Advanced Concepts on EEG and QEEG Assessment and Human Performance

International Symposium on Clinical Neuroscience – Feb 3-5, 2017

Linking Symptoms to qEEG Biomarkers and Neurofeedback

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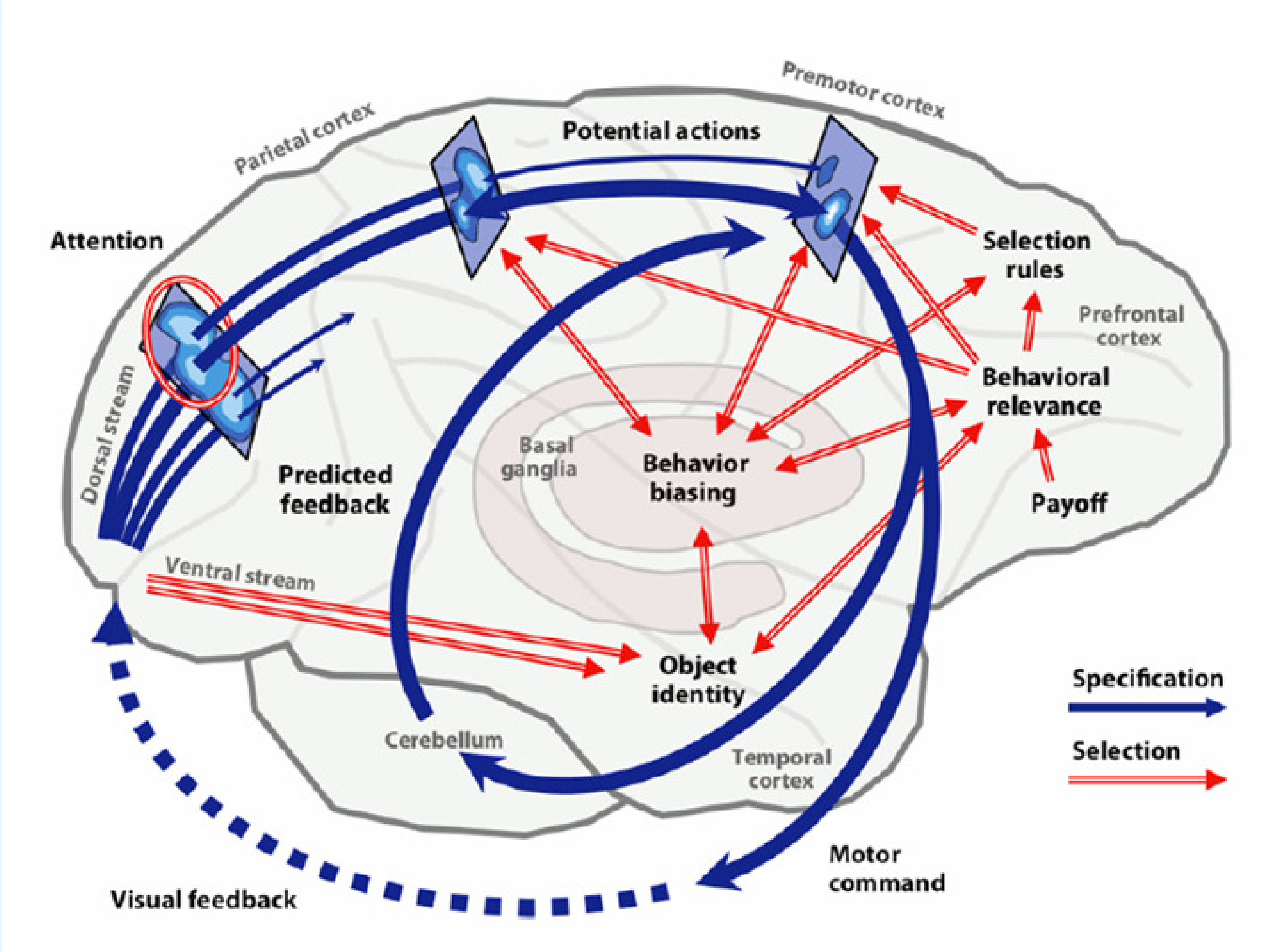
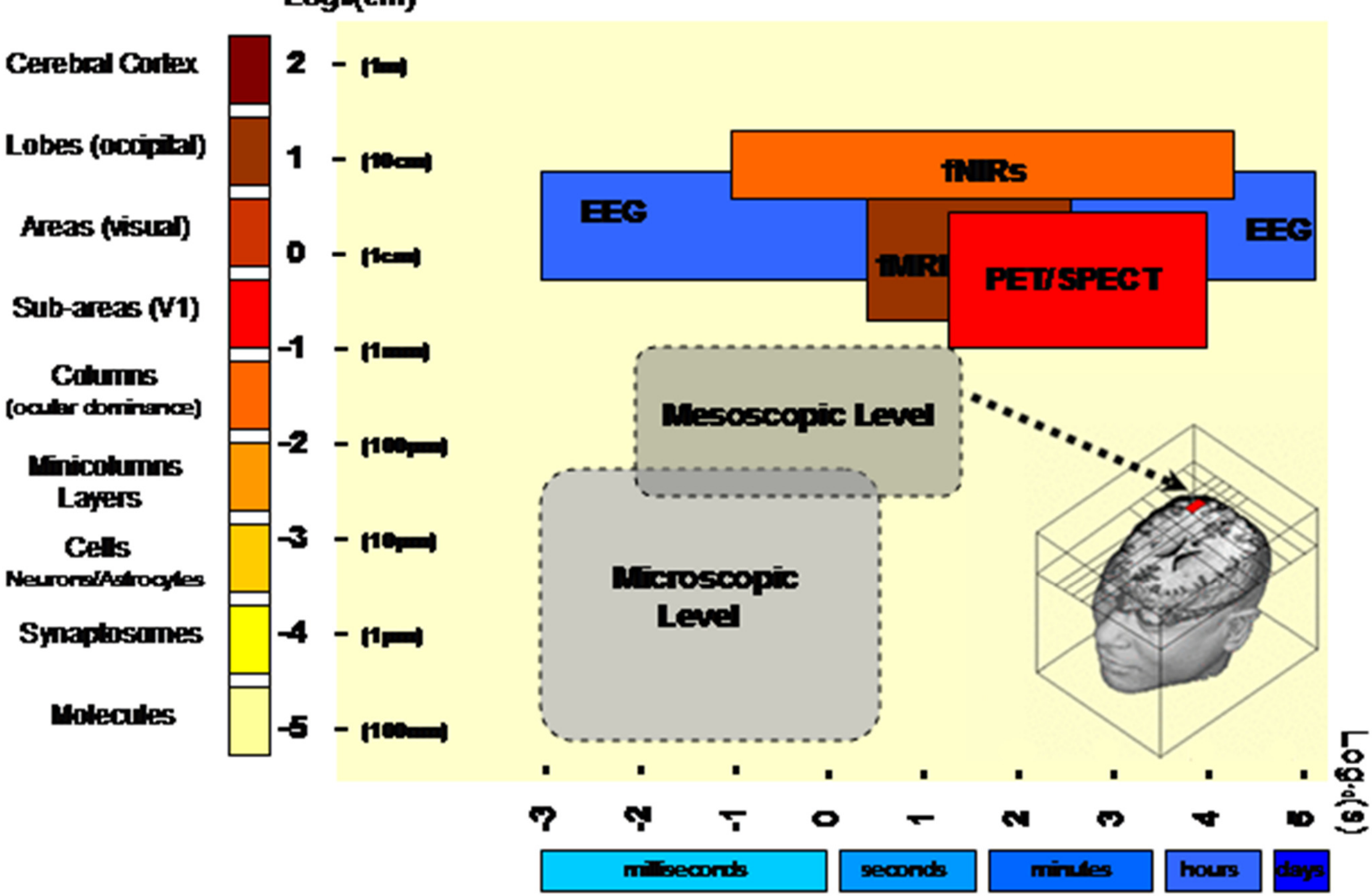
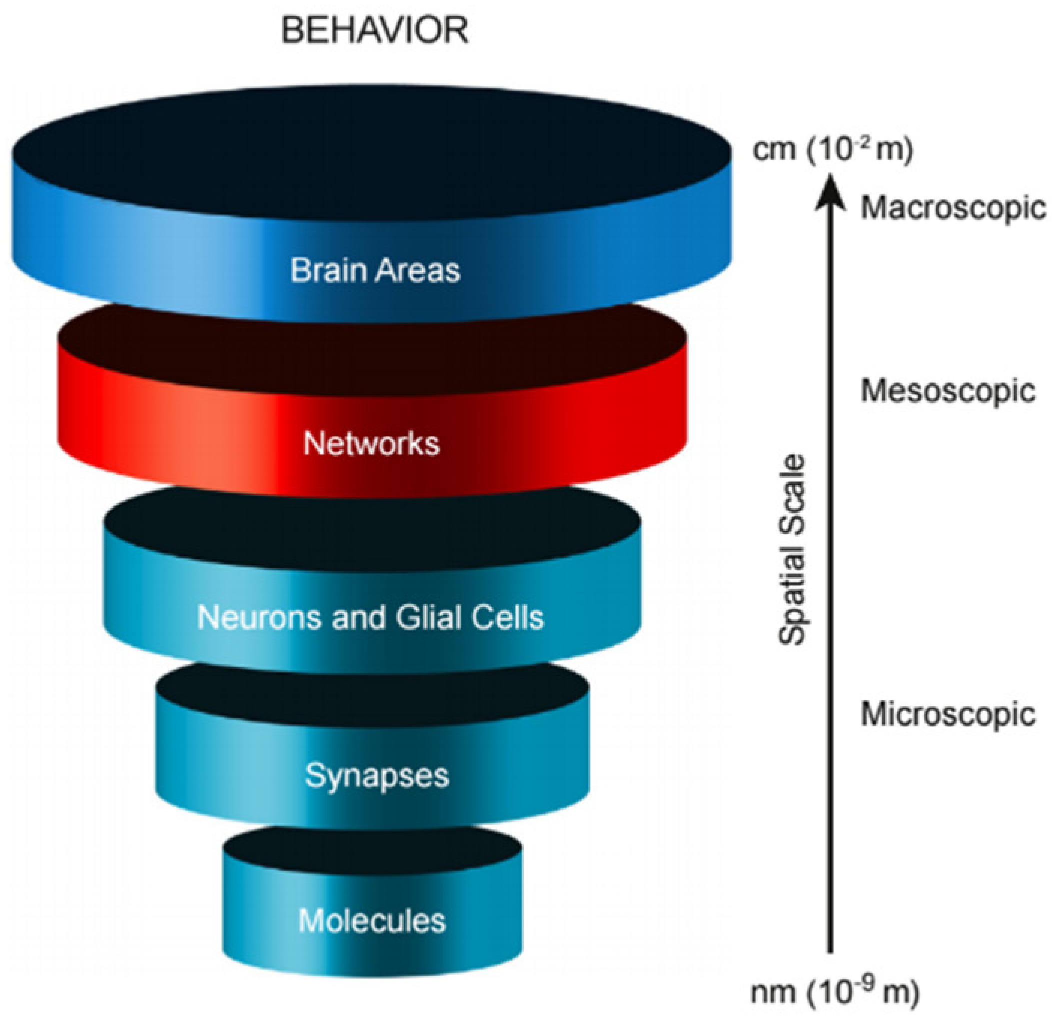


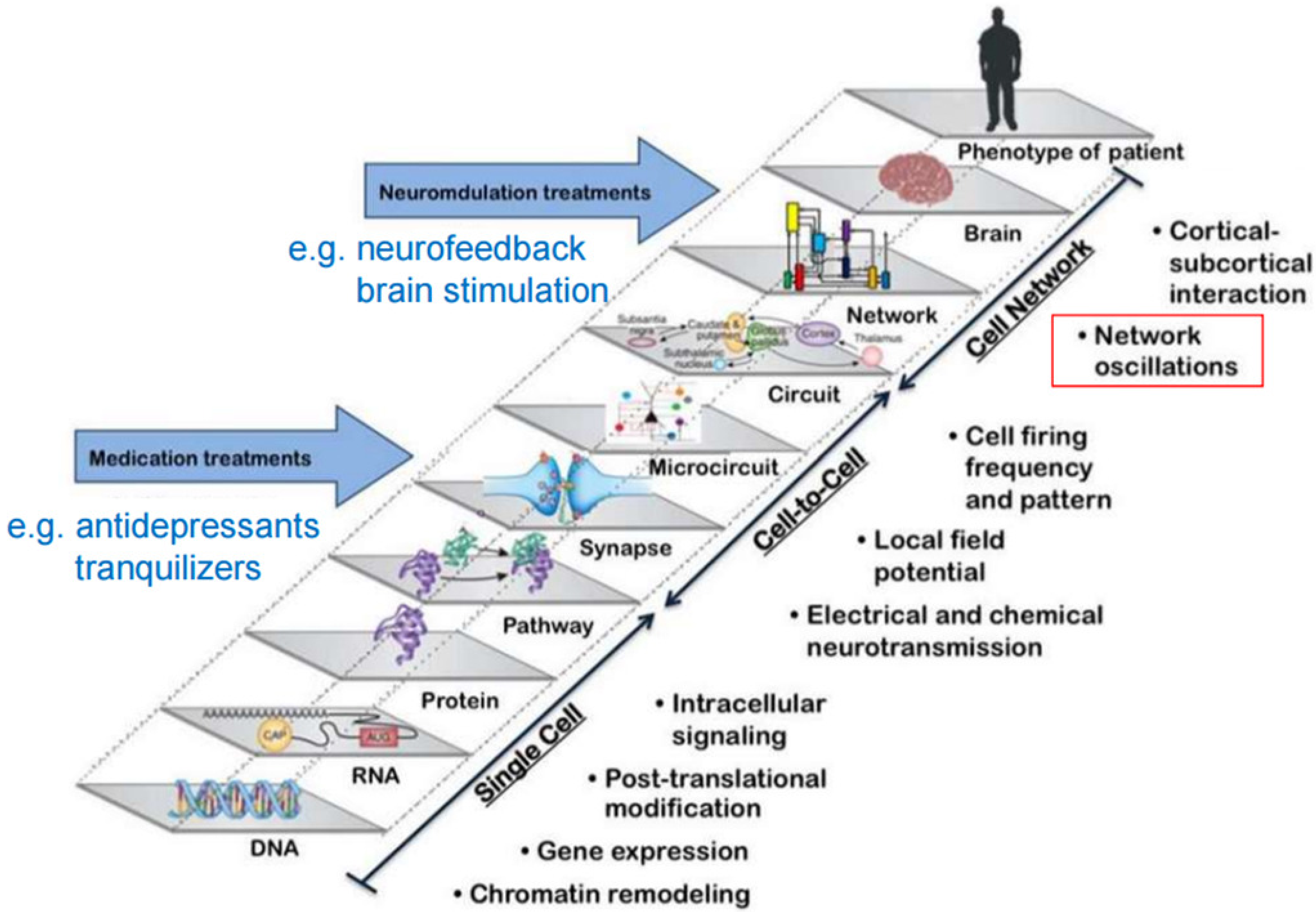
Illustration of brain information flow that can only be measured by the electroencephalogram using computers.
Information flow – Millisecond Match-Mismatch From Rabinovich et al, 2012

Functional Neuroimaging Modalities

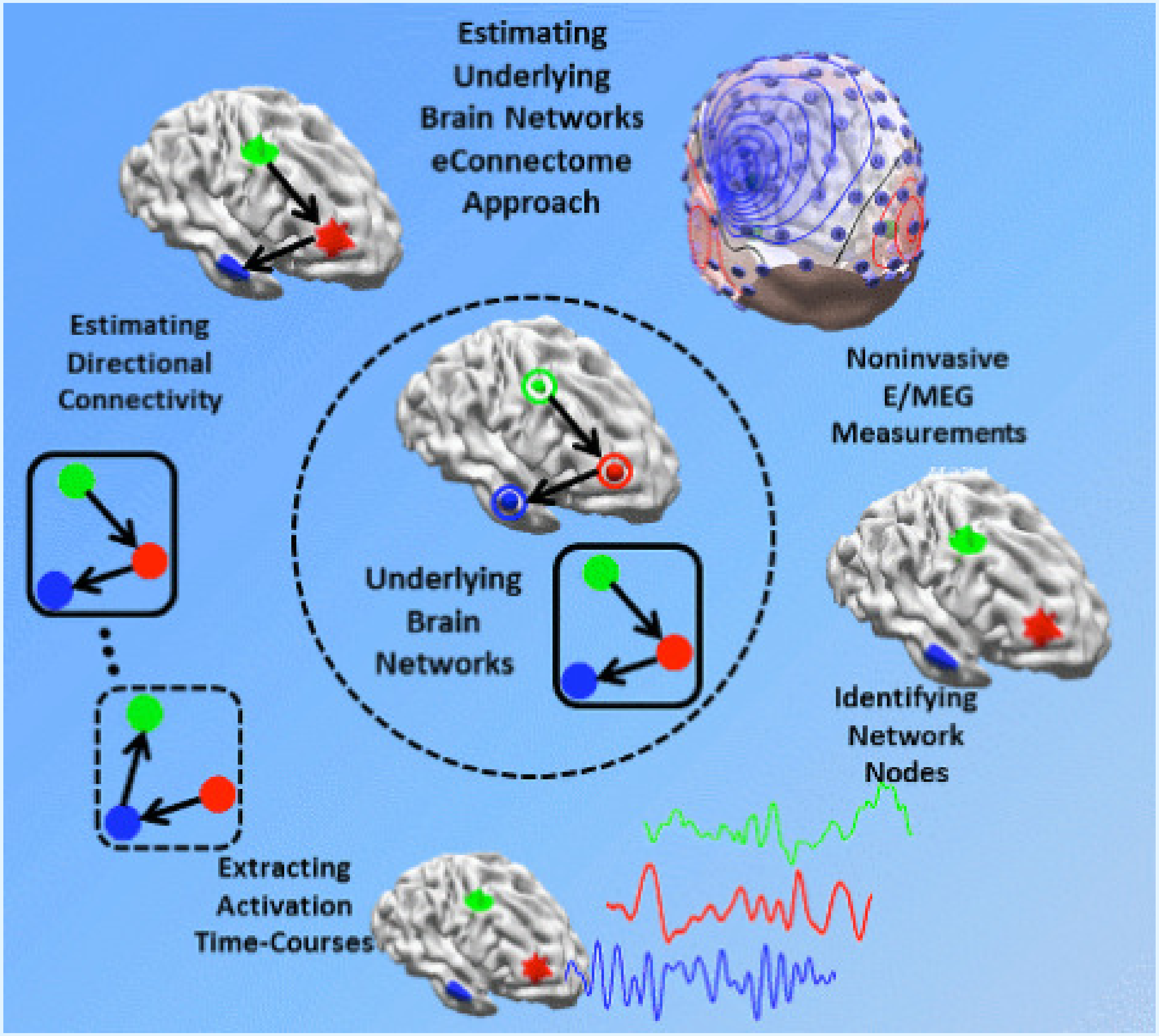




Frohlich, F., 2016. Network Neuroscience. Academic Press, NY



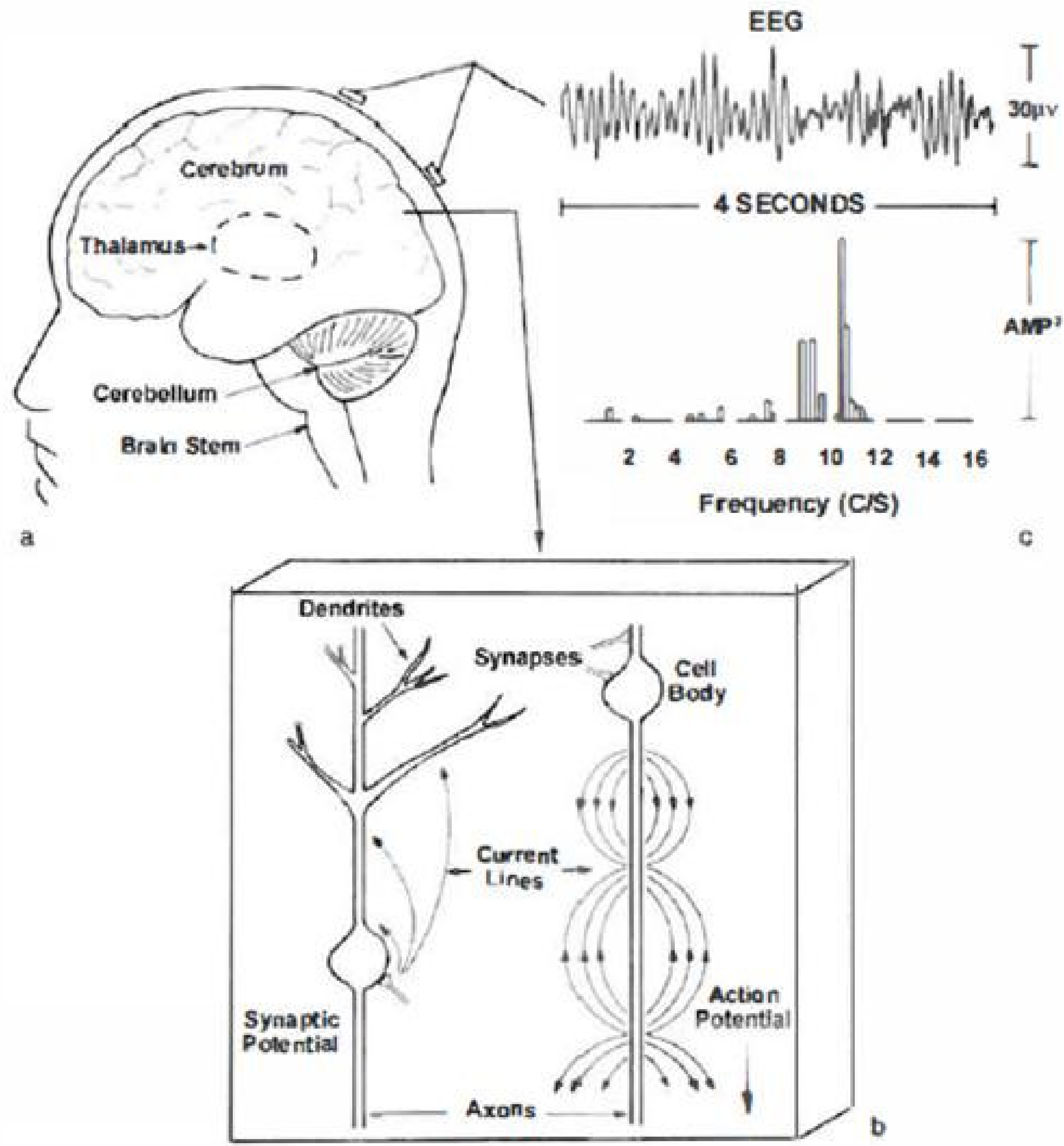
tuning-pathological-brain-oscillations-Thomas Ros-video -From Leuchter, 2015



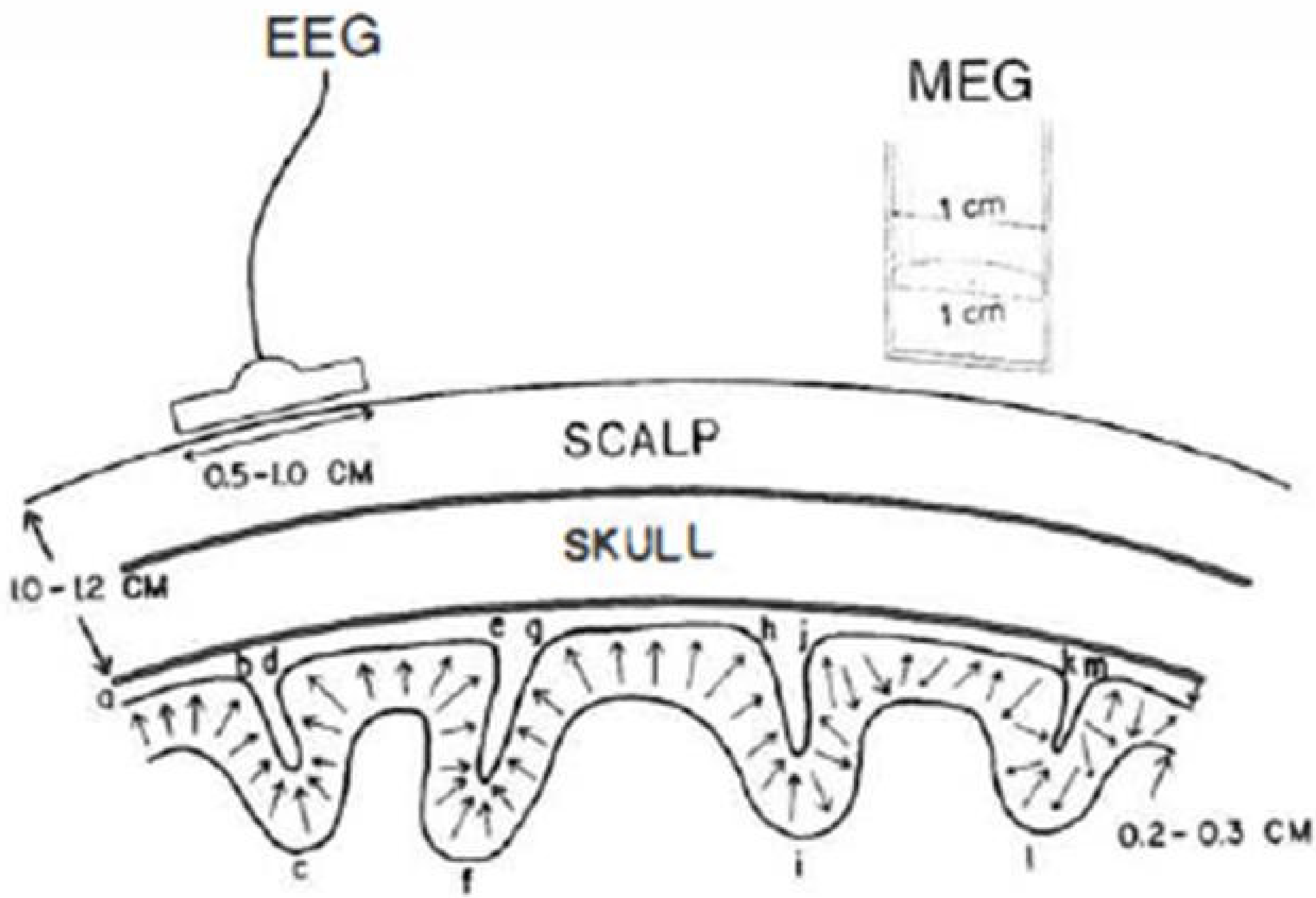
Noninvasive Electromagnetic Source Imaging and Granger Causality Analysis: An Electrophysiological Connectome (eConnectome) Approach ***Abbas Sohrabpour, Shuai Ye, Gregory Worrell, Wenbo Zhang, Bin He , University of Minnesota, USA,*** [*Volume: 63, Issue:12, Pages:2474-2487, 2016*]

Genesis of the Human Electroencephalogram - EEG

1- Pyramidal Neuron Dipoles
2- Oscillations In an Approx. 2mm thick sheet
3- Summated Local Field Potentials (LFP)
4- Amplitude = Proportion of Synchronous/Square Root of Proportion of Asynchronous Generators
5- Pacemakers and Resonance

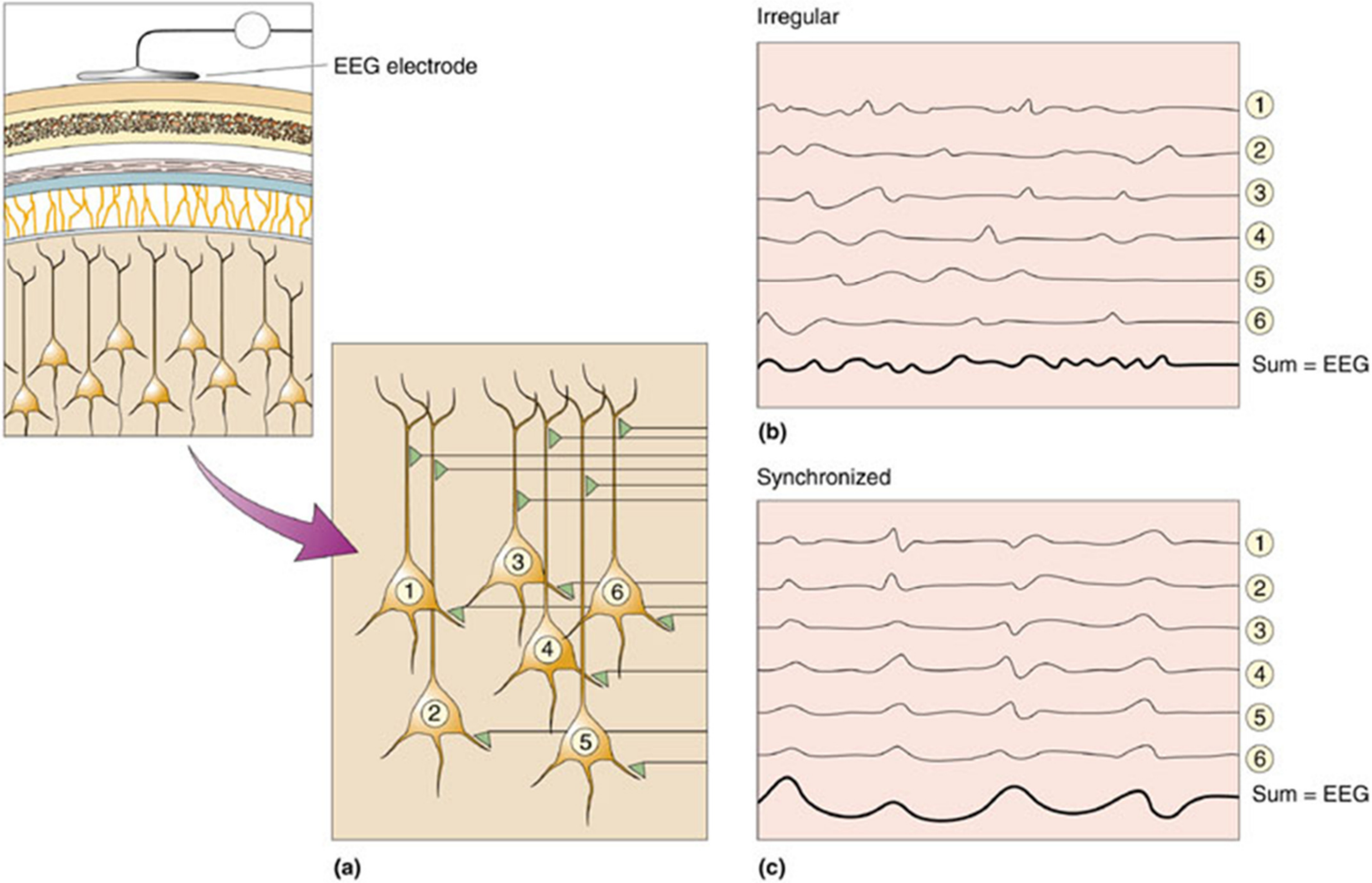


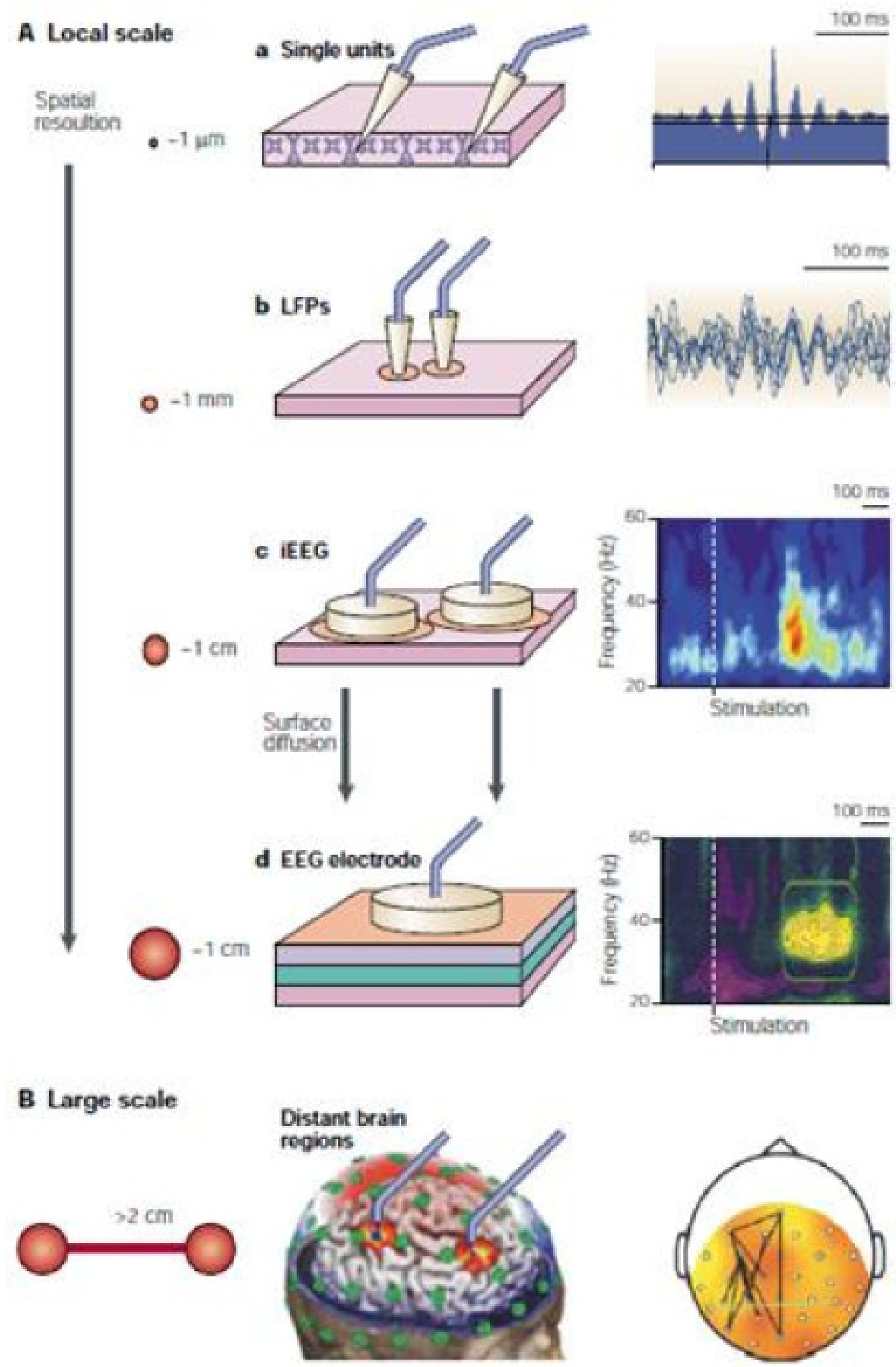
EEG
30μv
4 SECONDS
AMP²
2 4 6 8 10 12 14 16
Frequency (C/S)
Cerebrum
Thalamus
Cerebellum
Brain Stem
a
c
Dendrites
Synapses
Cell Body
Current Lines
Synaptic Potential
Action Potential
Axons
b



