FUNCTIONAL BRAIN COMPENSATION AFTER LESION

UNDERSTANDING COMPENSATORY MECHANISMS

USING VIRTUAL LESIONS AND NETWORK MODELS

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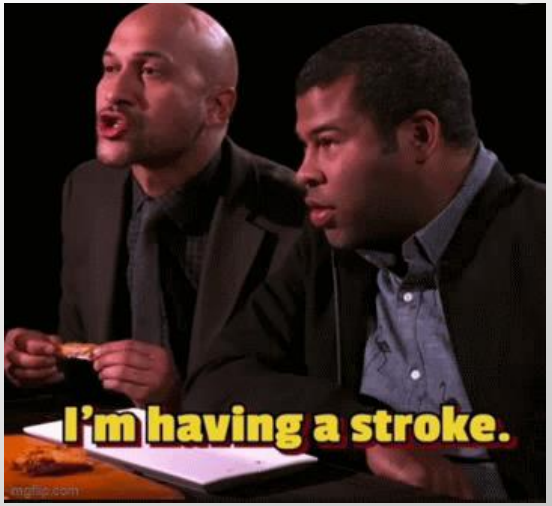
BACKGROUND

- WHAT IS A STROKE?



WHY SIMULATE A LESION?

- **IGNORING TEMPORAL AND ADAPTIVE REORGANIZATION**

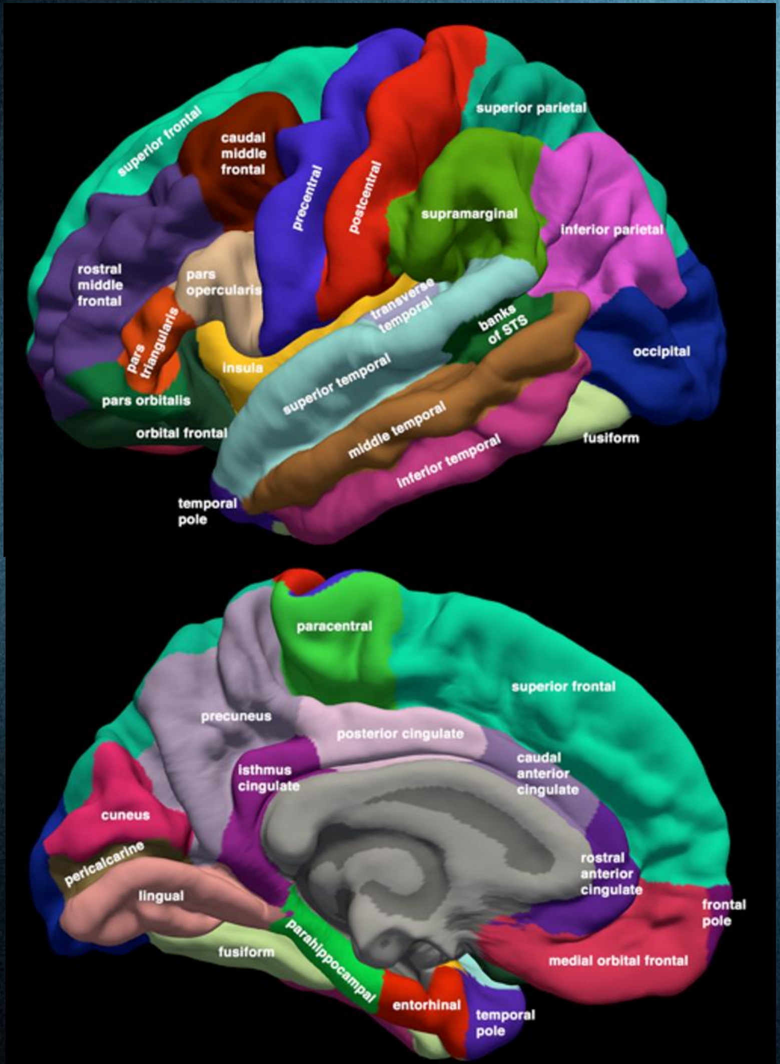
  CONVENTIONAL MODELS OFTEN TREAT BRAIN DAMAGE AS A STATIC INSULT, FAILING TO CAPTURE THE **DYNAMIC REORGANIZATION AND PLASTICITY**

