10 minutes (5 with eyes opened and 5 with eyes closed) as follows:
T0 (before tDCS), T1 (20 minutes after tDCS), T2 (30 minutes after tDCS), T3 (40 minutes after tDCS)
In order to reach optimal contact between the electrodes for tDCS the EEG cap was removed after T0 and re-placed following tDCS.



tDCS (NeuroConn GmbH, Ilmenau, Germany) was applied through square rubber electrodes (surface 25 cm^2) with fixed amplitude of 1000 μA for 12 minutes every time with a 30 s ramp of fade-in and fade-out.

Anodal tDCS was performed after placing the anode over the M1 of the dominant hemisphere and the reference over the frontopolar cortex of the controlateral hemisphere, while cathodal stimulation was performed by changes polarities in the bipolar montage.
In the tDCS sham condition current was ramped in for 30 s at the beginning of the stimulation and ramped out for another 30 s at the end of the session and no electrical stimulation was delivered during the remaining 11 minutes of the sham session.

EEG INVERSE PROBLEM

Brain connectivity of both hemispheres, separately and together, was computed by eLORETA software, on 42 ROIs based on 42 Brodmann areas for the left and 42 Brodmann areas for the right hemisphere (BAs: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47). ROIs are needed for the estimation of electric neuronal activity that is used to analyze brain functional connectivity.

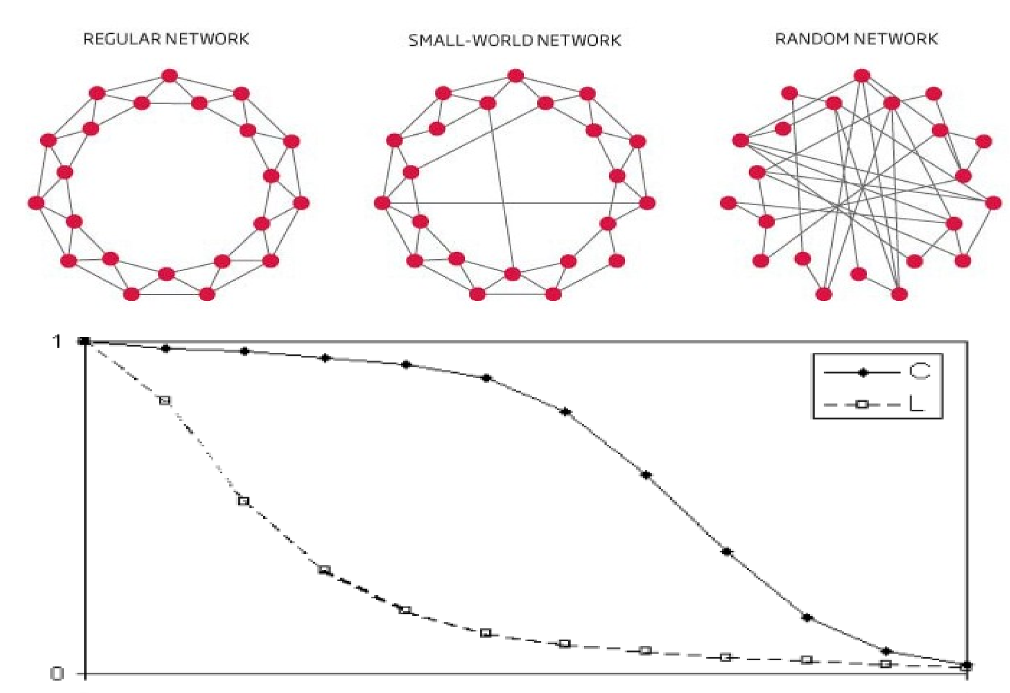
FUNCTIONAL CONNECTIVITY OF CORTICAL SOURCES OF CEREBRAL RHYTHMS

eLORETA intracortical lagged linear coherence in the frequency band ω

$$LagR^2_{xy\omega} = \frac{[ImCov(x,y)]^2}{Var(x)\,x\,Var(y) - [ReCov(x,y)]^2}$$

GRAPH ANALYSIS

Undirected and weighted network were built based on the connectivity between the eLORETA ROIs.
The nodes of the network are 42 ROIs for left and right hemisphere, corresponding to 42 Brodmann Areas.
The edges of the network are weighted by the lagged linear connectivity values.

