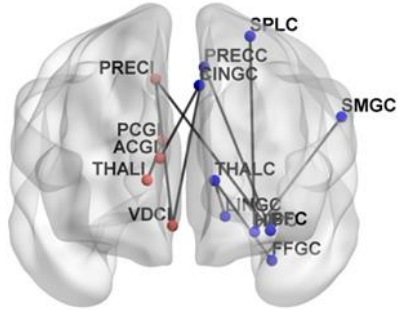
Osher Lifelong Learning Institute
Our Brains: An Operator's Manual – 11/9/2021

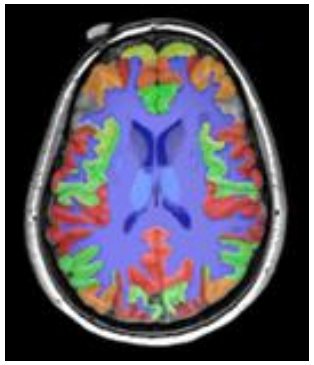


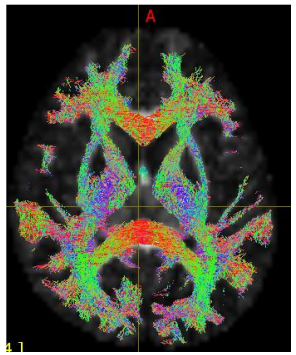
Brain Fingerprints with MRI

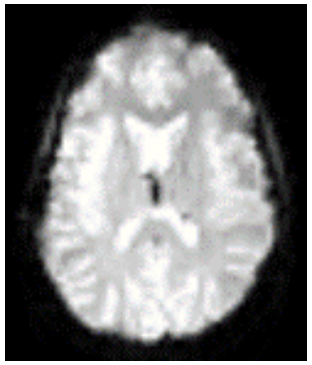
Victoria Morgan, PhD

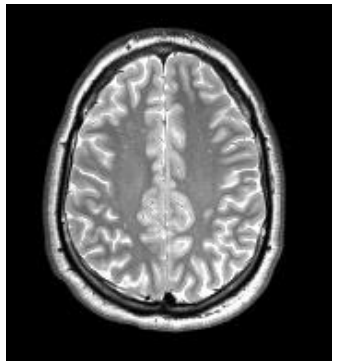
Professor

Vanderbilt University Institute of Imaging Science









VUIIS

Imaging & Engineering:
Catie Chang, PhD
Adam Anderson, PhD
Baxter Rogers, PhD
Bennett Landman, PhD
John Gore, PhD
Lucas Sainburg
Kurt Schilling, PhD
Hernan Gonzalez
Sarah Goodale
Graham Johnson
Andrew Jansen, PhD

Neurology:
Bassel Abou-Khalil, MD
Monica Jacobs, PhD

Neurosurgery:
Dario Englot, MD, PhD

VUIIS Human Imaging Core

Funding:
NIH R01 NS075270
NIH R01 NS108445
NIH R01 NS110130
NIH R01 NS097618 (DJE)

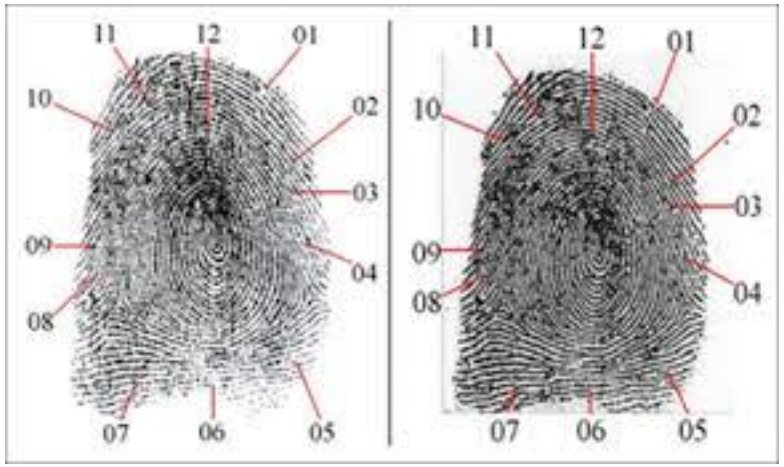
VUMC Neurosurgery
@VUMC_Neurosurg

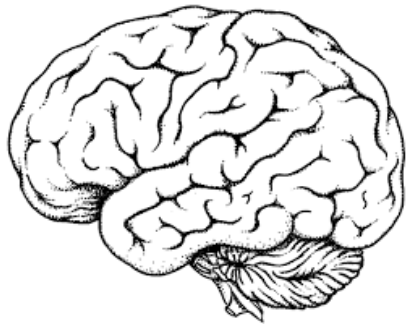
victoria.morgan@vanderbilt.edu

Why FINGERPRINT?

pattern

unique



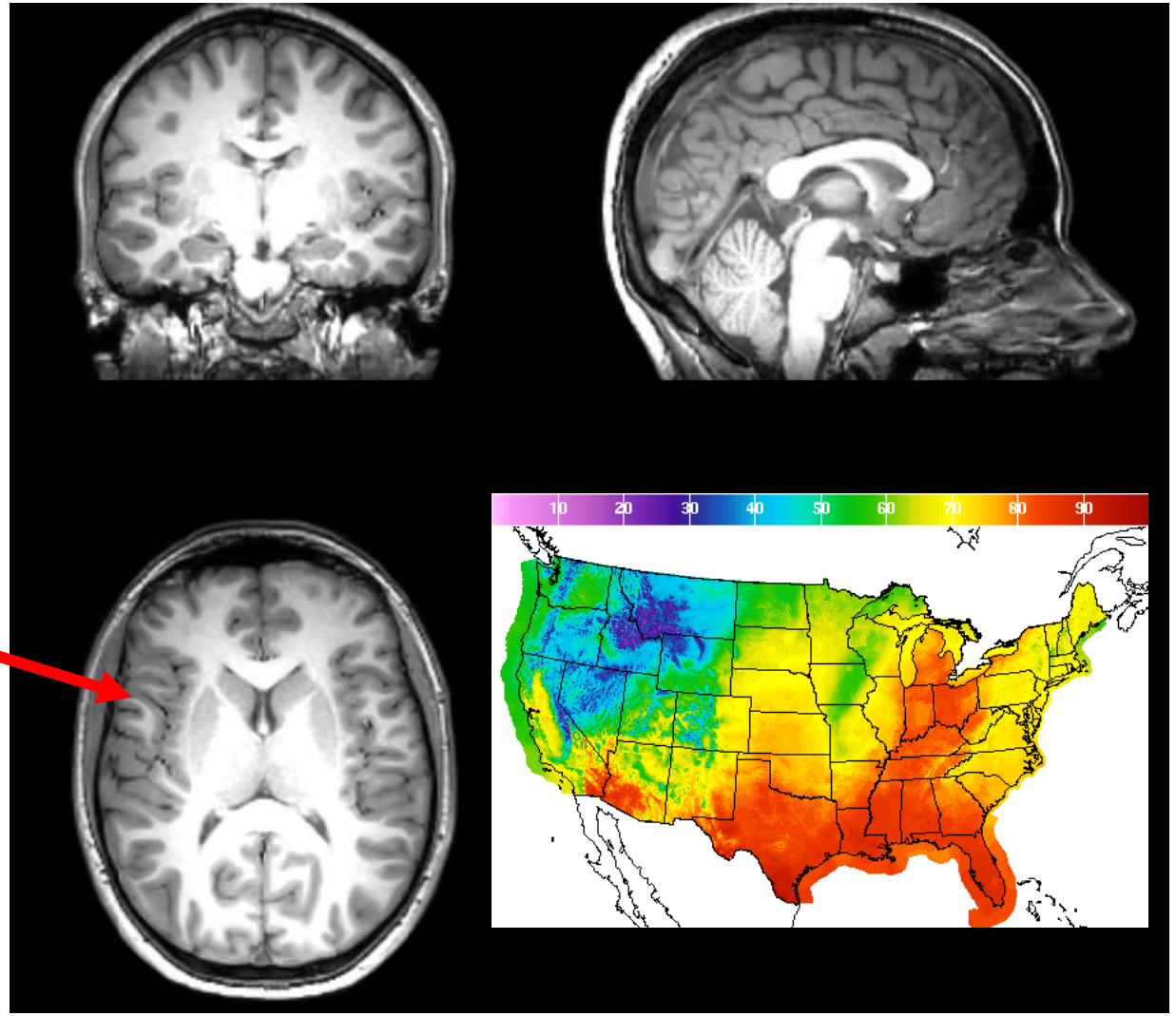


?