- **IMPROPER CONSIDERATION OF CAUSAL PATHWAYS OF RECOVERY**

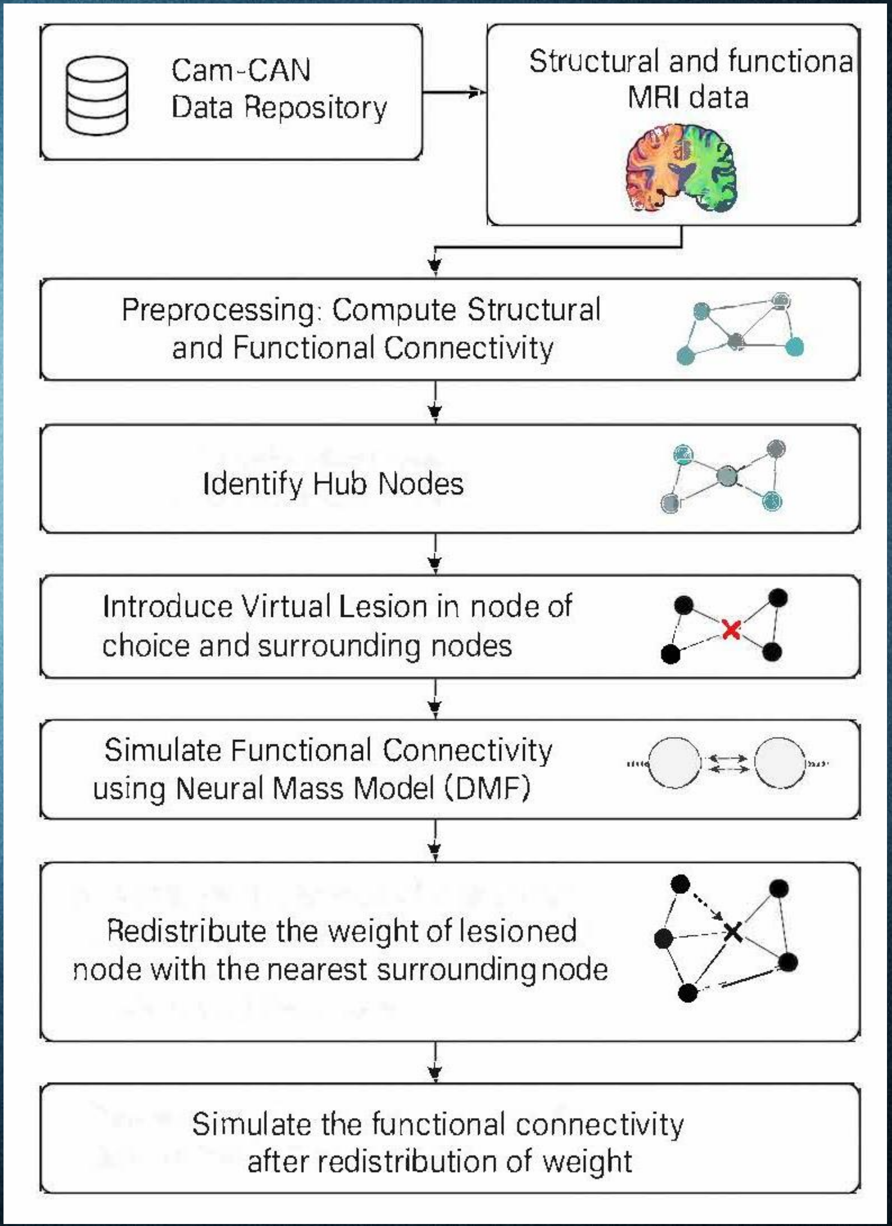
OBJECTIVE

- CAN NEARBY REGIONS HELP COMPENSATE FOR LOST FUNCTION AFTER LESIONS?
- HYPOTHESIS: ANATOMICAL SIMILARITY PREDICTS RECOVERY VIA VIRTUAL LESION MODELS.