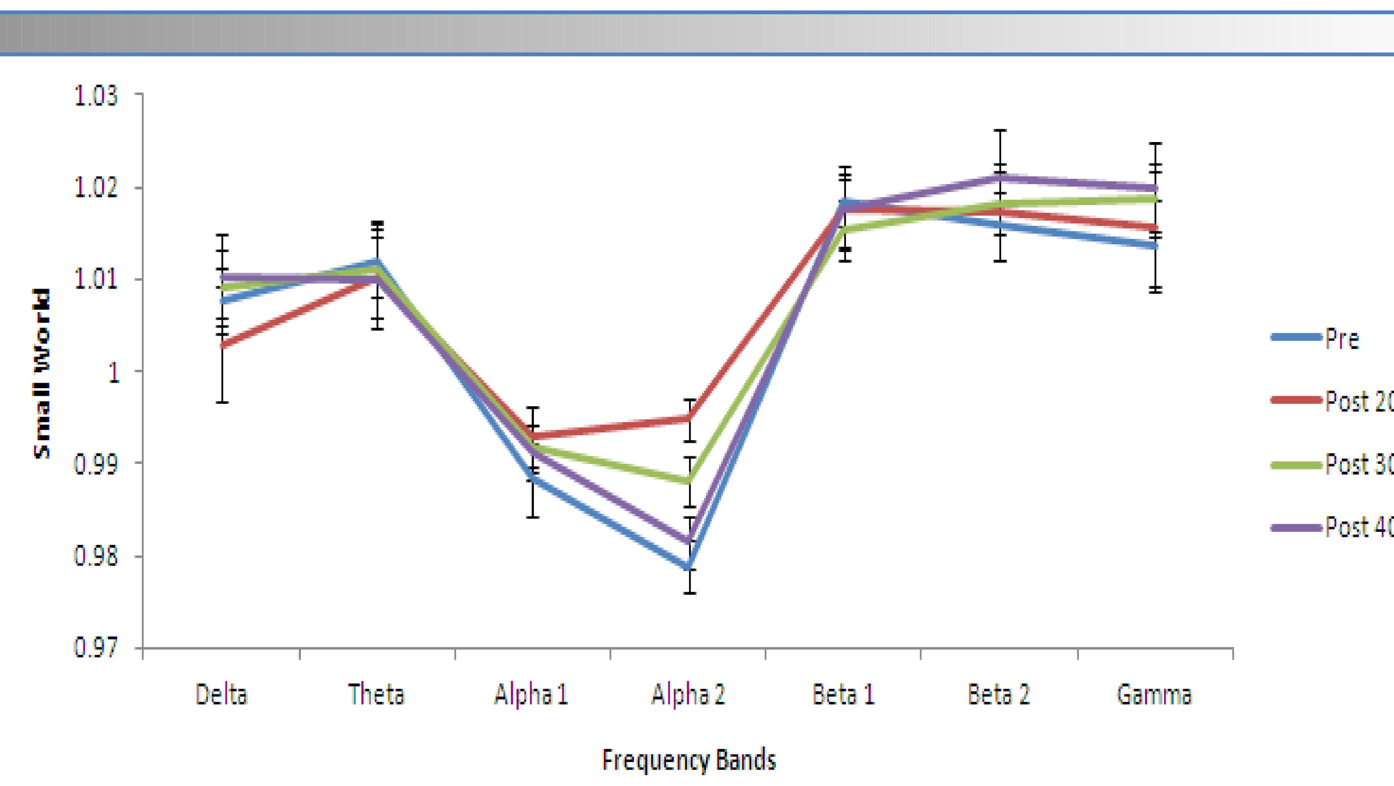


PARAMETERS

Brain network properties are well described by Small World index, which combines high level of local clustering C and short paths L that link network's nodes. It is defined as a balance between the local connectedness and the global integration of a network.
Small-worldness (SW) parameter is defined as the ratio between C and L individually normalized respect to the frequency bands.

RESULTS

ANOVA interaction showed that Small Worldnessy had statistically significant interaction ($F(36,468)=1.52$; $p=0.0296$) among the factors Time (T0, T1, T2, T3), Stimulation (Anodic, Cathodic, Sham) and Band (delta, theta, alpha 1, alpha 2, beta 1, beta 2, gamma).
Statistical differences were observed only in anodic stimulation, suggesting a selective effect of anodal tDCS (namely in the higher alpha band (alpha 2) SW in Pre was lower than those in Post 20 ($p=0.000357$), Post 30 ($p=0.05$), while SW in Post 40 was lower than in Post 20 ($p=0.006344$).
No statistical differences were found between Post 20 and Post 30, Post 30 and Post 40, and Pre and Post 40.



Results showed that, after bipolar anodal tDCS stimulation brain networks presented a less evident "small world" organization with a global tendency to be more random in its functional connections respect to prestimulus condition in both hemispheres.

CONCLUSIONS A statistically significant global increase of randomness networks architecture of both hemispheres in alpha 2 band, measured as an increase of SW index, after bipolar anodal tDCS performed was observed; this effect was transient as the baseline condition was regained 40 minutes after the end of exposure. Increasing randomness did not reach statistical threshold after cathodal or sham stimulations, suggesting a selective effect of anodal tDCS.
Results suggest that tDCS globally modulates the cortical connectivity of the brain, modifying the underlying functional organization of the stimulated networks, which might be related to changes in synaptic efficiency of the motor network and related brain areas.

SIGNIFICANCE This study demonstrated that graph analysis approach to EEG recordings is able to intercept changes in cortical functions mediated by bipolar anodal tDCS mainly involving the dominant M1 and related motor areas. Concluding, tDCS could be an useful technique to help understanding brain rhythms and their topographic functional organization and specificity.

Fabrizio Vecchio, Riccardo Di Iorio, Francesca Miraglia, Giuseppe Granata, Roberto Romanello, Placido Bramanti and Paolo Maria Rossini. Transcranial direct current stimulation generates a transient increase of small worldnessy in brain connectivity: an EEG graph theoretical analysis. Neuroscience. Under review