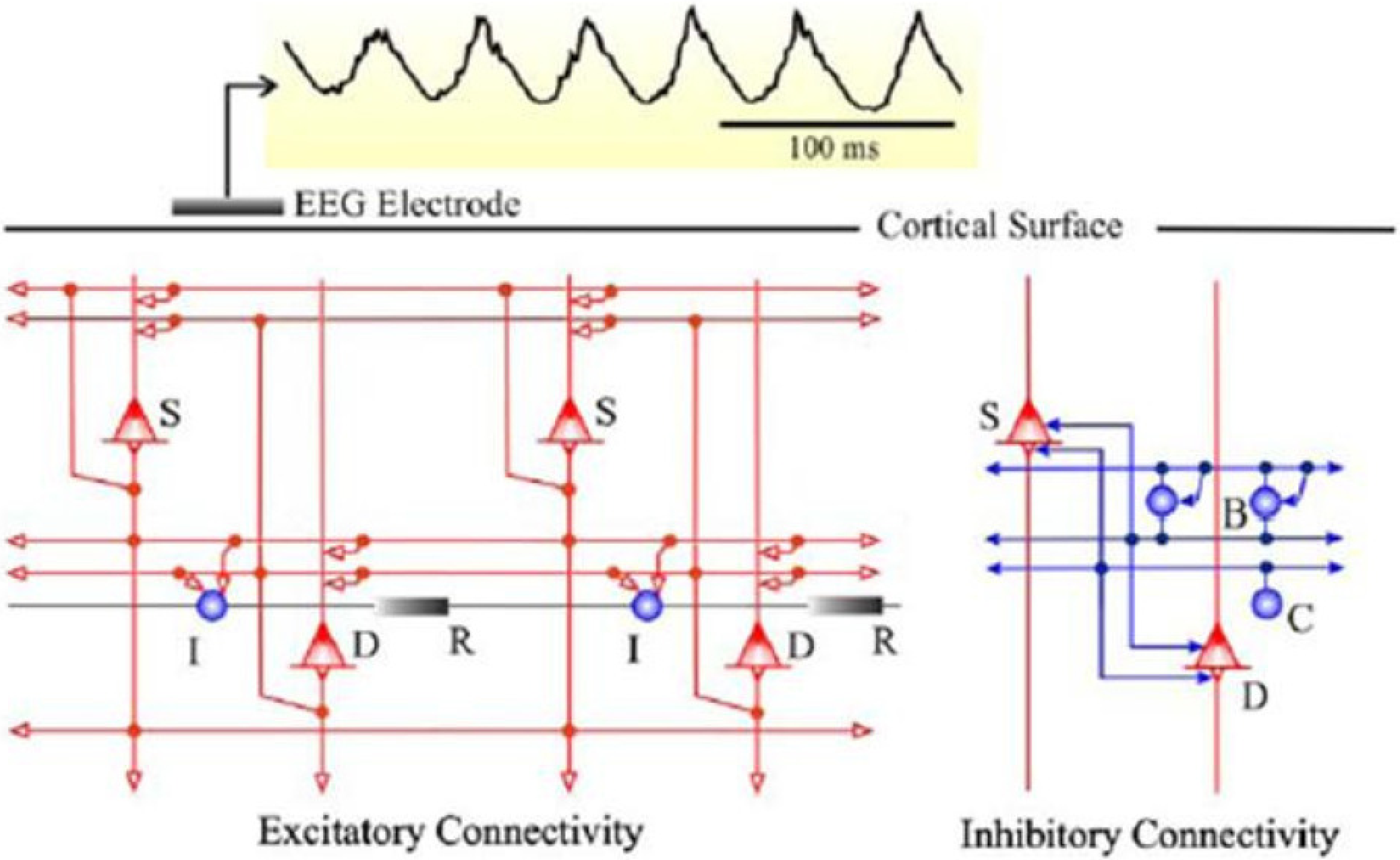
From Nunez, Electrical Fields of the Brain, Oxford Univ. Press, 1981

EEG = Summated Potentials at the Scalp



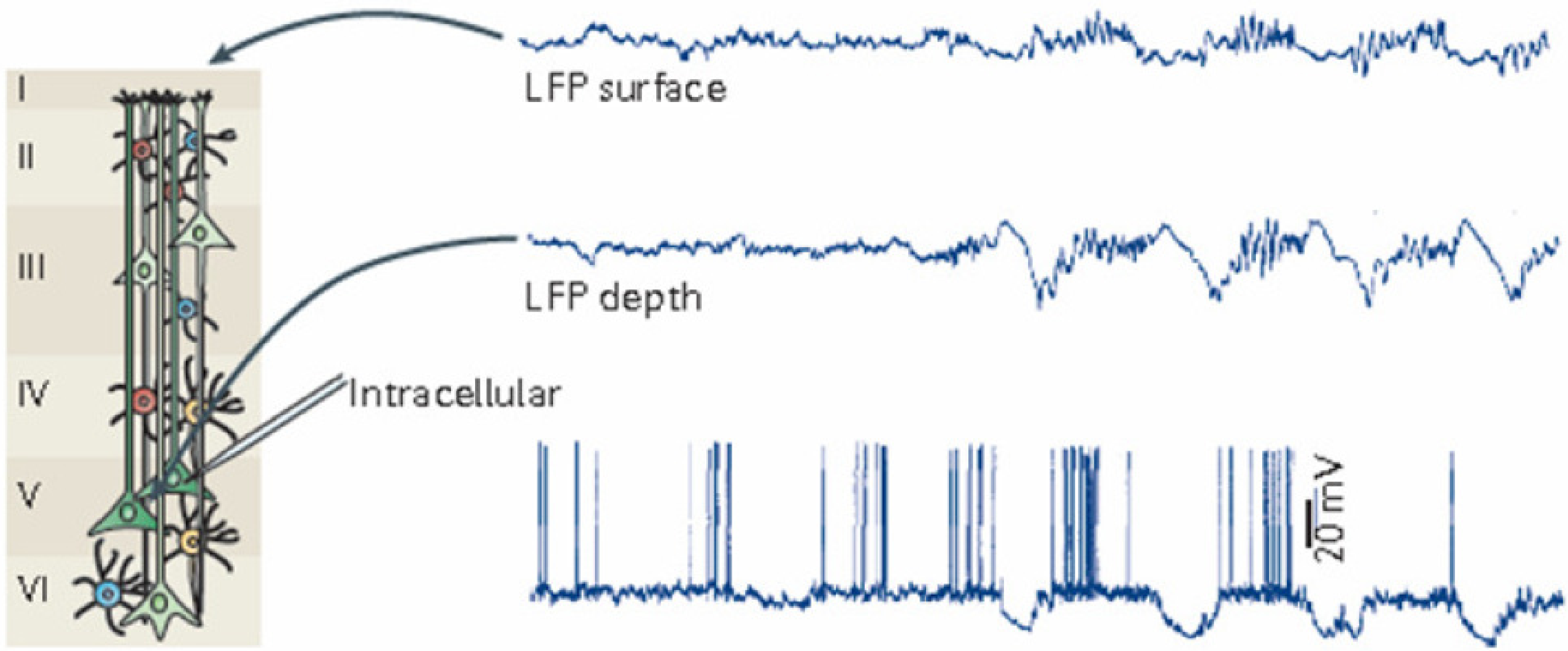


From Varela et al, 2001

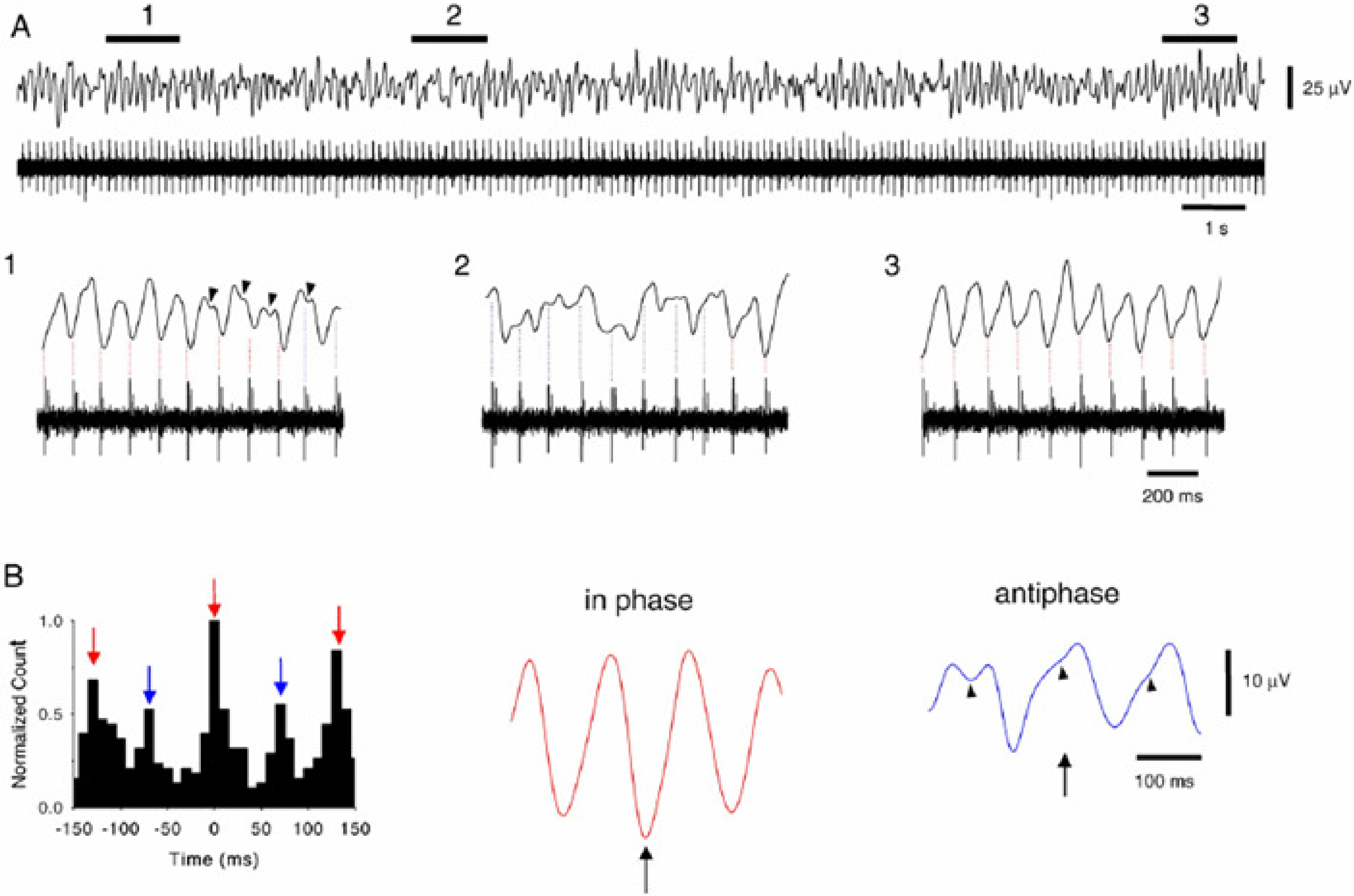

100 ms
EEG Electrode
Cortical Surface
S
S
S
B
I
D
R
I
D
R
C
D
Excitatory Connectivity
Inhibitory Connectivity

How Neurons are Selected For Brief Periods of Time

Shifting In-Phase vs Anti-Phase

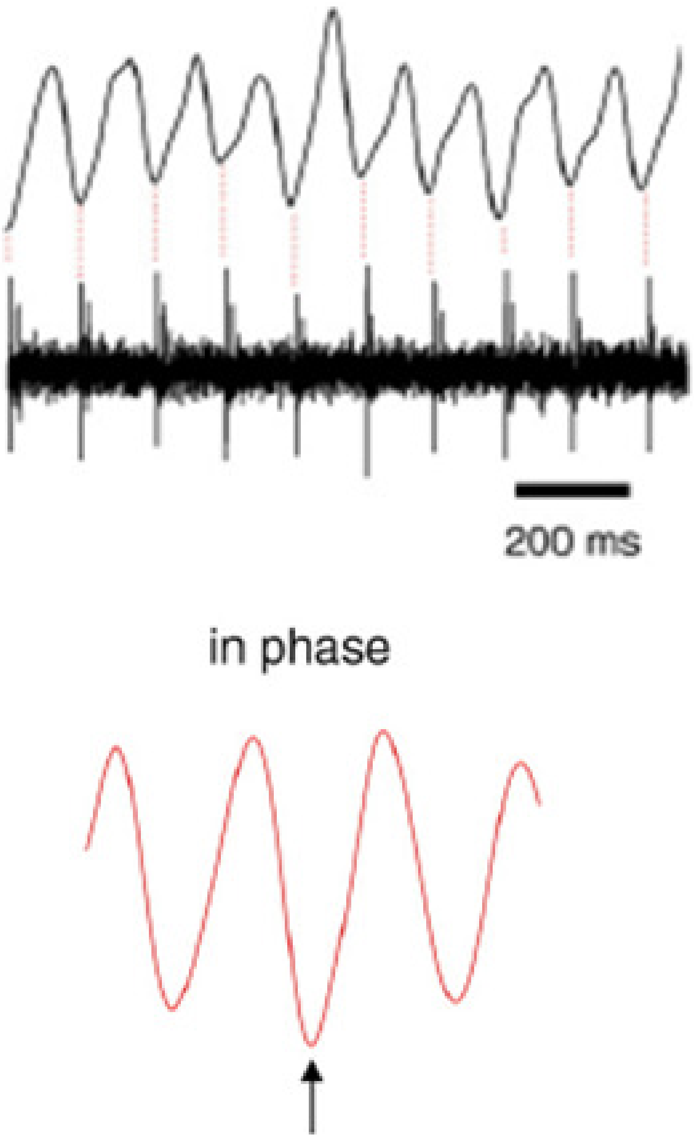


I
II
III
IV
V
VI
LFP surface
LFP depth
Intracellular
20 mV

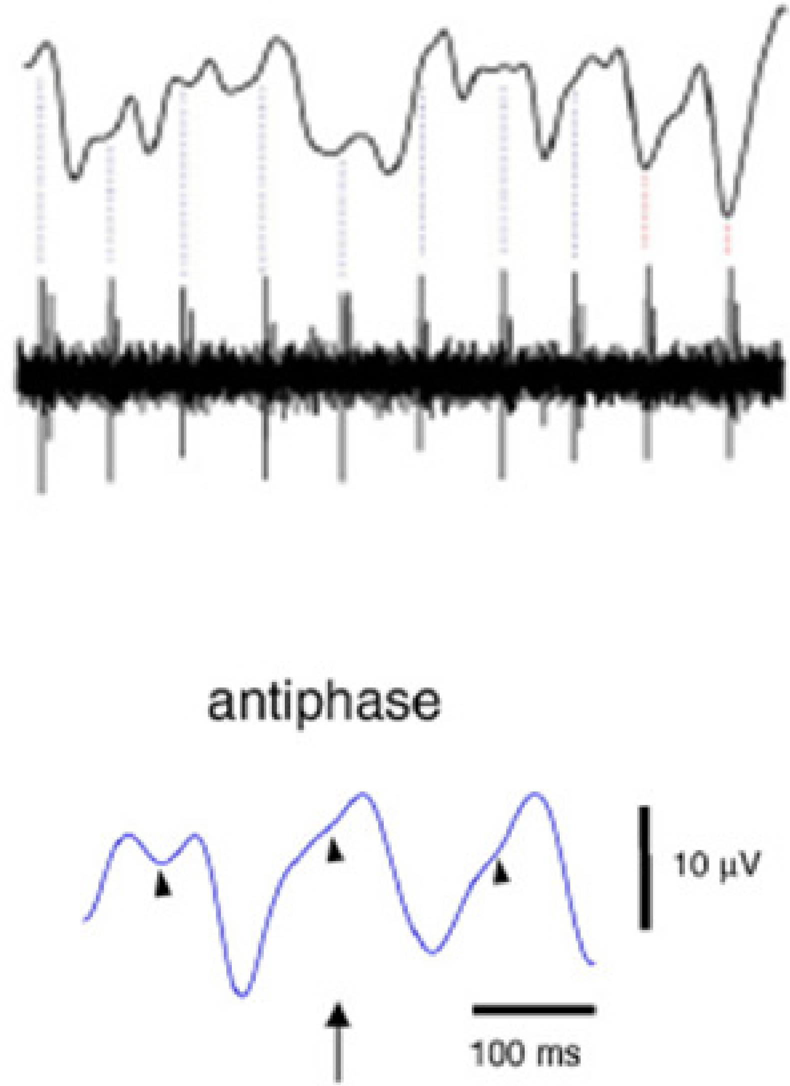


From Hughes et al, 2004

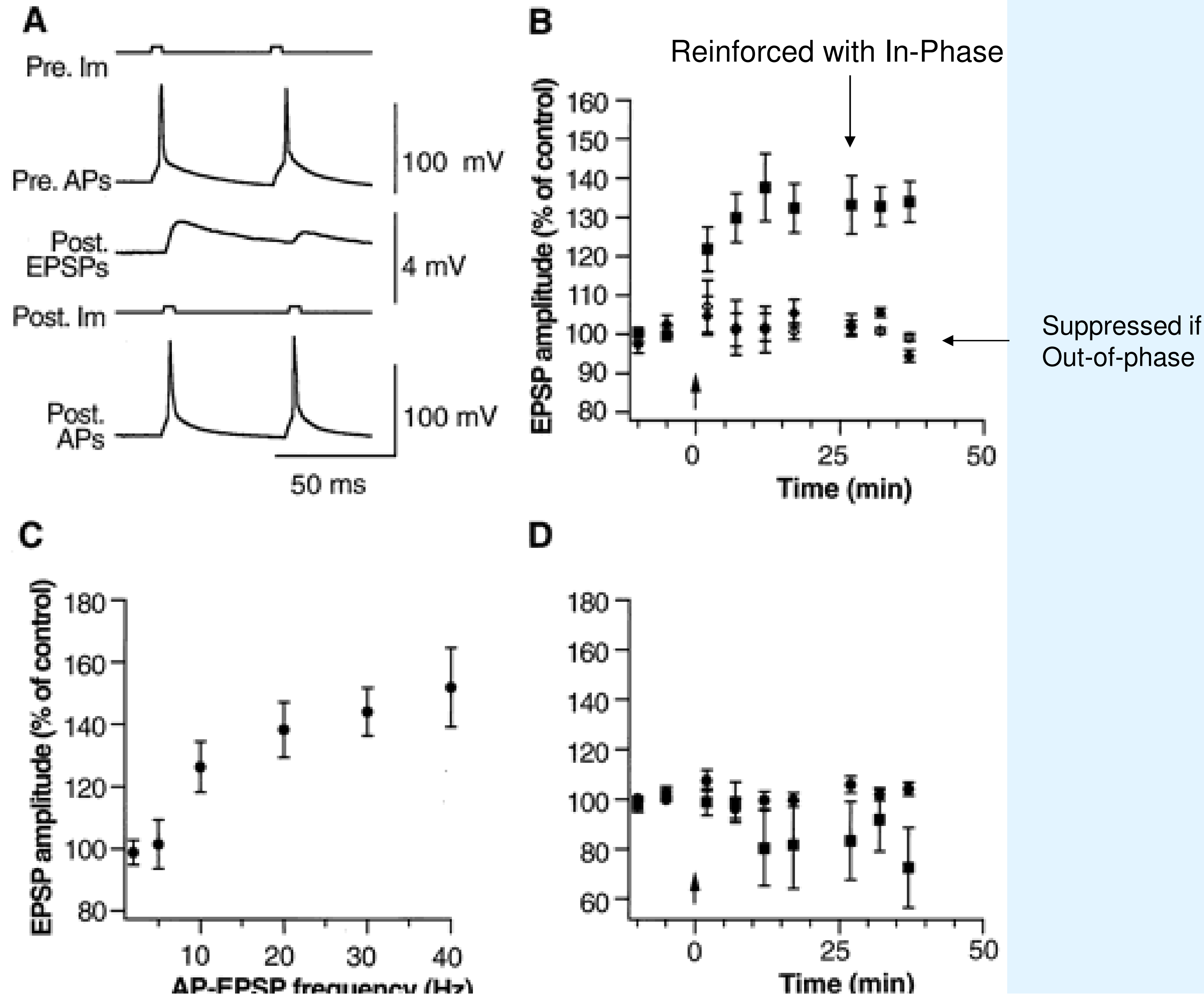
LFPs & In-Phase Action Potentials



LFPs & Anti-Phase Action Potentials

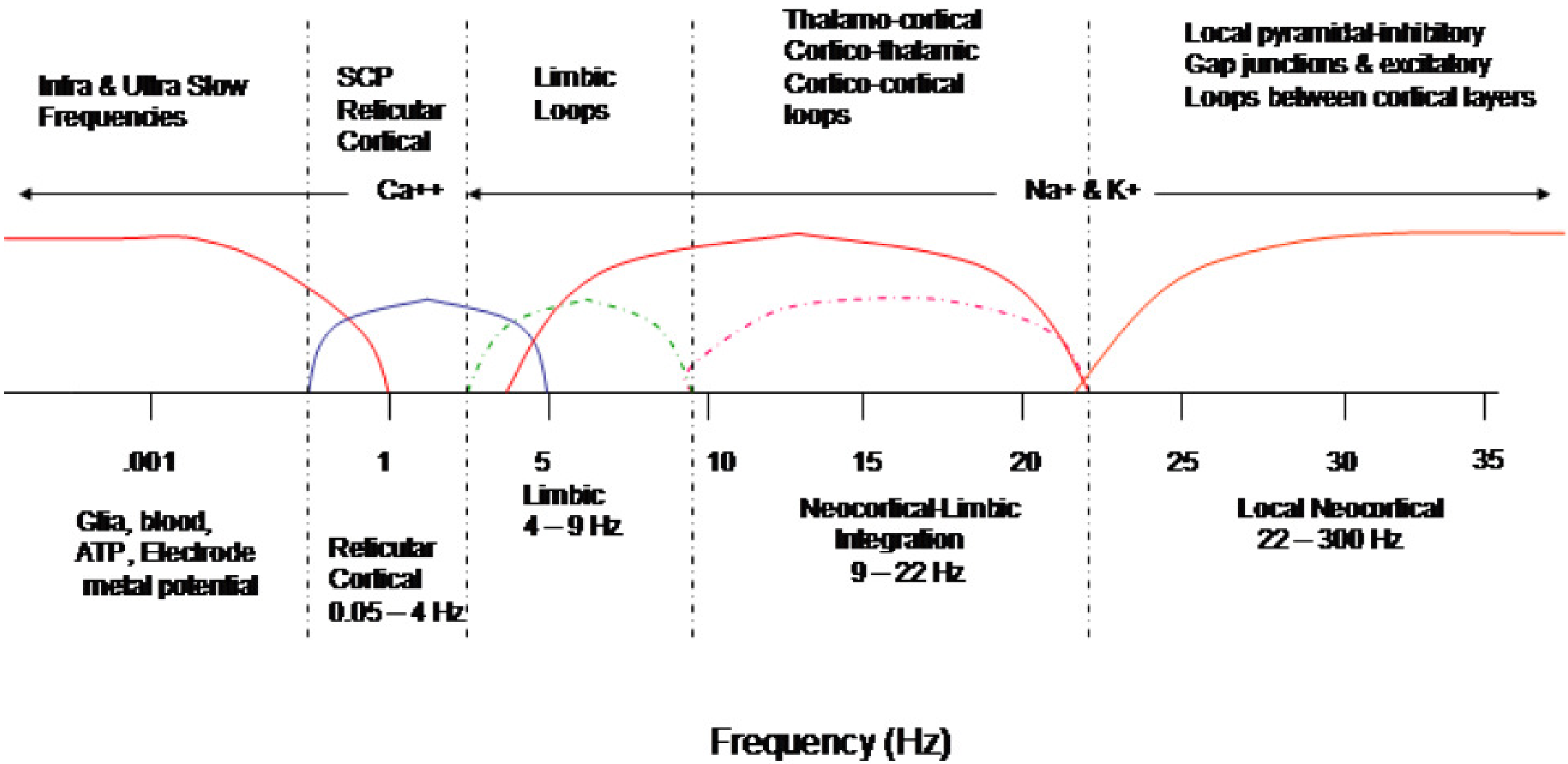


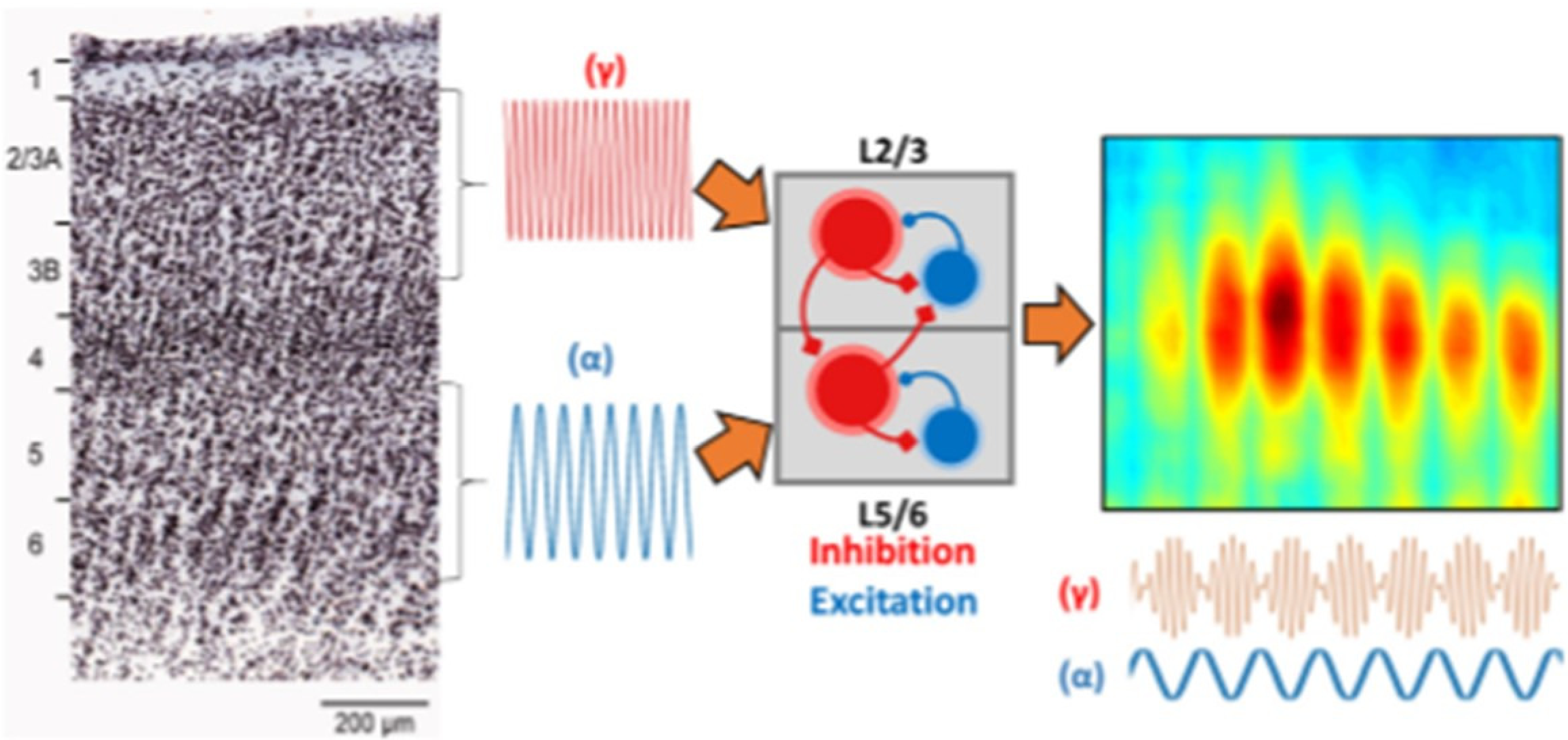
From Hughes et al, 2004



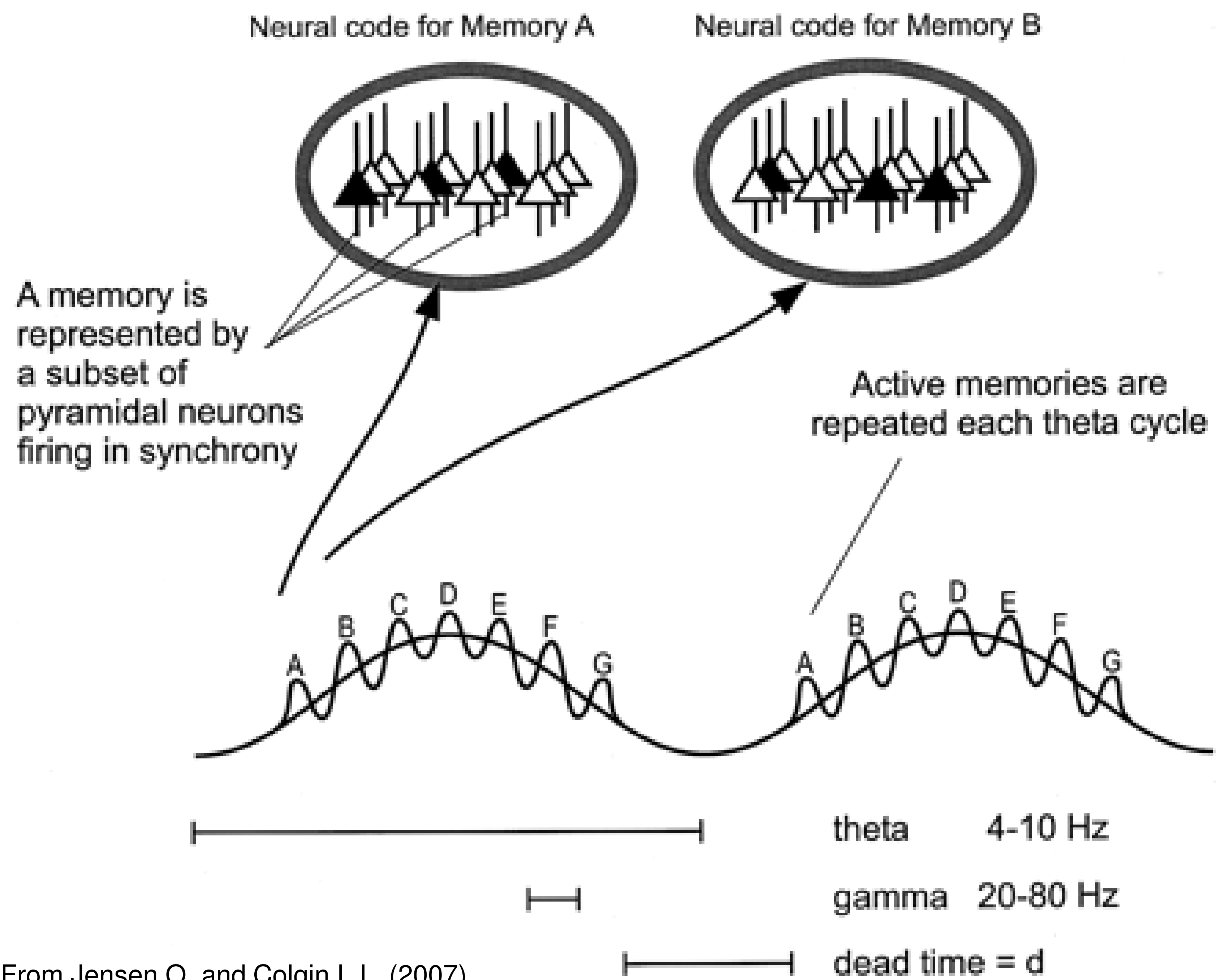
A
Pre. Im
Pre. APs
100 mV
Post. EPSPs
4 mV
Post. Im
Post. APs
100 mV
50 ms
B
Reinforced with In-Phase
EPSP amplitude (% of control)
160
150
140
130
120
110
100
90
80
0
25
50
Time (min)
Suppressed if Out-of-phase
C
EPSP amplitude (% of control)
180
160
140
120
100
80
10
20
30
40
AP-EPSP frequency (Hz)
D
180
160
140
120
100
80
60
0
25
50
Time (min)

Cross-Frequency Phase Lock and Phase Shift Spectrum

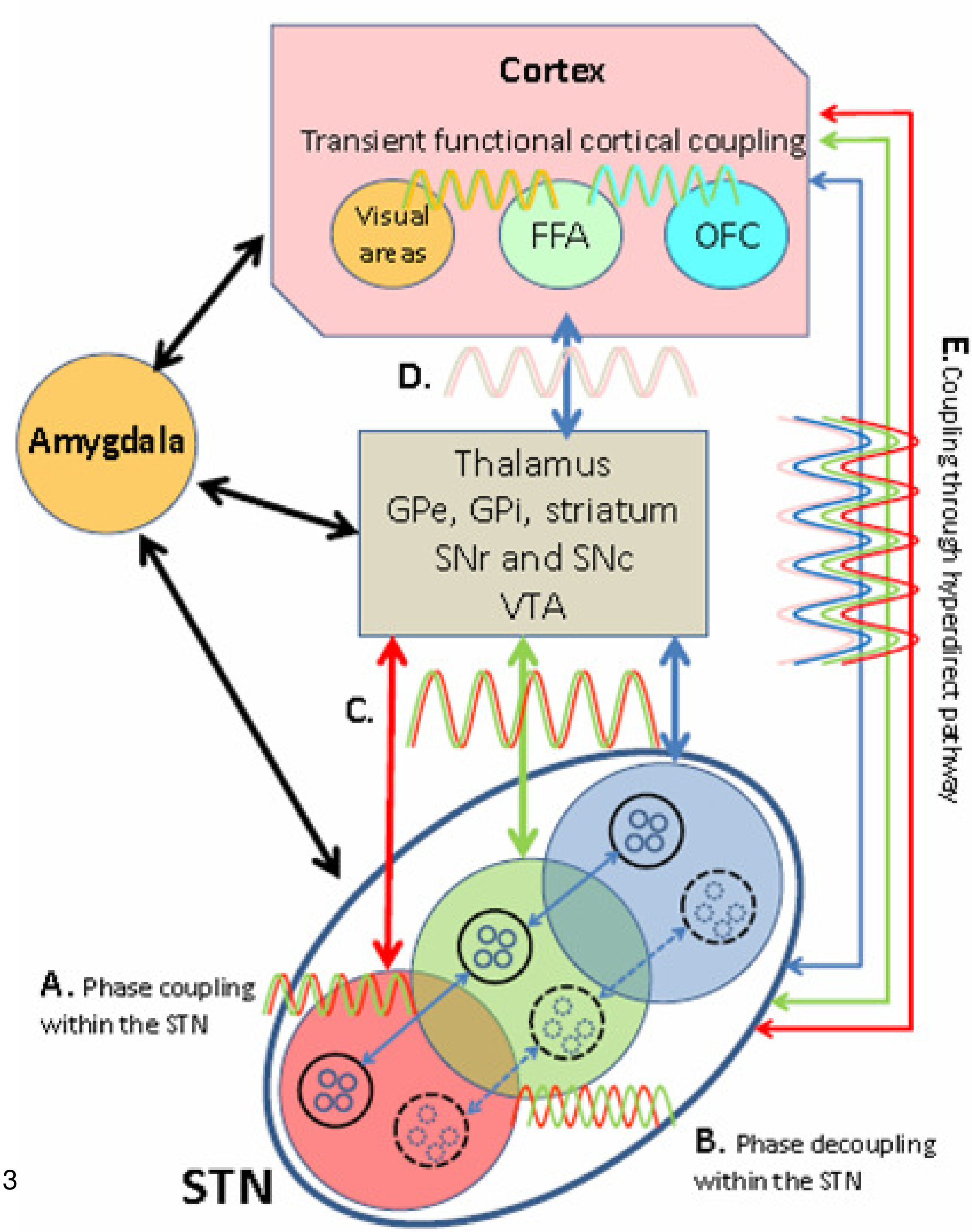




K. Kessler et al. J.; Neuroscience and Behavioral Reviews. 71(2016) 601-620



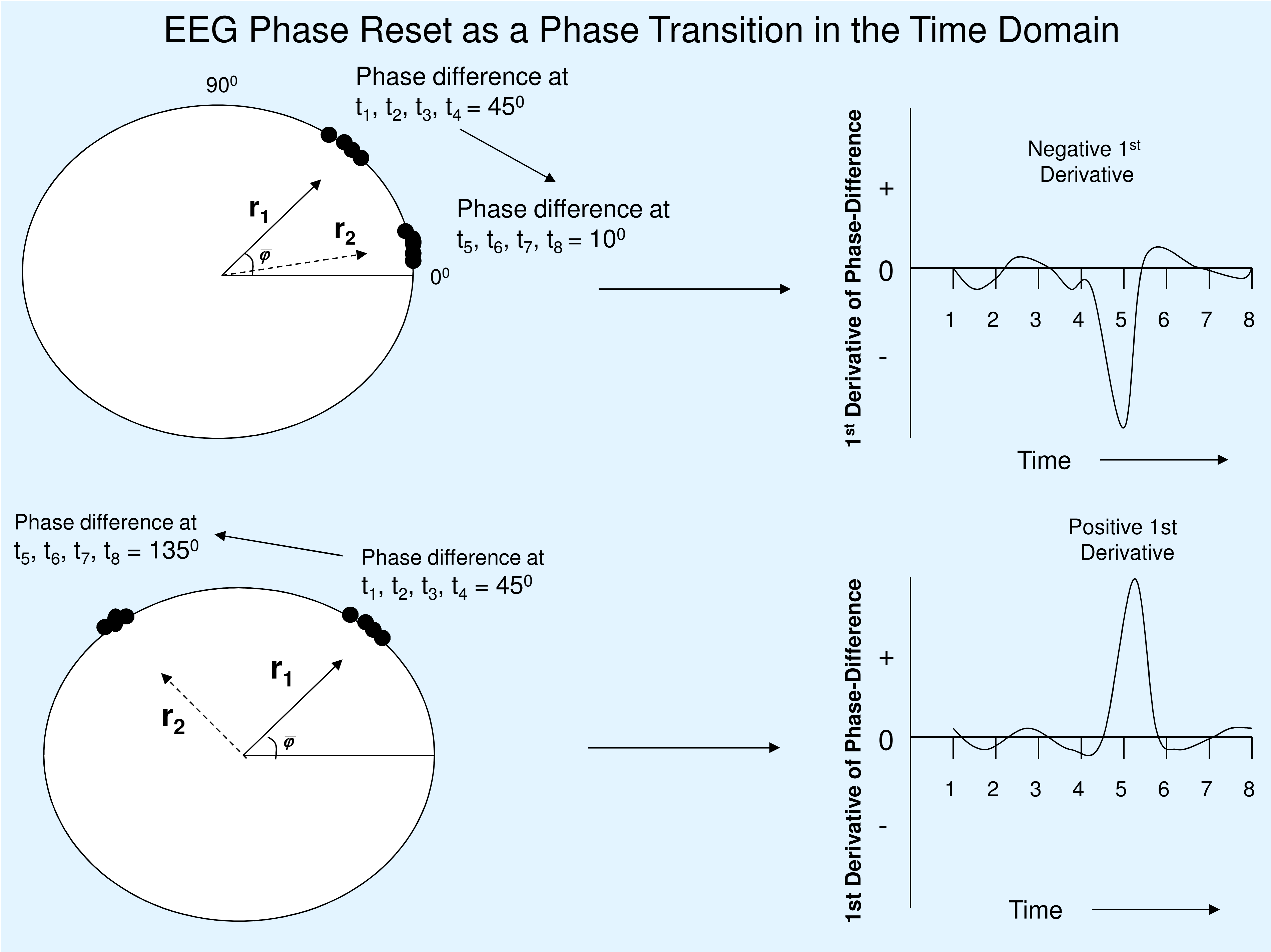
From Jensen,O.,and Colgin,L.L. (2007)