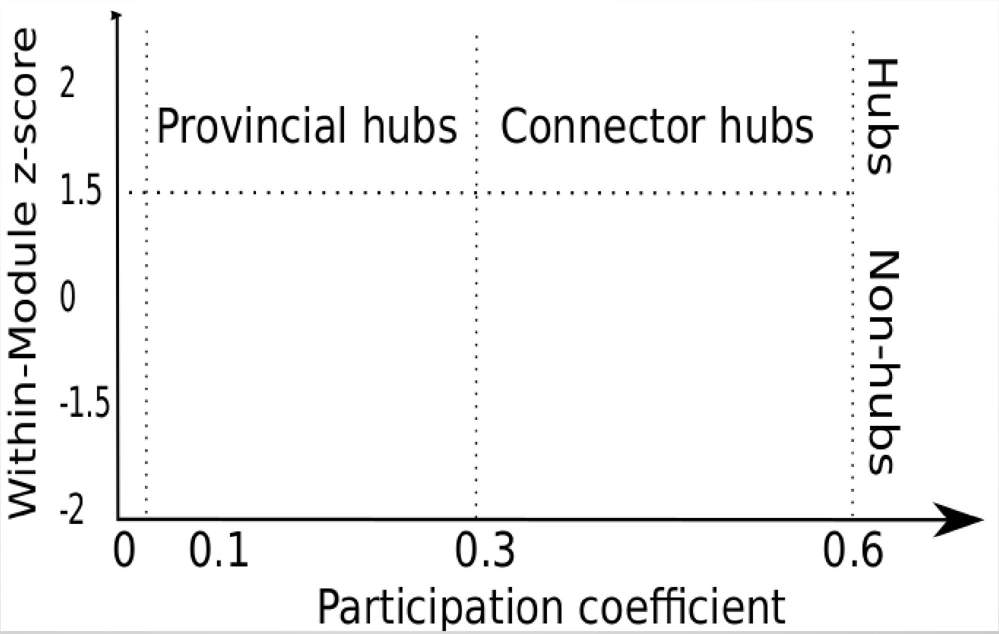
ANALYSIS PIPELINE



Desikan-Killiany atlas(cds.ismrm.org)

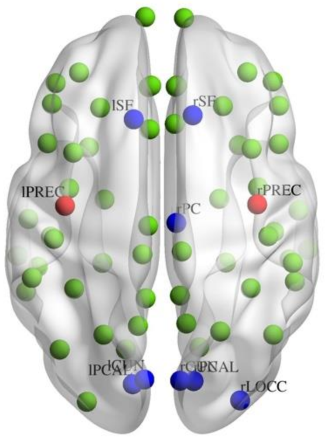


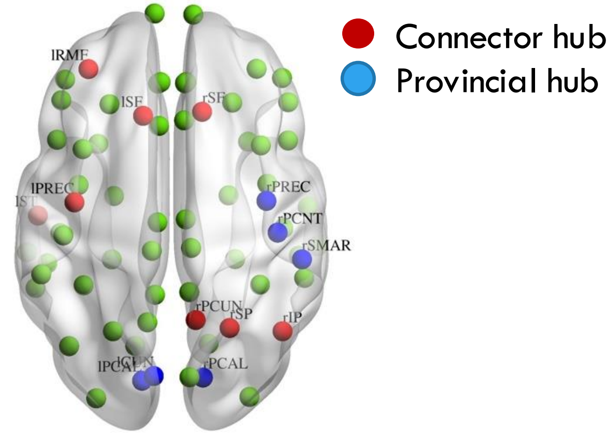
IDENTIFICATION OF CONNECTOR & PROVINCIAL HUBS

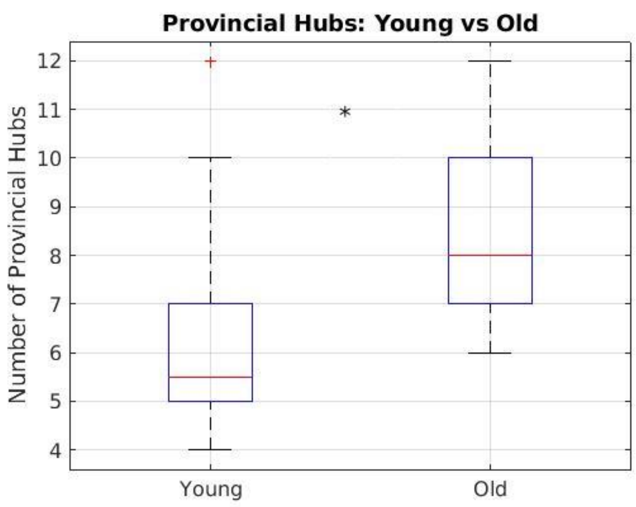


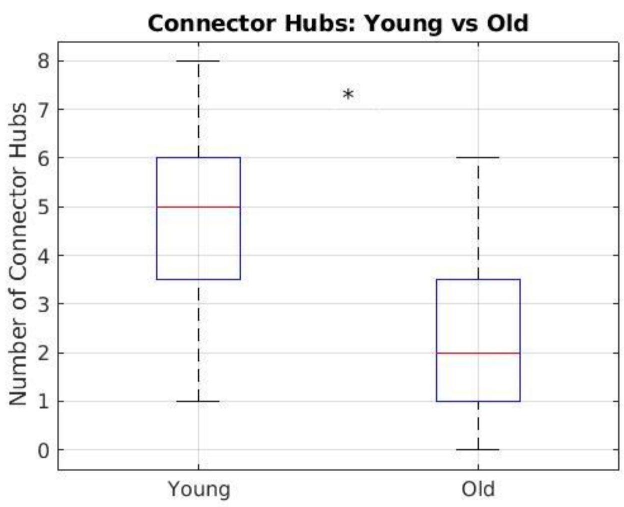
Interesting finding:

Younger brains have higher number of connector hubs in comparison to provincial hubs





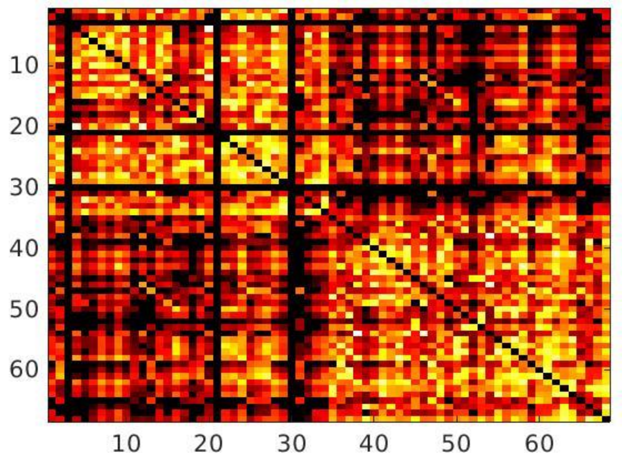




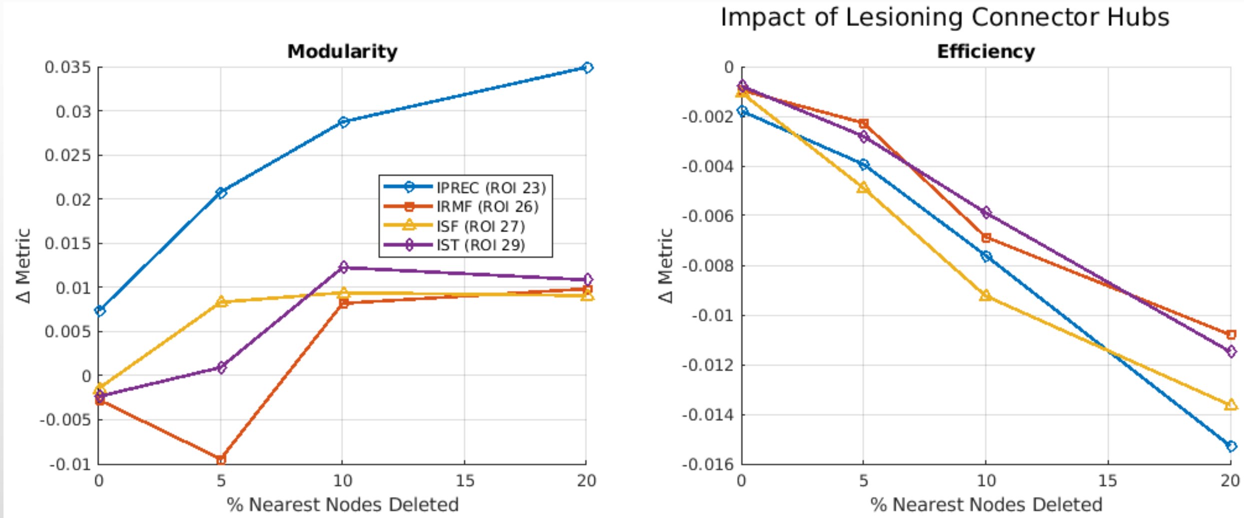
N =16 for both groups; Unpaired t-test, Two-tailed, p<0.05