Magnetic Resonance Imaging - MRI

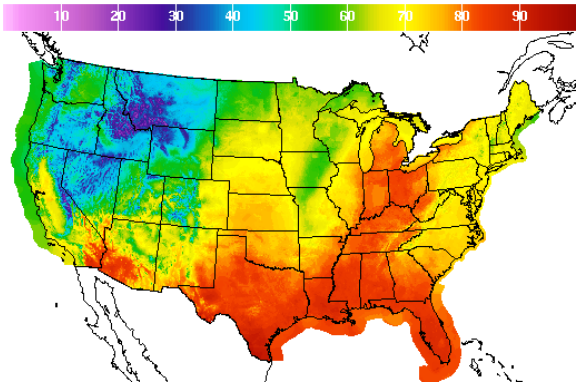
Makes an image from *tissue properties*

➡ parametric maps

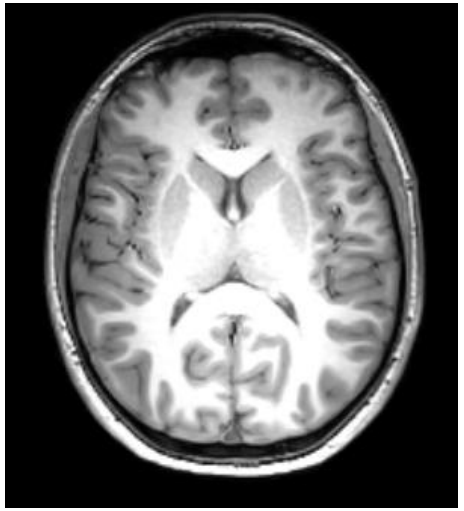


Magnetic Resonance Imaging - MRI

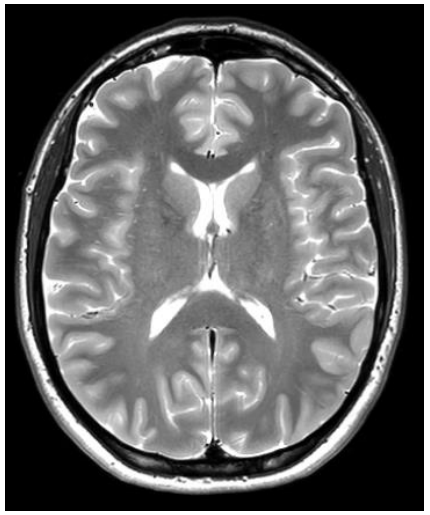
Makes an image from *tissue properties*



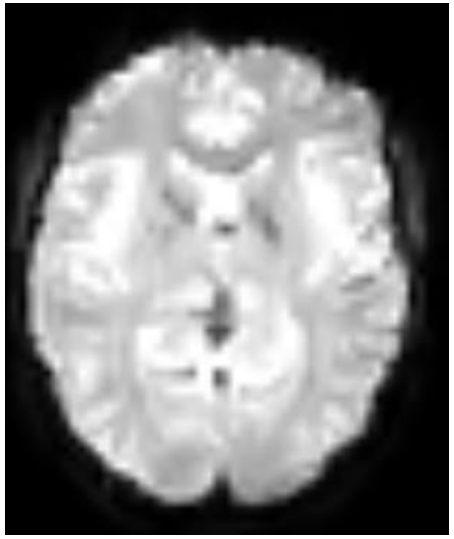
T1 weighted



T2 weighted



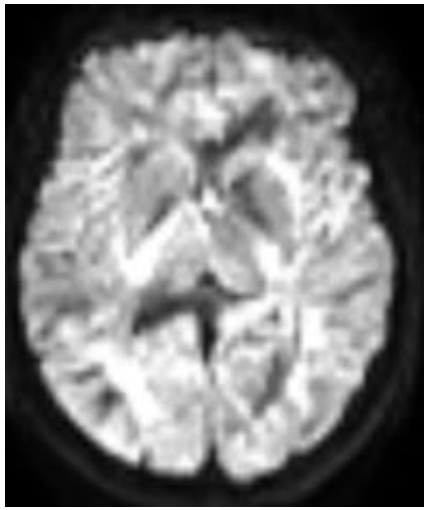
fMRI



Functional MRI

Intensity =
Oxyhemoglobin to deoxyhemoglobin ratio (BOLD) = Brain activity

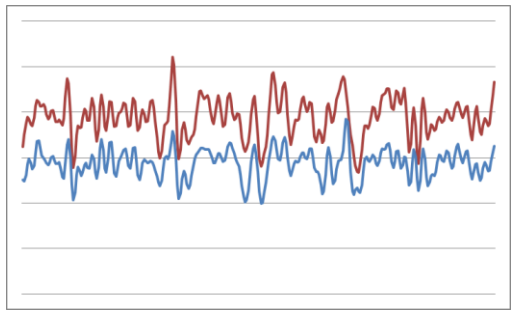
dMRI



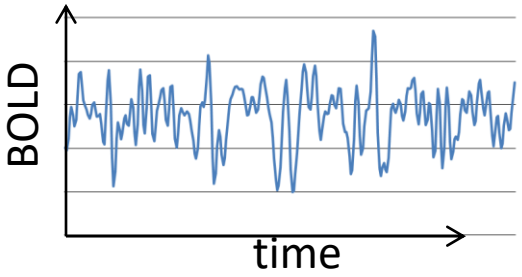
Diffusion Weighted MRI

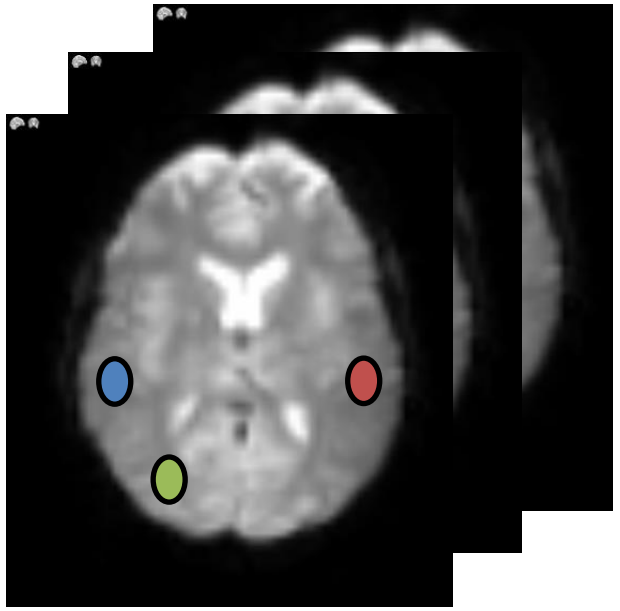
Intensity =
how much water diffuses along a specific axis

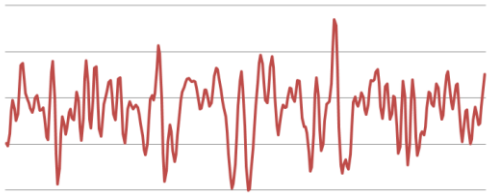
Functional MRI Connectivity

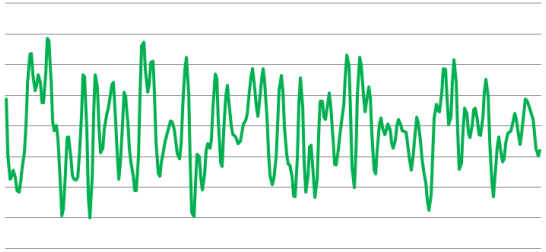


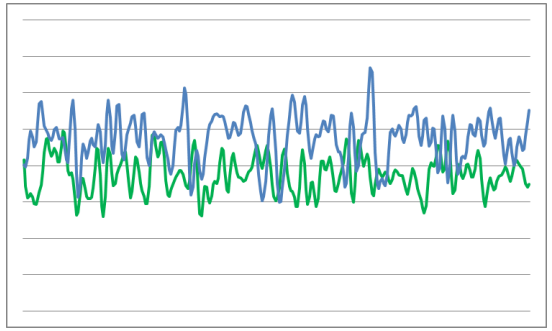
High linear correlation =
High functional connectivity







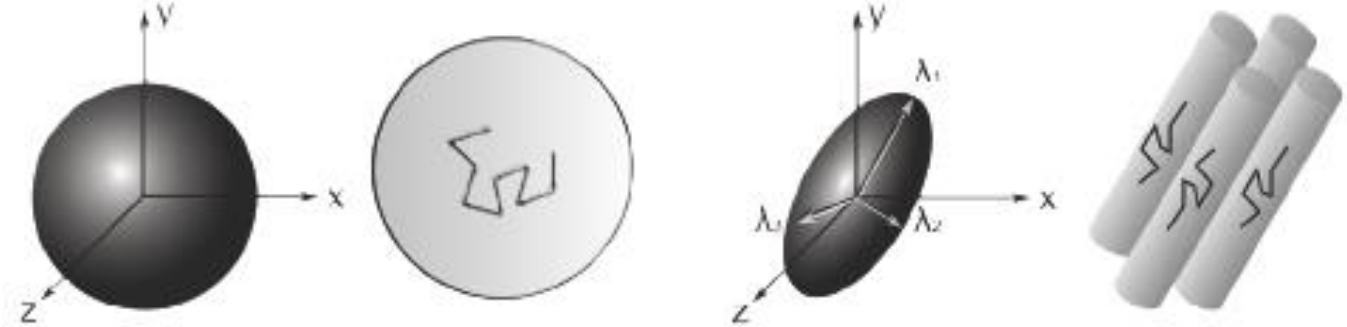




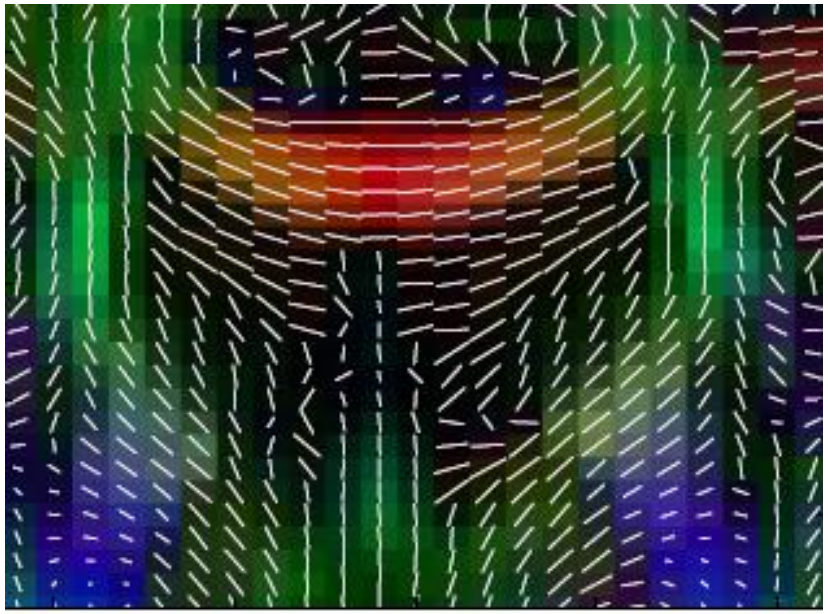
Low linear correlation =
Low functional connectivity

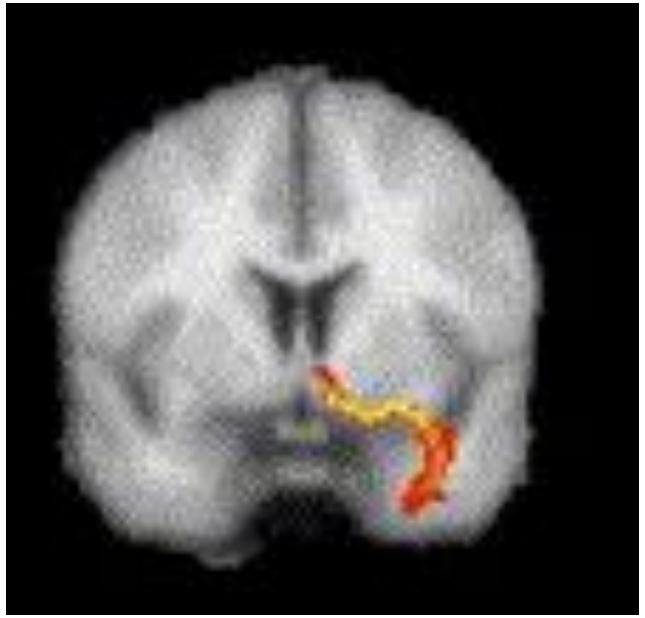
[Biswal 1995]

Diffusion MRI Connectivity



[http://qims.amegroups.com/article/view/1315/1771]

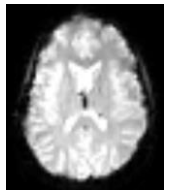




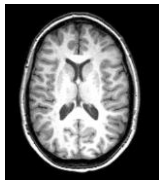
[Behrens 2007]

Structural connectivity = “trackability” of streamlines

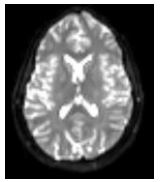
fMRI



T1weighted

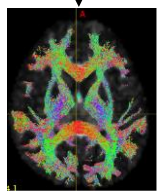


dMRI

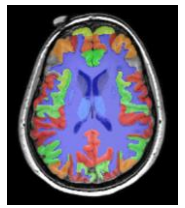


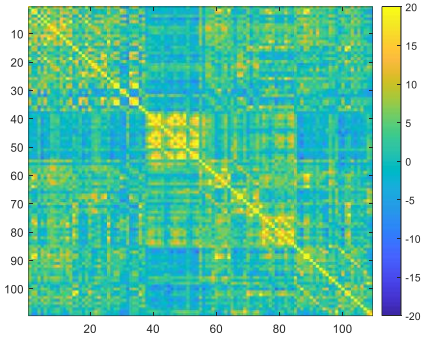
preprocessing

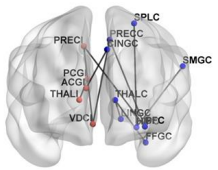
segmentation

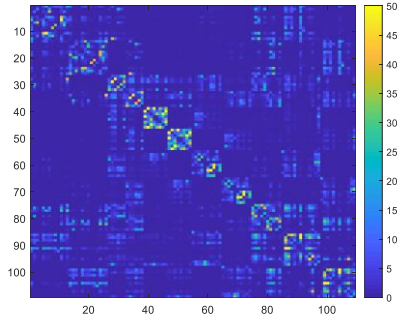


preprocess/tractography









Functional connectome

Structural connectome

Patterns!

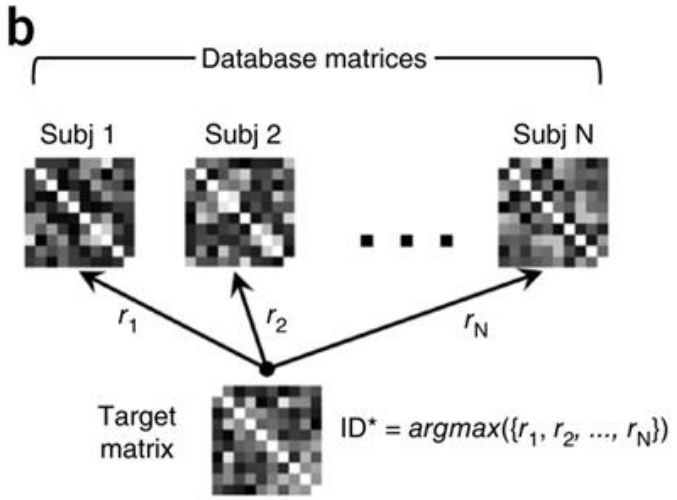
Are the patterns UNIQUE to individuals?