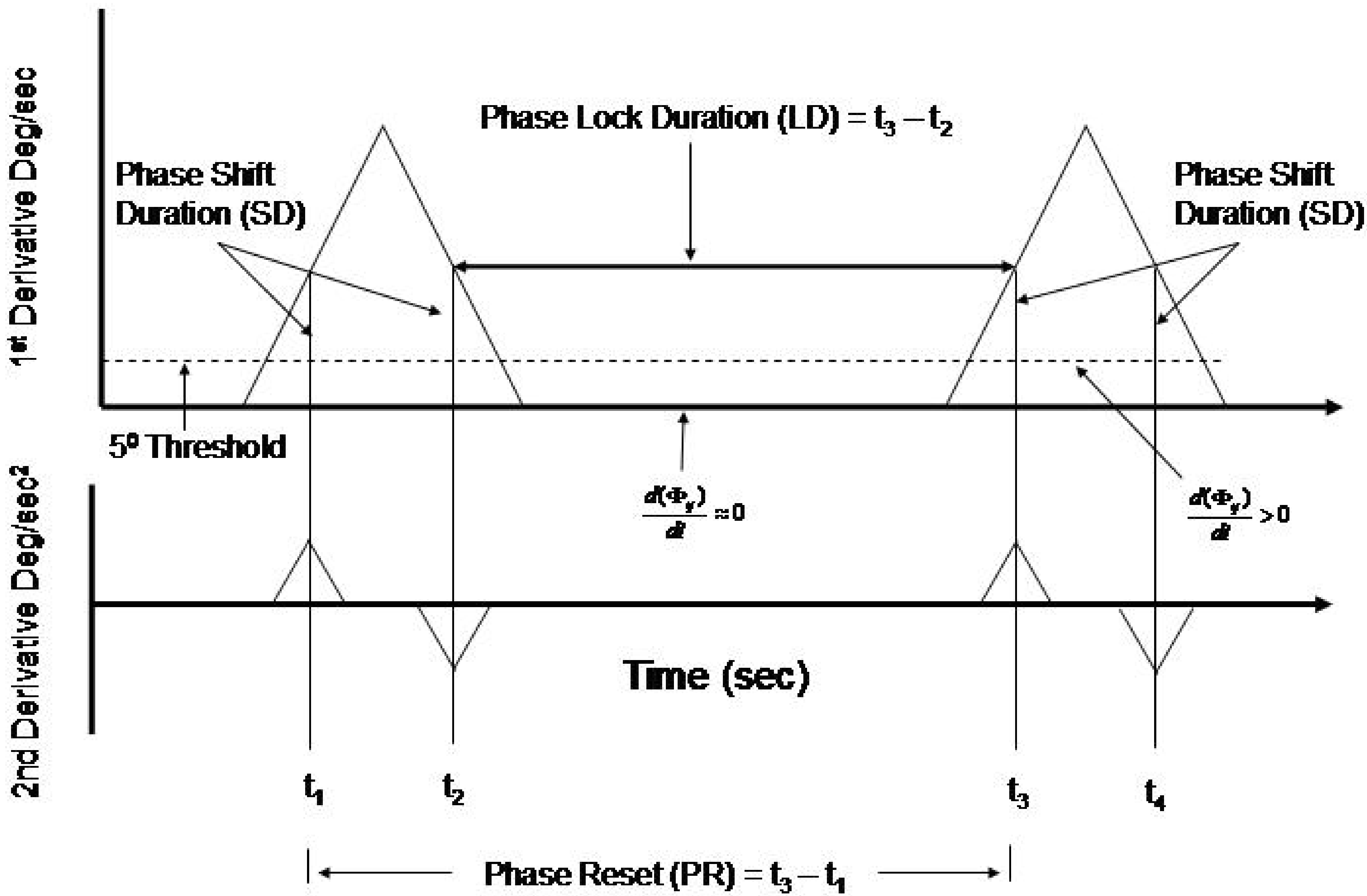
From Peron et al, 2013

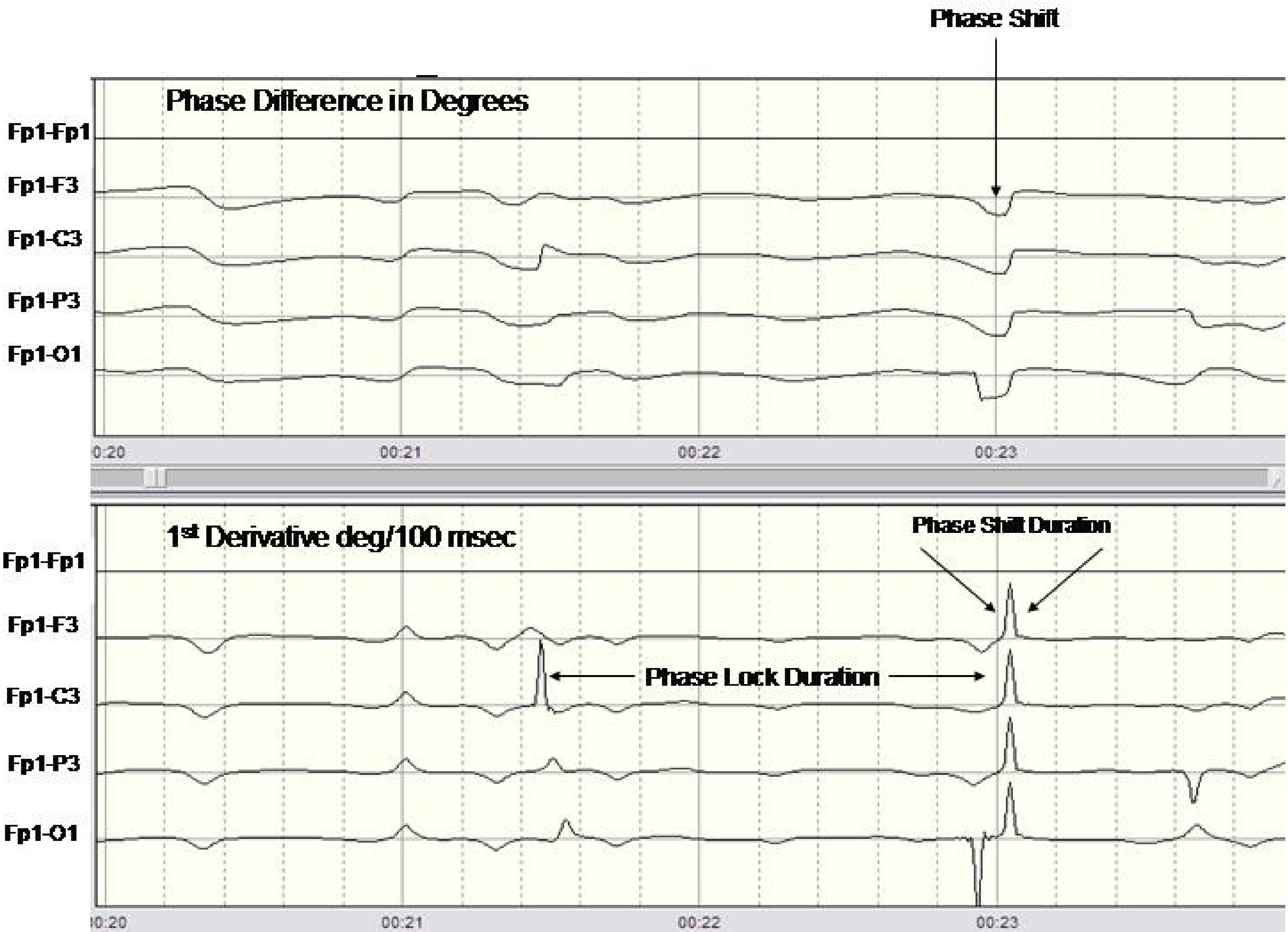
How to Measure Phase Shift and Phase Lock

Phase Reset and Neural Resource Selection and Allocation

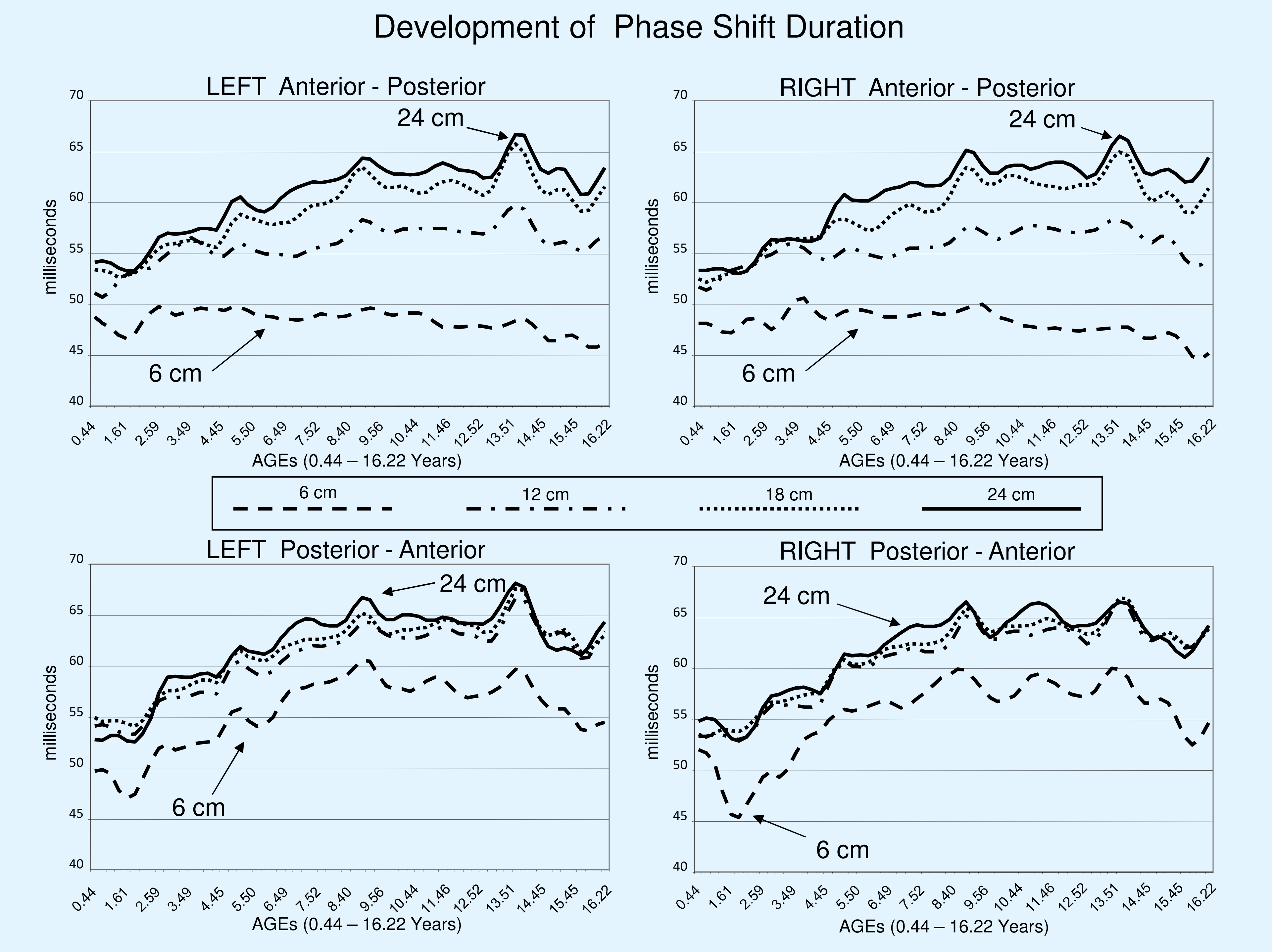

EEG Phase Reset as a Phase Transition in the Time Domain
90^0
Phase difference at
t_1, t_2, t_3, t_4 = 45^0
r_1
r_2
$\bar{\varphi}$
Phase difference at
t_5, t_6, t_7, t_8 = 10^0
0^0
1^{st} Derivative of Phase-Difference
+
0
-
Negative 1^{st}
Derivative
1 2 3 4 5 6 7 8
Time
Phase difference at
t_5, t_6, t_7, t_8 = 135^0
Phase difference at
t_1, t_2, t_3, t_4 = 45^0
r_1
r_2
$\bar{\varphi}$
1st Derivative of Phase-Difference
+
0
-
Positive 1st
Derivative
1 2 3 4 5 6 7 8
Time

Phase Reset Metrics

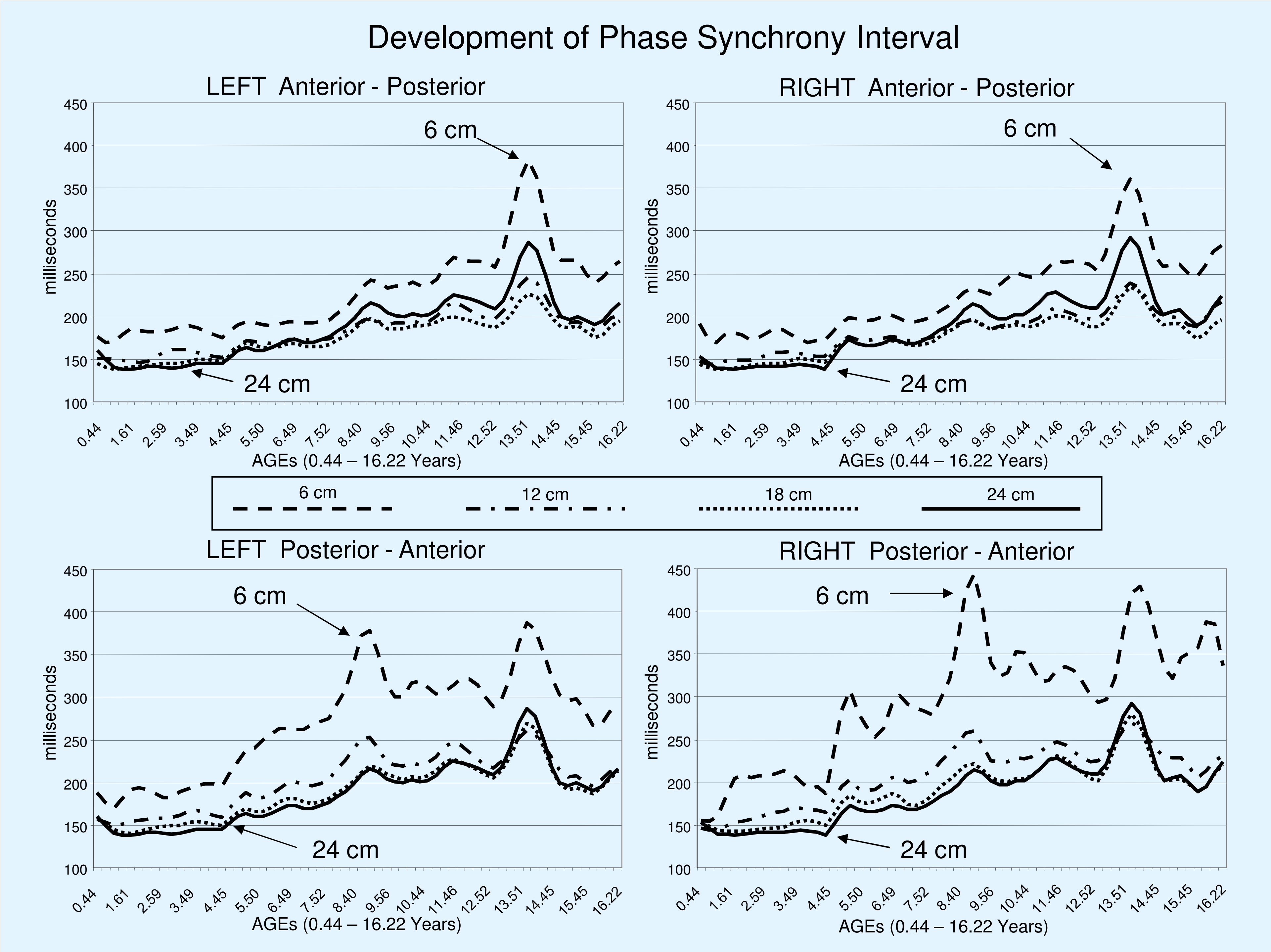




Phase Shift
Phase Difference in Degrees
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23
1st Derivative deg/100 msec
Phase Shift Duration
Fp1-Fp1
Fp1-F3
Fp1-C3
Phase Lock Duration
Fp1-P3
Fp1-O1
00:20
00:21
00:22
00:23



Development of Phase Shift Duration
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
24 cm
6 cm
milliseconds
70
65
60
55
50
45
40
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22
AGEs (0.44 – 16.22 Years)
6 cm
12 cm
18 cm
24 cm



Development of Phase Synchrony Interval
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
milliseconds
AGEs (0.44 – 16.22 Years)
6 cm
12 cm
18 cm
24 cm

Published in NeuroImage – NeuroImage, 42(4): 1639-1653, 2008.

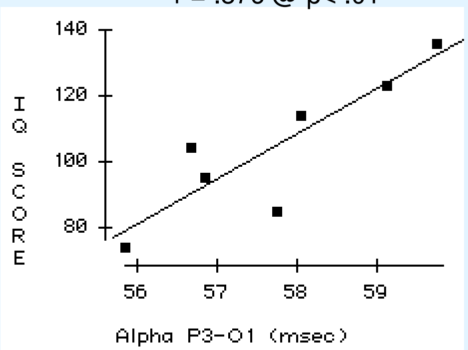
INTELLIGENCE AND EEG PHASE RESET: A TWO COMPARTMENTAL MODEL OF PHASE SHIFT AND LOCK

Thatcher, R. W. [1,2], North, D. M.[1], and Biver, C. J.[1]

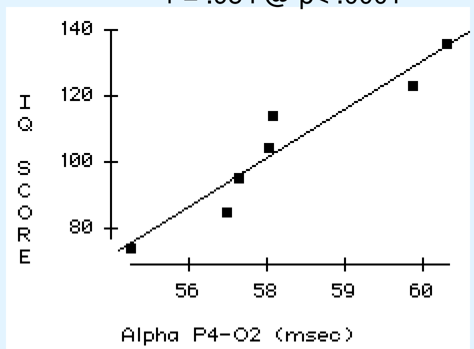
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute. St. Petersburg, Fl[1] and Department of Neurology, University of South Florida College of Medicine, Tampa, Fl.[2]

Regressions & Correlations of Phase Shift Duration Short Distances (6 cm)

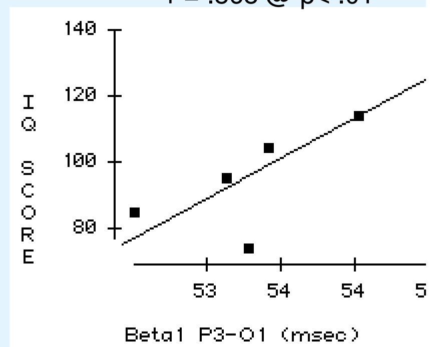
IQ = 78 + 13.78 x (msec)
r = .876 @ p< .01



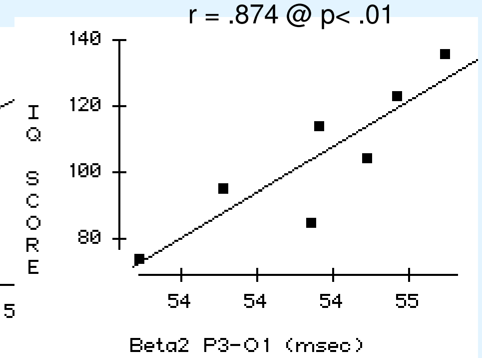
IQ = 70 +11.85 x (msec)
r = .954 @ p< .0001



IQ = 75 + 24.45 x (msec)
r = .868 @ p< .01

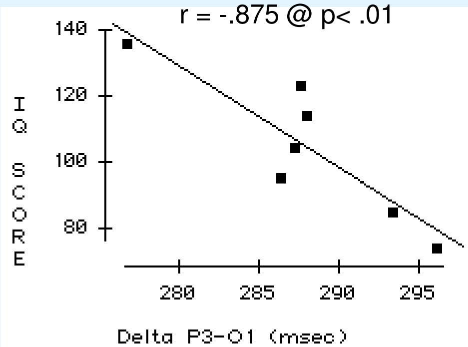


IQ = 68 + 34.40 x (msec)
r = .874 @ p< .01

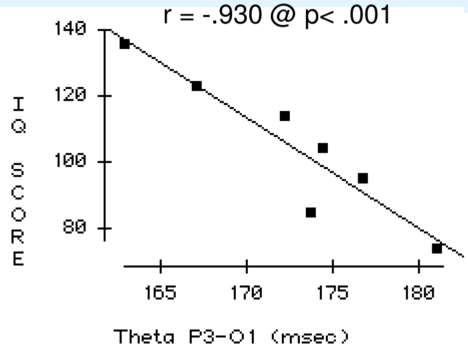


Regressions & Correlations of Phase Locking Interval Short Distances (6 cm)

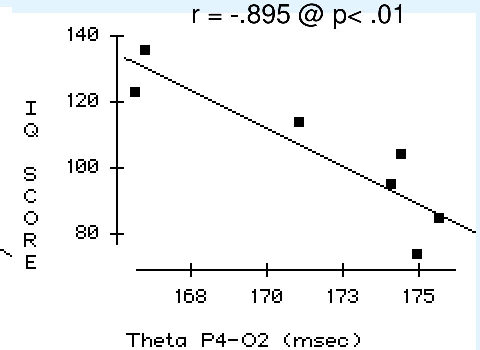
IQ = 143 - 3.11 x (msec)
r = -.875 @ p< .01



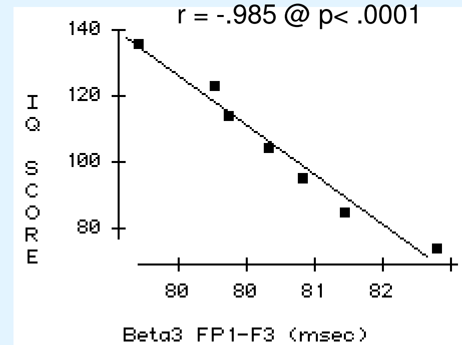
IQ = 142 - 3.36 x (msec)
r = -.930 @ p< .001



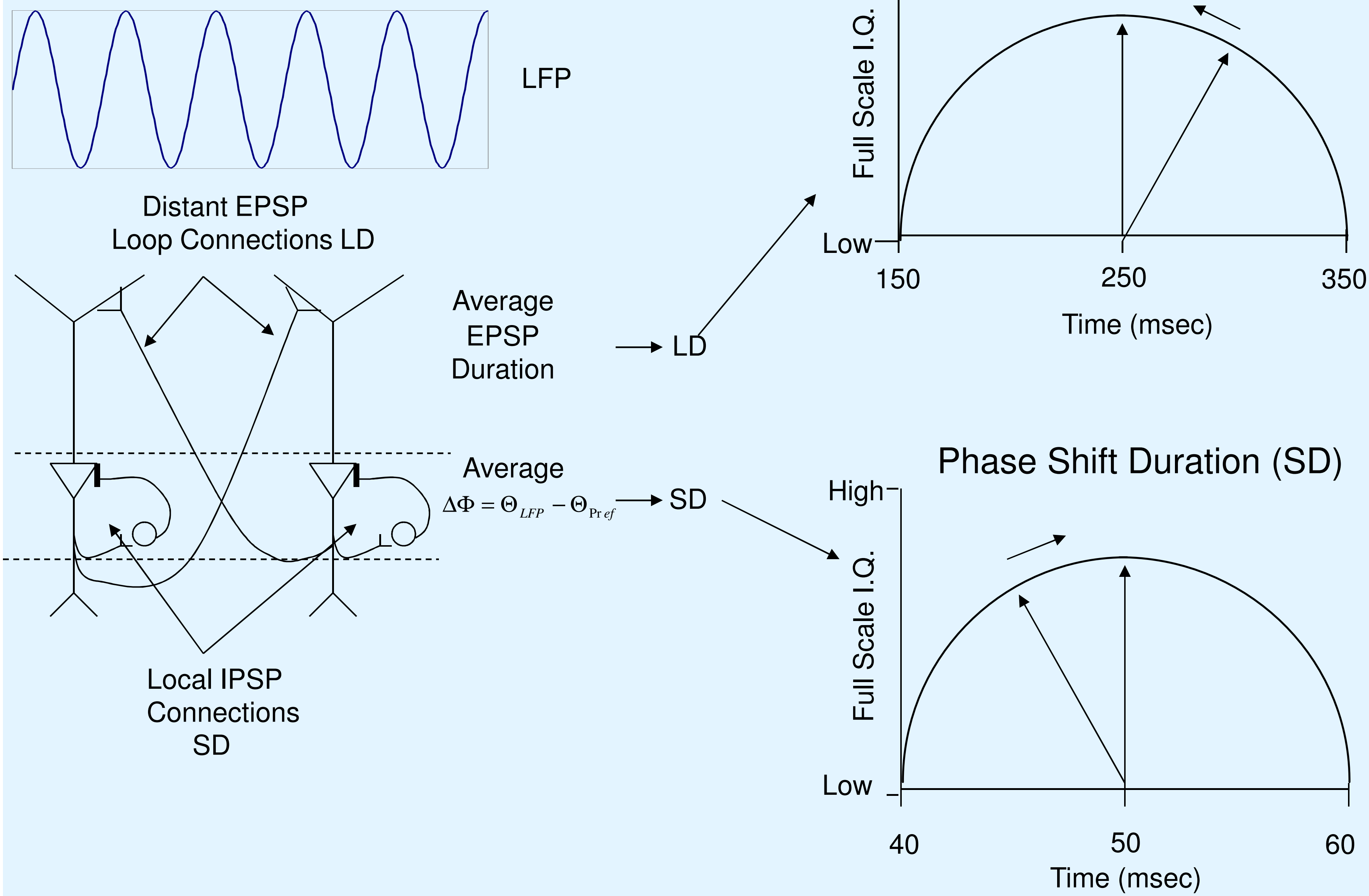
IQ = 132 - 4.57 x (msec)
r = -.895 @ p< .01



IQ = 140 - 20.08 x (msec)
r = -.985 @ p< .0001



Pyramidal Cell Model of EEG Phase Reset and Full Scale I.Q.



SCIENTIFIC REPORTS

OPEN

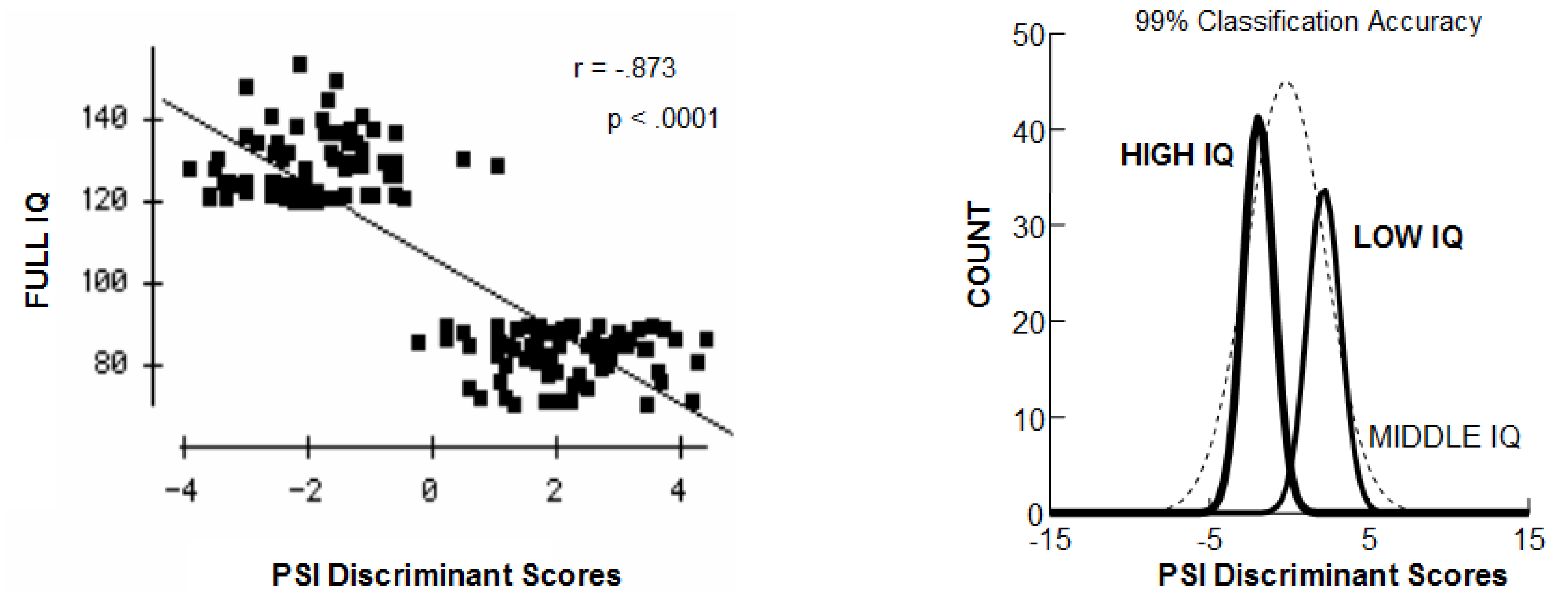
Intelligence and eeg measures of information flow: efficiency and homeostatic neuroplasticity

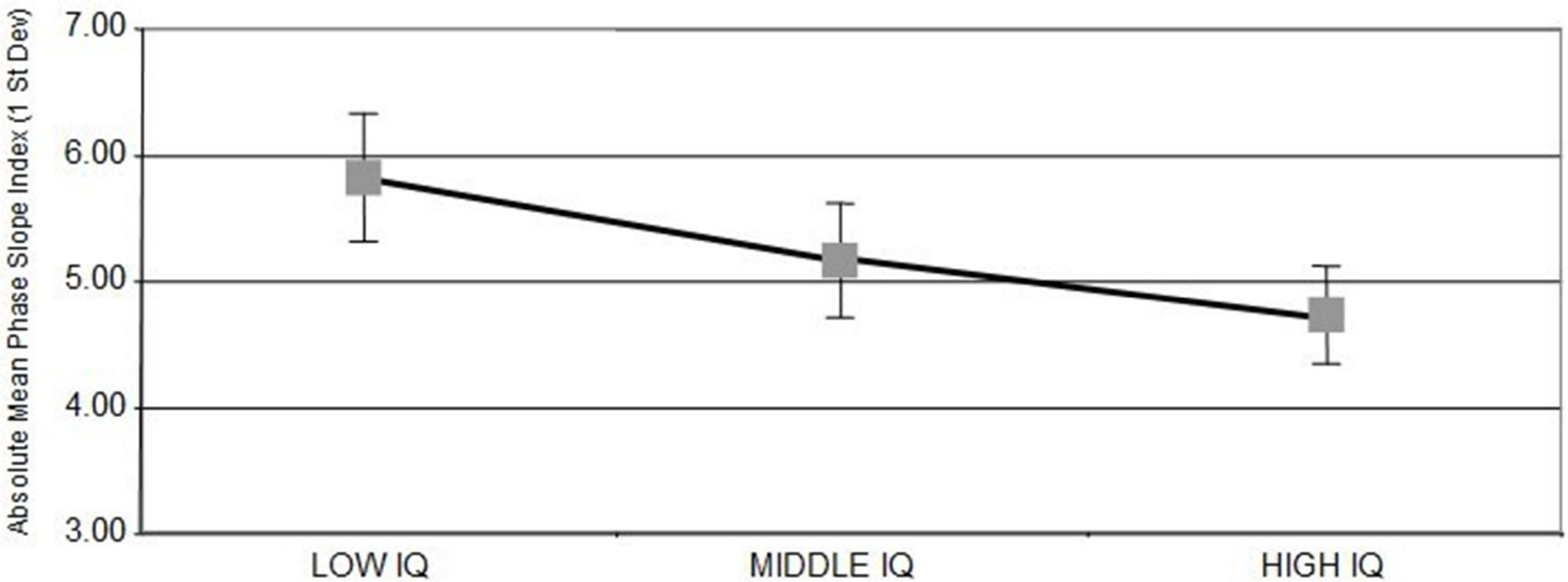
Received: 25 July 2016
Accepted: 14 November 2016
Published: 20 December 2016