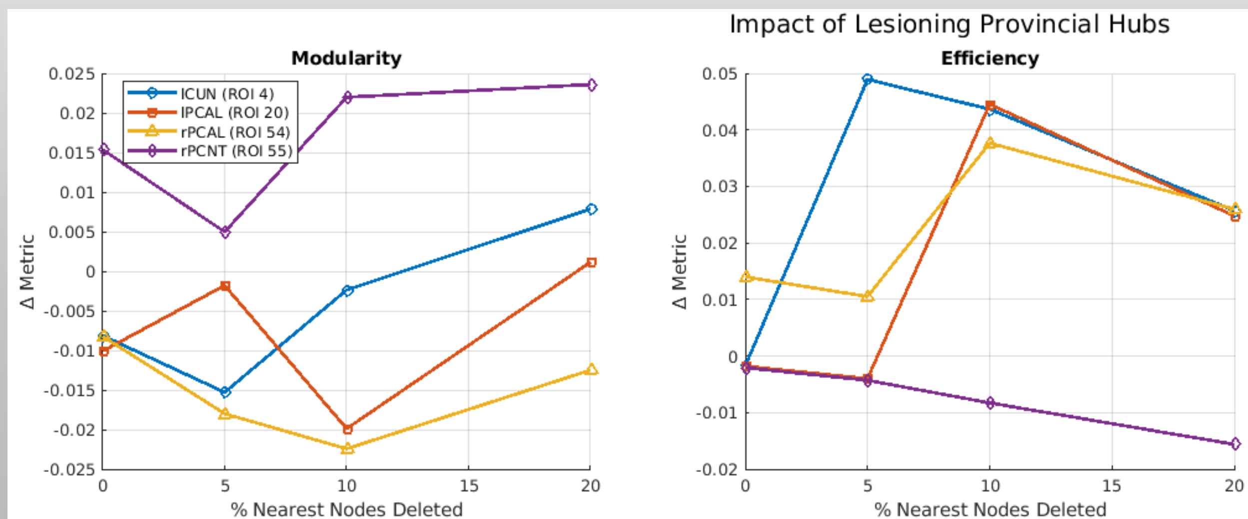
INTRODUCTION OF VIRTUAL LESION

Lesioned Strctural connectivity



Center Name	Coordinate	5% nearest nodes
lPREC	(-5.7, -18.3, 38.4)	lCMF,lPCNT,lSMAR
lPOPE	(-45.7,14.5, 11.8)	lPTRI, lINS, lRMF
rMT	(58.2, -27.9, -13.5)	rIT,rST,rBSTS


Impact of Lesioning Connector Hubs
Modularity
Efficiency
lPREC (ROI 23)
lRMF (ROI 26)
lSF (ROI 27)
lST (ROI 29)
Δ Metric
% Nearest Nodes Deleted


Impact of Lesioning Provincial Hubs
Modularity
Efficiency
lCUN (ROI 4)
lPCAL (ROI 20)
rPCAL (ROI 54)
rPCNT (ROI 55)
Δ Metric
% Nearest Nodes Deleted

DYNAMIC MEAN FIELD (DMF) MODEL

Pipeline of Analysis

$$I_i^{(E)} = W_E I_0 + w_+ J_{NMDA} + G J_{NMDA} \sum_j C_{ij} S_j^{(E)} - J_i S_i^{(I)} \tag{1}$$

$$I_i^{(I)} = W_I I_0 + J_{NMDA} S_i^{(E)} - S_i^{(I)} \tag{2}$$

Excitatory and inhibitory current of an area i

$$r_i^{(E)} = \frac{a_E I_i^{(E)} - b_E}{1 - e^{(-d_E (a_E I_i^{(E)} - b_E))}} \tag{3}$$

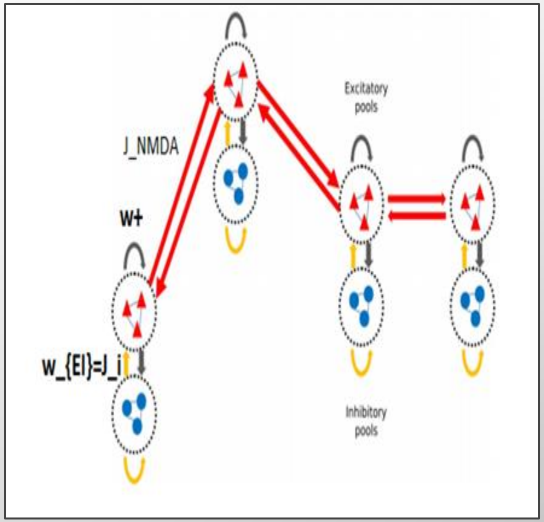
$$r_i^{(I)} = \frac{a_I I_i^{(I)} - b_I}{1 - e^{(-d_I (a_I I_i^{(I)} - b_I))}} \tag{4}$$

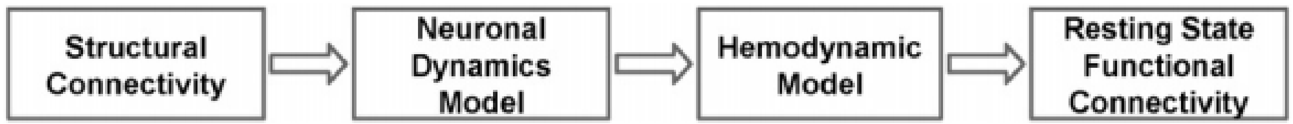
Firing rate for Excitatory and inhibitory Population area i

$$\frac{dS_i^{(E)}}{dt}(t) = -\frac{S_i^{(E)}}{\tau_E} + (1 - S_i^{(E)}) \gamma r_i^{(E)} + \sigma v_i(t) \tag{5}$$