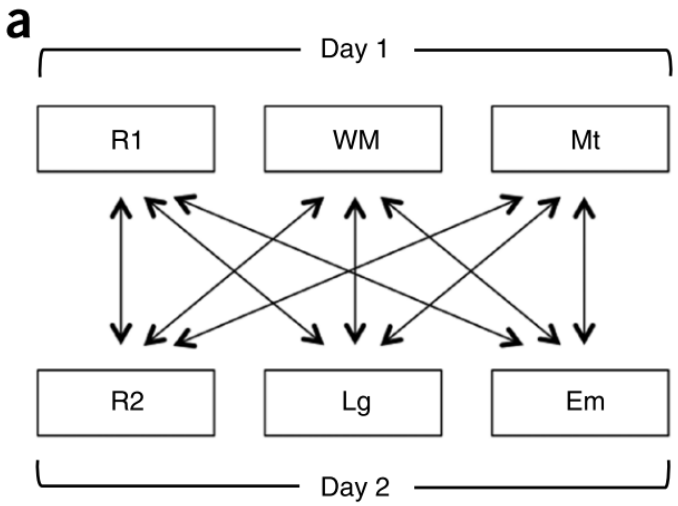
nature neuroscience
2015

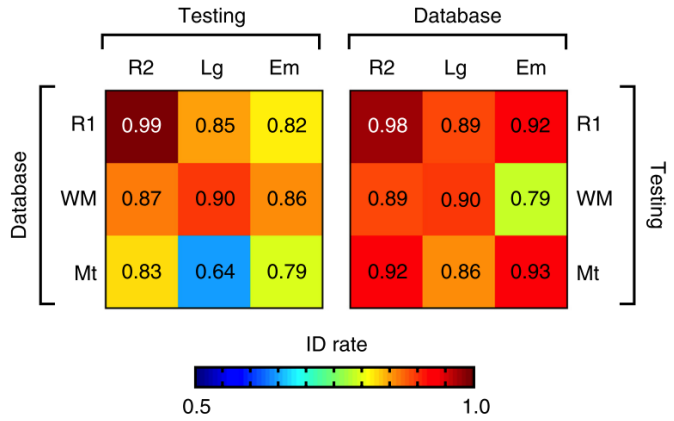
Functional connectome fingerprinting: identifying individuals using patterns of brain connectivity

Emily S Finn[1,7], Xilin Shen[2,7], Dustin Scheinost[2], Monica D Rosenberg[3], Jessica Huang[2], Marvin M Chun[1,3,4], Xenophon Papademetris[2,5] & R Todd Constable[1,2,6]

- 126 subjects
- Different types of scans
- Different subsets of regions







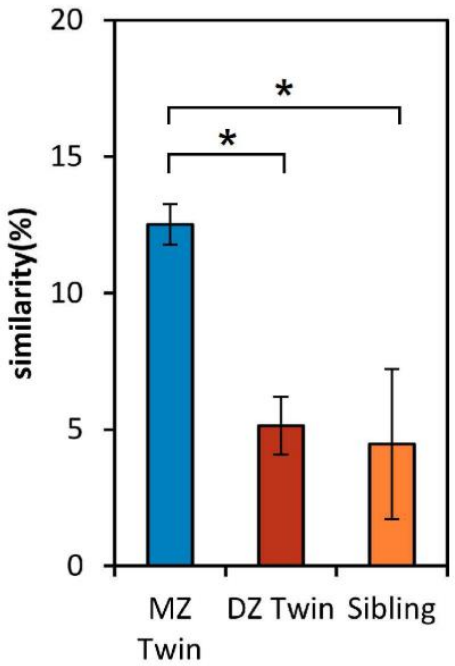
Here we show that an individual's functional brain connectivity profile is both unique and reliable, similarly to a fingerprint. We demonstrate that it is possible, with near-perfect accuracy in many cases, to identify an individual from a large group of subjects solely on the basis of his or her connectivity matrix. Although inter-individual

PLOS | COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

Quantifying Differences and Similarities in Whole-Brain White Matter Architecture Using Local Connectome Fingerprints

Fang-Cheng Yeh[1]*, Jean M. Vettel[2,3,4], Aarti Singh[5], Barnabas Poczos[5], Scott T. Grafton[3], Kirk I. Erickson[6], Wen-Yih I. Tseng[7], Timothy D. Verstynen[6]*



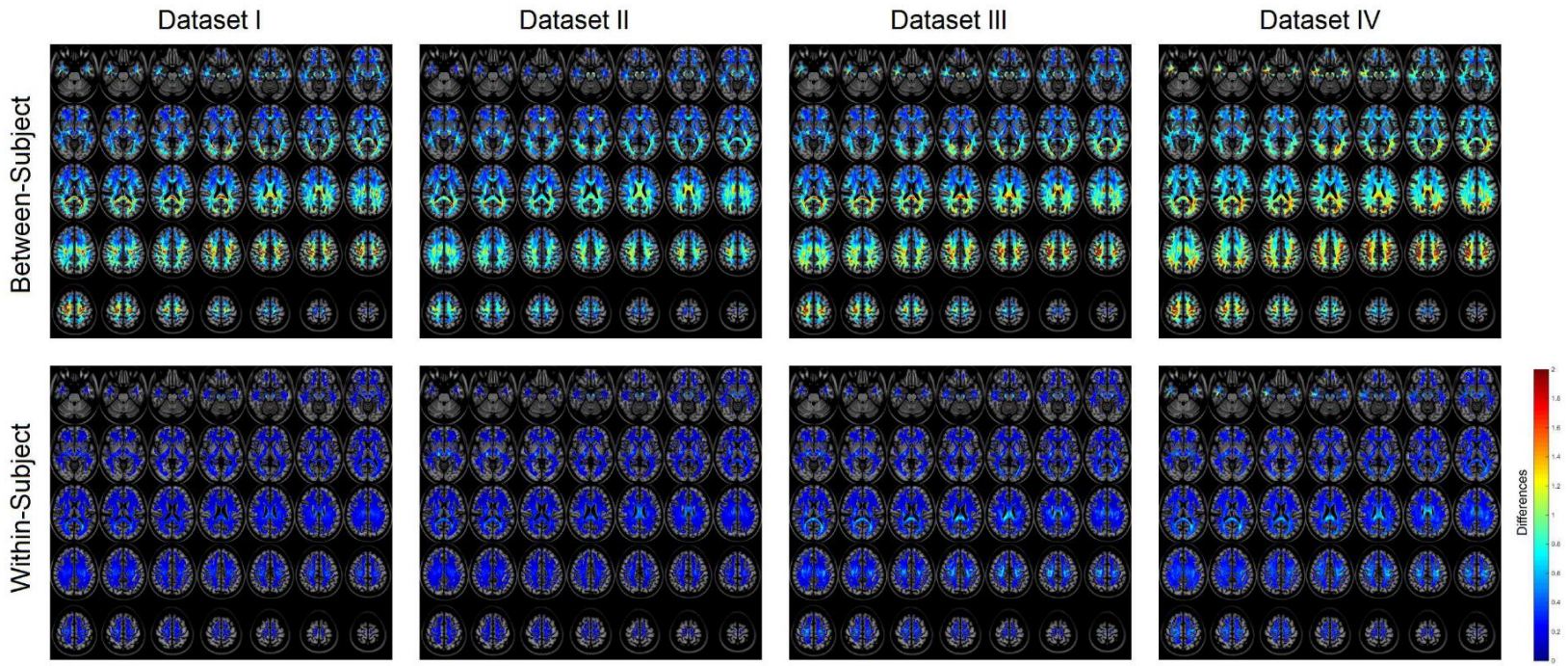


Fig 4. The spatial mapping of between-subject (first row) and within-subject (second row). Dataset I was acquired within 16 days, whereas dataset II (1~3 months), dataset III (6 months) and dataset IV (a year) were acquired at longer time intervals. High between-subject differences can be observed in white matter tissue, especially the corpus callosum and central semiovale. The within-subject differences are much smaller, and repeat scans with longer time intervals show higher within-subject differences.

SCIENTIFIC REPORTS

OPEN

The quest for identifiability in human functional connectomes

2018

Enrico Amico[1,2] & Joaquín Goñi[1,2,3]

Original Article

CHRONIC STRESS

Pretreatment Brain Connectome Fingerprint Predicts Treatment Response in Major Depressive Disorder

Chronic Stress
Volume 4: 1–8

DOI: 10.1177/2470547020984726
journals.sagepub.com/home/css
SAGE

Siyan Fan[1,2], Samaneh Nemati[1,2], Teddy J. Akiki[1,2,3], Jeremy Roscoe[1,2], Christopher L. Averill[4,5], Samar Fouda[1,2], Lynnette A. Averill[1,2,4,5], and Chadi G. Abdallah[1,2,4,5]

2020

RESEARCH ARTICLE

2021 WILEY

Functional connectome fingerprinting: Identifying individuals and predicting cognitive functions via autoencoder

Biao Cai[1] | Gemeng Zhang[1] | Aiying Zhang[1] | Li Xiao[1] | Wenxing Hu[1] | Julia M. Stephen[2] | Tony W. Wilson[3] | Vince D. Calhoun[4] | Yu-Ping Wang[1]

NeuroImage 221 (2020) 117122

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

ELSEVIER

Personalized connectome fingerprints: Their importance in cognition from childhood to adult years

B.C. Munsell[d,e,*], E. Gleichgerrcht[a], E. Hofesmann[c], J. Delgaizo[a], C.R. McDonald[b], B. Marebwa[a], M.A. Styner[d,e], J. Fridriksson[f], C. Rorden[g], N.K. Focke[h], J.H. Gilmore[d], L. Bonilha[a]

NeuroImage 238 (2021) 118253

Contents lists available at ScienceDirect

NeuroImage

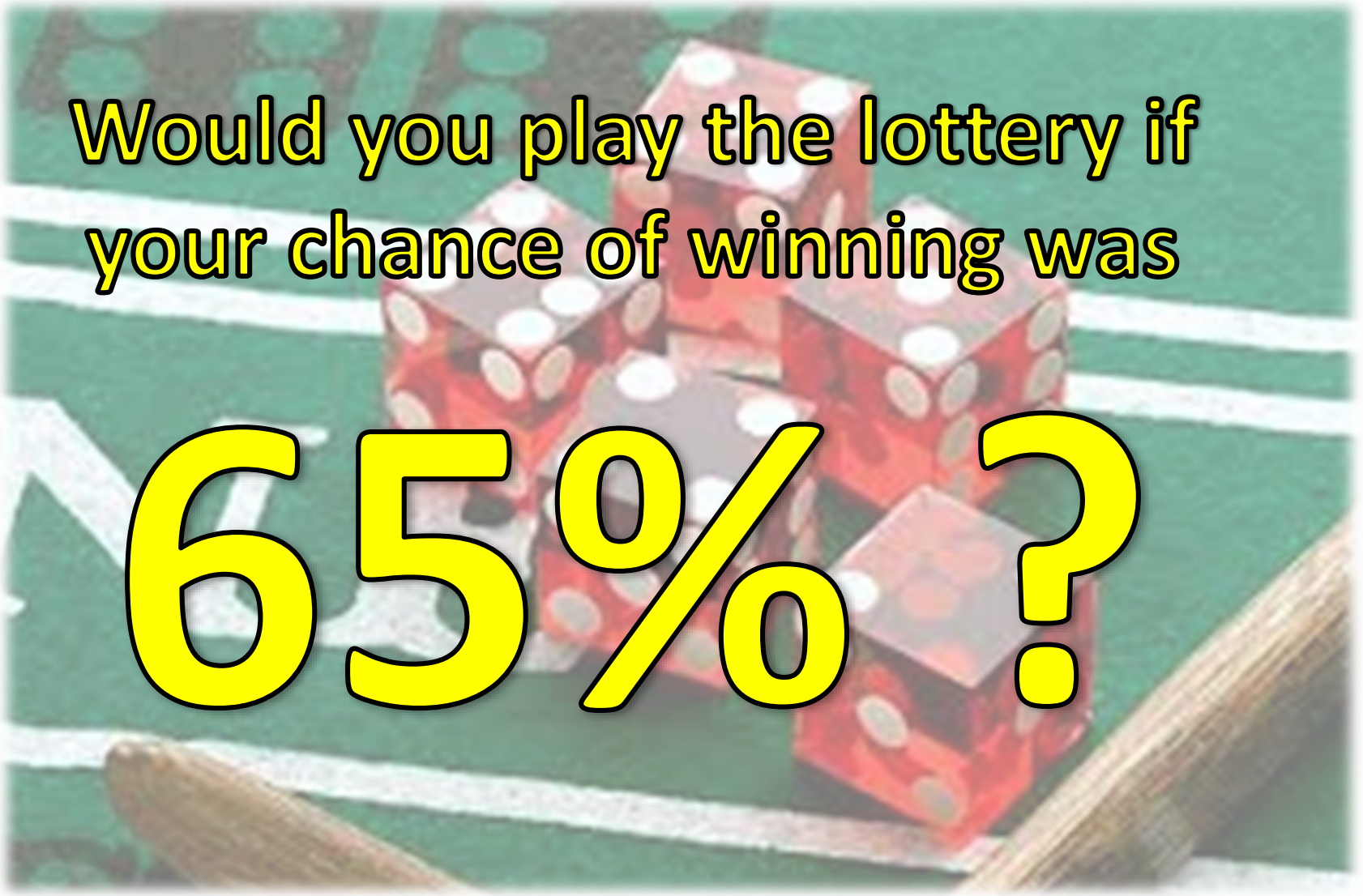
journal homepage: www.elsevier.com/locate/neuroimage