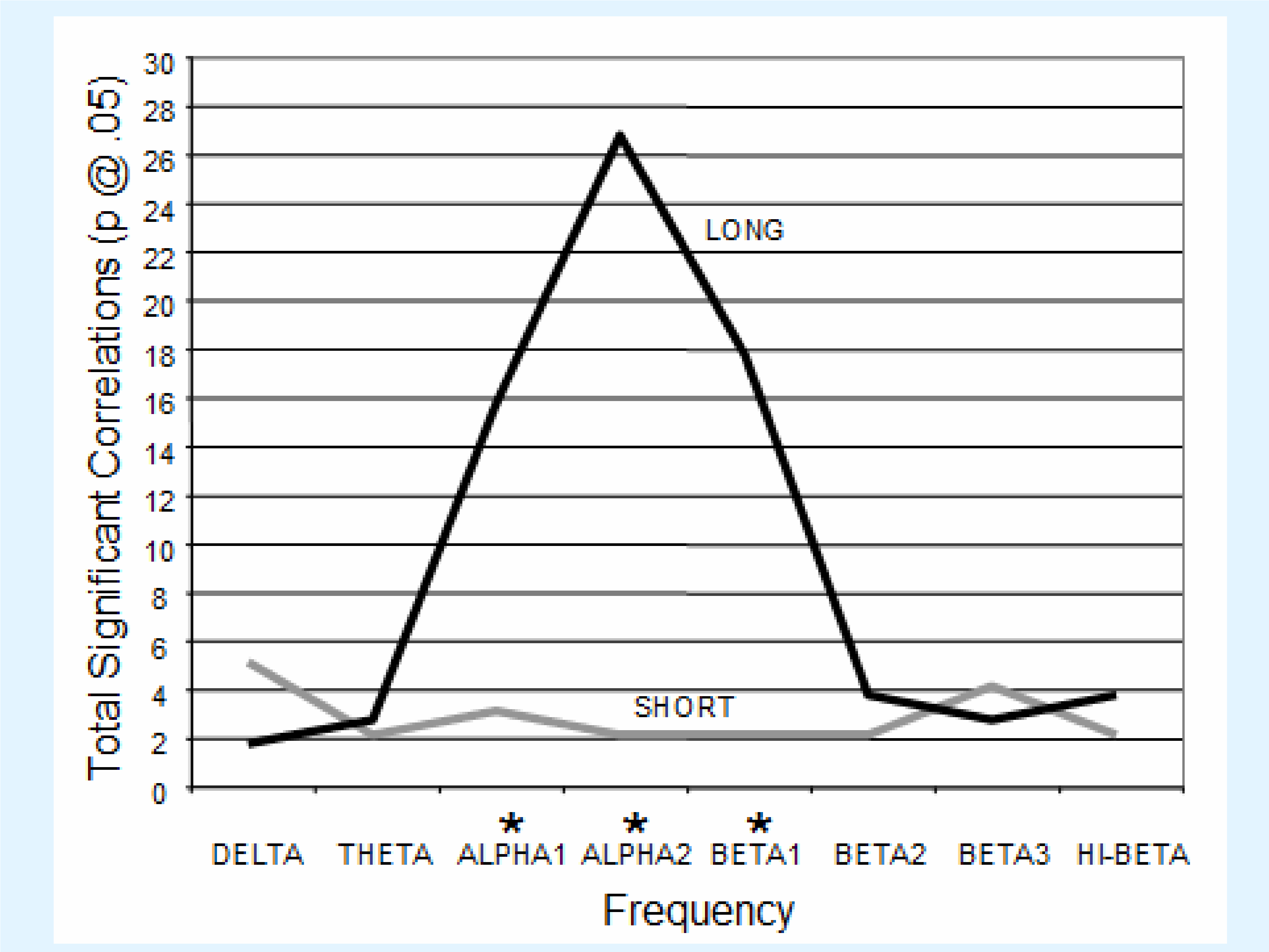
R. W. Thatcher, E. Palmero-Soler, D. M. North & C. J. Biver

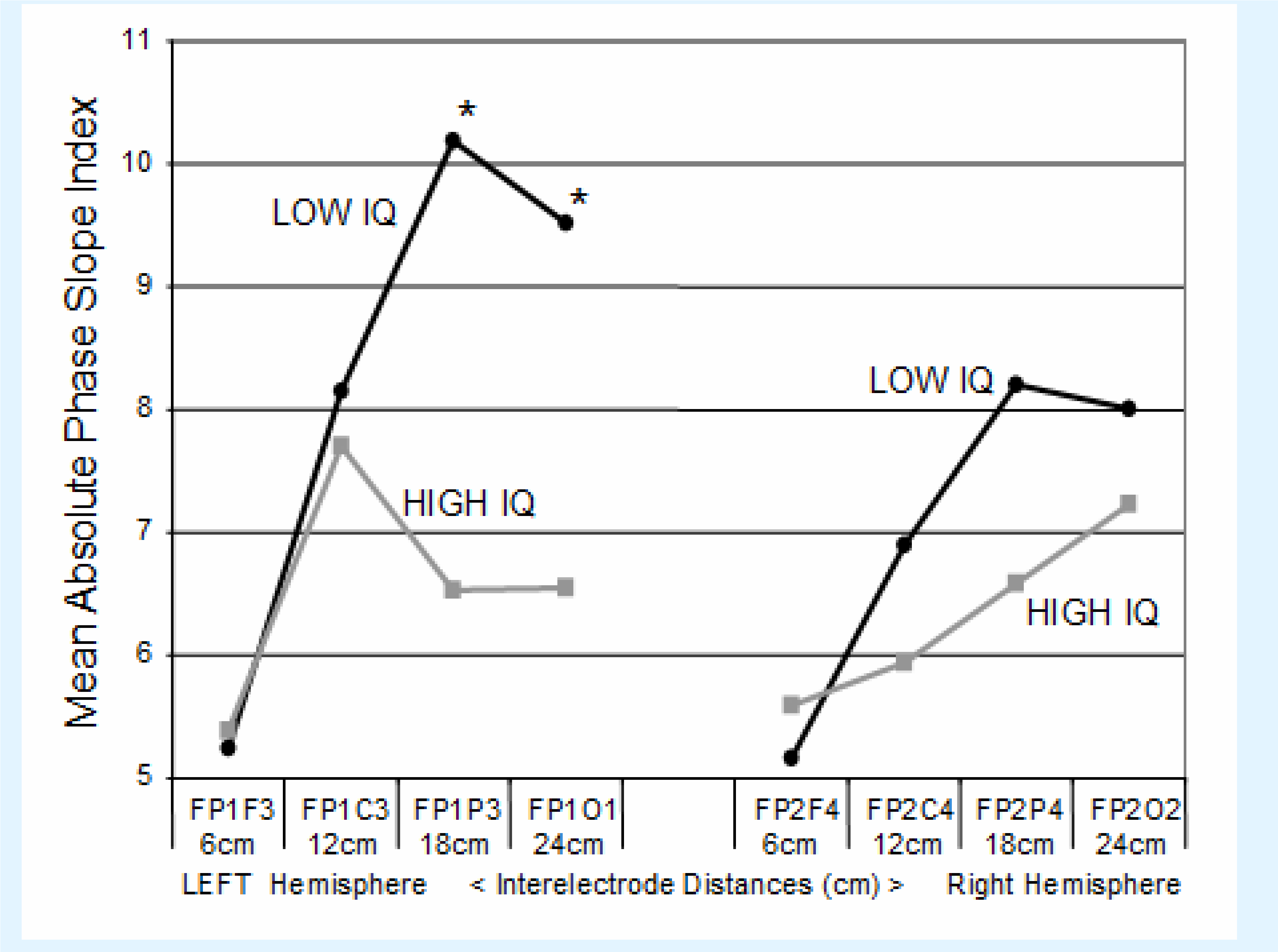
The purpose of this study was to explore the relationship between the magnitude of EEG information flow and intelligence. The electroencephalogram (EEG) was recorded from 19 scalp locations from 371 subjects ranging in age from 5 years to 17.6 years. The Wechler Intelligence Scale for Children (WISC-R) was administered for individuals between 5 years of age and 16 years and the Weschler Adult Intelligence Scale revised (WAIS-R) was administered to subjects older than 16 years to estimate I.Q. The phase slope index estimated the magnitude of information flow between all electrode combinations for difference frequency bands. Discriminant analyses were performed between high I.Q. (>120) and low I.Q. groups (<90). The magnitude of information flow was inversely related to I.Q. especially in the alpha and beta frequency bands. Long distance inter-electrode distances exhibited greater information flow than short inter-electrode distances. Frontal-parietal correlations were the most significant. It is concluded that higher I.Q. is related to increased efficiency of local information processing and reduced long distance compensatory dynamics that supports a small-world model of intelligence.

Discriminant Scores of the Magnitude of Phase Slope Index (PSI) with Full Scale IQ

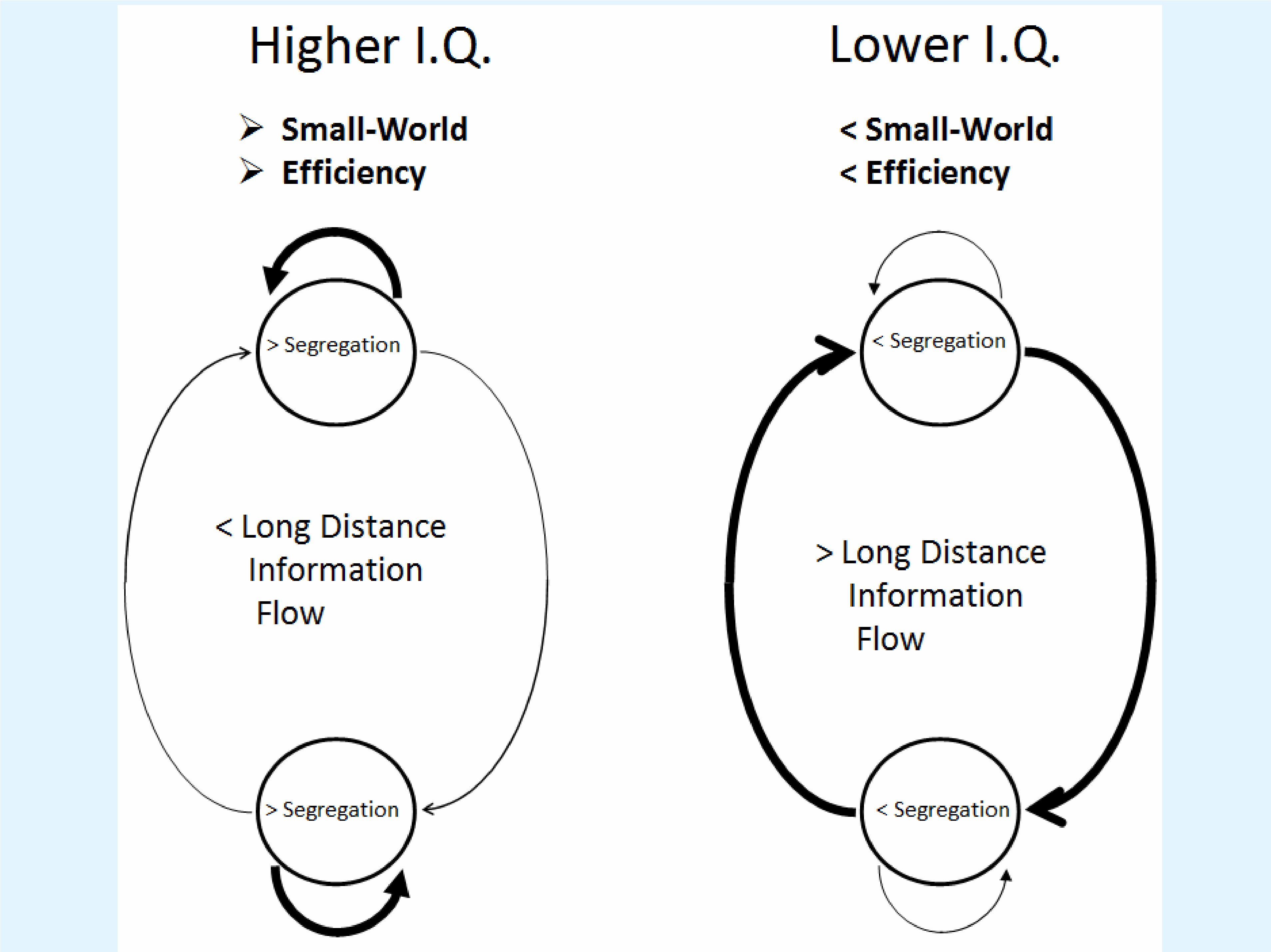



Absolute Mean Phase Slope Index (1 St Dev)
7.00
6.00
5.00
4.00
3.00
LOW IQ
MIDDLE IQ
HIGH IQ


Total Significant Correlations (p @ .05)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
LONG
SHORT
*
*
*
DELTA
THETA
ALPHA1
ALPHA2
BETA1
BETA2
BETA3
HI-BETA
Frequency



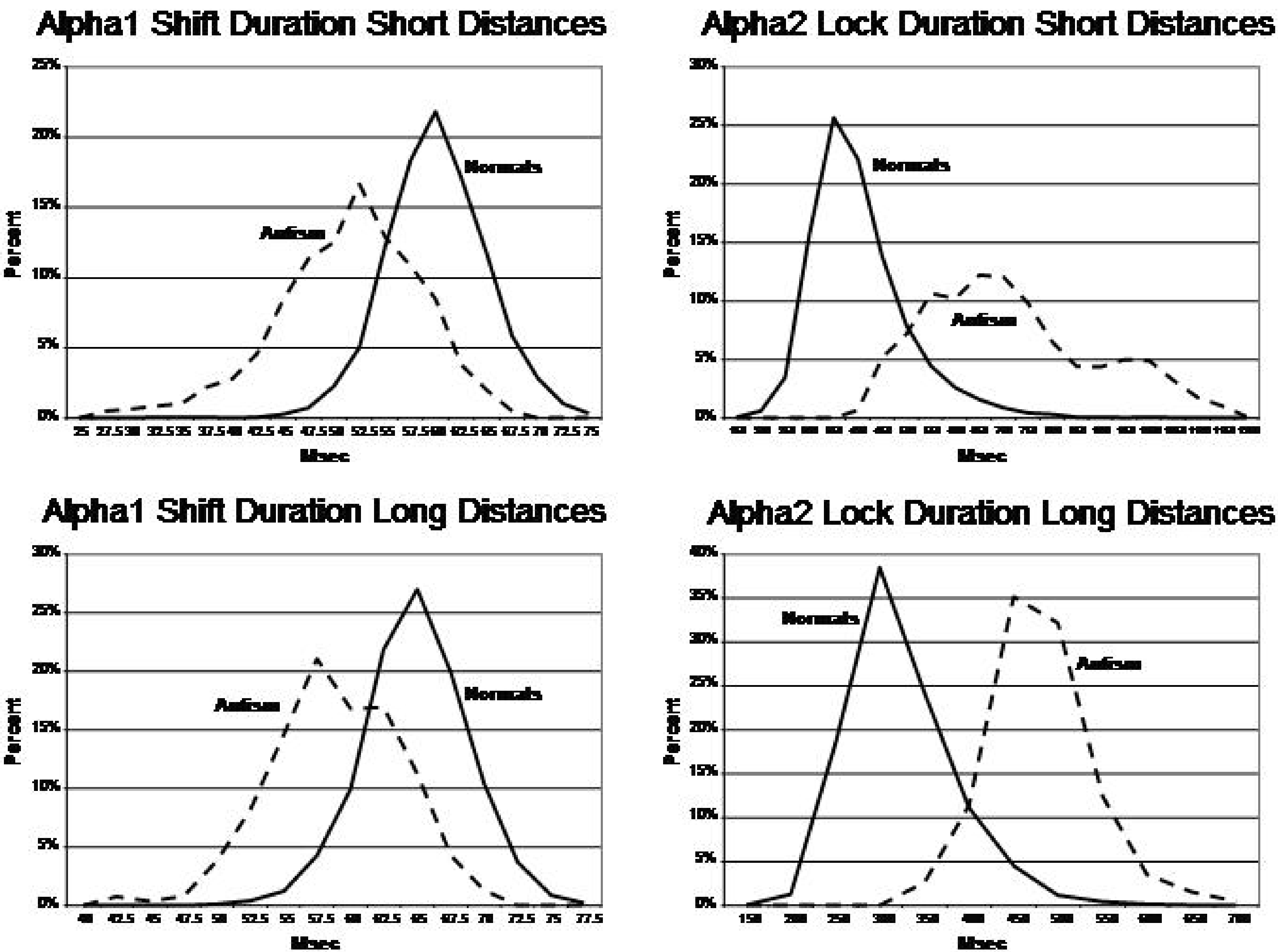
Mean Absolute Phase Slope Index
11
10
9
8
7
6
5
LOW IQ
HIGH IQ
LOW IQ
HIGH IQ
*
*
FP1F3 6cm
FP1C3 12cm
FP1P3 18cm
FP1O1 24cm
FP2F4 6cm
FP2C4 12cm
FP2P4 18cm
FP2O2 24cm
LEFT Hemisphere < Interelectrode Distances (cm) > Right Hemisphere


Higher I.Q.
Small-World
Efficiency
> Segregation
< Long Distance Information Flow
> Segregation
Lower I.Q.
< Small-World
< Efficiency
< Segregation
> Long Distance Information Flow
< Segregation

AUTISM AND EEG PHASE RESET: A UNIFIED THEORY OF DEFICIENT GABA MEDIATED INHIBITION IN THALAMO-CORTICAL CONNECTIONS

Thatcher, R. W. 1,2, Phillip DeFina2, James Neurbrander2, North, D. M.1, and Biver, C. J.1

EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute., St. Petersburg, Fl1 and the International Brain Research Foundation, Menlo Park, NJ2



Alpha1 Shift Duration Short Distances
Percent
Msec
Normals
Autism
Alpha2 Lock Duration Short Distances
Percent
Msec
Normals
Autism
Alpha1 Shift Duration Long Distances
Percent
Msec
Normals
Autism
Alpha2 Lock Duration Long Distances
Percent
Msec
Normals
Autism

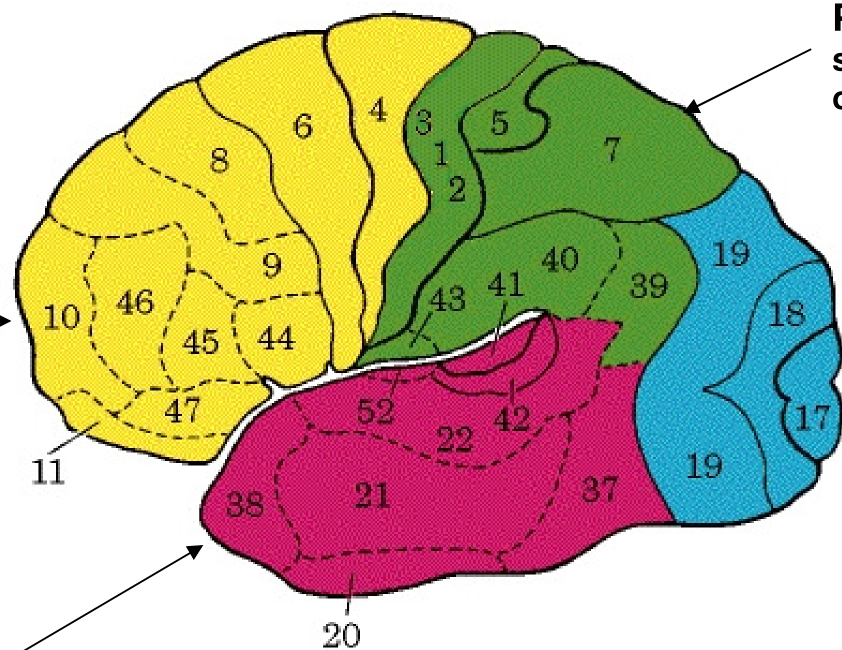
Electrical NeuroImaging of Functional Modules and Hubs as Measured by fMRI and PET

Phase Shift and Phase Lock Switch Dynamics that “Animate” Information Flow Within and Between Modules and Hubs

Brodmann Areas

Parietal Lobe
somatosensory perception integration of visual & somatospatial information

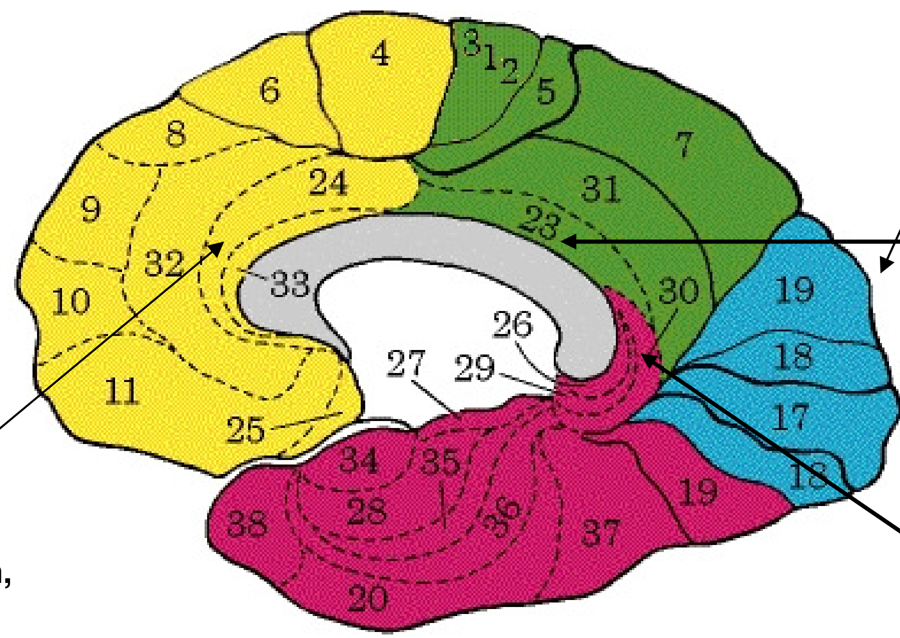
Frontal Lobe
Thinking, Planning, Motor execution, Executive Functions, Mood Control



Temporal Lobe
language function and auditory perception involved in long term memory and emotion

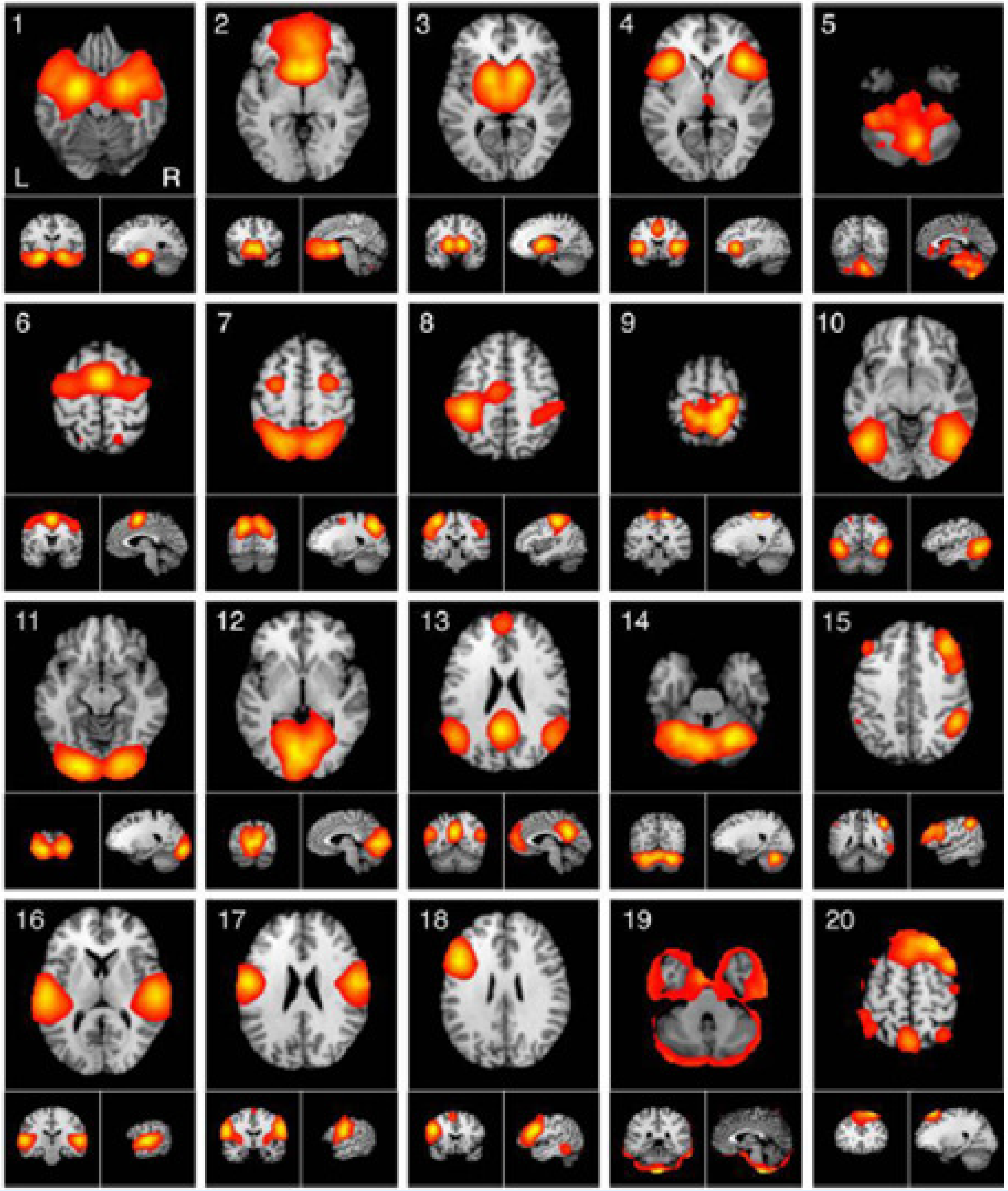
Occipital Lobe
Visual perception & Spatial processing

Posterior Cingulate
attention, long-term memory



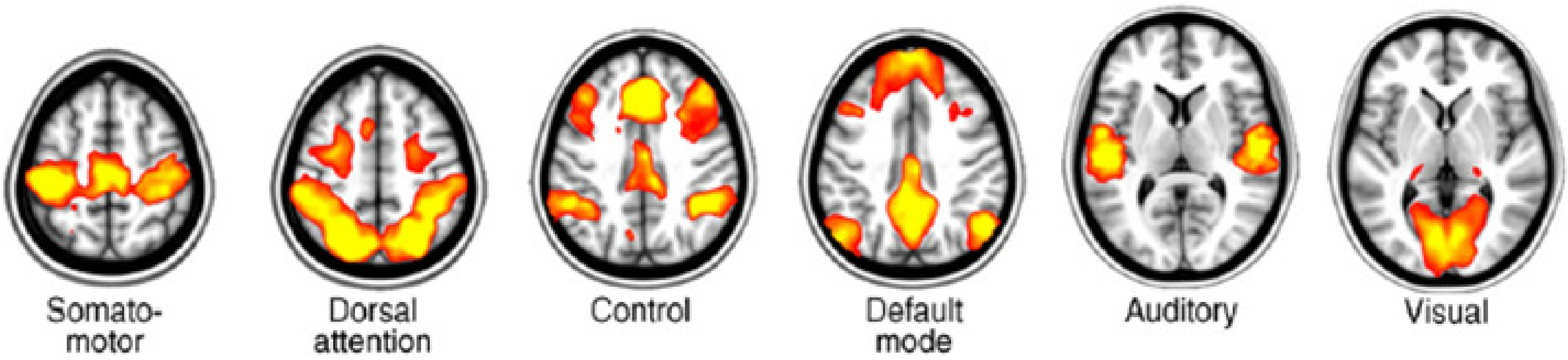
Anterior Cingulate Gyrus
Volitional movement, attention, long term memory

Parahippocampal Gyrus
Short-term memory, attention



Laird et al (2011) summarized the various "intrinsic connectivity networks" or ICNs into eighteen specific groupings based upon 30,000 fMRI and PET studies

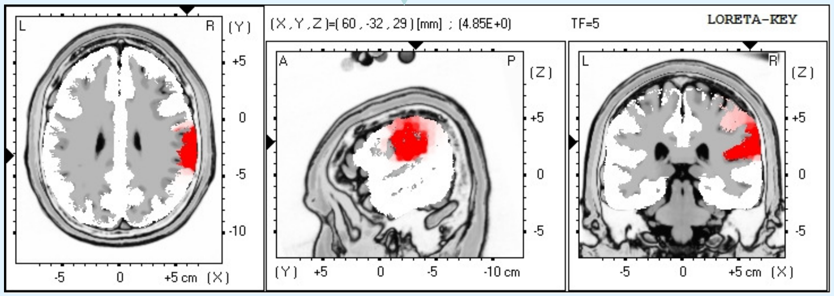
Six Functional Modules as Measured by fMRI



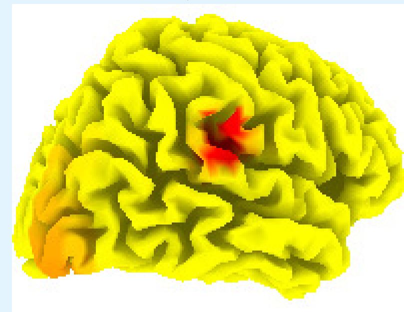
From Raichle, 2010

Electrical Neuroimaging and Cortical Source Localization

Horizontal, Sagital & Coronal Views of a Single Slice



Cortical Surface Projection



Tomographic Slice Display

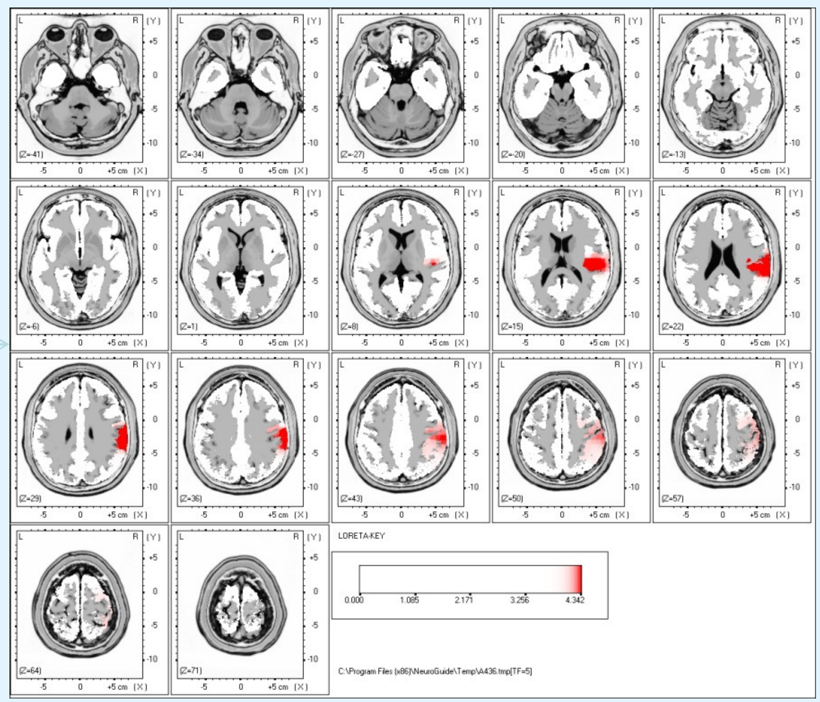


Table 5: Error measure ED1 for the four inverse algorithms, with regularization, under four different noise levels: 25 dB, 15 dB, 10 dB and 5 dB. Each cell value gives the mean and standard deviation.