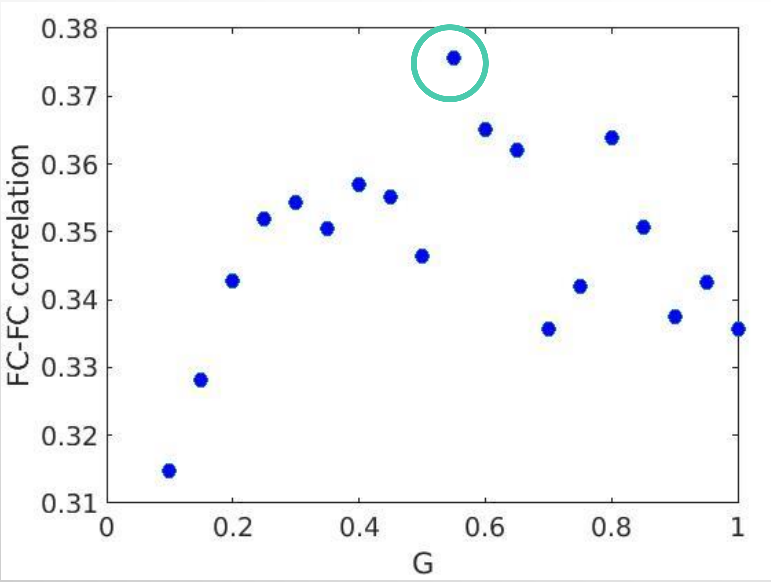
$$\frac{dS_i^{(I)}}{dt}(t) = -\frac{S_i^{(I)}}{\tau_I} + r_i^{(I)} + \sigma v_i(t) \tag{6}$$

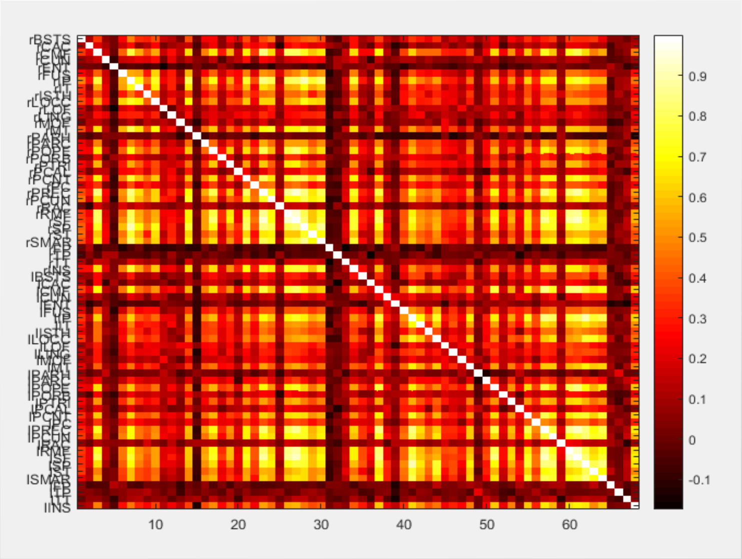
Synaptic gating variables for excitatory and inhibitory population





PARAMETER OPTIMIZATION





Optimal value of G=0.55

Weight redistribution: The road to recovery?

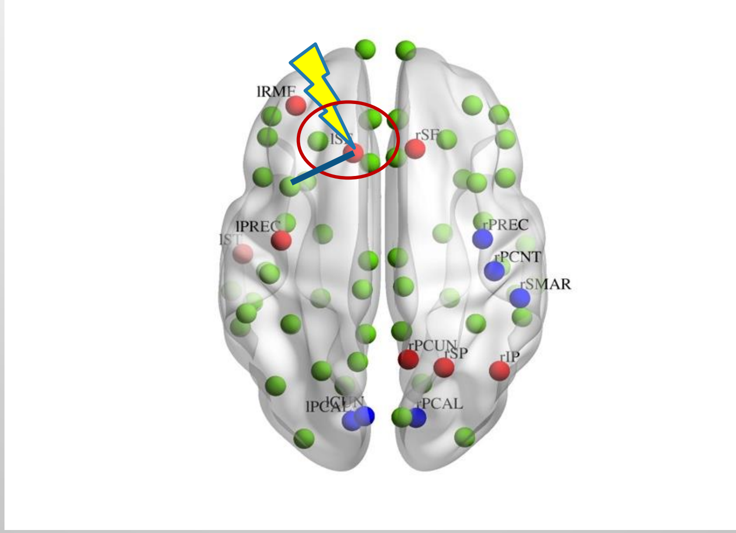
$$\text{Recovery Quotient (RQ)} = \frac{norm\ (FCUnlesioned, FCRe_{distributed})}{norm(FCUnlesione_{d}, FCLe_{sioned})}$$