ELSEVIER

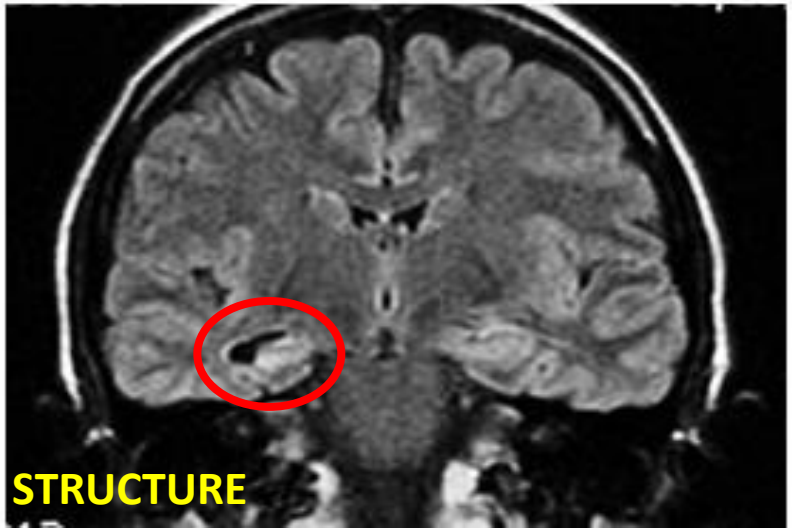
Clinical connectome fingerprints of cognitive decline

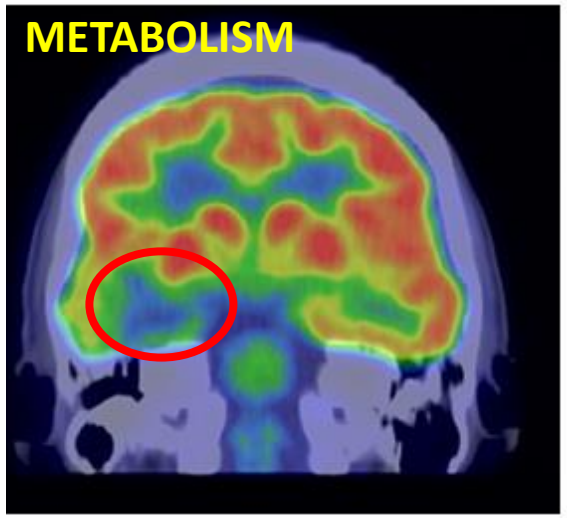
Pierpaolo Sorrentino[a,1], Rosaria Rucco[b,c,1], Anna Lardone[d], Marianna Liparoti[c], Emahnuel Troisi Lopez[c], Carlo Cavaliere[e], Andrea Soricelli[c,e], Viktor Jirsa[a], Giuseppe Sorrentino[b,c,f,*], Enrico Amico[g,h,**]

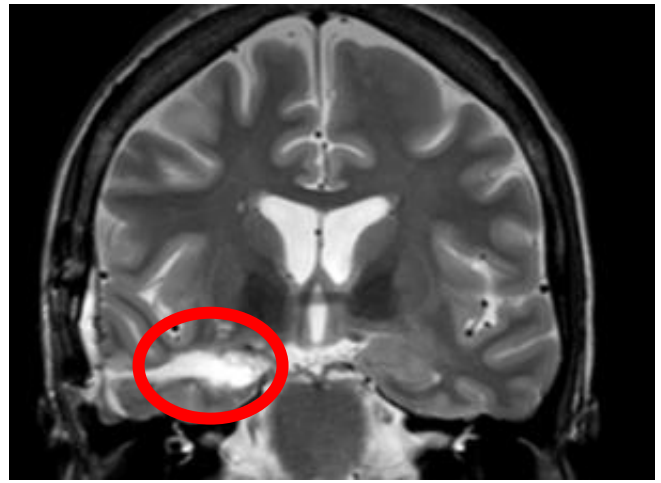
Why am I interested in brain fingerprinting?

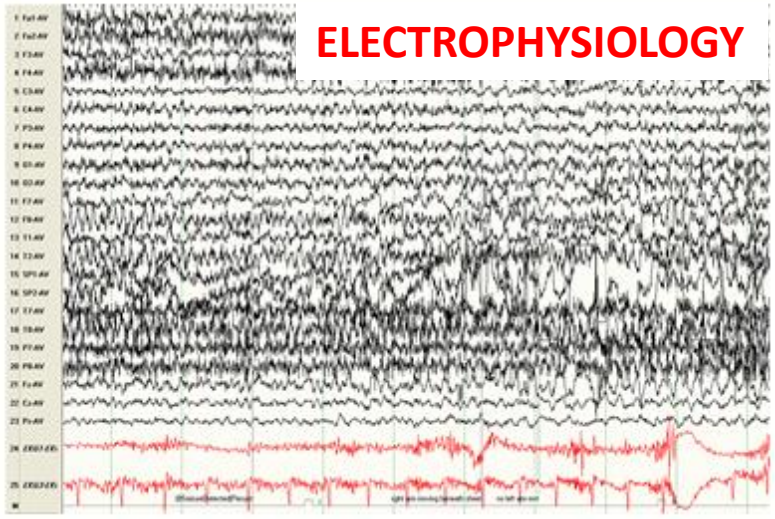


temporal lobe epilepsy (TLE)









65%?

Improvements in identifying the focus have not led to better outcomes

Contents lists available at ScienceDirect

Epilepsy & Behavior

journal homepage: www.elsevier.com/locate/yebeh

Review

History of surgery for temporal lobe epilepsy

Ali A. Asadi-Pooya [a,b,*], Cyrus Rostami [a]

2017

markable and revolutionary progress. This progress has resulted in tremendous advancements in understanding the underlying causes and pathophysiology of epilepsies. With the help of these technologies and advancements, we may now offer surgery as a safer therapeutic option to more patients who are suffering from drug-resistant temporal lobe epilepsy. However, the degree of improvement in surgery outcome has not been proportionate to the technological progress.

SUPPLEMENT ARTICLE

Epilepsia

Algorithms in clinical epilepsy practice: Can they really help us predict epilepsy outcomes?

Lara Jehi

2021

best. The "stepwise process" we follow to get to this end can be simplified into the following steps: (1) identify the surgical candidate, (2) localize the epilepsy, (3) resect the epileptogenic zone, and (4) the end to reach: the patient will be seizure-free. Over the past few decades, steps 1 through 3 have witnessed significant progress, yet our end has not improved proportionally. Heaps of academic literature has

How does a focal seizure affect the rest of the brain?

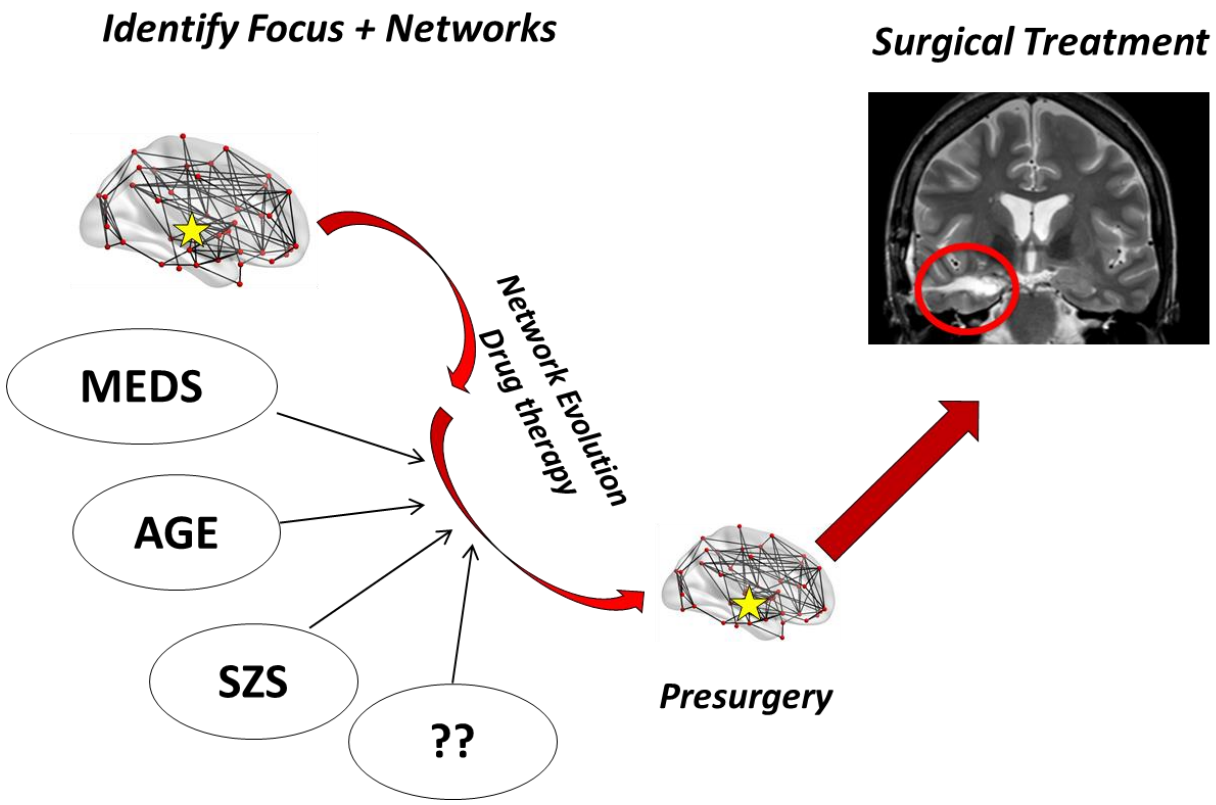
Equal to all regions, transient

specific, along unique path, transient

Along pre-existing, fixed paths

Unique paths, progressive

Networks evolve prior to surgery



Multivariate white matter alterations are associated with epilepsy duration

Thomas W. Owen[1], Jane de Tisi[3], Sjoerd B. Vos[3,4,5], Gavin P. Winston[3,5,6], John S Duncan[3,5], Yujiang Wang[1,2,3], Peter N. Taylor[1,2,3]

bioRχiv THE PREPRINT SERVER FOR BIOLOGY 2020

BRAIN CONNECTIVITY
Volume 0, Number 0, 2014
© Mary Ann Liebert, Inc.
DOI: 10.1089/brain.2014.0251

ORIGINAL ARTICLE

Evolution of Functional Connectivity of Brain Networks and Their Dynamic Interaction in Temporal Lobe Epilepsy

Victoria L. Morgan,[1] Bassel Abou-Khalil,[2] and Baxter P. Rogers[1]

Epilepsia, 52(9):1741–1749, 2011
doi: 10.1111/j.1528-1167.2011.03196.x

FULL-LENGTH ORIGINAL RESEARCH

Cross hippocampal influence in mesial temporal lobe epilepsy measured with high temporal resolution functional magnetic resonance imaging

*Victoria L. Morgan, *Baxter P. Rogers, †Hasan H. Sonmezturk, *John C. Gore, and †Bassel Abou-Khalil

Functional connectivity homogeneity correlates with duration of temporal lobe epilepsy

Zulfi Haneef [a,b,*,1], Sharon Chiang [c,1], Hsiang J. Yeh [d], Jerome Engel Jr. [d,e], John M. Stern [d]

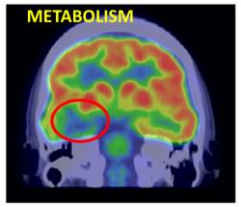
Z. Haneef et al. / Epilepsy & Behavior 46 (2015) 227–233

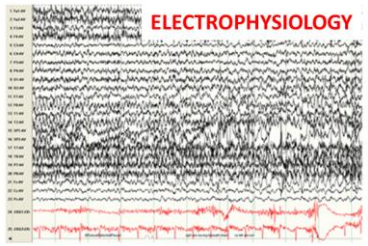
Our hypothesis – The temporal lobe epilepsy *FINGERPRINT*