		ED1			
		Regularised			
	SNR/dB	5	10	15	25
	Layer				
WMN	Surface	3.46 ± 0.42	2.10 ± 0.28	1.34 ± 0.11	1.13 ± 0.03
	Middle	5.08 ± 0.50	3.94 ± 0.38	2.95 ± 0.21	2.40 ± 0.03
	Deep	5.91 ± 0.39	5.31 ± 0.36	4.61 ± 0.24	3.89 ± 0.15
sLORETA	Surface	0.99 ± 0.1	0.49 ± 0.08	0.11 ± 0.04	0.00 ± 0.00
	Middle	1.61 ± 0.13	0.84 ± 0.11	0.25 ± 0.07	0.00 ± 0.00
	Deep	1.79 ± 0.25	0.95 ± 0.16	0.39 ± 0.13	0.00 ± 0.00
LORETA	Surface	2.32 ± 0.08	2.18 ± 0.04	2.16 ± 0.03	2.21 ± 0.02
	Middle	1.51 ± 0.13	1.15 ± 0.08	0.95 ± 0.07	1.05 ± 0.06
	Deep	2.30 ± 0.21	1.81 ± 0.13	1.59 ± 0.11	1.53 ± 0.09
SLF	Surface	5.27 ± 0.30	4.50 ± 0.28	3.81 ± 0.20	2.98 ± 0.13
	Middle	4.53 ± 0.39	4.09 ± 0.35	3.50 ± 0.31	2.51 ± 0.15
	Deep	3.89 ± 0.55	3.70 ± 0.45	3.27 ± 0.48	1.73 ± 0.30

Electrical Neuroimaging – Assessment and Treatment

Advantages of Electrical Neuroimaging

1- Spatial Resolution – 1 cm to 3 cm

2- Temporal Resolution – 1 msec

3- Imaging of Current Sources

4- Imaging of Network Connections

5- Integration with DTI & fMRI (Brodmann Areas)

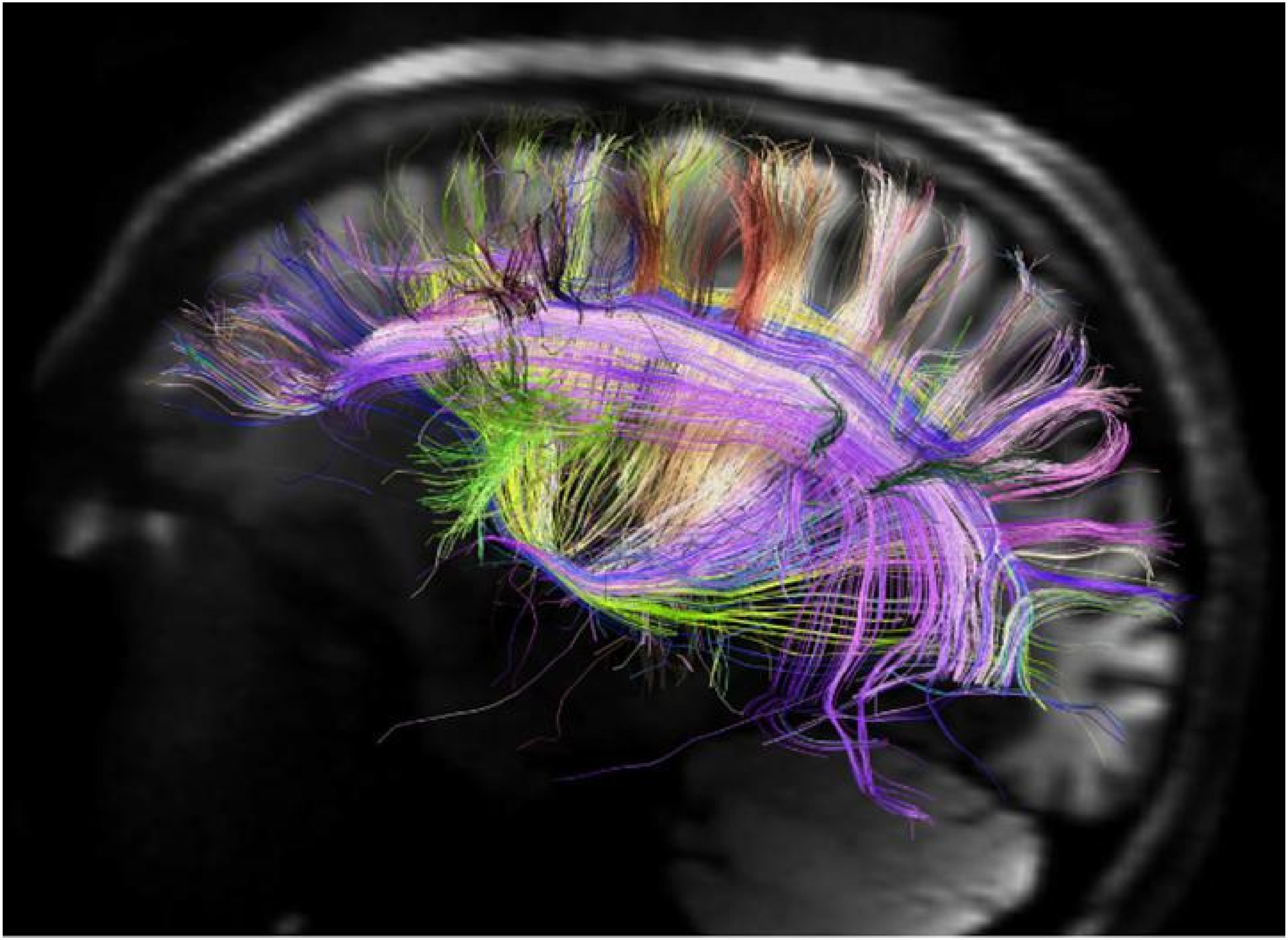
6- Inexpensive ($10,000 vs $3,000,000)

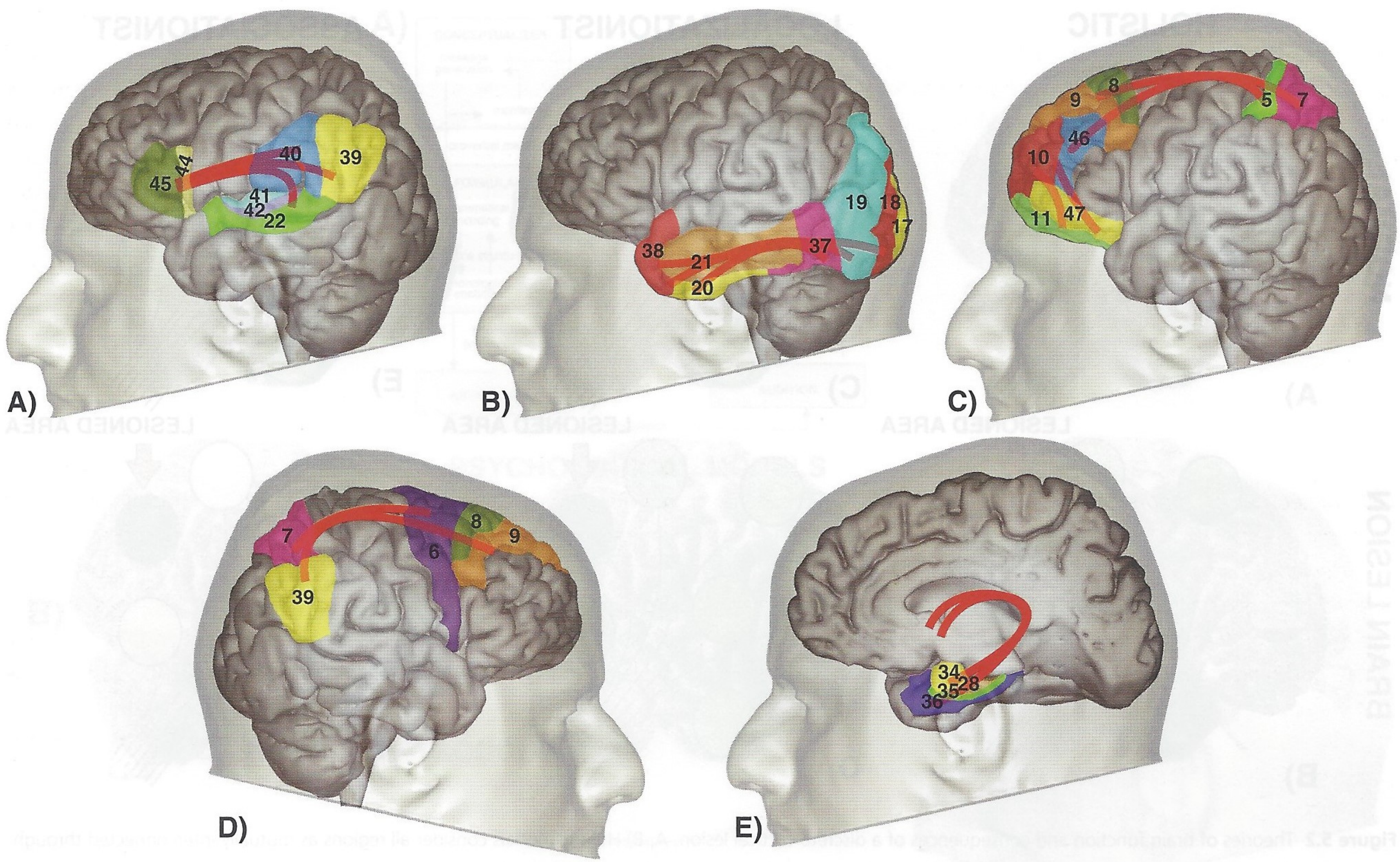
7- Dry Electrodes & Wireless Caps

8- Portable

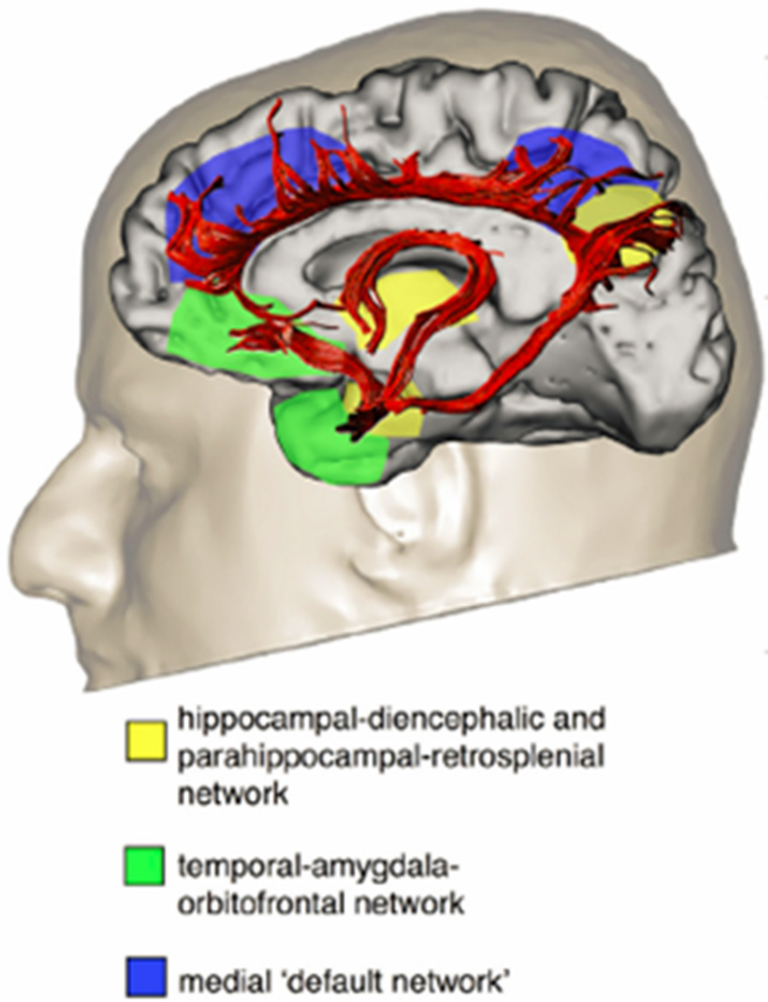
9- Integration with Smart Phones & Tablets

10- Can Assess & Treat in Real-Time1



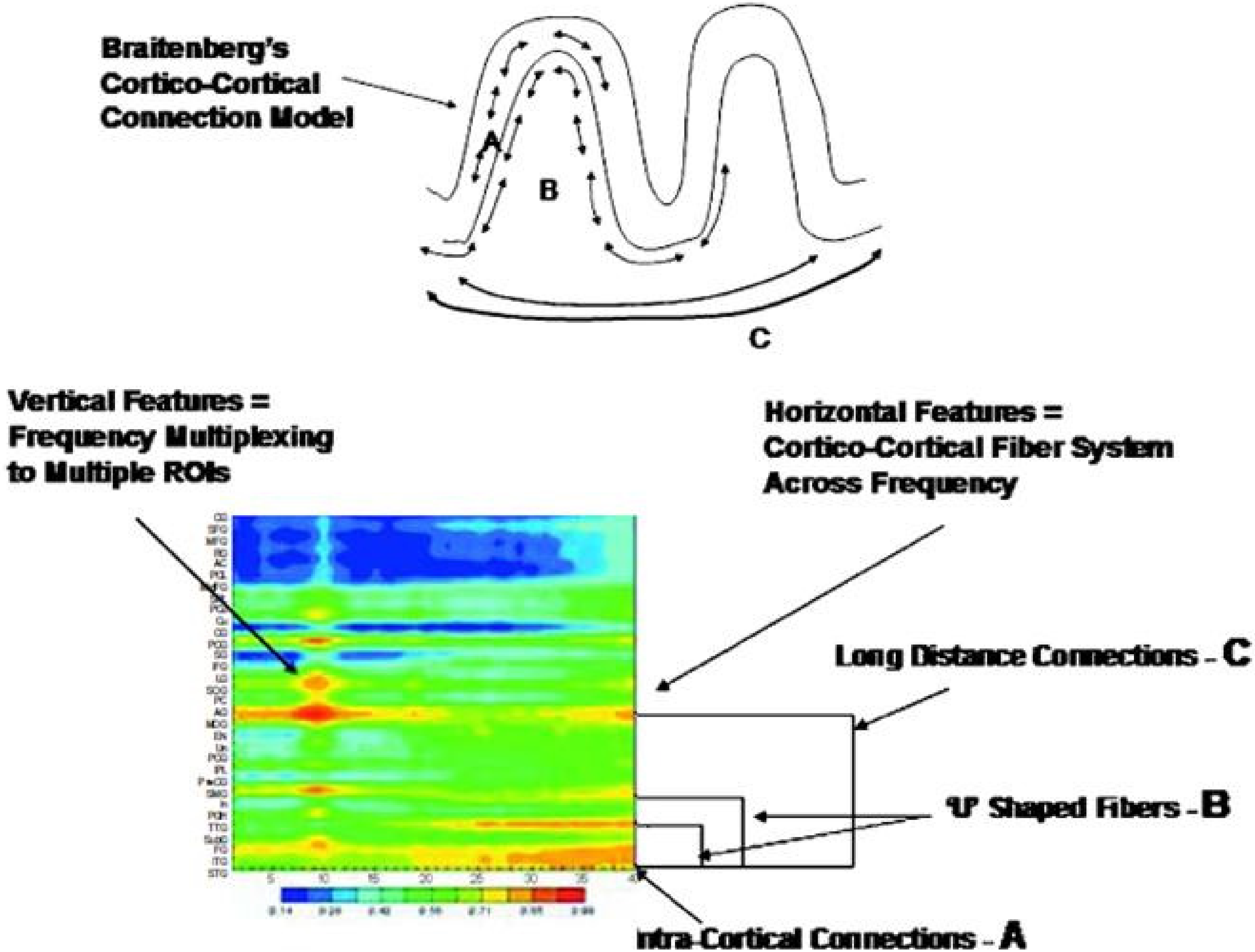


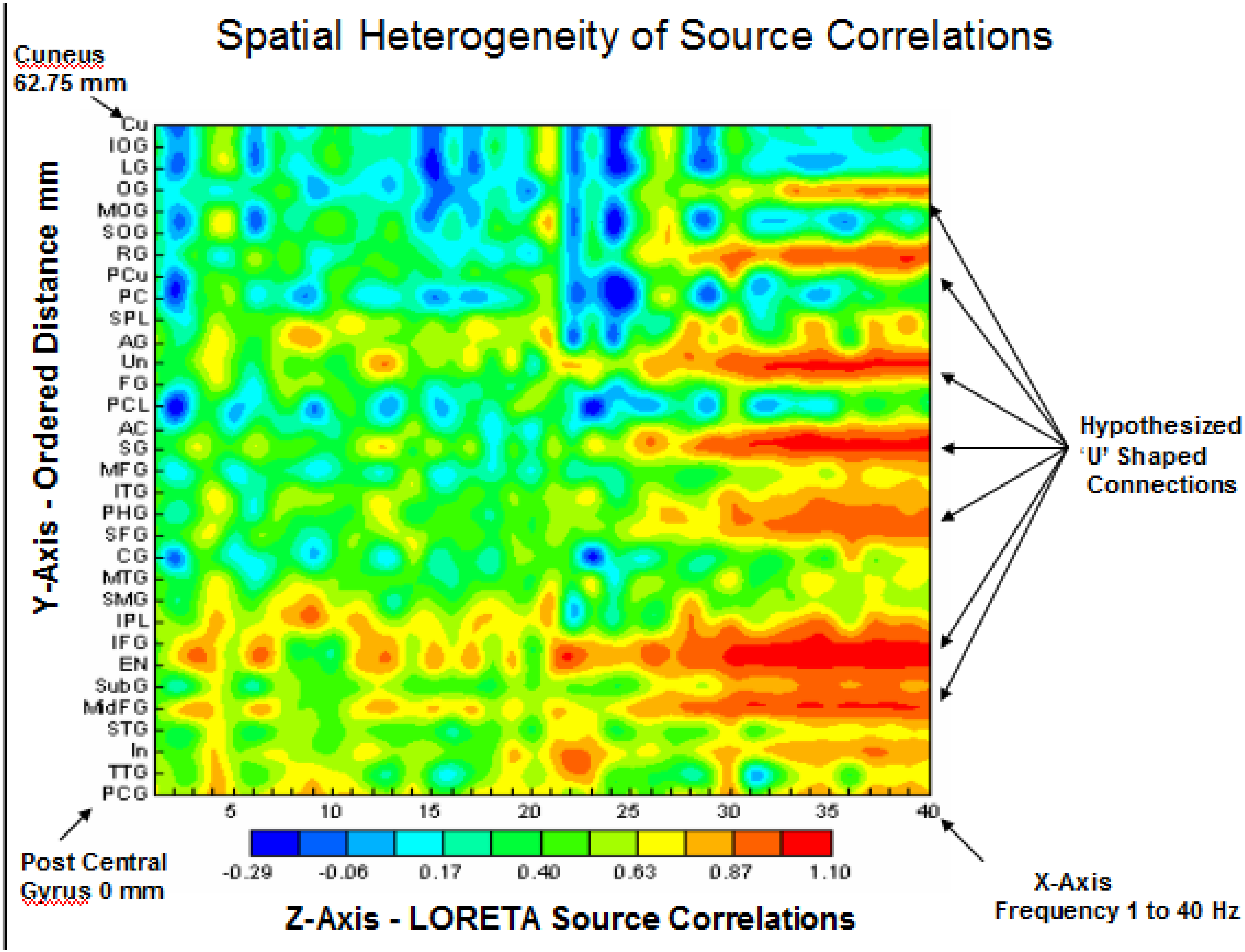
From Catani and deShotten, 2012



Network	Function	Disorder
Hippocampal-diencephalic and parahippocampal-retrosplenial	•memory •spatial orientation	•Amnesias •Korsakoff's syndrome •Mild Cognitive impairment •Alzheimer's disease (early) •Balint syndrome
Temporo-amydgala-orbitofrontal	•Behavioural inhibition •Memory for temporally complex visual information •Olfactory-gustatory-visceral functions •Multimodal sensory integration •Object-reward association learning •Outcome monitoring	•Alzheimer's Disease (advanced) •Semantic dementia •Klüver-Bucy syndrome •Temporal lobe epilepsy •Geschwind's syndromes •Psychopathy •Bipolar affective disorders
Dorsomedial default network	•Pain perception •Self-knowledge •Attention •Mentalizing •Empathy •Response selection and action monitoring •Autobiographical memory •Person perception	•Depression •Autism •Schizophrenia •Obsessive compulsive disorder •Mild Cognitive Impairmentt •Alzheimer's Disease (early) •Attention Deficit Hyperactivity Disorder •Anxiety

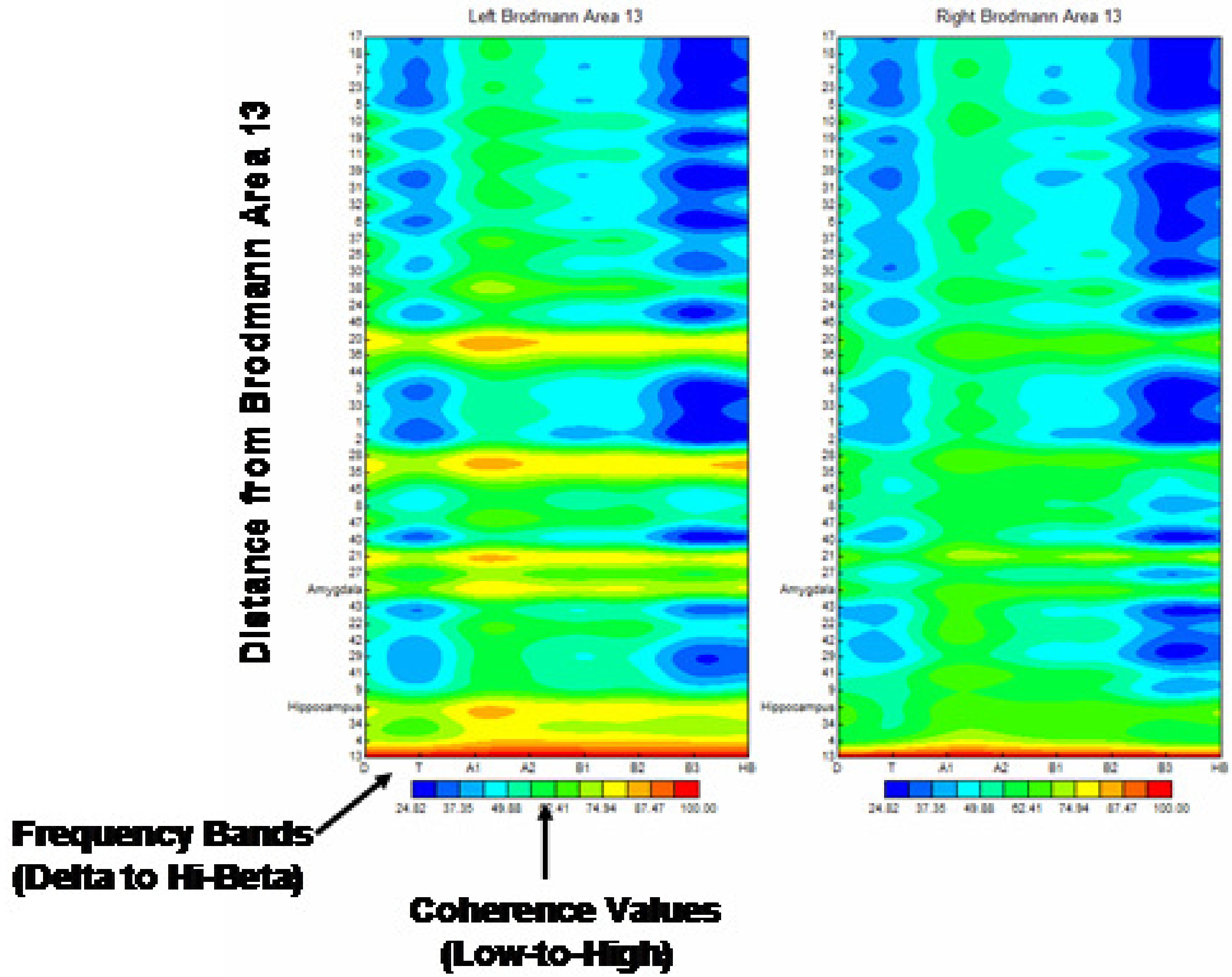
From Catani and deShotten, 2012


Braitenberg's
Cortico-Cortical
Connection Model
A
B
C
Vertical Features =
Frequency Multiplexing
to Multiple ROIs
Horizontal Features =
Cortico-Cortical Fiber System
Across Frequency
Long Distance Connections - C
'U' Shaped Fibers - B
ntra-Cortical Connections - A

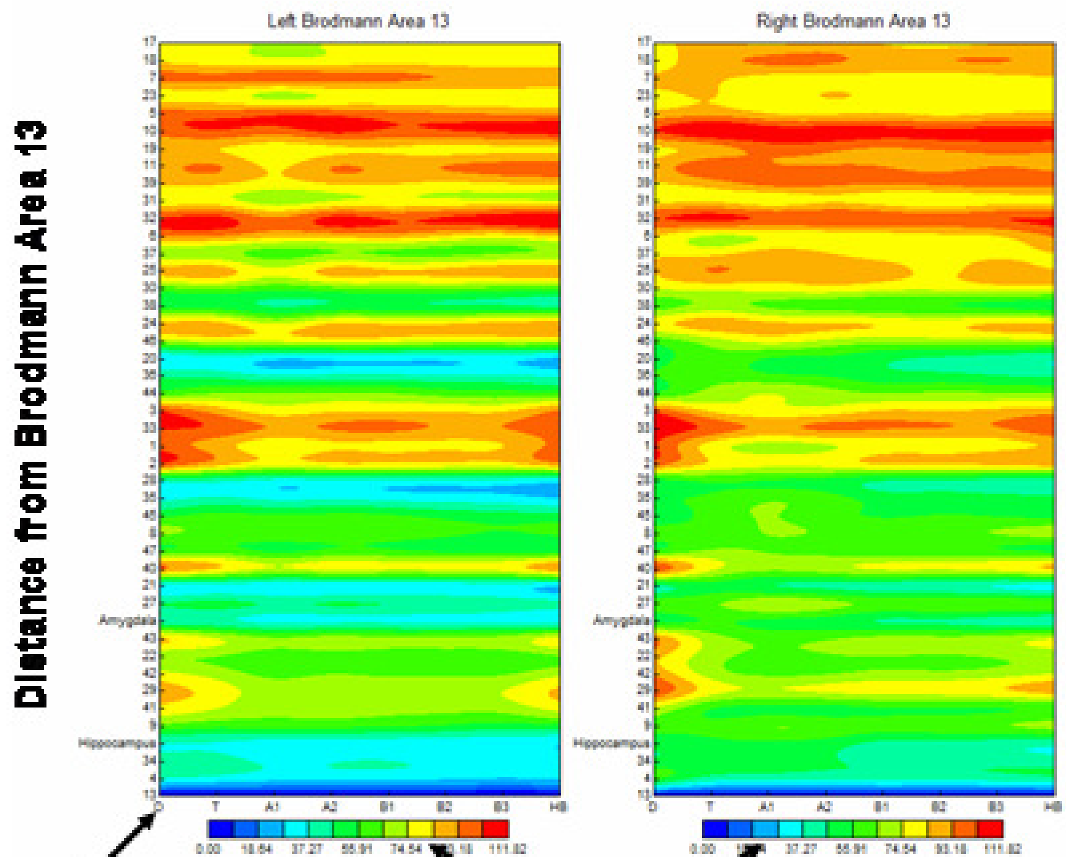


Spatial Heterogeneity of Source Correlations
Cuneus
62.75 mm
Y-Axis - Ordered Distance mm
Cu
IOG
LG
OG
MOG
SOG
RG
PCu
PC
SPL
AG
Un
FG
PCL
AC
SG
MFG
ITG
PHG
SFG
CG
MTG
SMG
IPL
IFG
EN
SubG
MidFG
STG
In
TTG
PCG
5
10
15
20
25
30
35
40
Hypothesized
'U' Shaped
Connections
-0.29
-0.06
0.17
0.40
0.63
0.87
1.10
Post Central
Gyrus 0 mm
Z-Axis - LORETA Source Correlations
X-Axis
Frequency 1 to 40 Hz

LORETA Coherence



LORETA Absolute Phase



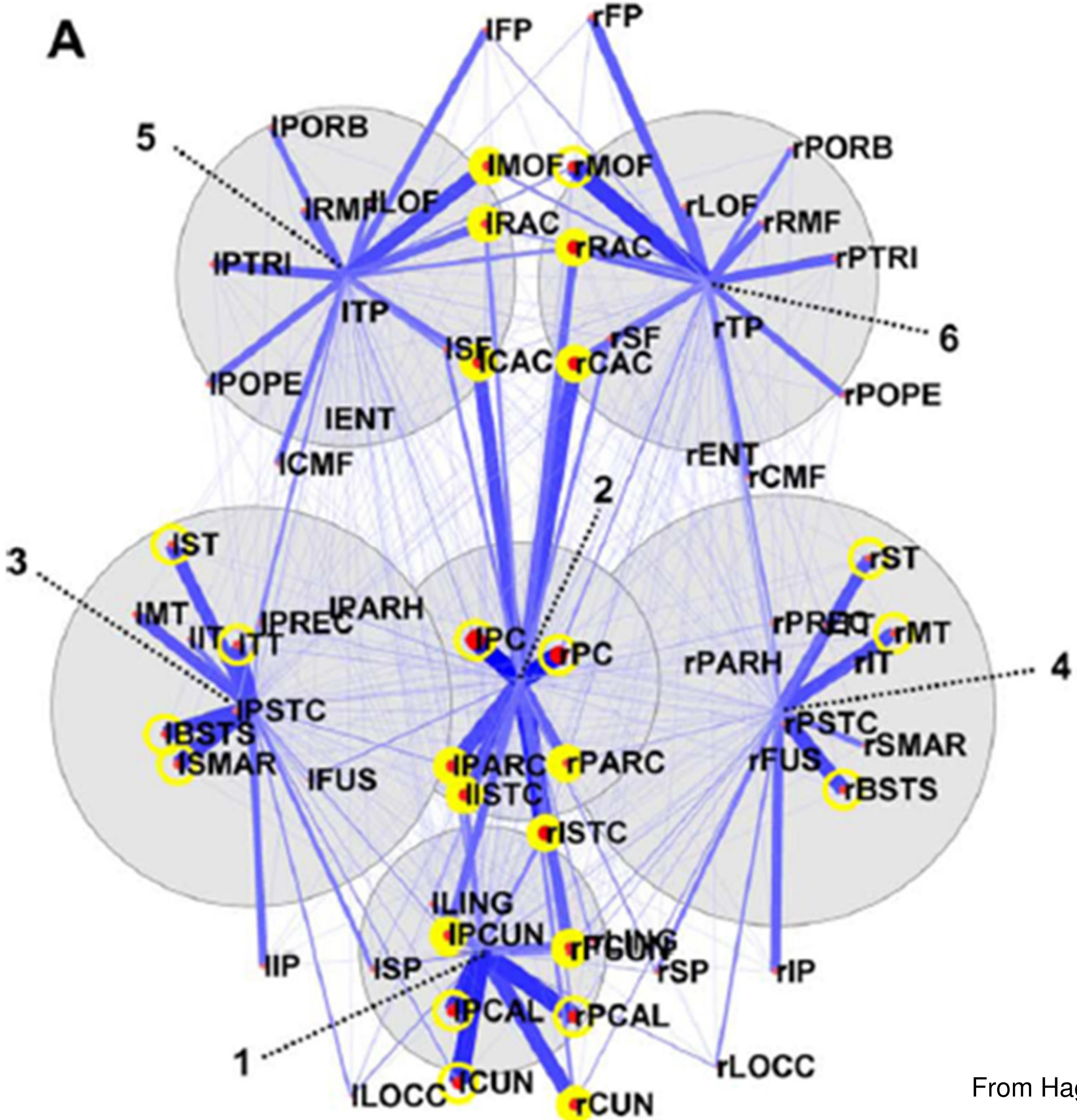
Frequency Bands (Delta to Hi-Beta)

Phase Difference (Deg) (short to long differences)

♦ Human Brain Mapping 33:1062–1075 (2012) ♦

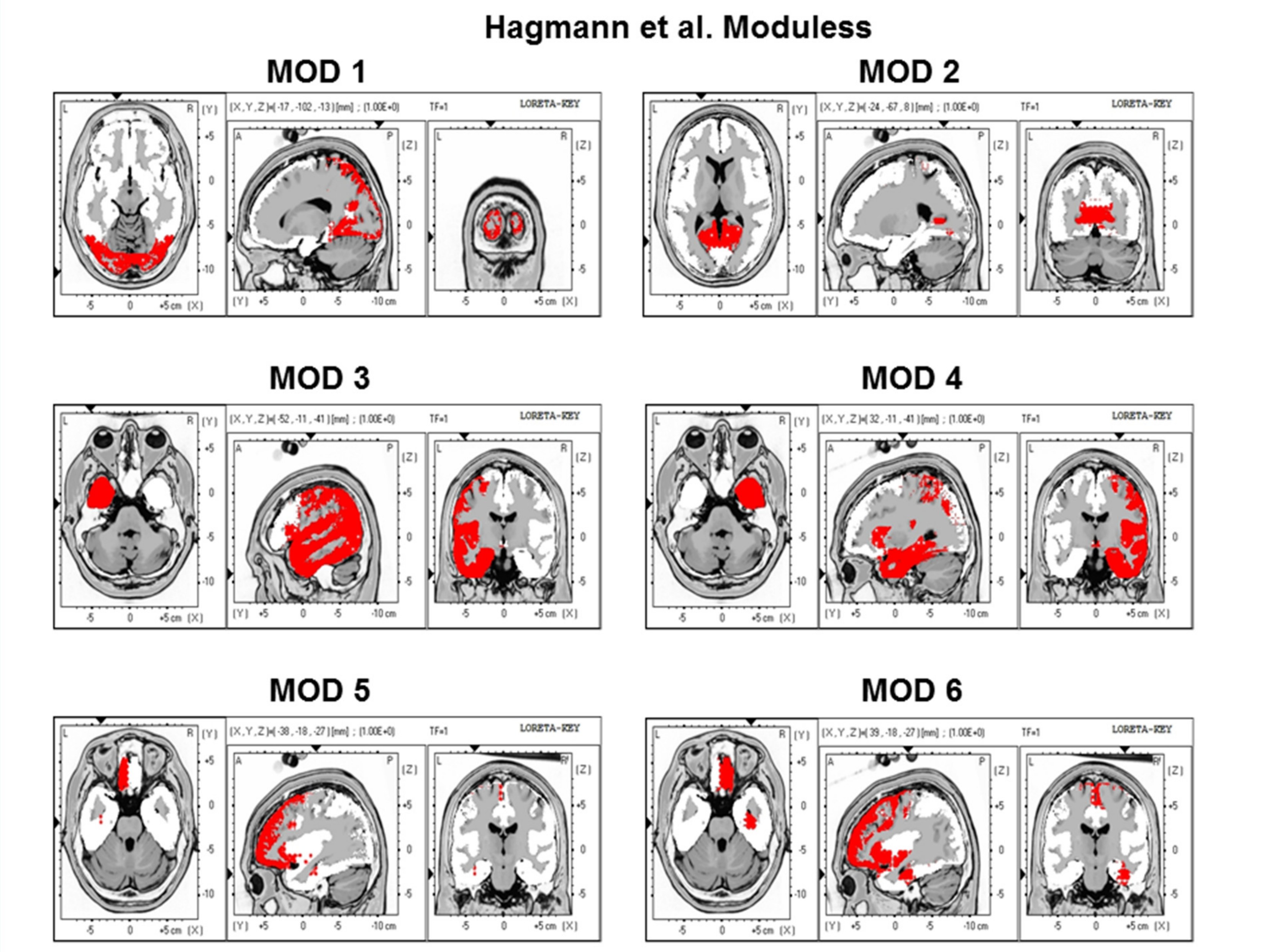
Diffusion Spectral Imaging Modules Correlate With EEG LORETA Neuroimaging Modules

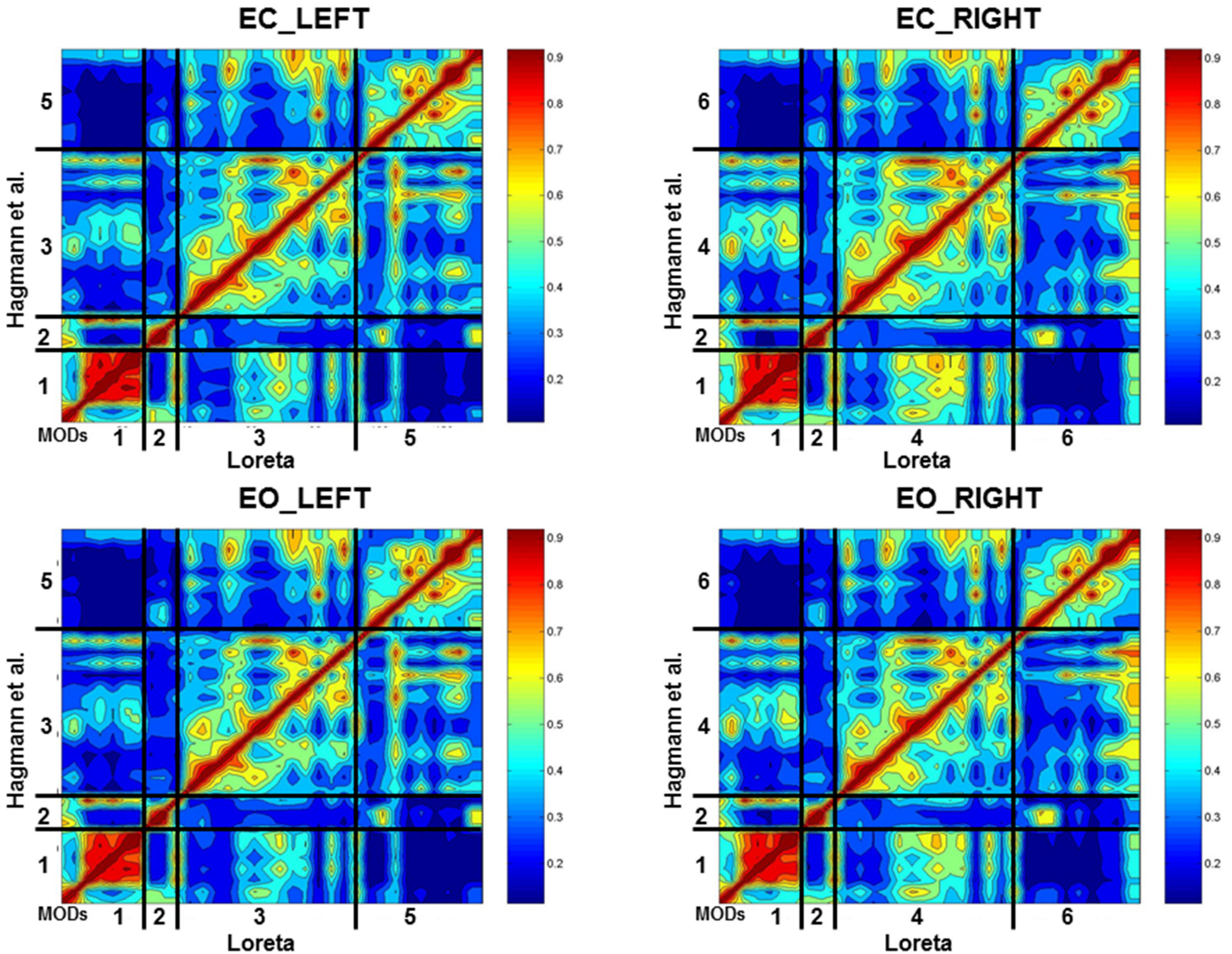
Robert W. Thatcher,* Duane M. North, and Carl J. Biver



From Hagmann et al, 2008

Correlations Between EEG Neuroimaging and Diffusion Spectral Imaging (DTI)





EC_LEFT
EC_RIGHT
EO_LEFT
EO_RIGHT
Hagmann et al.
Loreta
MODs
1
2
3
4
5
6
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2

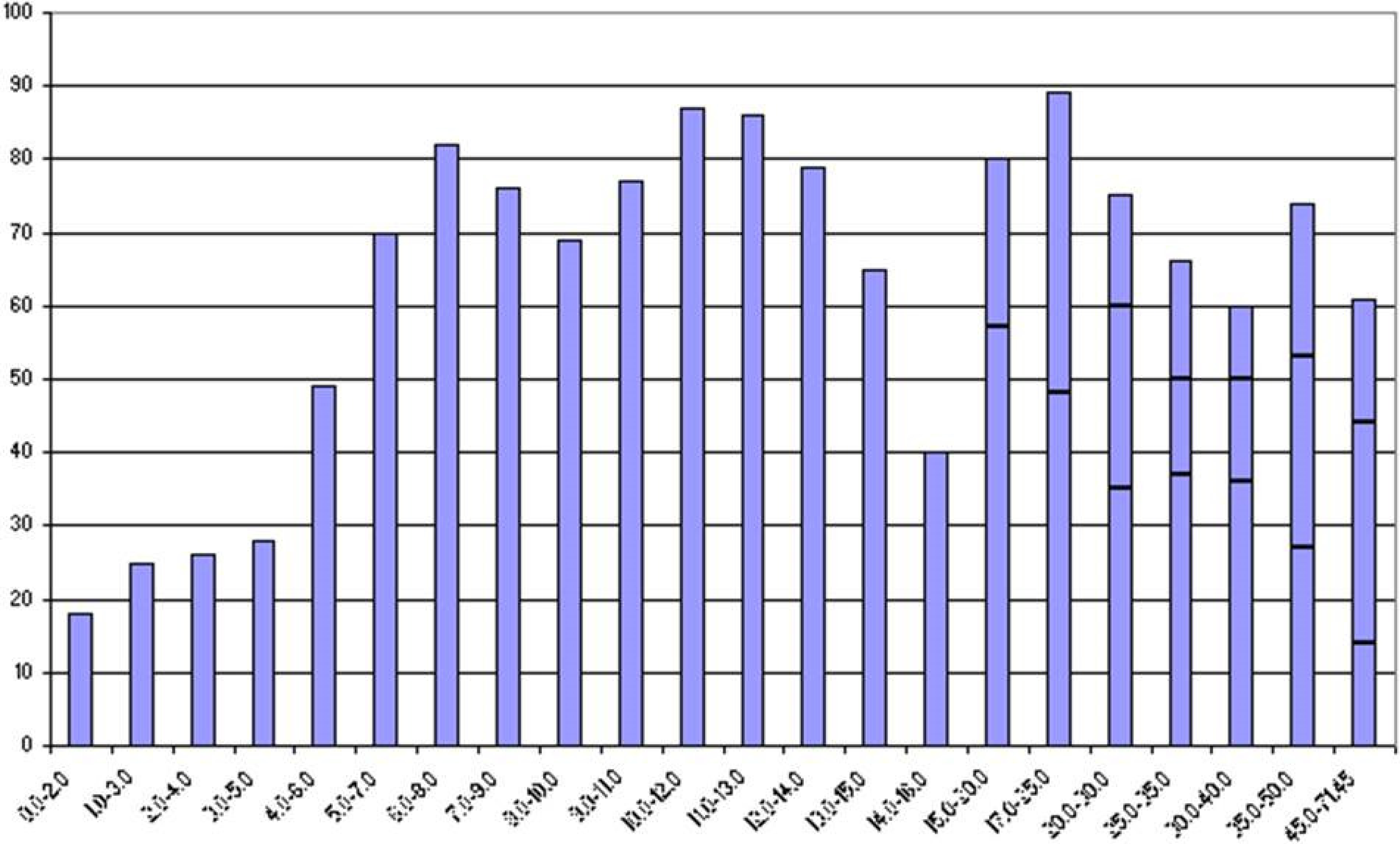
Published as a chapter in "Introduction to QEEG and Neurofeedback: Advanced Theory and Applications" Thomas Budzinsky, H. Budzinski, J. Evans and A. Abarbanel editors, Academic Press, San Diego, Calif, 2008.