RQ < 1 : Redistribution of weight drives the network closer to empirical functional network

RQ > 1 : Redistribution of weight drives the network away from empirical functional network

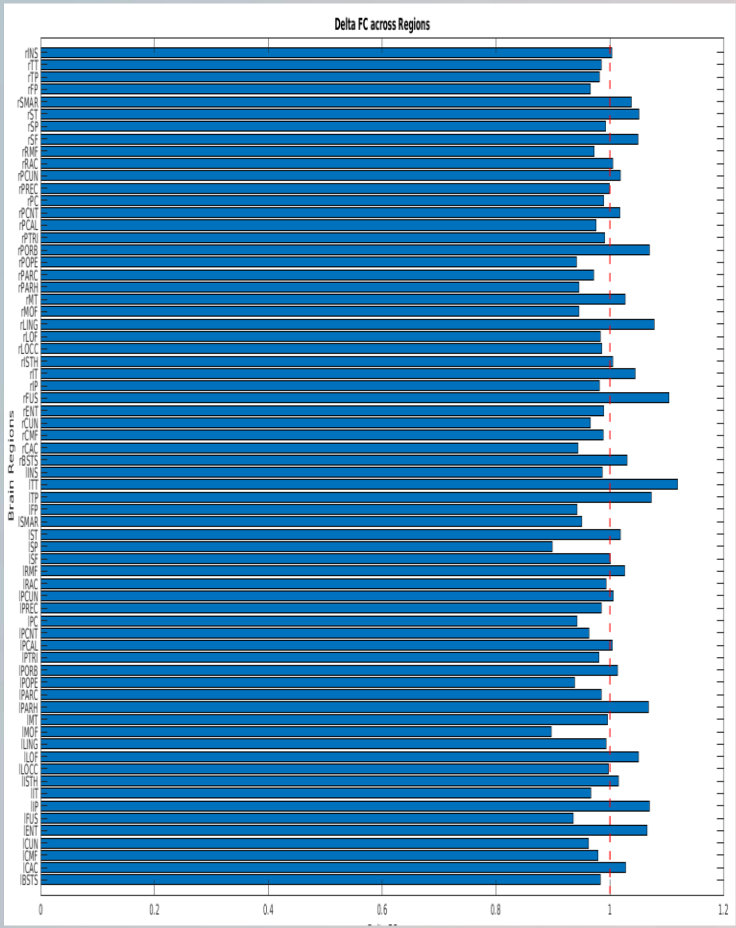
LESION SIMULATION EXAMPLE

- LESION AT LEFT CONNECTOR HUB (E.G LSF)
- SF AND NEAREST 5% NODE DELETED
- IDENTIFY THE MOST SIMILAR NODE WITH SF (STRONGEST WEIGHT)
- STRUCTURAL CONNECTIVITY (SC) UPDATED: REDISTRIBUTE THAT WEIGHT AMONG NEAREST 5% NODE OF THE LESION NODE (E.G LSF)
- •SIMULATED FC REVEALS ALTERED PATTERNS OF COMPENSATION