The focus may be the same, but the connections are different

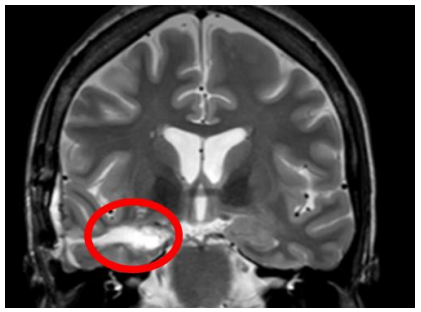
A pattern of network connections in the brain at the time of surgery that will result in seizure free outcome


STRUCTURE


METABOLISM

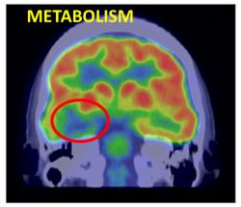

ELECTROPHYSIOLOGY

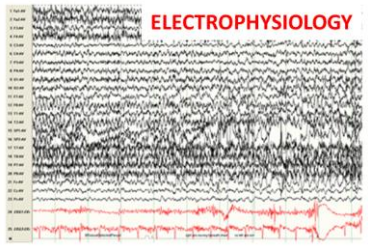

SEIZURE SYMPTOMS

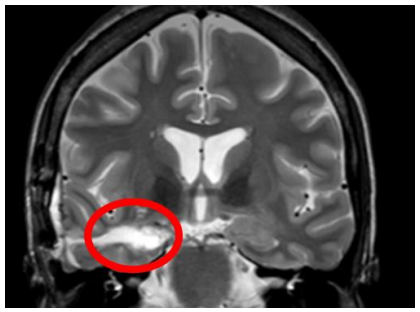


Seizure free

No improvement

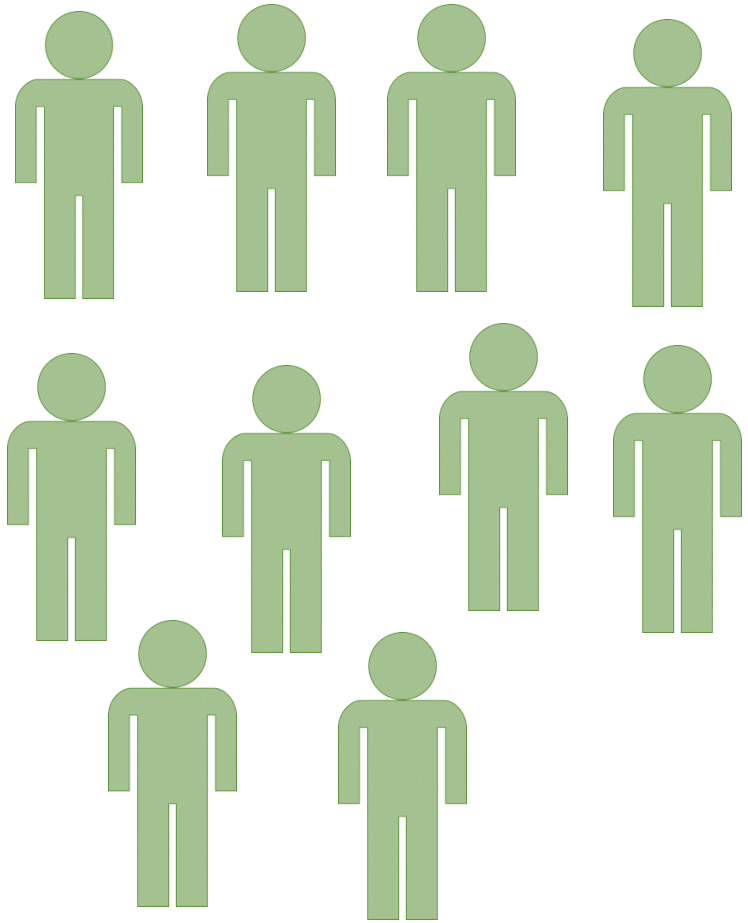




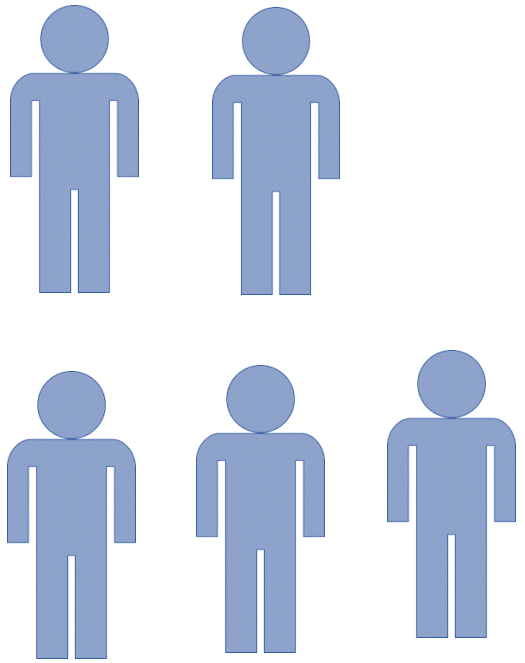


Much improved

Seizure free

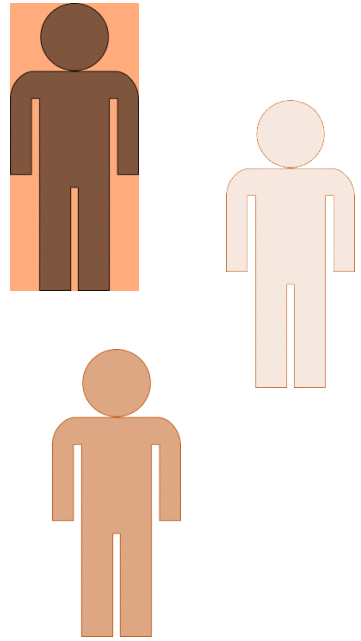


Much improved



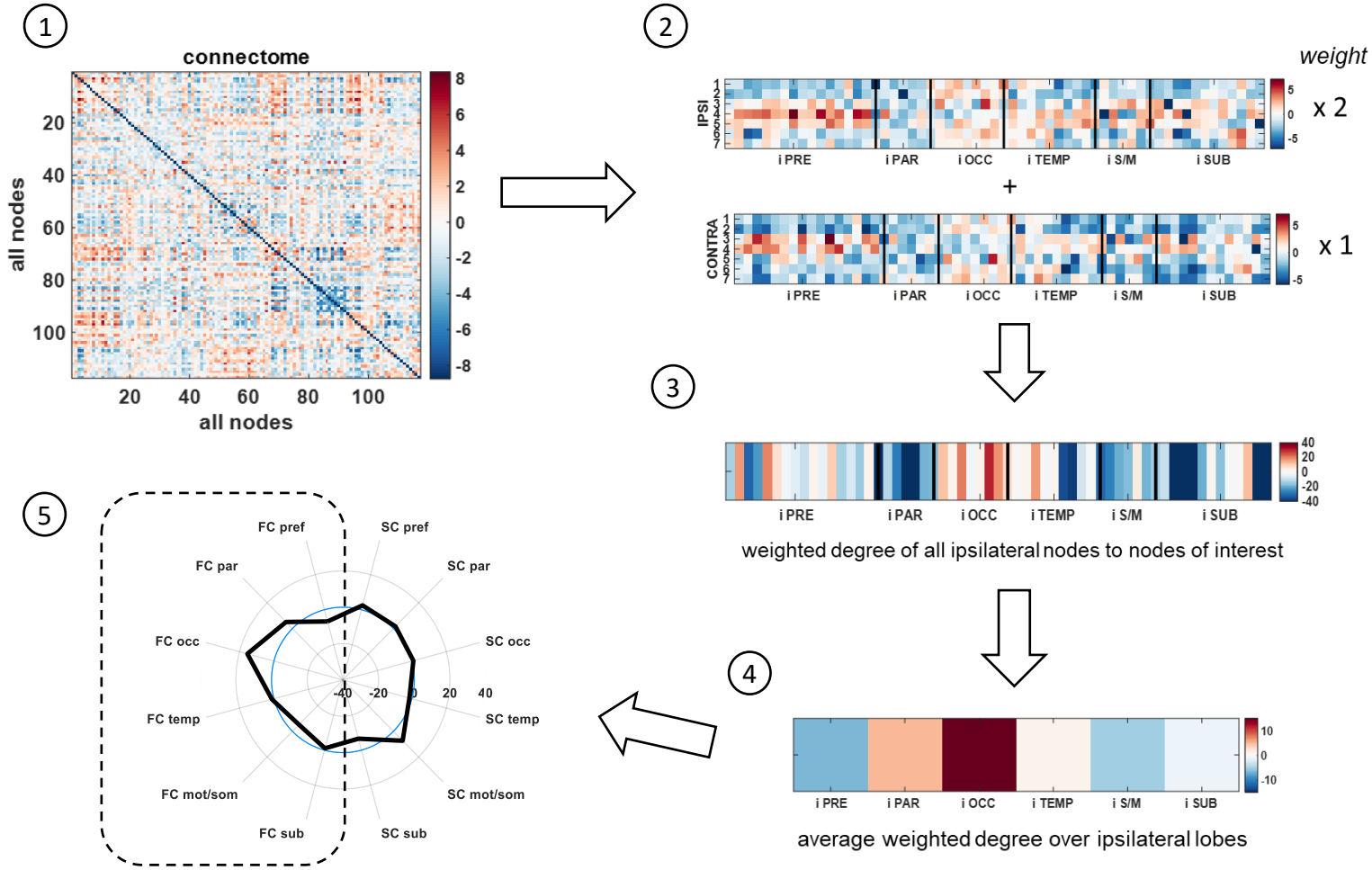
?

No improvement

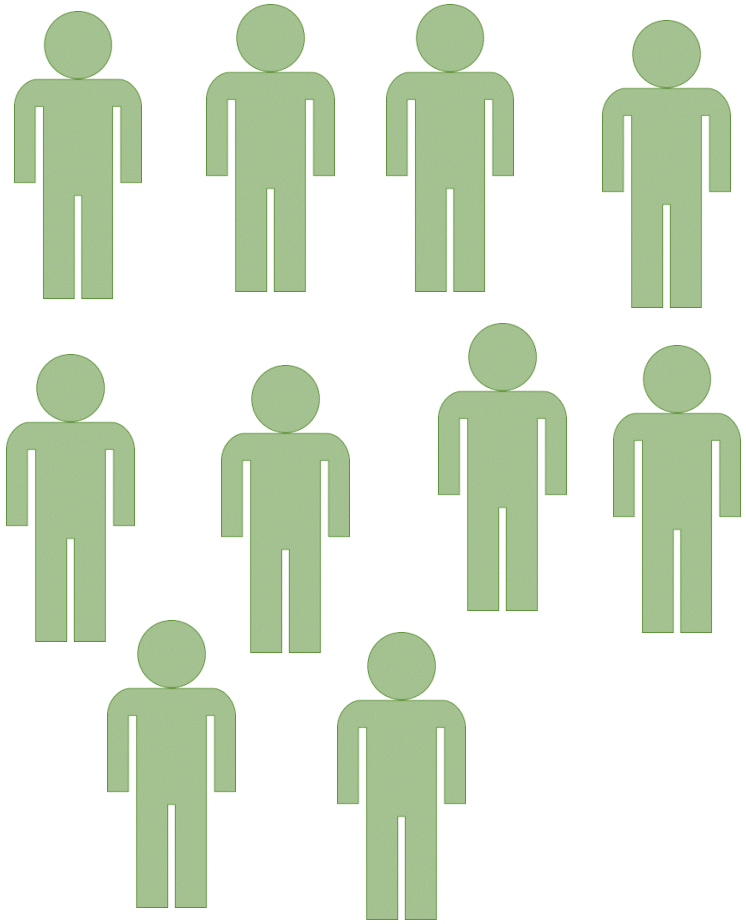


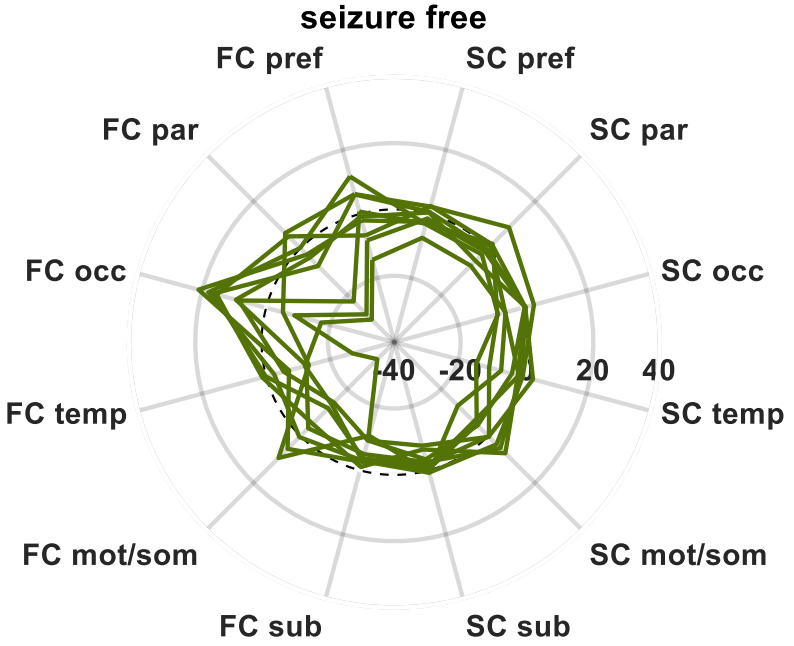
Different from pattern in various ways.