HISTORY OF THE SCIENTIFIC STANDARDS OF QEEG NORMATIVE DATABASES

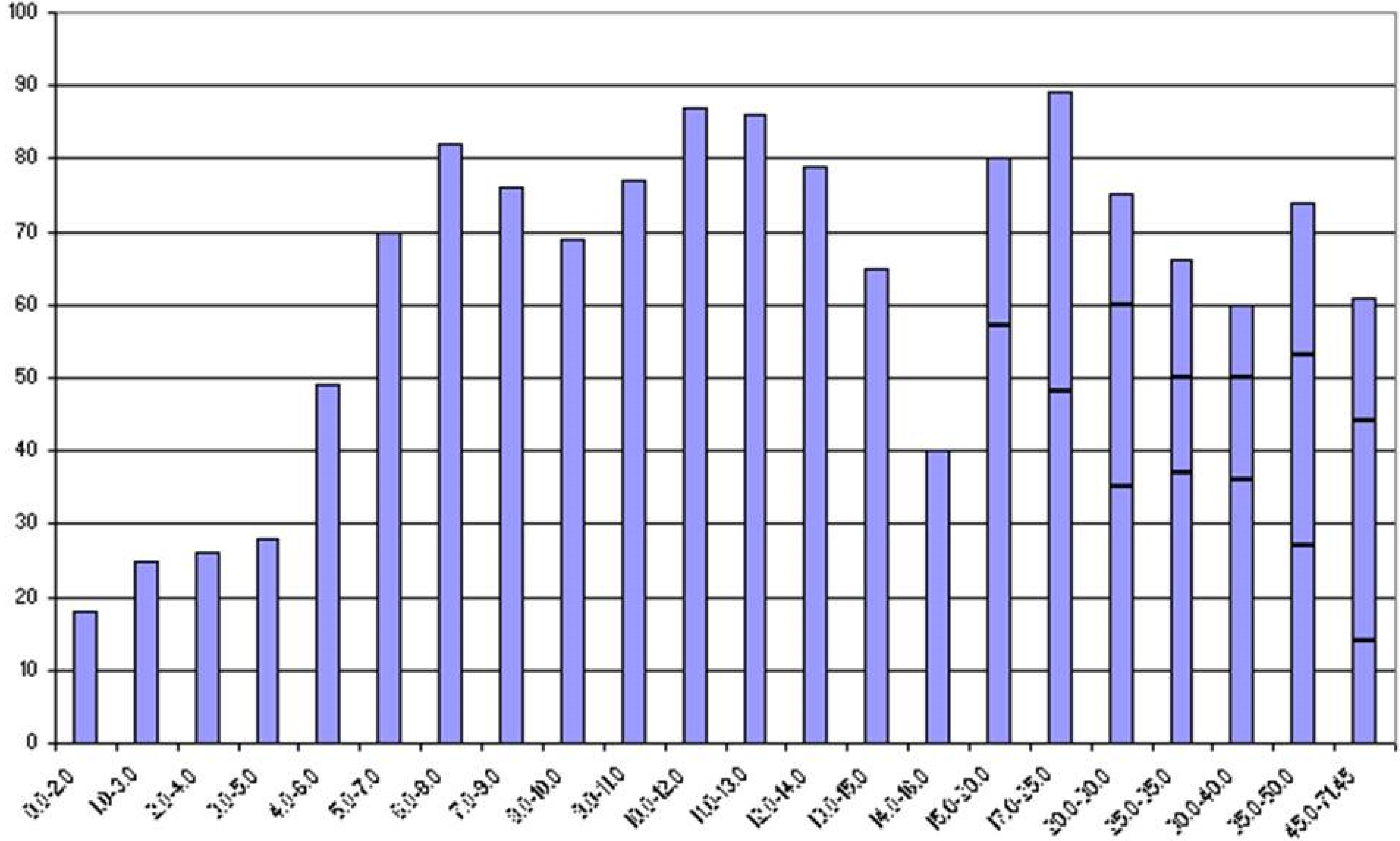
Thatcher, R.W. [1,2] and Lubar, J.F.[3]

Department of Neurology, University of South Florida College of Medicine, Tampa, Fl.[1] and EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, Fl[2] , Brain Research and Neuropsychology Lab, University of Tennessee, Knoxville, TN[3].

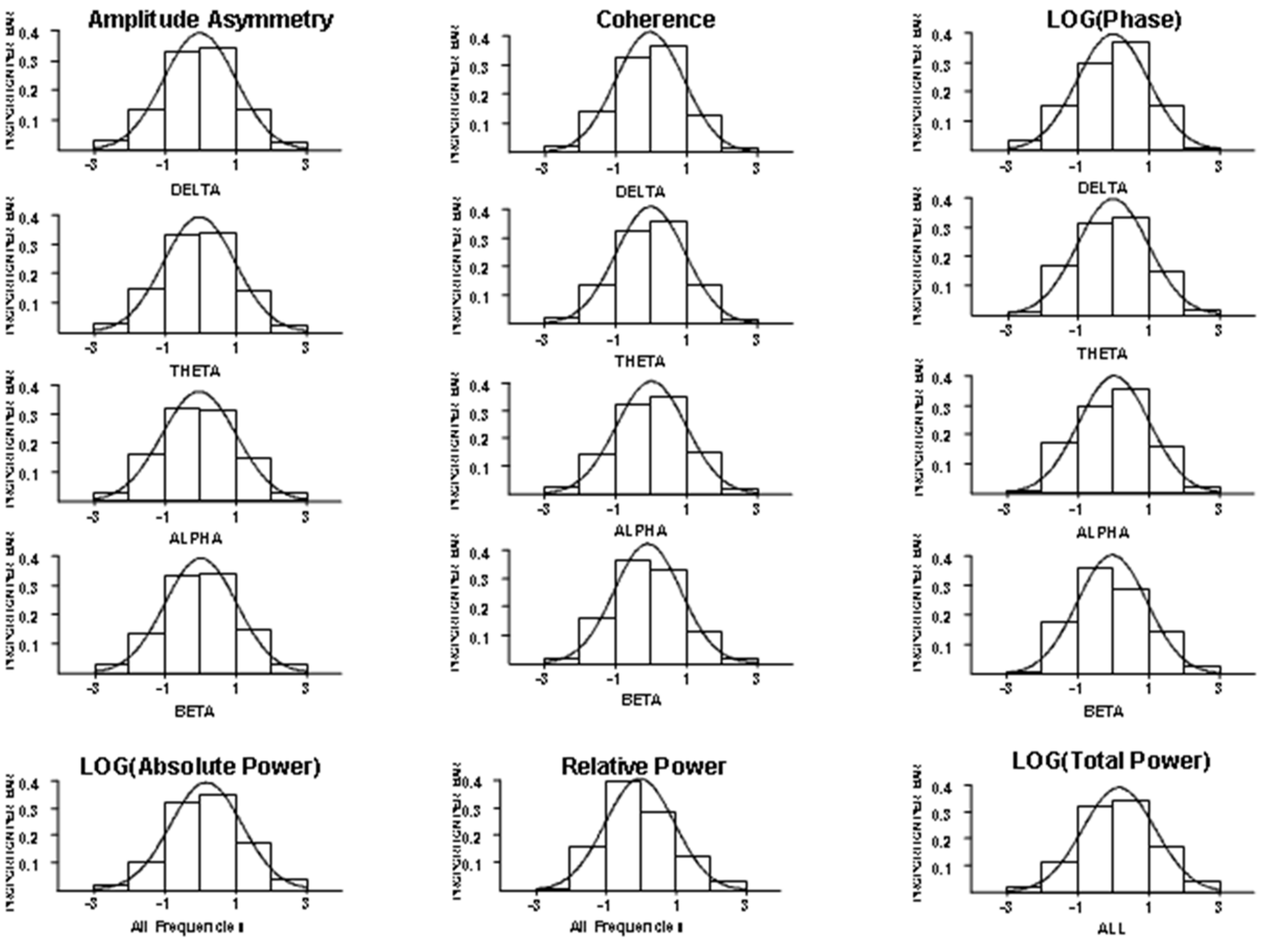
NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011



NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011

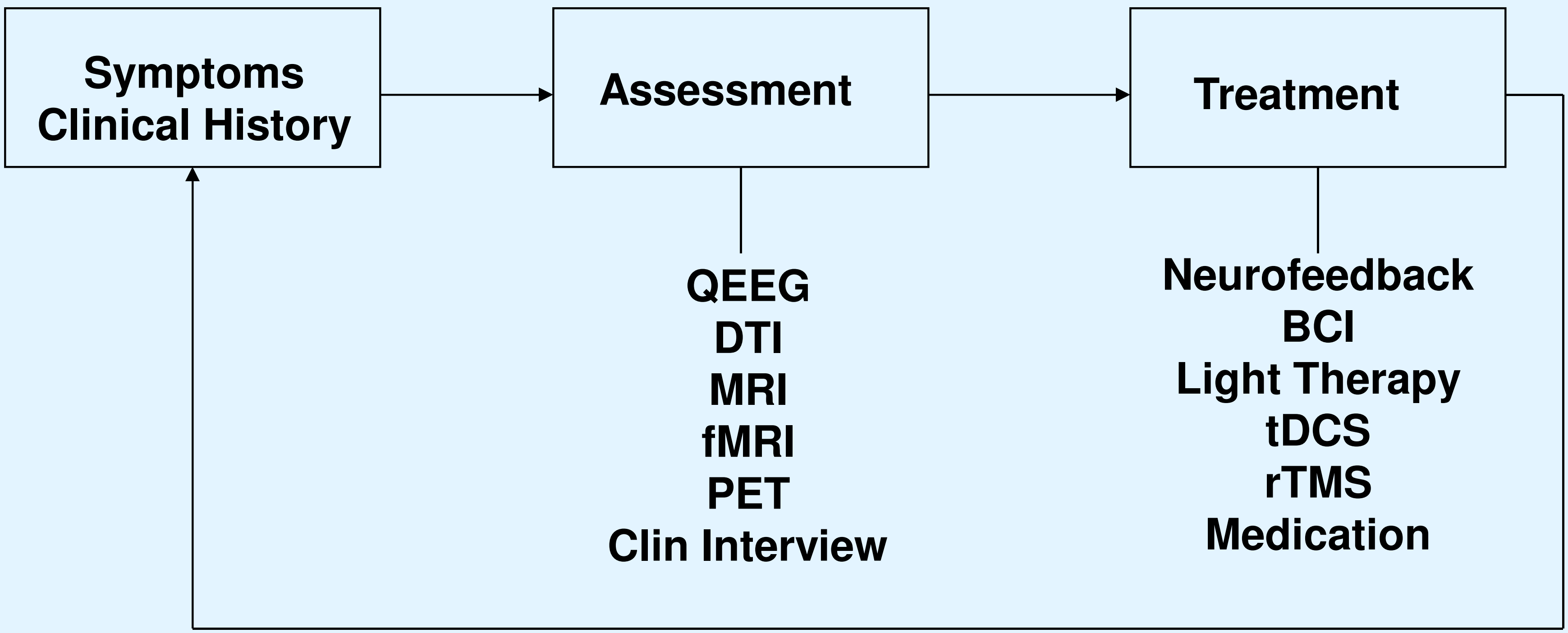


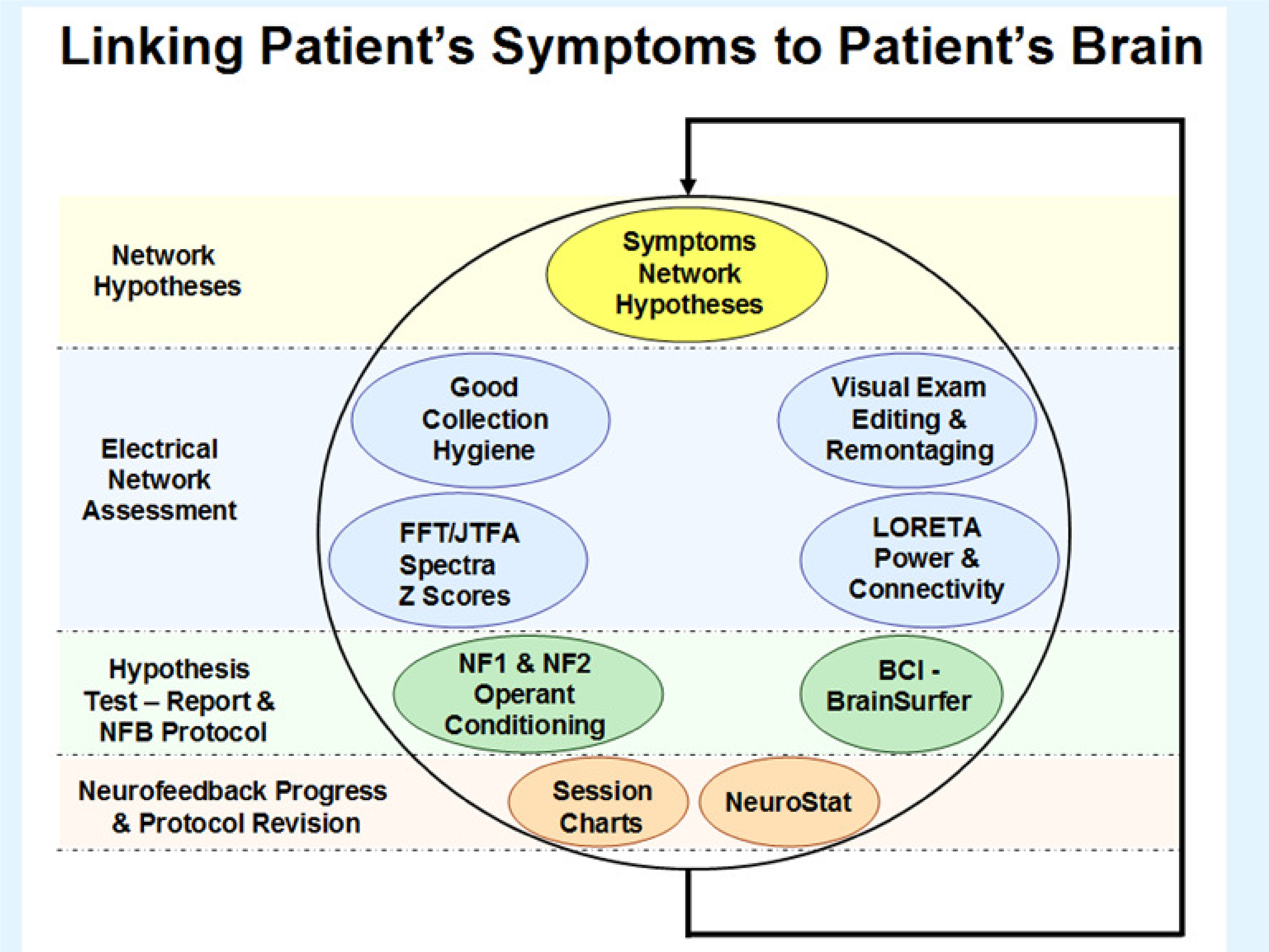
Cross-Validation Birth to 82 Year EEG Normative Database



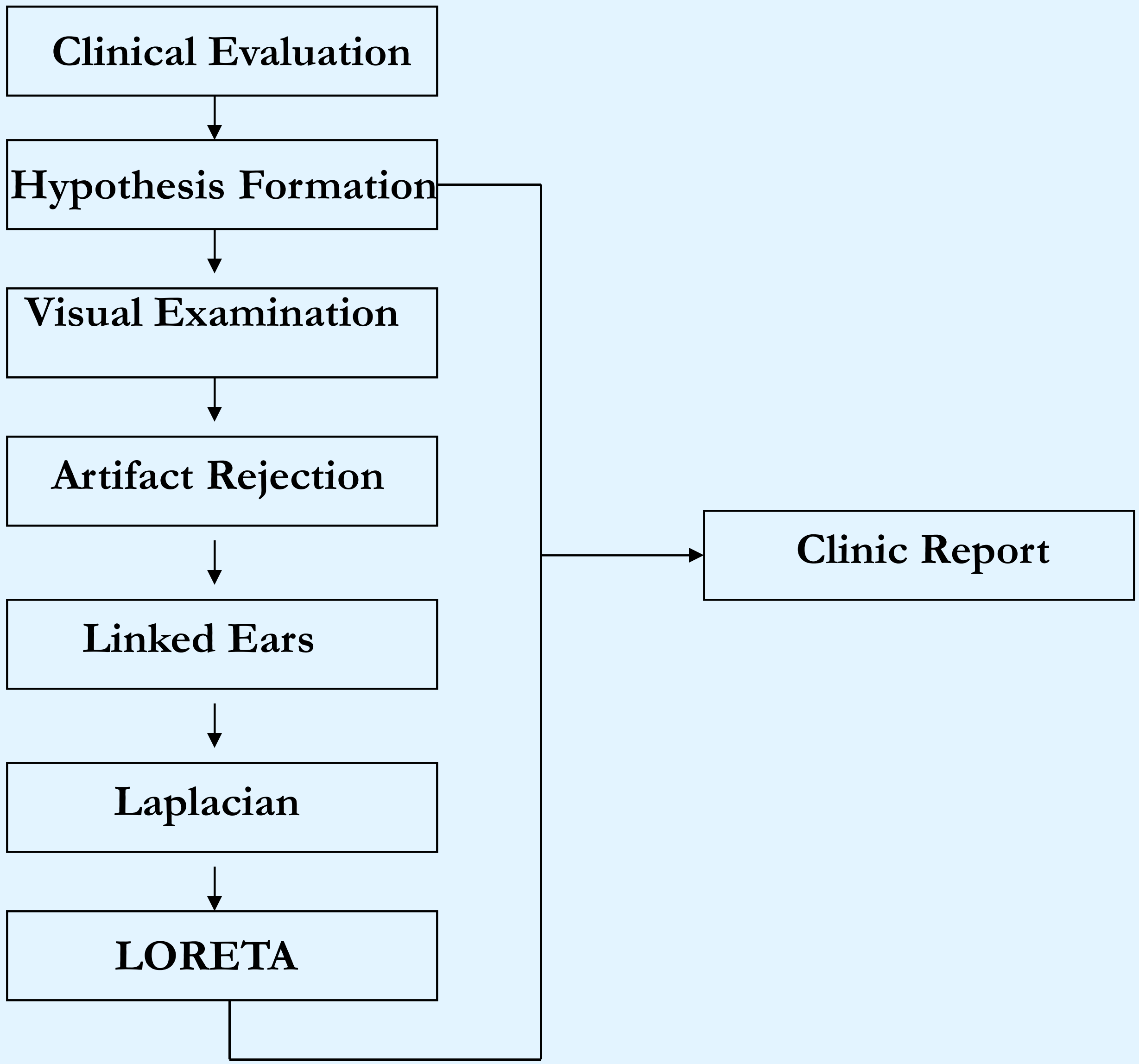
Essential Steps in Helping Patients with Neurological/Psychological Problems

Assess, Address, Reassess …

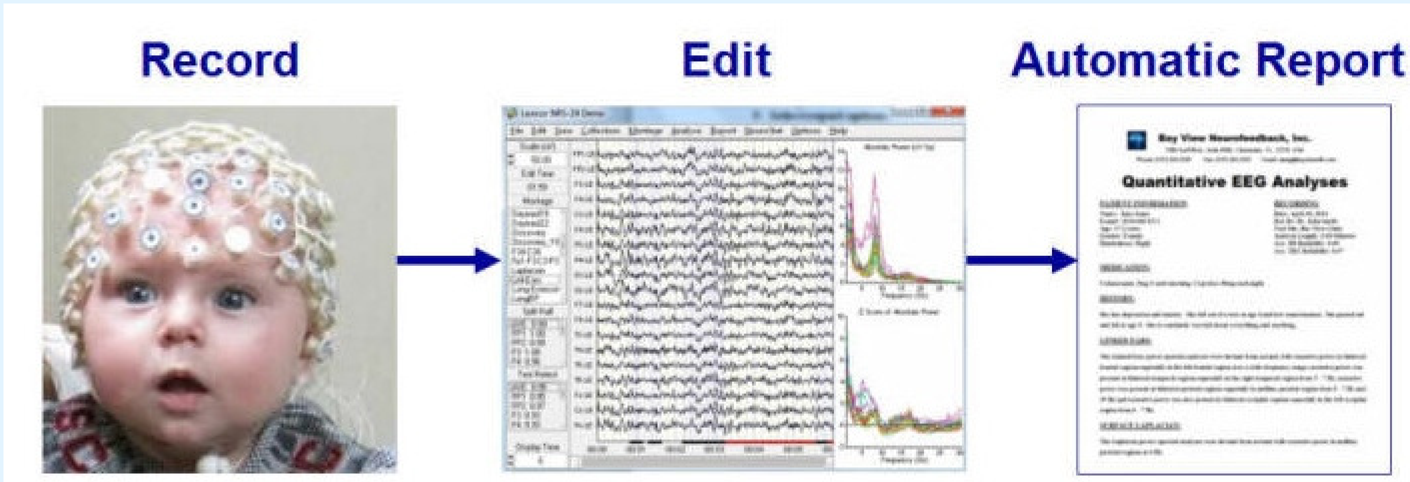



Linking Patient's Symptoms to Patient's Brain
Network Hypotheses
Symptoms Network Hypotheses
Electrical Network Assessment
Good Collection Hygiene
Visual Exam Editing & Remontaging
FFT/JTFA Spectra Z Scores
LORETA Power & Connectivity
Hypothesis Test – Report & NFB Protocol
NF1 & NF2 Operant Conditioning
BCI - BrainSurfer
Neurofeedback Progress & Protocol Revision
Session Charts
NeuroStat

QEEG Report Generation Sequence



Automatic Clinical Report Writer (ACR)



•No Delays with Minimal Expense for a Professional Quality In-House QEEG Clinical Report

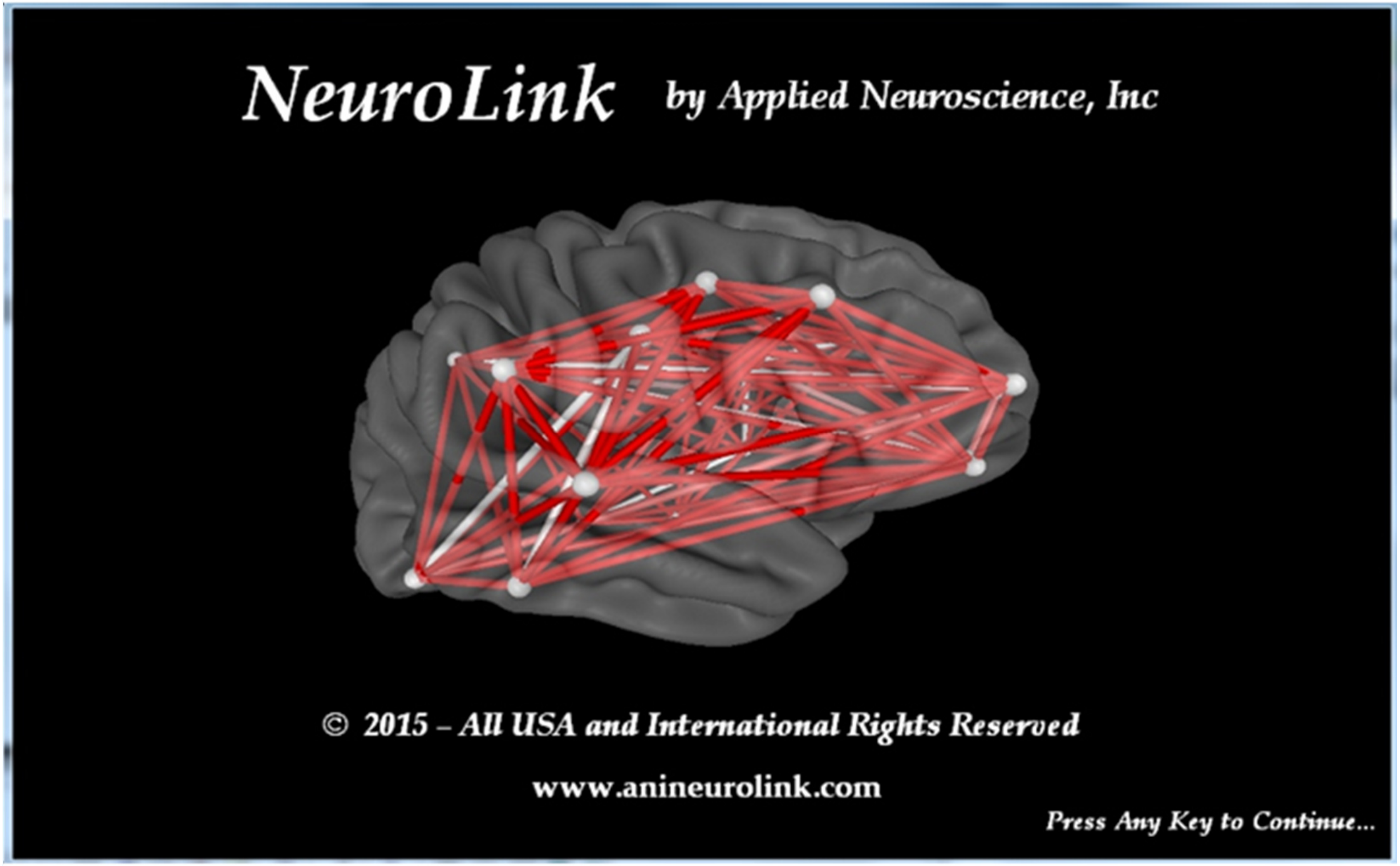
•Less than One Minute to Produce a Professional QEEG Clinical Report, in Microsoft Word format

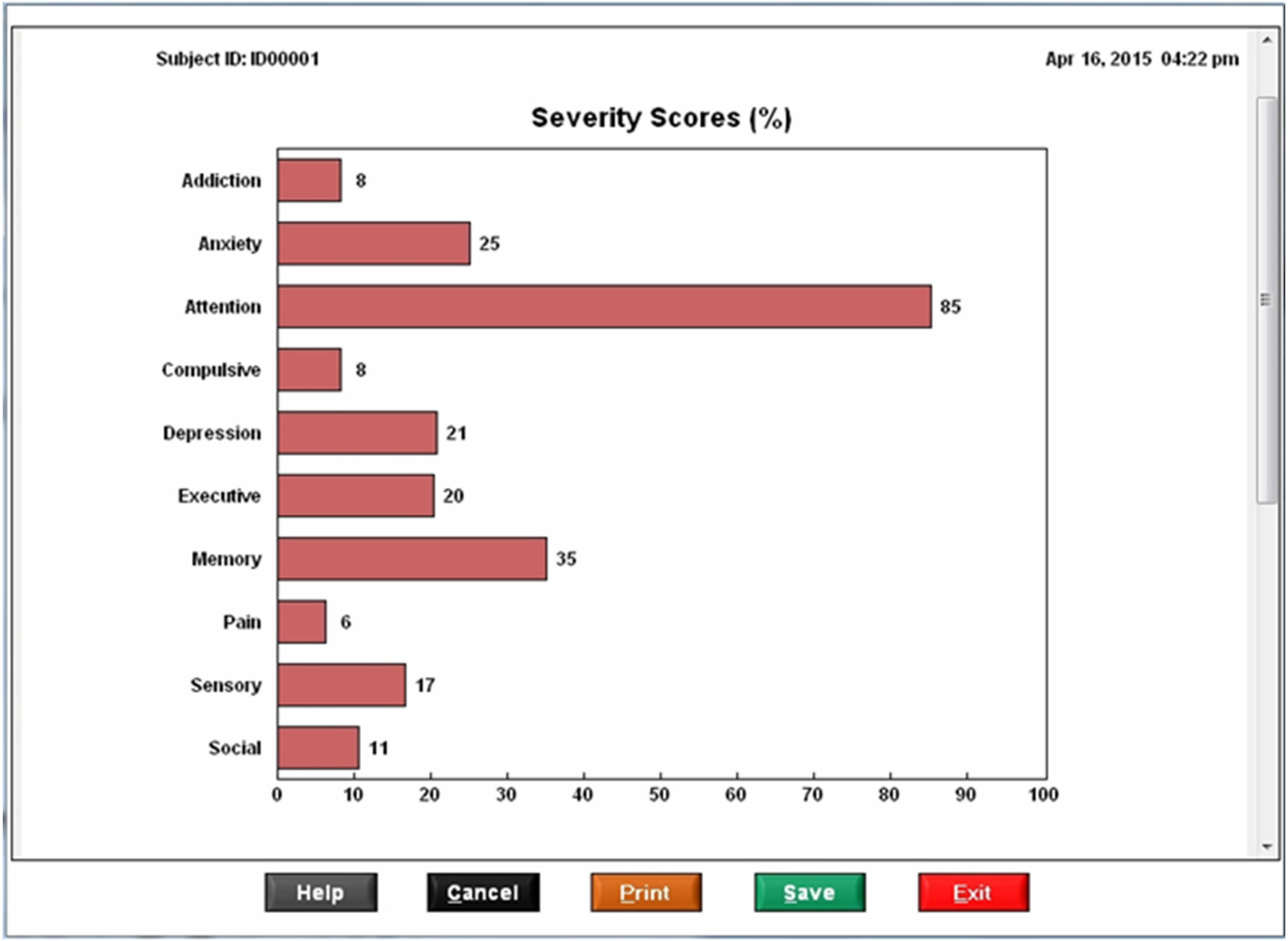
•ACR Provides: Empowerment, Simplicity, Accuracy & Efficiency!

•Get Valid Normative Database Comparisons using without Depending on Internet Q-EEG Report Services!

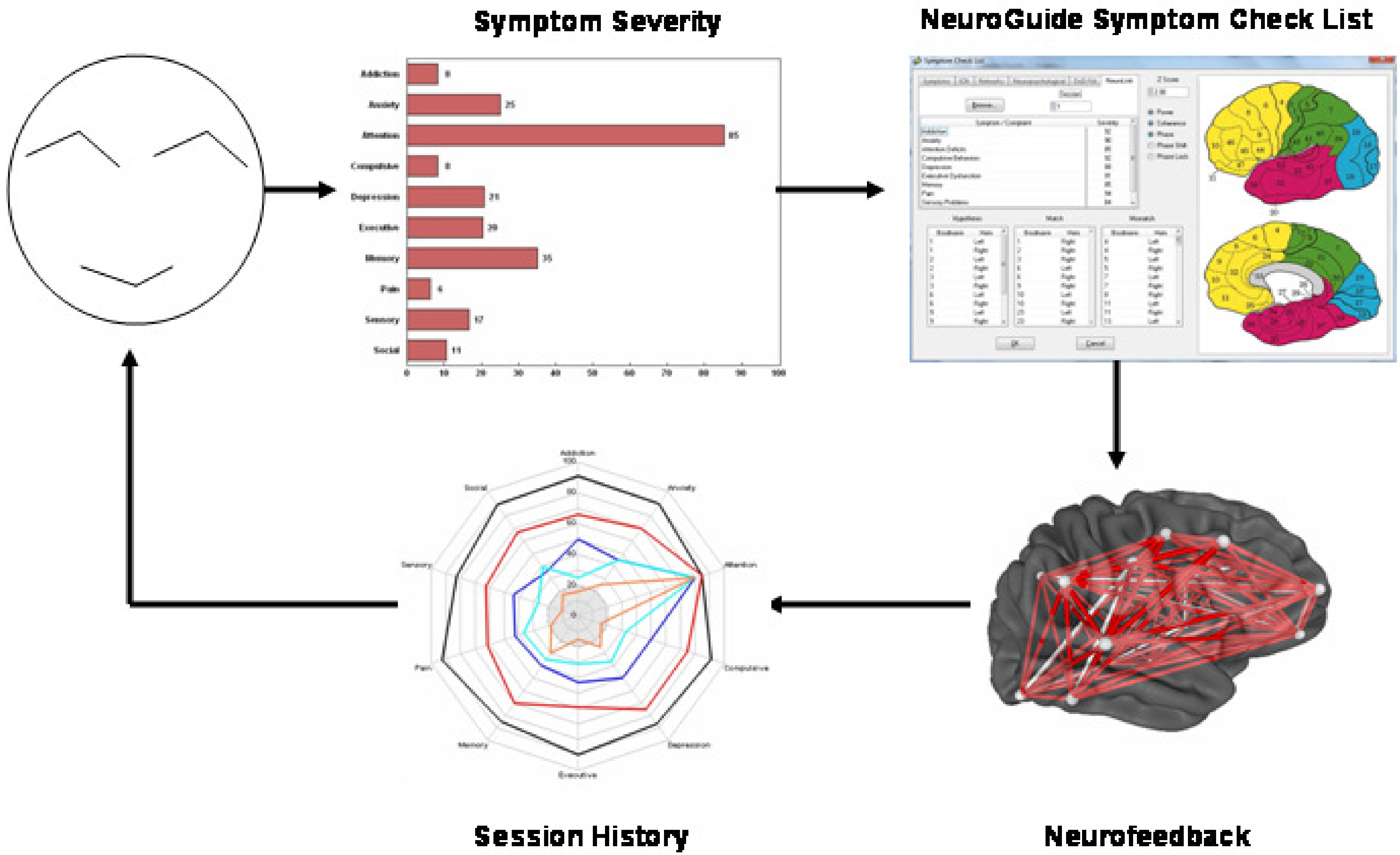
•Get Relevant Content and Displays, plus Helpful NFB Recommendations in Less than a Minute.