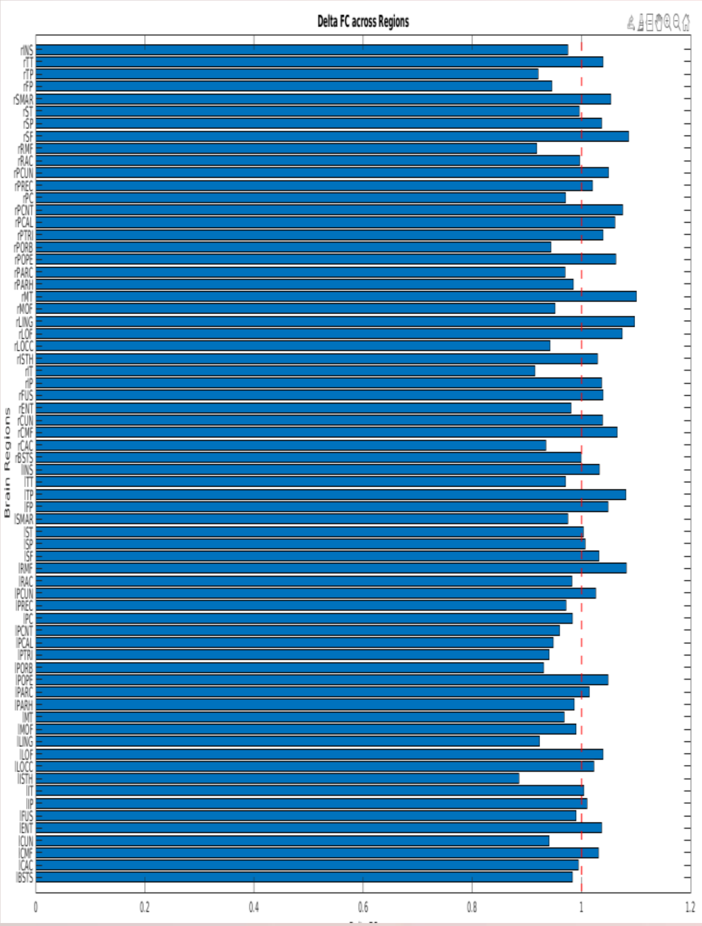


Deleting nearest nodes show higher recovery towards empirical functional connectome

5%

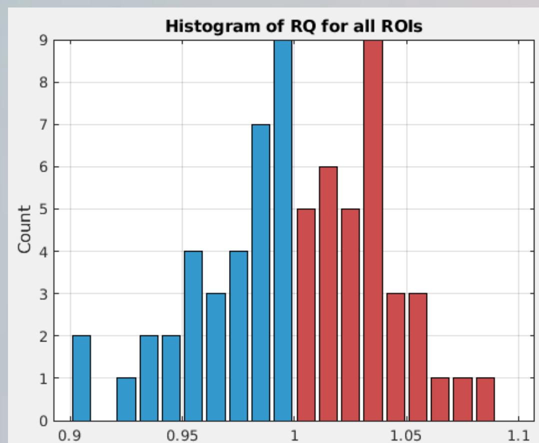


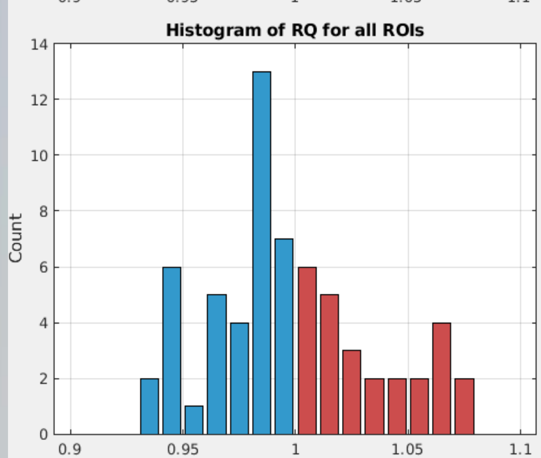
10%



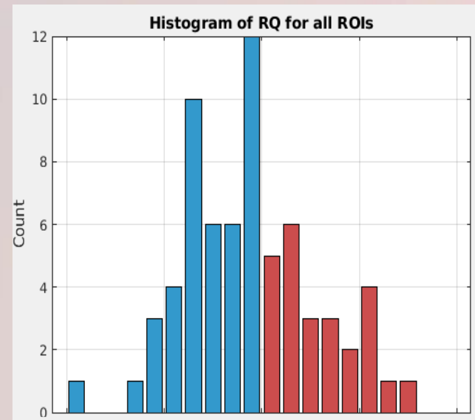
Redistribution of weight to nearest nodes show higher recovery towards empirical functional connectome

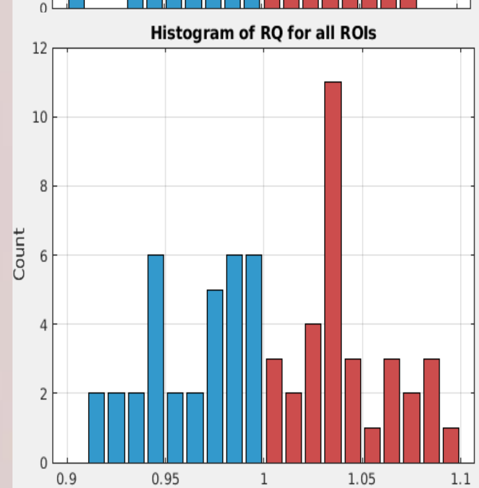
Redistribution of weight near 5% neighbour





Redistribution of weight near 10% neighbour





CONCLUSION

- OUR SIMULATION SHOWS THAT POST-LESION REDISTRIBUTION OF WEIGHT WITH THE NEAREST NEIGHBOUR CAN AID IN RECOVERY OF THE FUNCTIONAL CONNECTOME TOWARDS THE UNLESIONED CONDITION