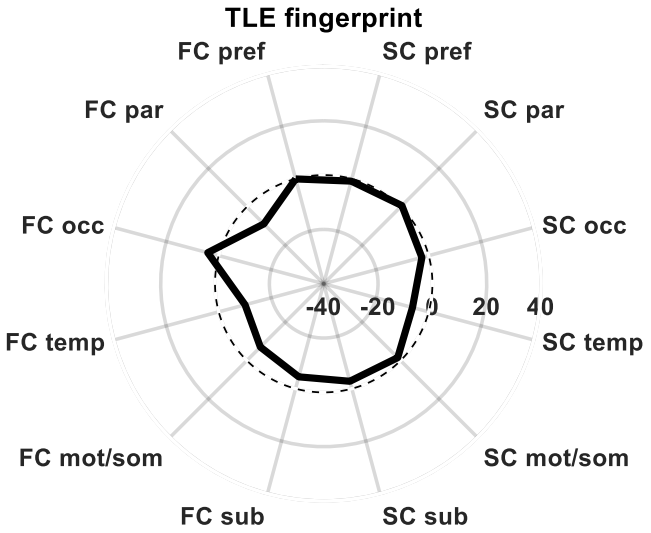
Multi focus?
Bilateral?


1
connectome
all nodes
all nodes
2
weight
IPSI
CONTRA
x 2
x 1
i PRE
i PAR
i OCC
i TEMP
i S/M
i SUB
3
weighted degree of all ipsilateral nodes to nodes of interest
4
average weighted degree over ipsilateral lobes
5
FC pref
SC pref
FC par
SC par
FC occ
SC occ
FC temp
SC temp
FC mot/som
SC mot/som
FC sub
SC sub

Seizure free

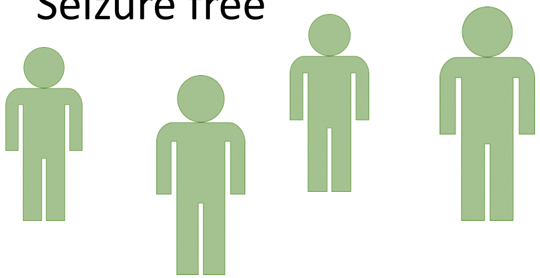


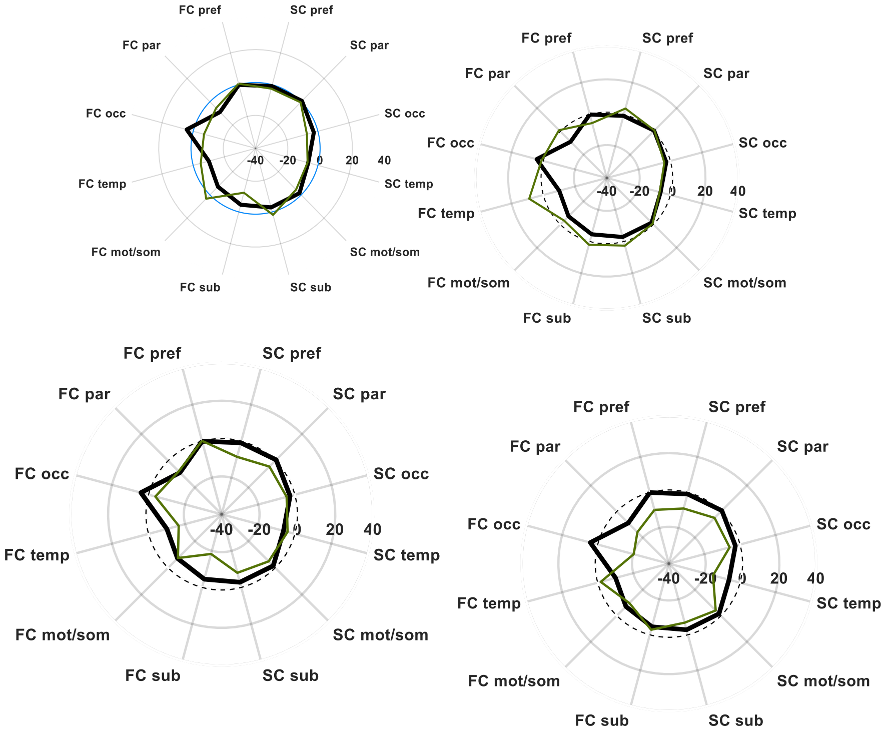




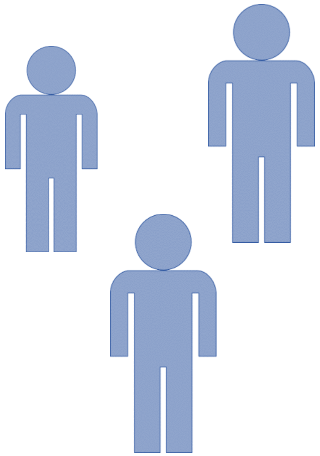
Now to test this!

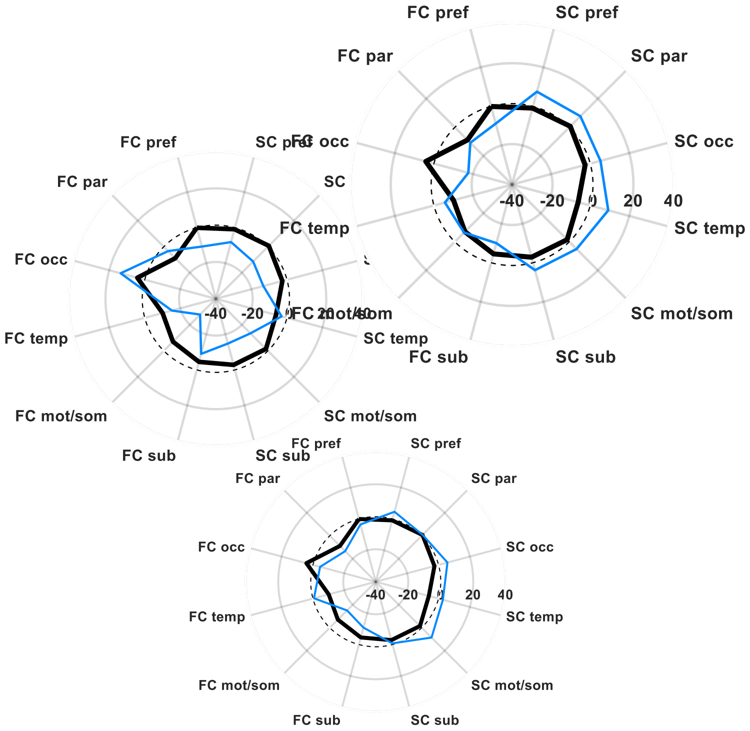
Seizure free



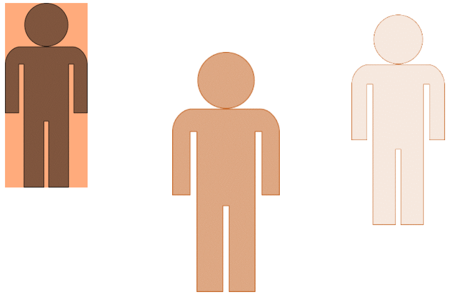


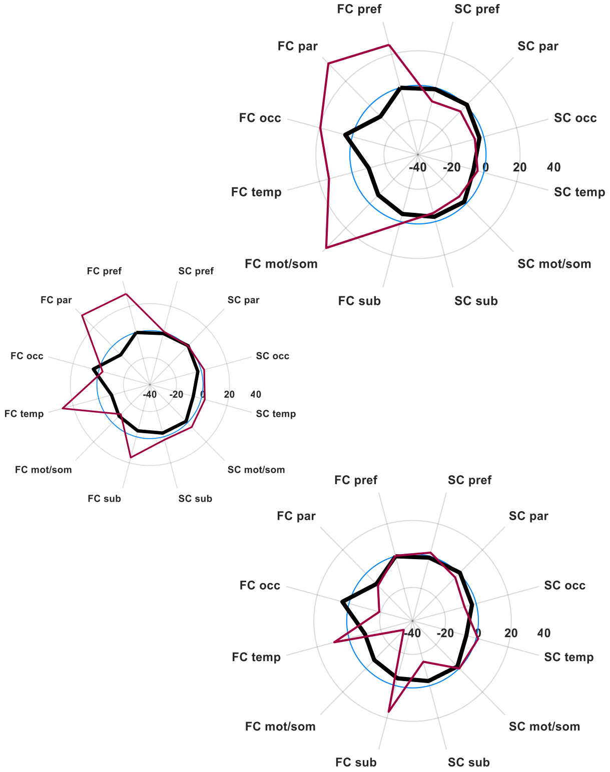
Much improved

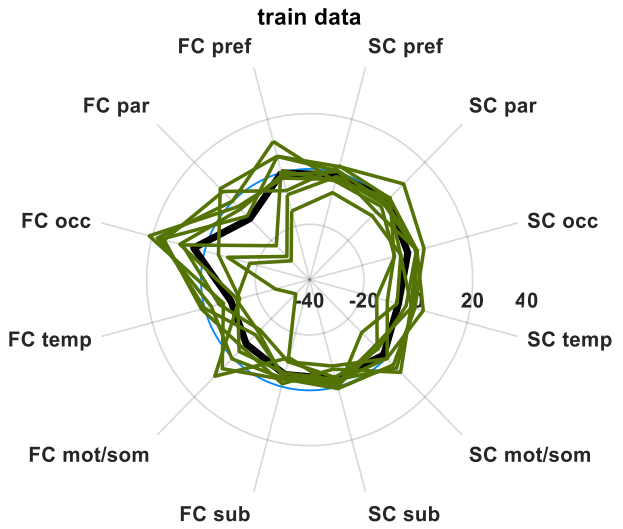




No improvement







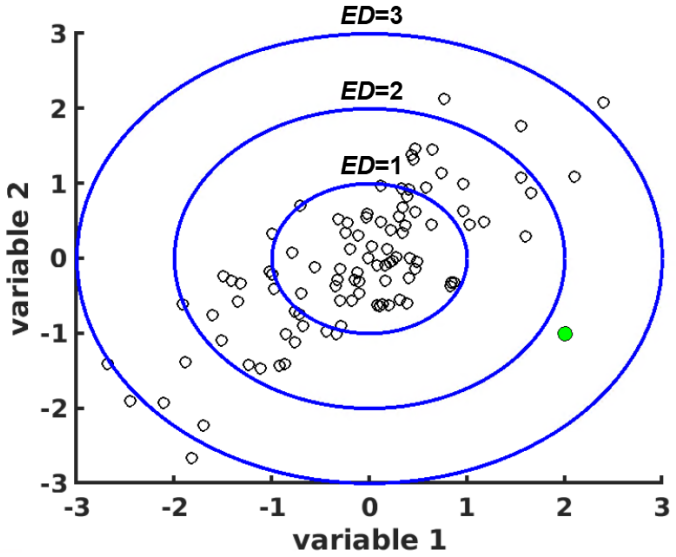
Similarity to fingerprint indicates better chance of good outcome.