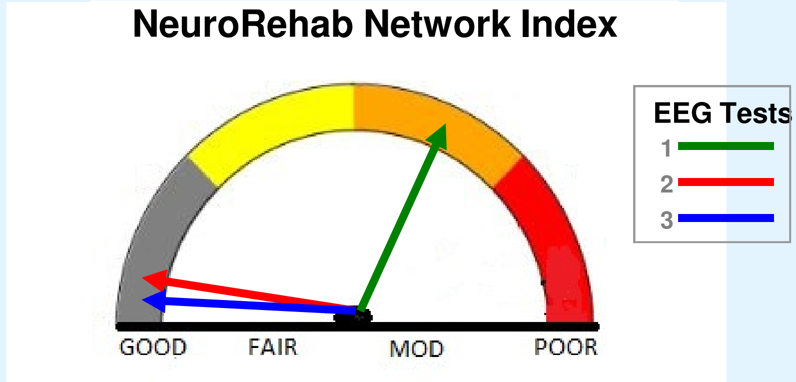
•Increased Productivity by at Least 10 Fold, e.g. Ten Reports in an Hour!


NeuroLink
by Applied Neuroscience, Inc
© 2015 – All USA and International Rights Reserved
www.anineurolink.com
Press Any Key to Continue...


Subject ID: ID00001
Apr 16, 2015 04:22 pm
Severity Scores (%)
Addiction 8
Anxiety 25
Attention 85
Compulsive 8
Depression 21
Executive 20
Memory 35
Pain 6
Sensory 17
Social 11
0 10 20 30 40 50 60 70 80 90 100
Help
Cancel
Print
Save
Exit

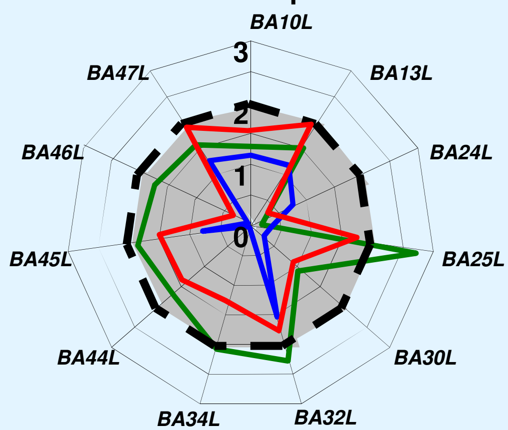
NeuroLink and NeuroGuide Integration – Linking Symptoms to the Brain



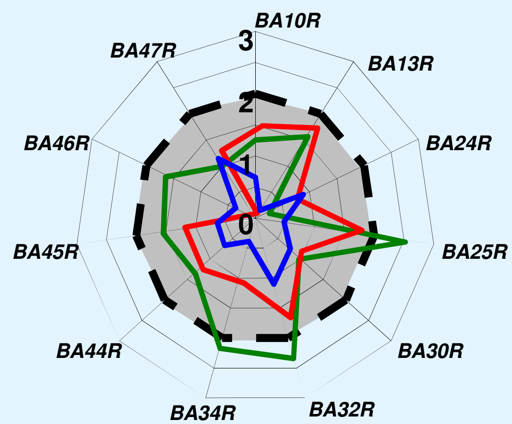


Addiction Network Z Scores

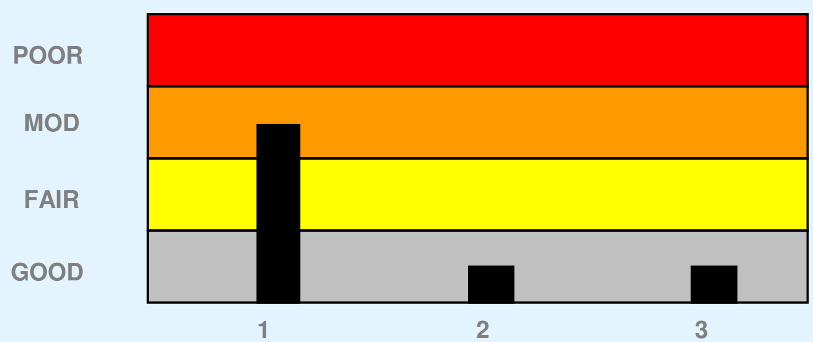
Left Hemisphere

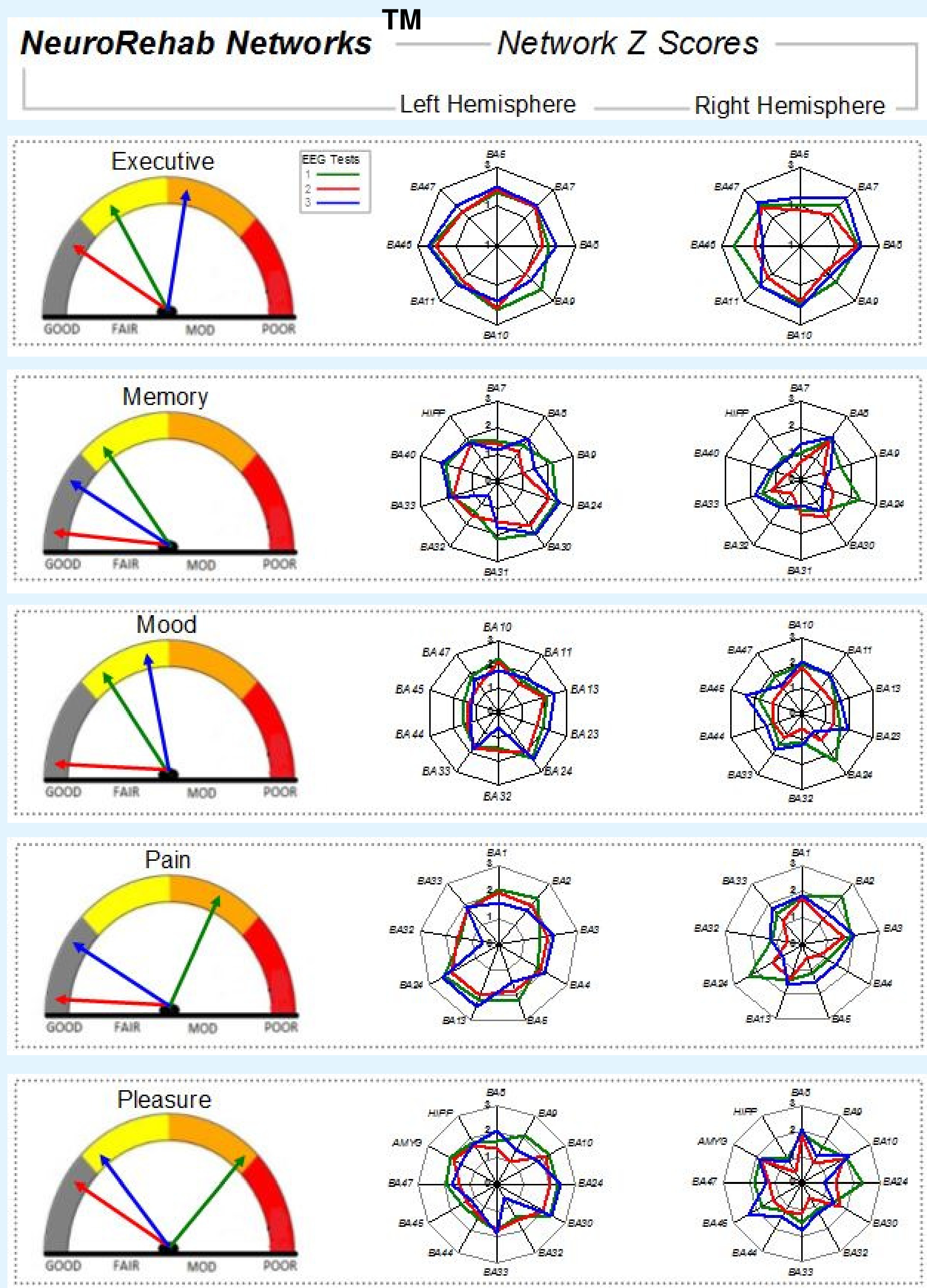


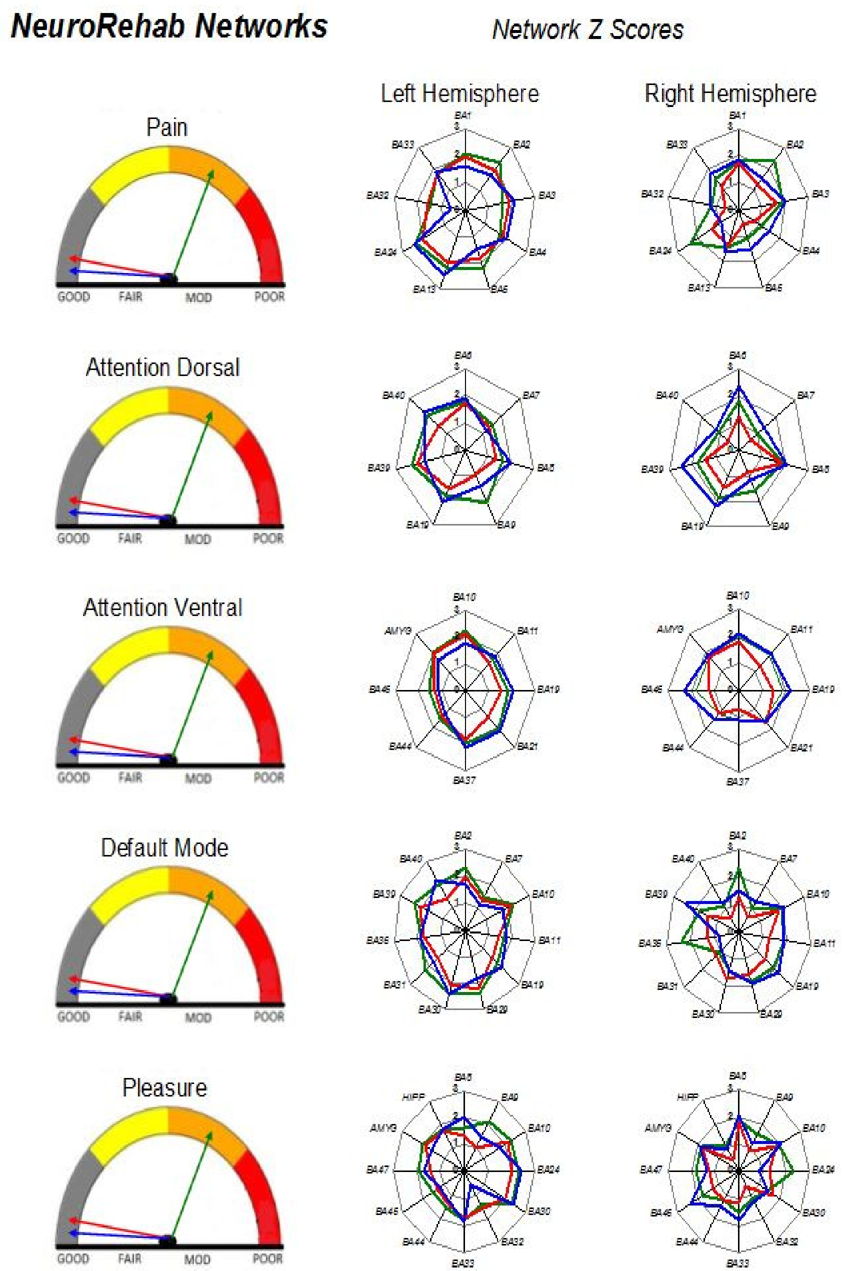
Right Hemisphere



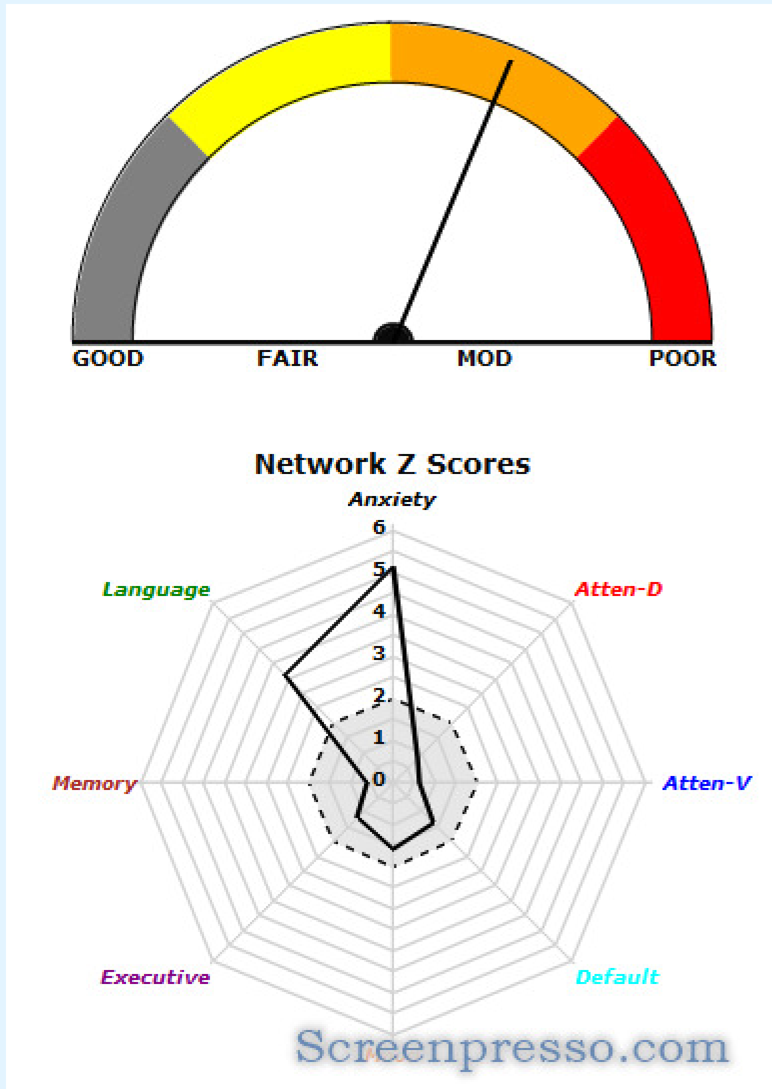
Rehabilitation History




NeuroRehab Networks TM
Network Z Scores
Left Hemisphere
Right Hemisphere
Executive
EEG Tests
1
2
3
GOOD
FAIR
MOD
POOR
Memory
Mood
Pain
Pleasure


NeuroRehab Networks
Network Z Scores
Left Hemisphere
Right Hemisphere
Pain
Attention Dorsal
Attention Ventral
Default Mode
Pleasure
GOOD
FAIR
MOD
POOR

The BrainRehab Index



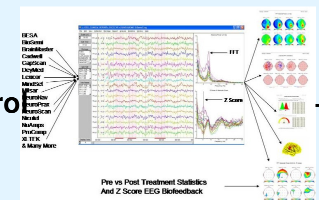
The BrainRehabilitator ™

Portable System

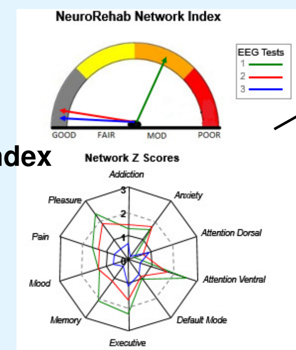
Assessment

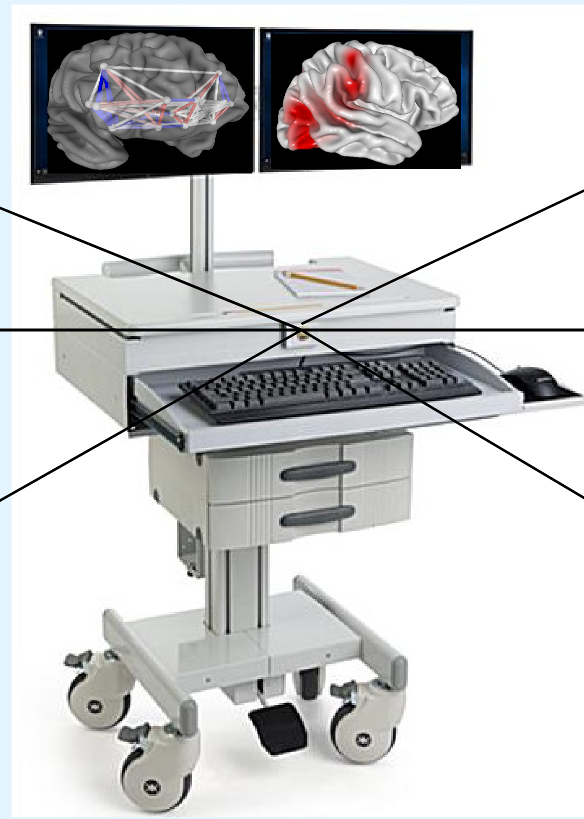
Dry EEG Headset

EEG Control

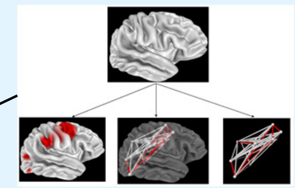


BrainRehab Index

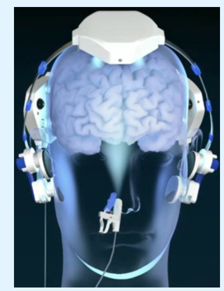




Treatment

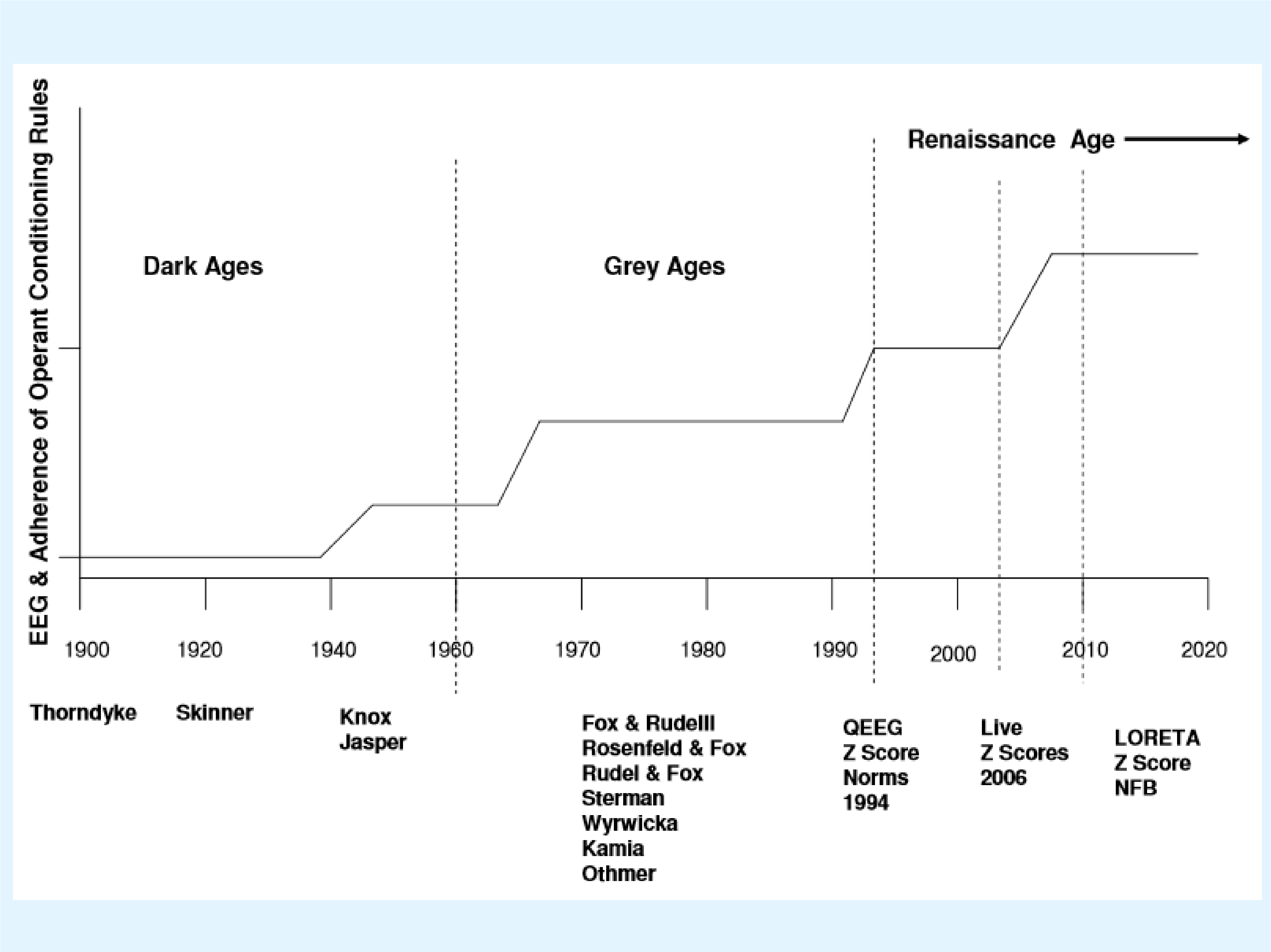


NeuroFeedback



Photobiomodulation

Electrical Brain
Stimulation tDC



EEG & Adherence of Operant Conditioning Rules
Renaissance Age
Dark Ages
Grey Ages
1900
1920
1940
1960
1970
1980
1990
2000
2010
2020
Thorndyke
Skinner
Knox
Jasper
Fox & Rudelll
Rosenfeld & Fox
Rudel & Fox
Sterman
Wyrwicka
Kamia
Othmer
QEEG
Z Score
Norms
1994
Live
Z Scores
2006
LORETA
Z Score
NFB

What is the Future for Z Score Neurofeedback?

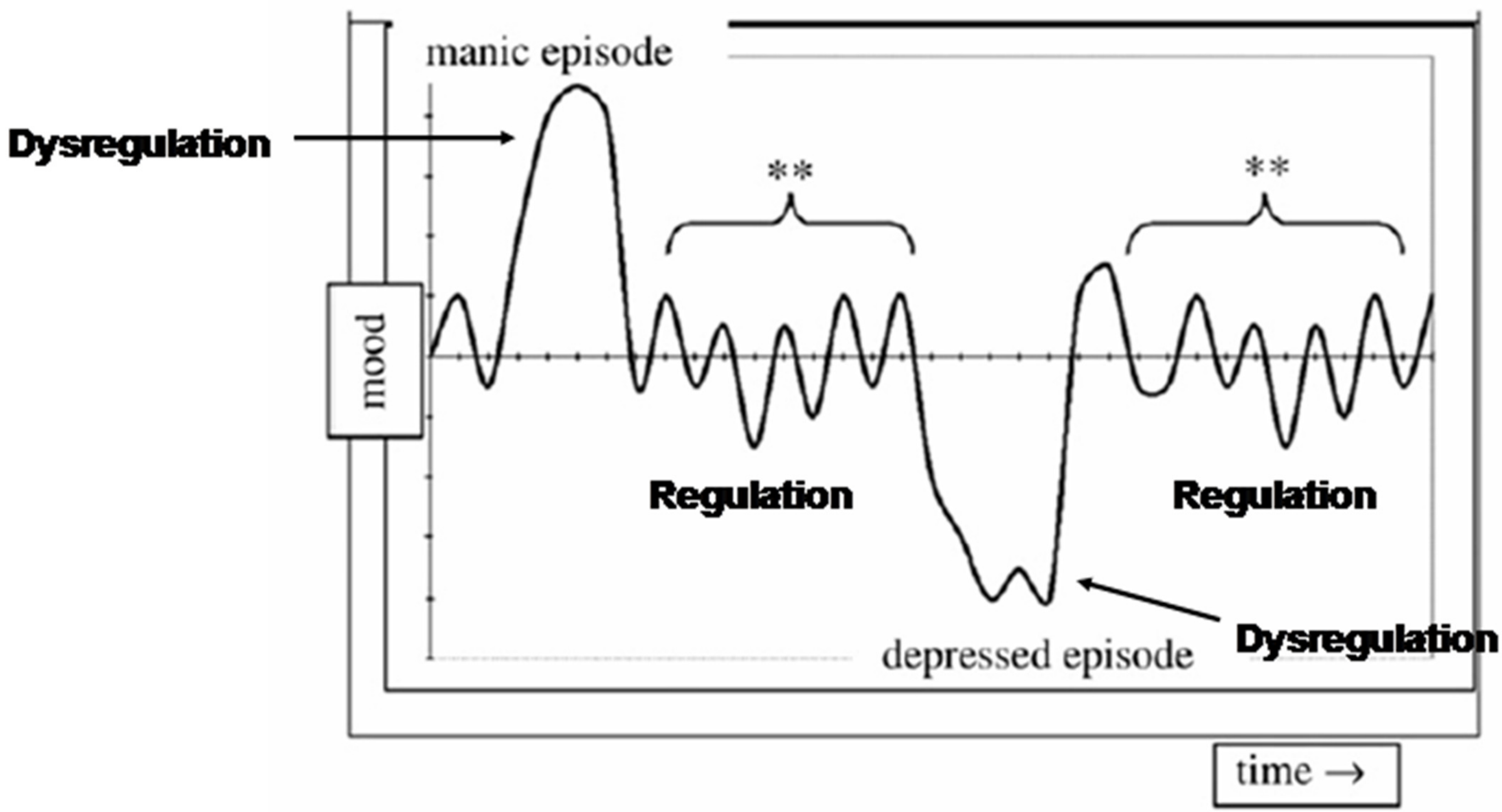
1- Expanding Number or Clinicians Using Z Score NFB

2- Expanding Number of Metrics:
- a- Effective Connectivity
- b- Cross-Frequency Coherence
- c- Cross-Frequency Effective Connectivity
- d- Phase Amplitude Cross-Frequency Coupling
- e- swLORETA – Individualized MRI & NFB

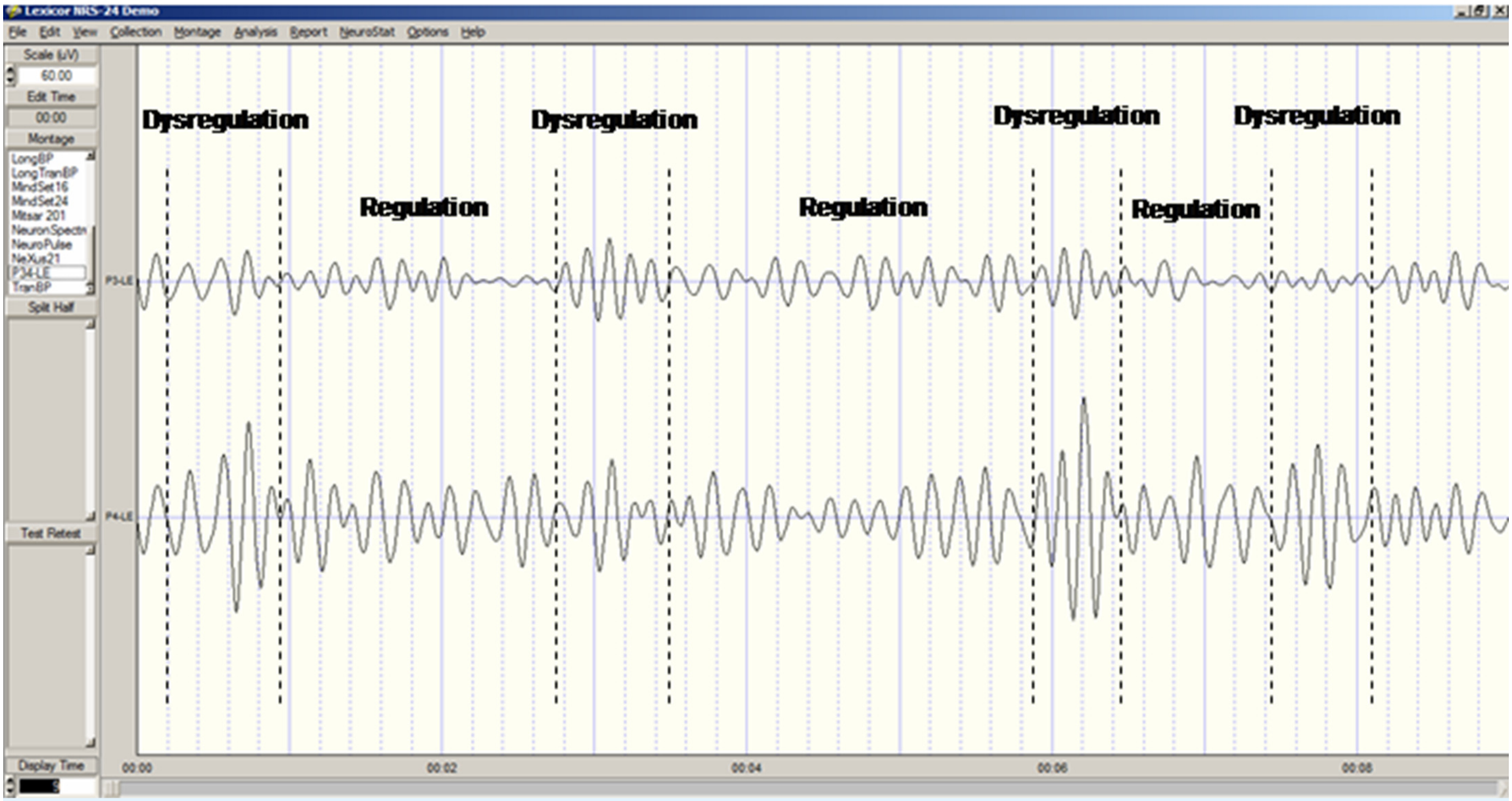
3- New Brain Imaging Technology

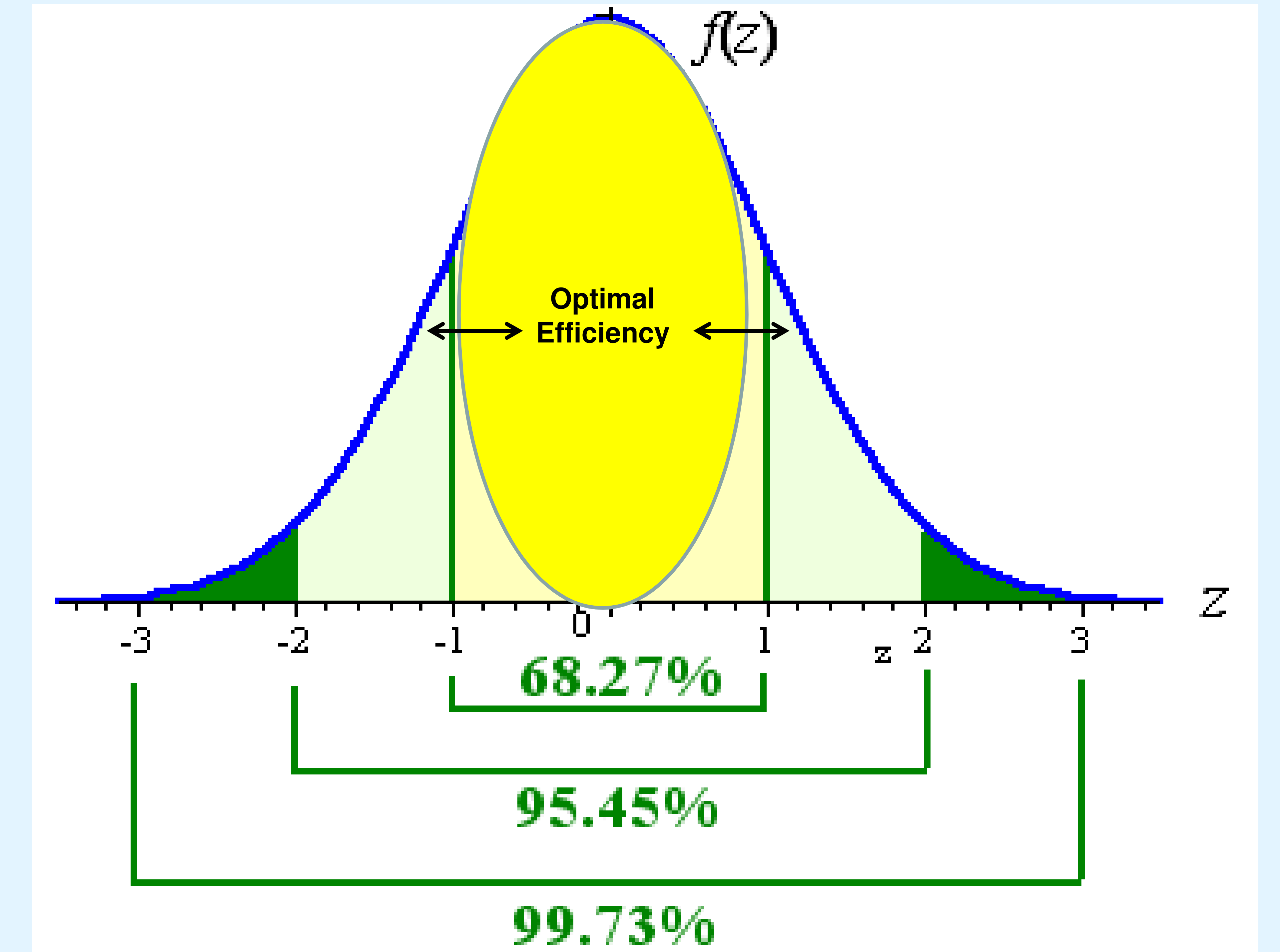
4- Smart Phone and Tablet Techology

Moment-to-Moment “Regulation” and “Dysregulation”