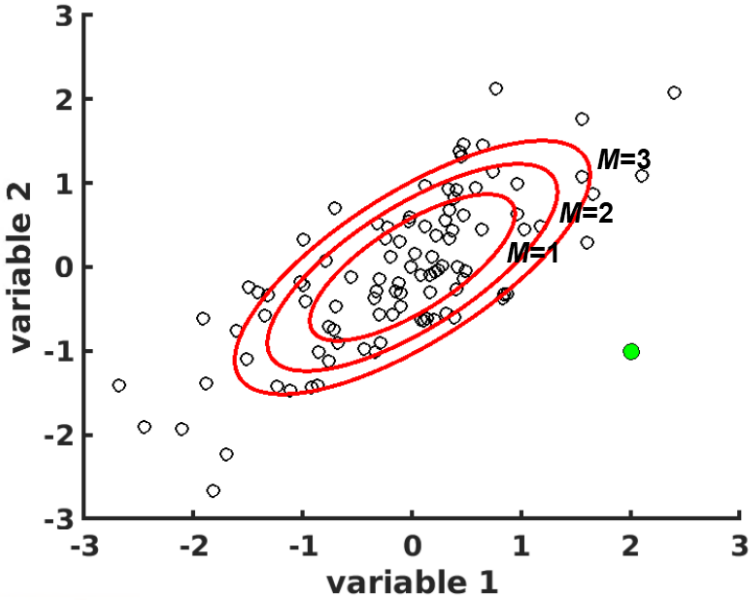
Quantify similarity using 2 distances – Euclidean and Mahalanobis
for magnitude and pattern

functional and structural connectivity distance

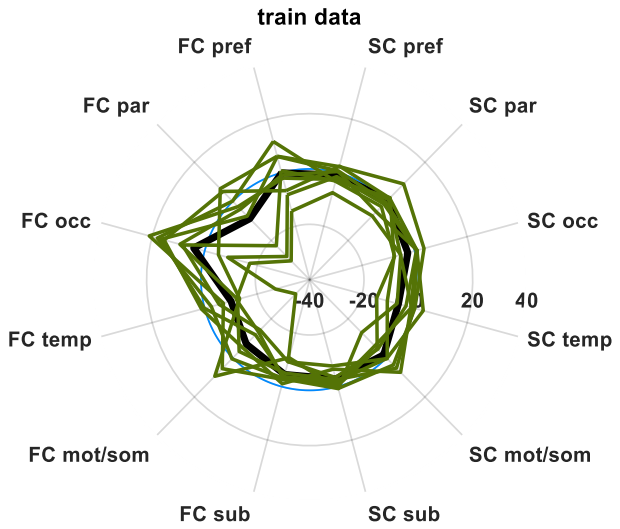
Also calculate total distance

ED=2.2





M=21.5

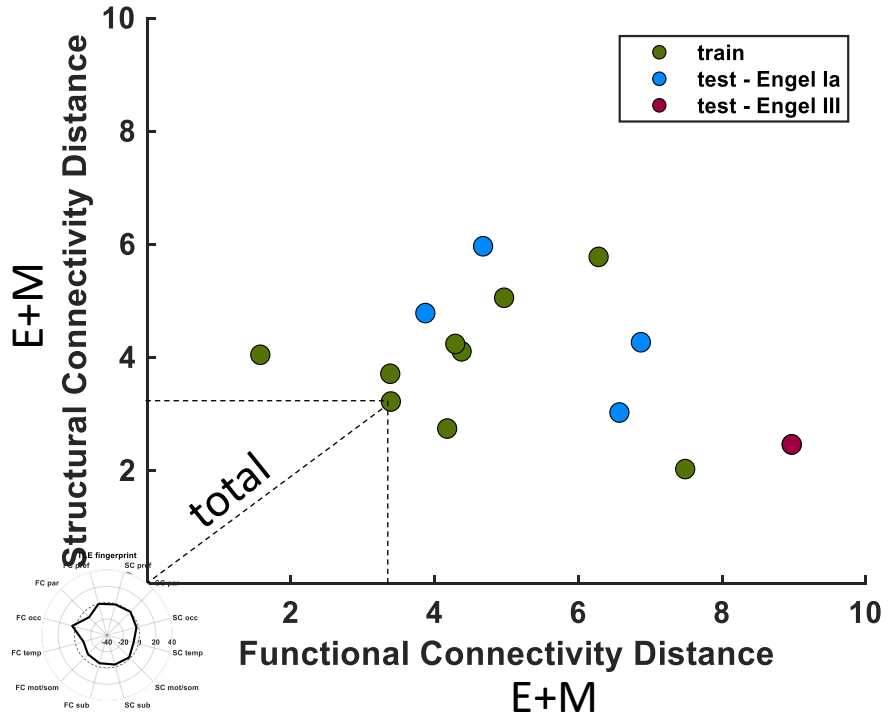


Similarity to fingerprint indicates better chance of good outcome.

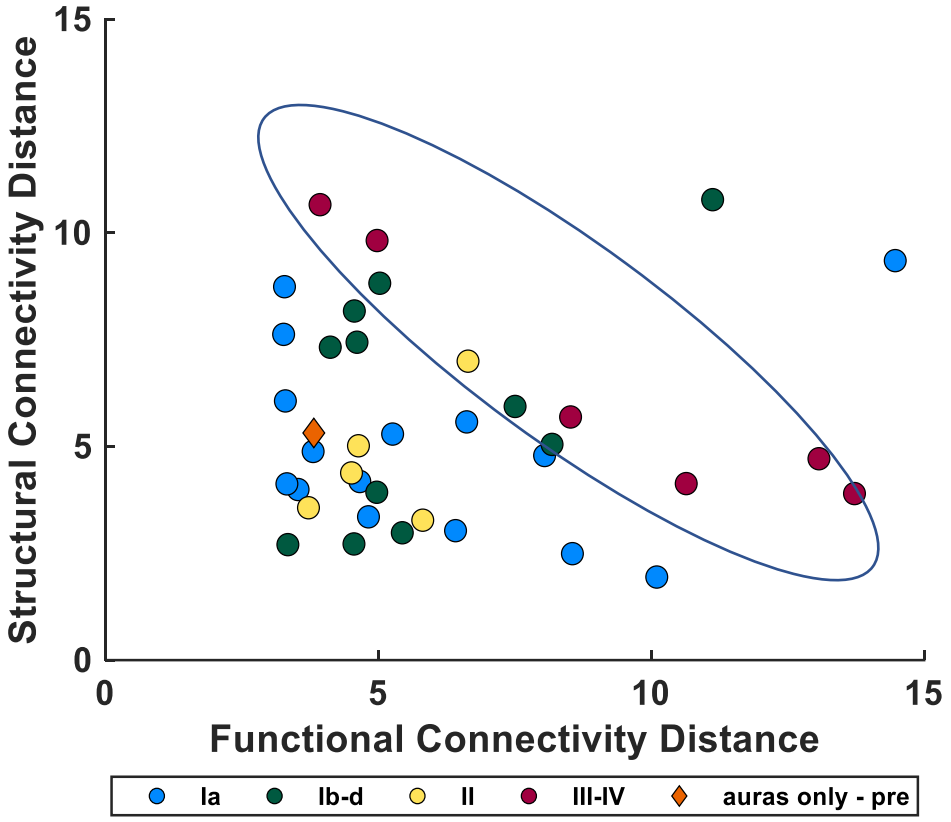
Quantify similarity using 2 distances – Euclidean and Mahalanobis
for magnitude and pattern

functional and structural connectivity distance

Also calculate Total distance from (0,0) in plot



Testing data



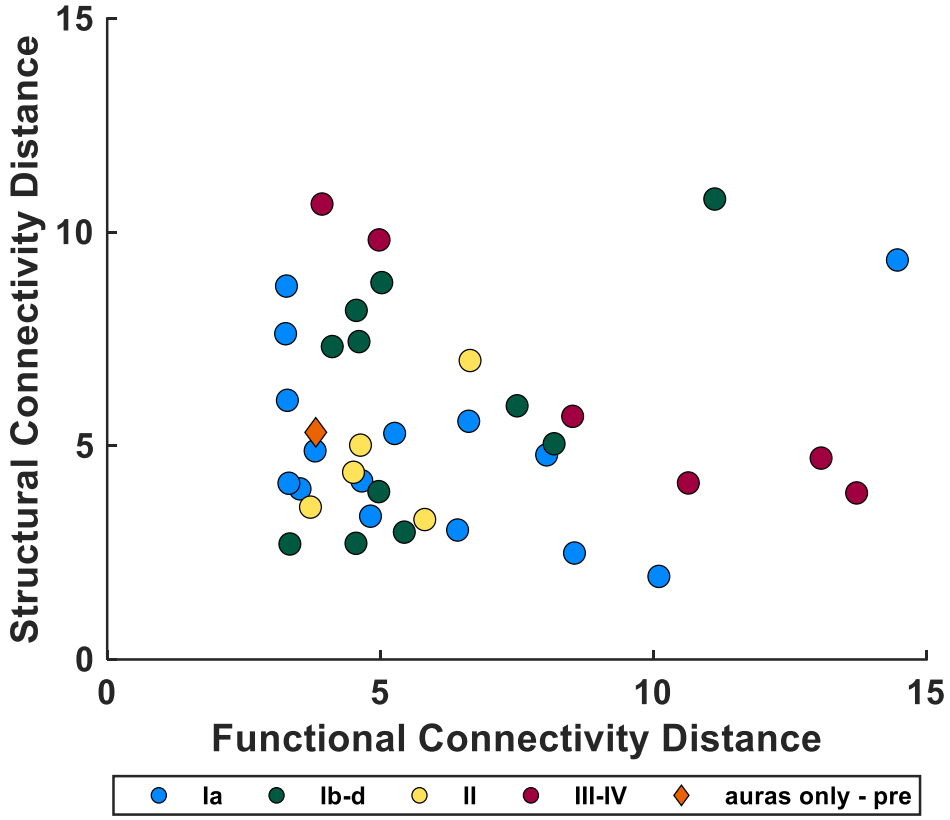
Class I	Free of disabling seizures
Class II	Rare disabling seizures ("almost seizure-free")
Class III	Worthwhile improvement
Class IV	No worthwhile improvement

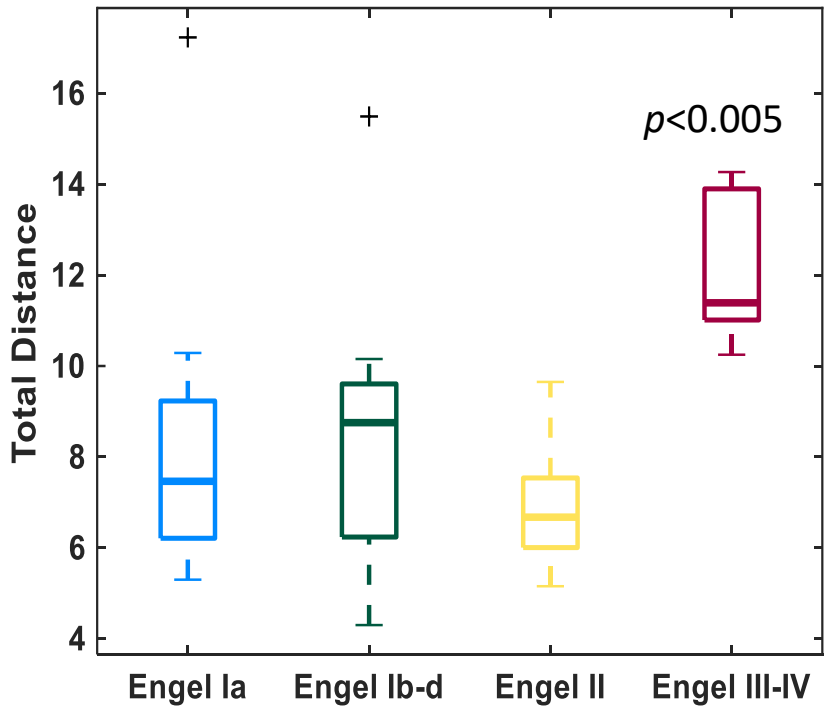
Observations:

Functional vs. structural

I and II mixed

Few outliers

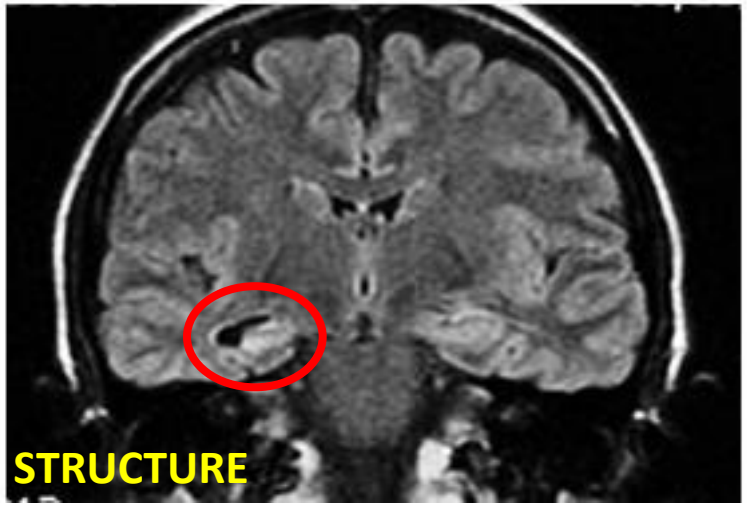


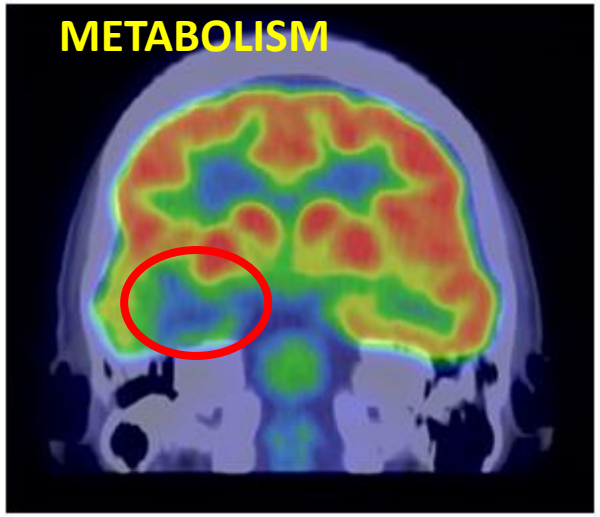


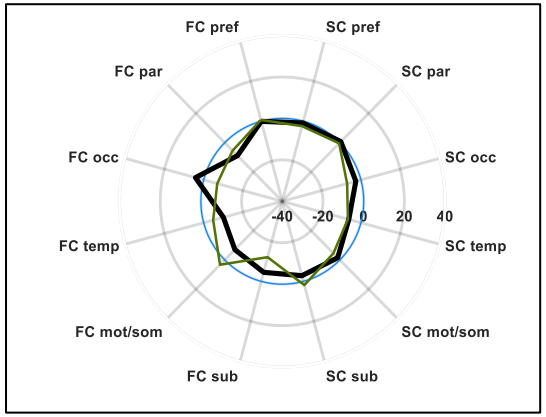
Patients with seizure recurrence have larger total distance from TLE fingerprint.

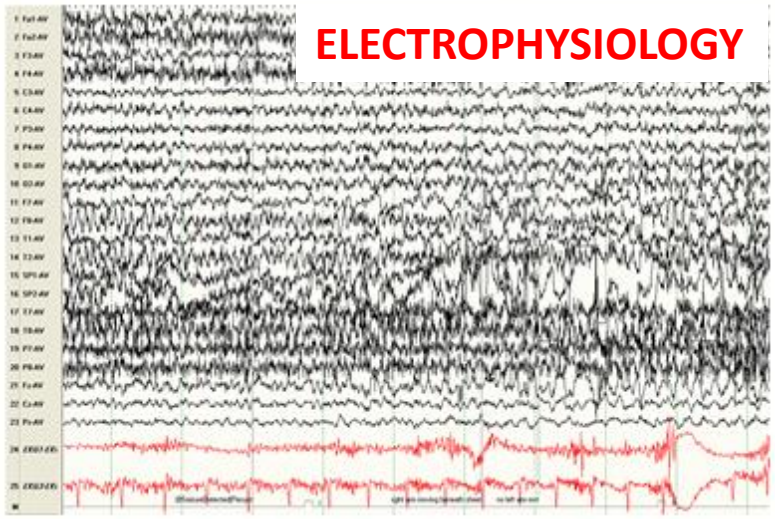
- Not in functional, structural, Euclidean or Mahalanobis only

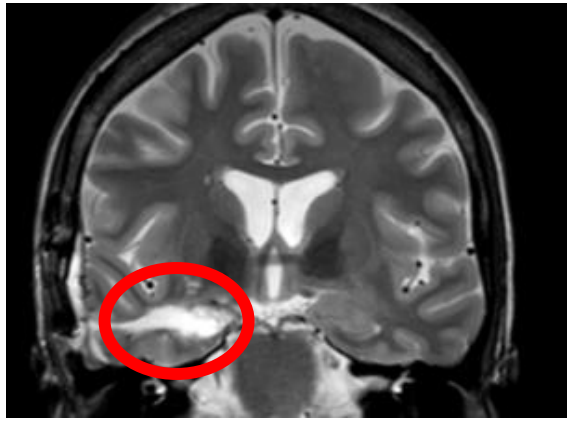
temporal lobe epilepsy (TLE)





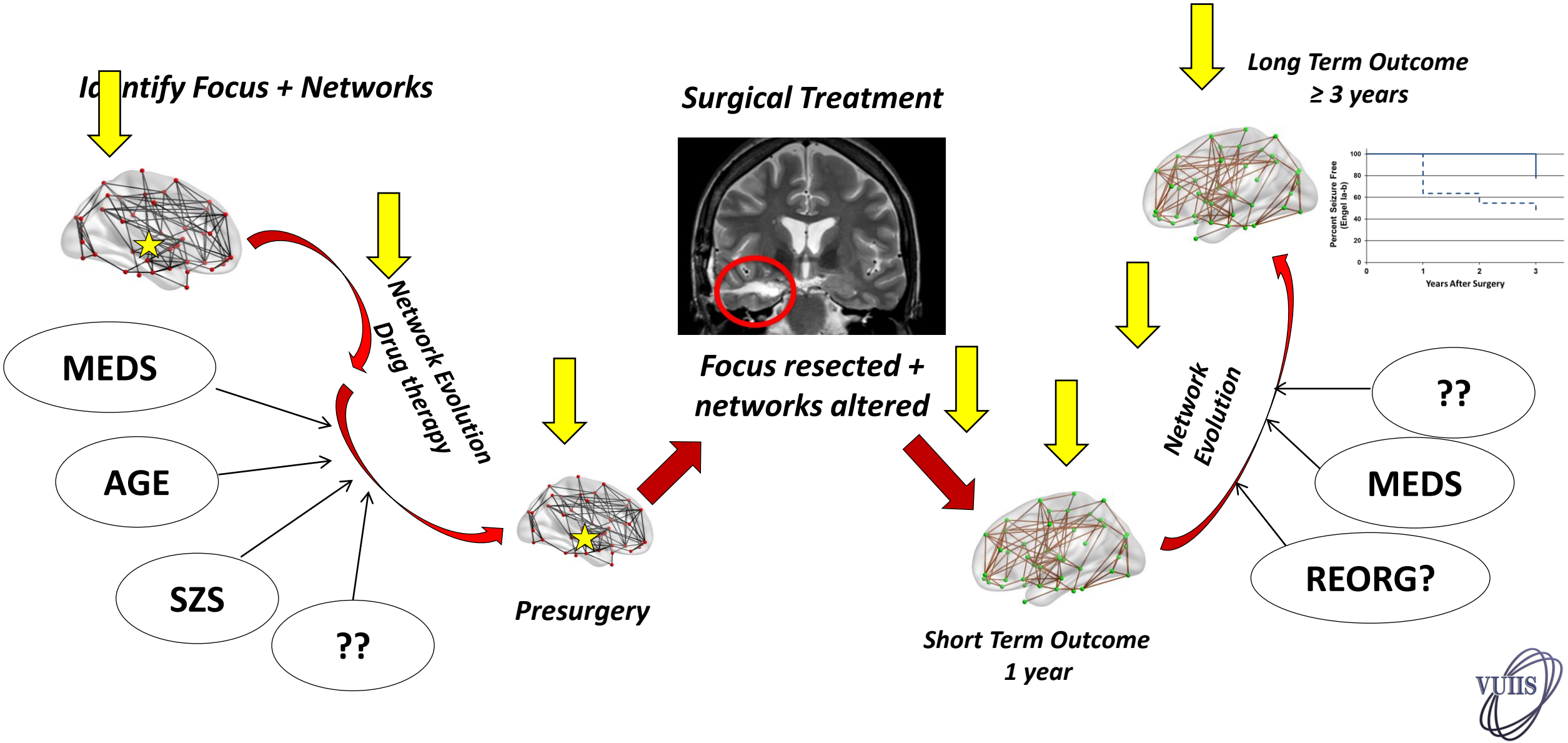


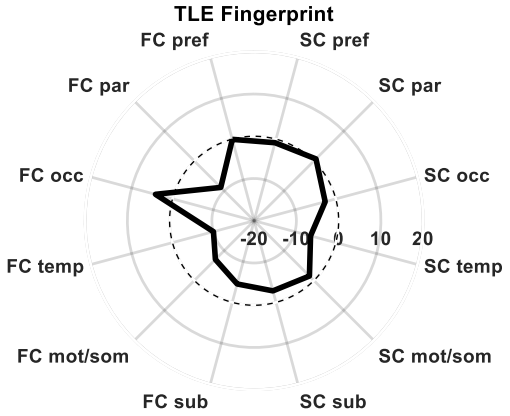




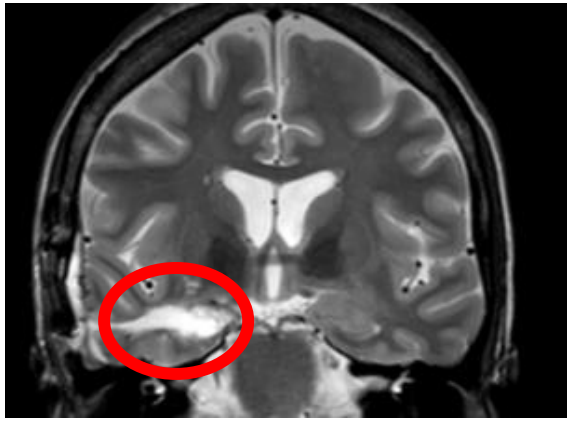
>65%?

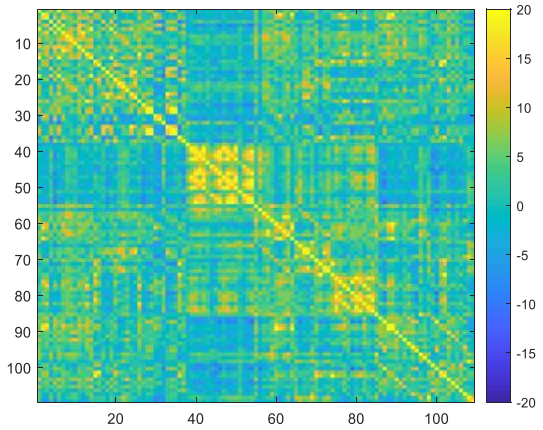
Moving forward

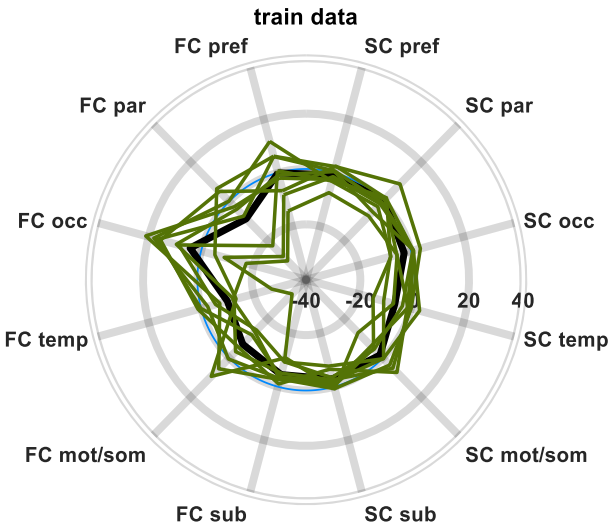



TLE Fingerprint
FC pref
SC pref
FC par
SC par
FC occ
SC occ
FC temp
SC temp
FC mot/som
SC mot/som
FC sub
SC sub
-20
-10
0
10
20

QUESTIONS??




10
20
30
40
50
60
70
80
90
100
20
40
60
80
100
20
15
10
5
0
-5
-10
-15
-20


train data
FC pref
SC pref
FC par
SC par
FC occ
SC occ
FC temp
SC temp
FC mot/som
SC mot/som
FC sub
SC sub
-40
-20
20
40