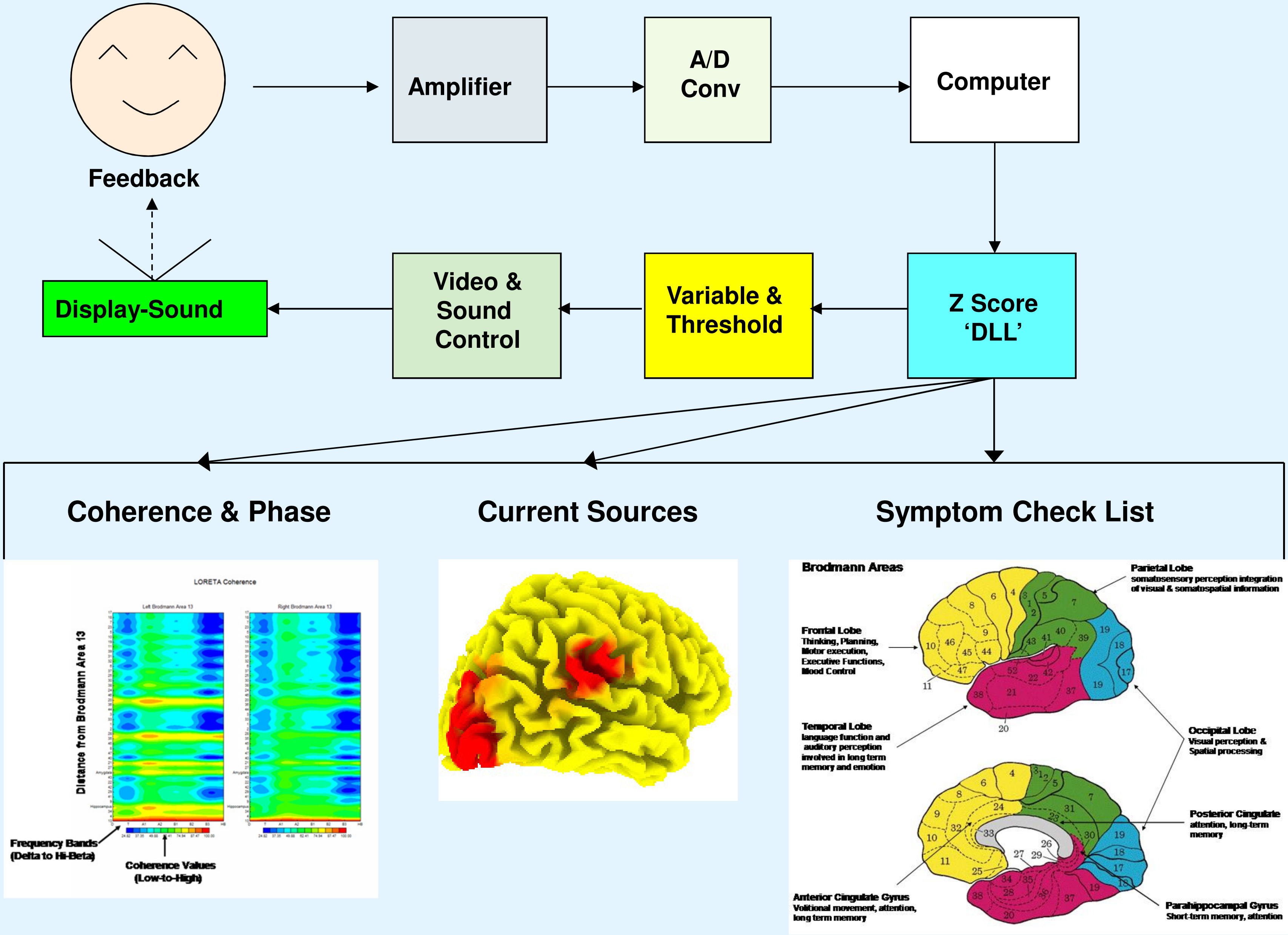
TBI Demo Right Parietal Lobe Alternating Degrees of Regulation Biofeedback's Goal is to Reduce the Frequency, Duration and Intensity of Dysregulation





f(z)
Optimal
Efficiency
Z
-3
-2
-1
0
1
z
2
3
68.27%
95.45%
99.73%

Neuroimaging Neurofeedback - Fort Campbell



LMU
KLINIKUM
DER UNIVERSITÄT MÜNCHEN
DEPARTMENT OF PSYCHIATRY
INSTITUTE OF CLINICAL RADIOLOGY

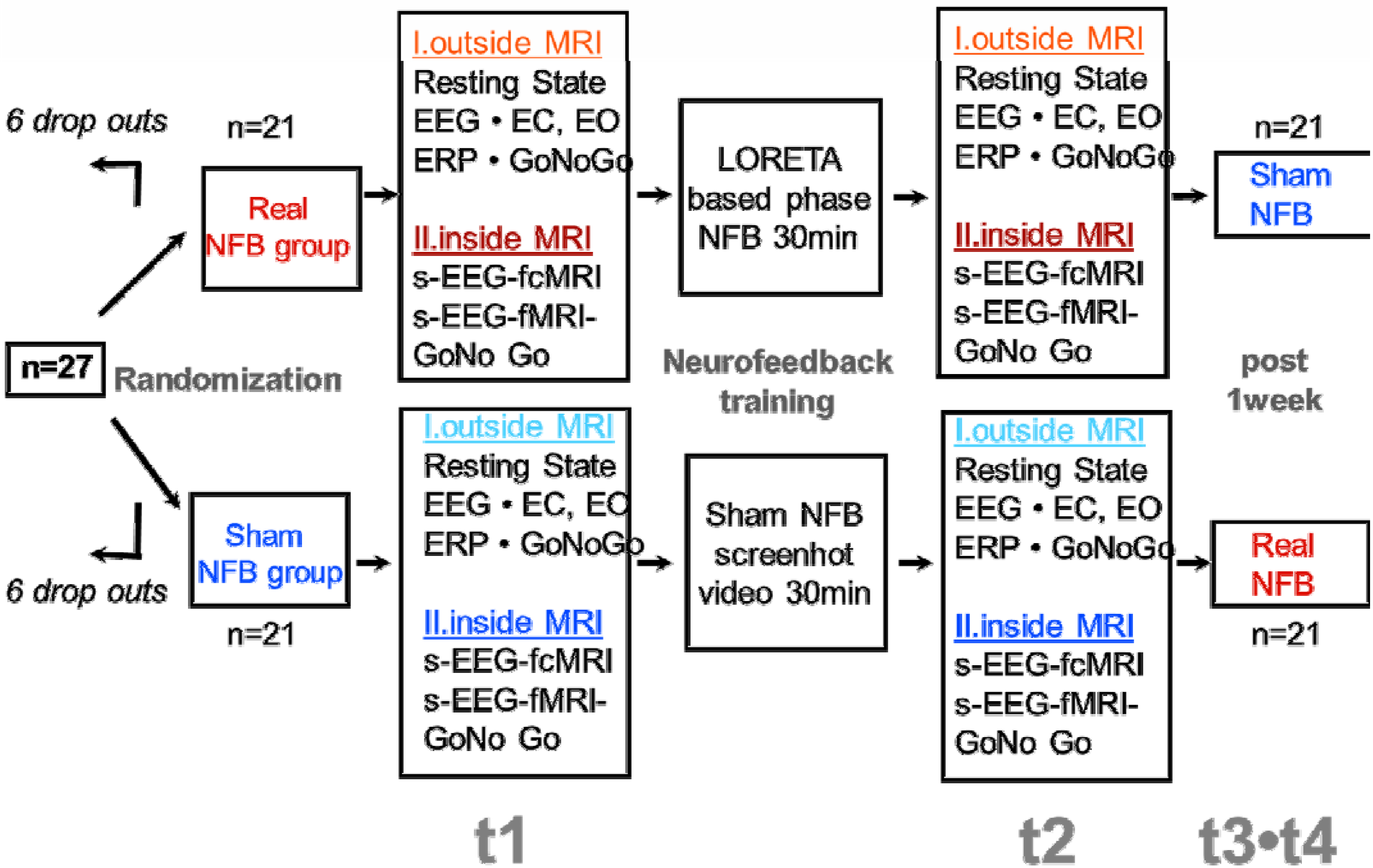
The impact of source-localized EEG phase neurofeedback on brain activity

A double-blinded placebo-controlled study using simultaneously EEG-fMRI – preliminary results

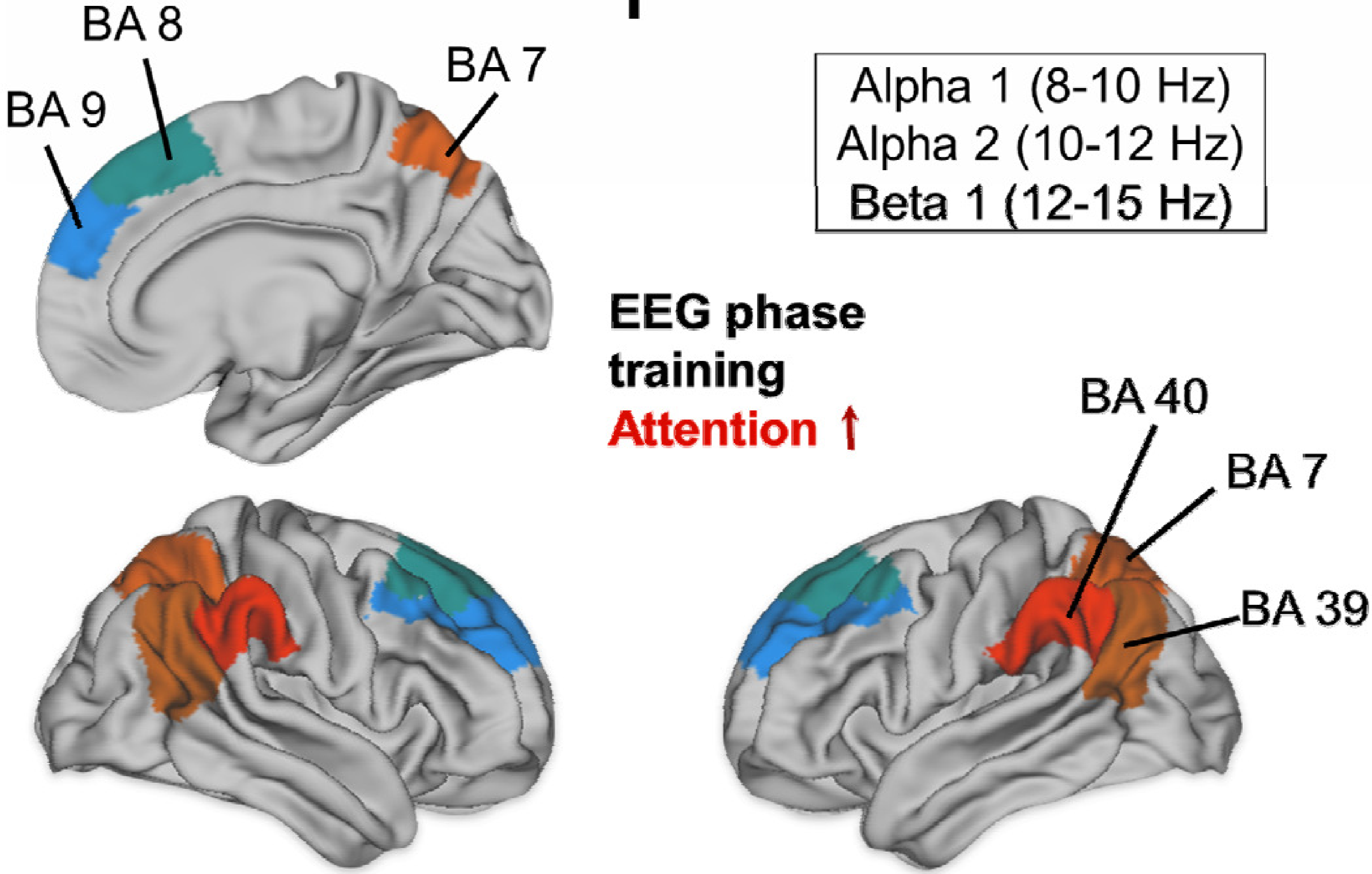
Daniel Keeser

Valerie Kirsch, Boris Rauchmann, Brian Stamm, Paul Reidler, Robert Thatcher, Susanne Karch, Oliver Pogarell, Birgit Ertl-Wagner

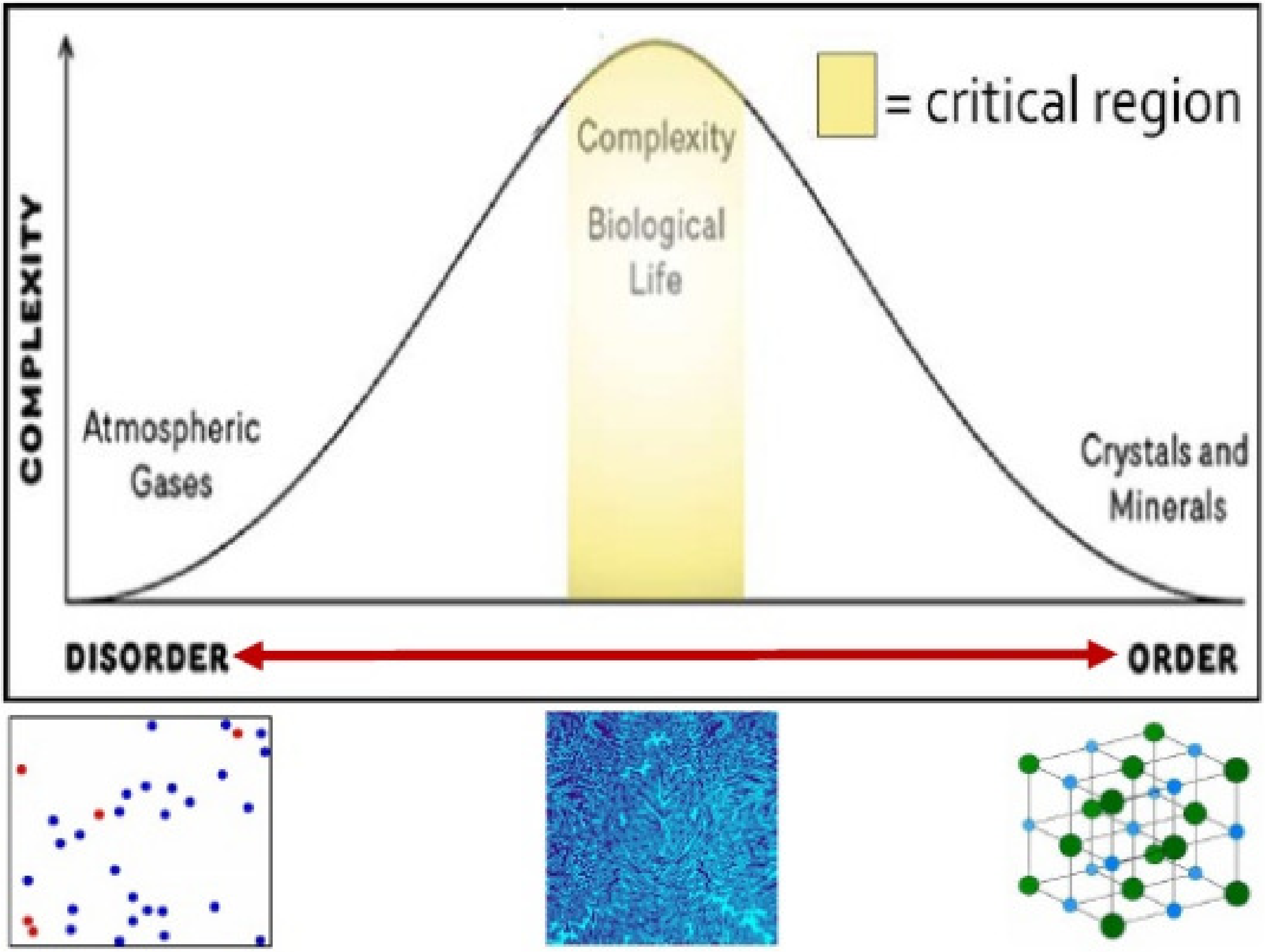
s-EEG-fcMRI neurofeedback study design



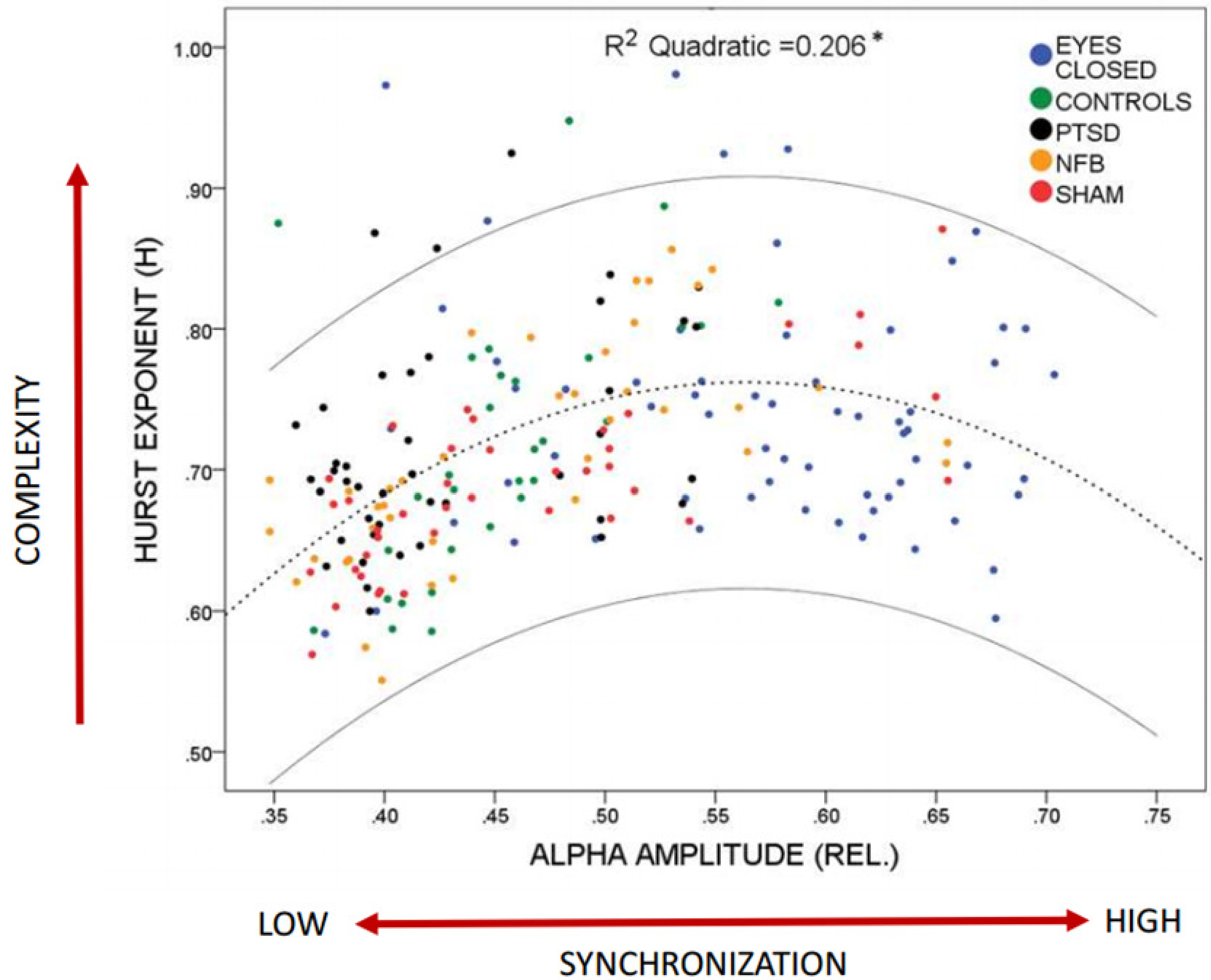
NFB protocol



The Theory of Self-Organised Criticality

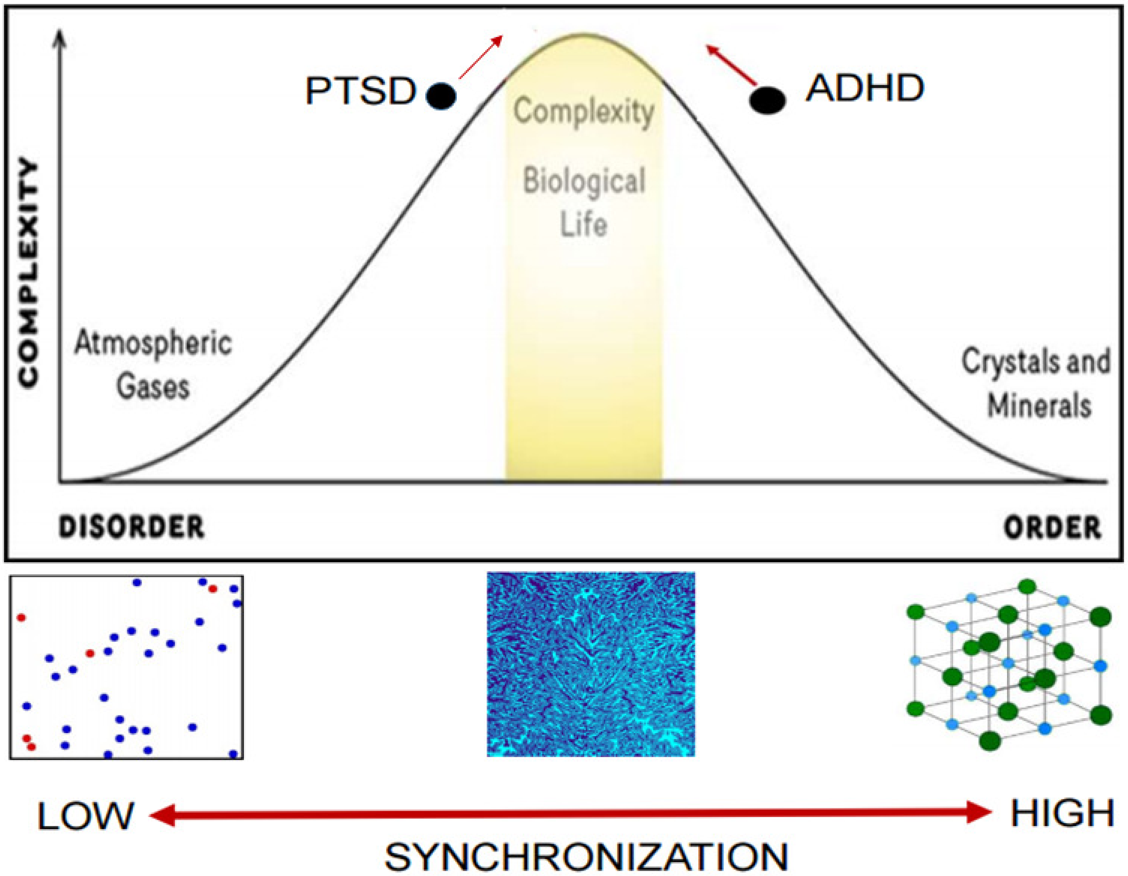


Tuning-pathological-brain-oscillations-Thomas Ros- 2016



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

Self-Organised Criticality: a potential mechanism?



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

frontiers in
HUMAN NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE
published: 18 December 2014
doi: 10.3389/fnhum.2014.01008

Tuning pathological brain oscillations with neurofeedback: a systems neuroscience framework

Tomas Ros[1]*, Bernard J. Baars[2], Ruth A. Lanius[3] and Patrik Vuilleumier[1]

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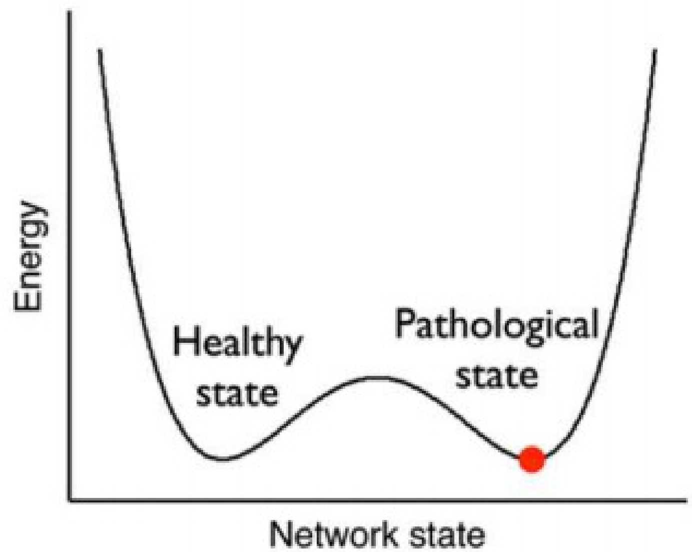
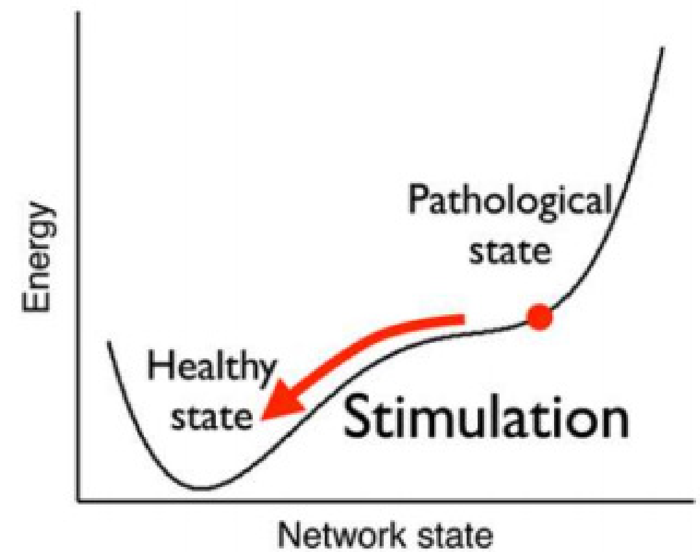
e-mail: dr.t.ros@gmail.com





Select a Network or Symptoms, Frequency and Metric

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Network	Severity
Addiction	0
Anxiety	0
Attention - Dorsal	0
Attention - Ventral	0
Attention - Emotional	0
Default Mode	0
Executive Function	0
Face, Object Recognition	0
Language	0
Memory - Emotion	0
Mirror Neuron	0
Mood	0
Pain	0
Pleasure	0
Salience	0
Schizophrenia	0
Working Memory	0
DTI - Frontal Limbic	0
DTI - Frontal Occipital	0
DTI - Frontal Parietal	0
DTI - Frontal Temporal	0
DTI - Local Frontal	0
DTI - Local Limbic	0
DTI - Local Occipital	0
DTI - Local Parietal	0
DTI - Local Temporal	0
Hagmann Module 1 (Vision)	0
Hagmann Module 2 (Attention, Working Memory)	0
Hagmann Module 3 (Auditory, Language, Memory)	0
Hagmann Module 4 (Auditory, Language, Memory)	0
Hagmann Module 5 (Executive, Sequential Planning)	0
Hagmann Module 6 (Executive, Social Skills)	0
Isocortex Hippocampocentric	0
Isocortex Olfactocentric	0
Mesocortex Hippocampocentric	0
Mesocortex Olfactocentric	0
Mesulam - Emotional Memory	0
Mesulam - Executive Function	0
Mesulam - Face/Object Indentification	0
Mesulam - Language	0
Mesulam - Spatial Attention	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Intrinsic Connectivity Network	Severity
ICN 1 (Limbic, Medial-Temporal, Emotion)	0
ICN 2 (Reward, Emotion)	0
ICN 4 (Language, Executive)	0
ICN 6 (Premotor, Supplemental Motor)	0
ICN 7 (Visual-Spatial Processing)	0
ICN 8, 17 (Primary Sensory Motor)	0
ICN 9 (Parietal)	0
ICN 10 (Picture Naming, Visual Tracking)	0
ICN 11, 12 (Visual System)	0
ICN 13 (Default Mode Network)	0
ICN 15 (Right Hemisphere, Attention, Reasoning, Memory)	0
ICN 16 (Auditory, Music)	0
ICN 18 (Left Hemisphere, Language)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Neuropsychological Diagnosis	Severity
Agnosia of Action Apperceptive	0
Agnosia of Action Associative	0
Agnosia Auditory Apperceptive	0
Agnosia Auditory Associative	0
Agnosia Auditory Space	0
Agnosia Prosopagnosia (Face)	0
Agnosia Social Emotional	0
Agnosia Social of Action - Theory of Mind	0
Agnosia Somatosensory Autotopagnosia	0
Agnosia Somatosensory Finger	0

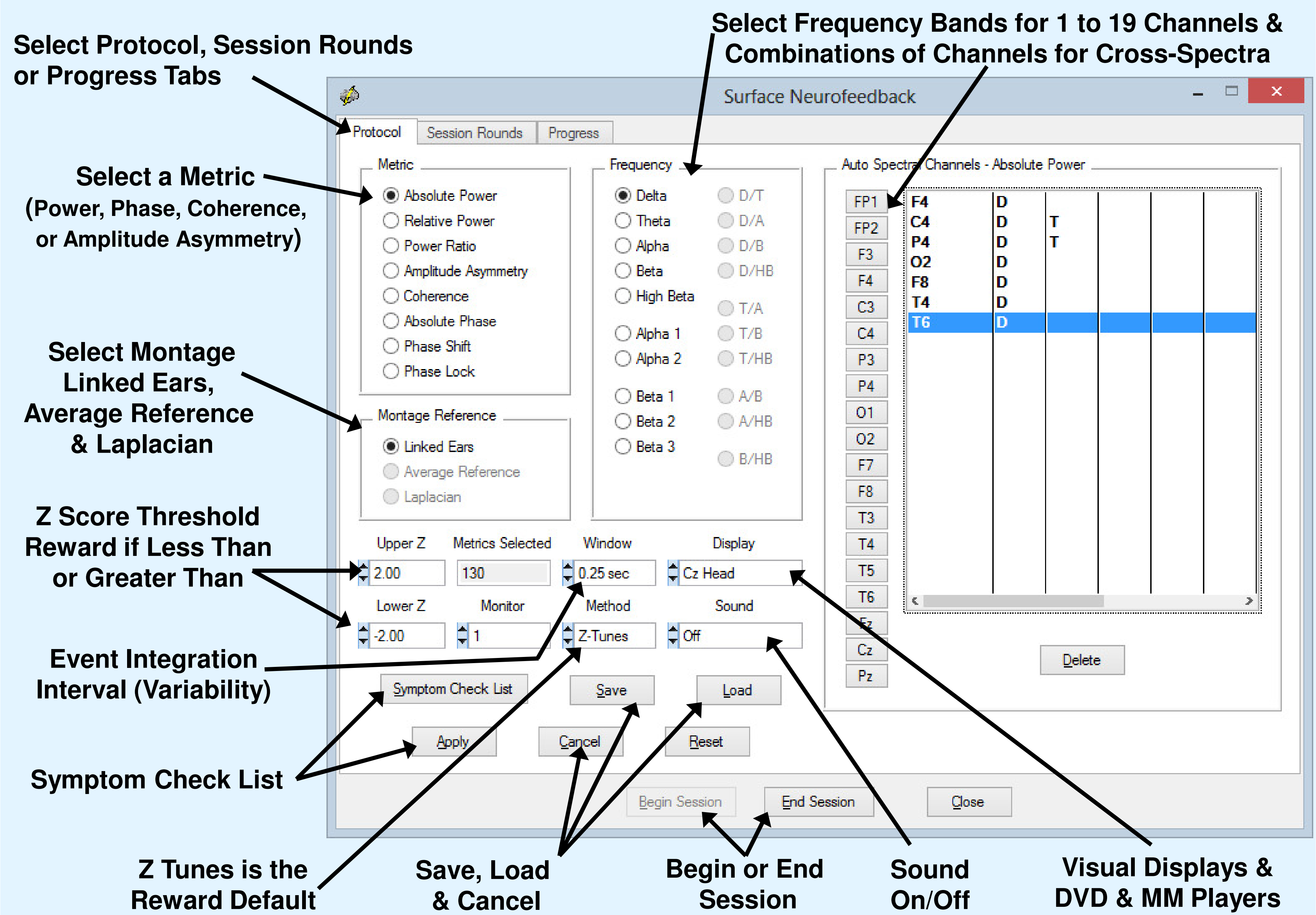
Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Attention - Re-Experiences Intrusive Memories	0
Attention - Emotional Numbing	0
Attention - Distracting Pain	0
Attention - Difficulty Multi-Tasking	0
Attention - Worsens with Emotional Stress	0
Attention - Dissociative Episodes	0
Attention - Worsens With Withdrawl Symptoms	0
Chronic Pain - Neuropathic	0
Chronic Pain - Musculoskeletal	0
Chronic Pain - Diffuse Pain (Entire Body)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Anosognosia - Denial of a Problem	0
Anxiety	0
Attention Deficits - Easily Distractible	0
Auditory Sequencing Problems	0
Balance Problems	0
Blurred Vision	0
Chronic Pain	0
Compulsive Behaviors and/or Thoughts	0
Concentration Problems	0
Decreased Tactile or Skin Sensitivity	0
Delusional	0
Depression (Sad & Blue)	0
Difficulty Comprehending Social Cues	0
Dyscalcula - Problems Calculating	0
Dyslexia - Letter Reversal	0
Executive Function Problems	0
Face Recognition Problems	0
Failure to Initiate Actions	0
Hyperactive and/or Agitation	0
Impulsive Behaviors	0
Insensitive to Others Emotional Expressions	0
Insensitive to Other's Feelings	0
Low Motivation	0
Low Threshold for Anger & Loss of Control	0
Migrane Headaches	0
Mood Swings	0
Multi-Tasking Problems	0
Obsessive Thoughts about Self	0
Obsessive Thoughts and/or Hyper Focused	0
Oppositional Defiant Conduct	0
Orientation in Space Problems	0
Perception of Letters Problems	0
Poor Judgement	0
Poor Skilled Motor Movements	0
Poor Social Skills	0
Receptive Language Problems	0
Recognizing Objects by Touch Problems	0
Self-Esteem Problems	0
Sequential Planning Problems	0
Short-Term Memory Problems	0
Slow Reader	0
Slowness of Thought - Easily Confused	0
Spatial Perception Problems	0
Speech Articulation Problems	0
Substance Abuse	0
Symptoms of Fibromyalgia	0
Word Finding Problems	0

Z Score Neurofeedback Panel



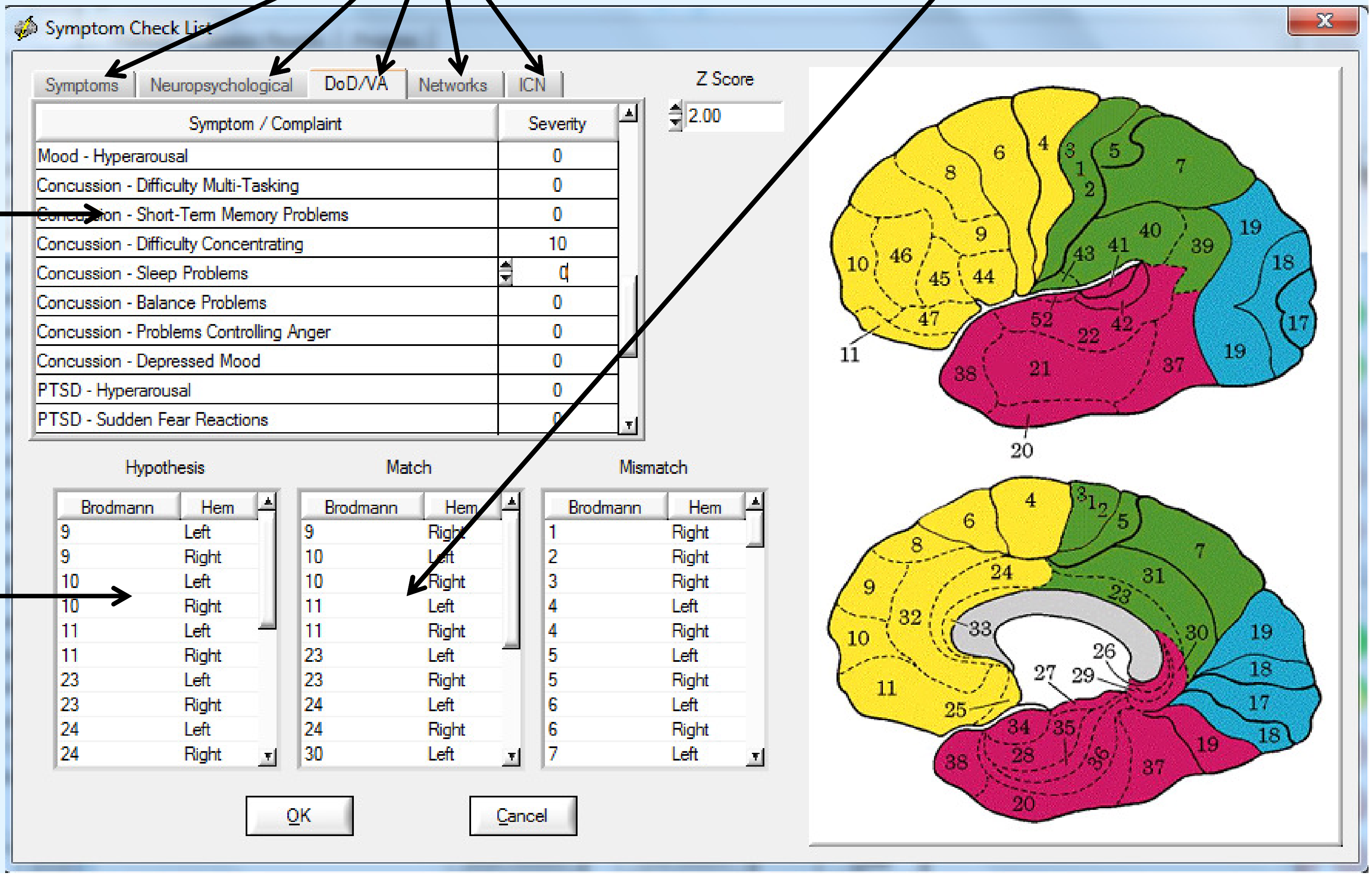
Neuroimaging Neurofeedback Symptom Check List

Click Symptoms or Neuropsychological Diagnoses or DoD/VA List or Networks & Severity

List of Matching Brodmann Areas

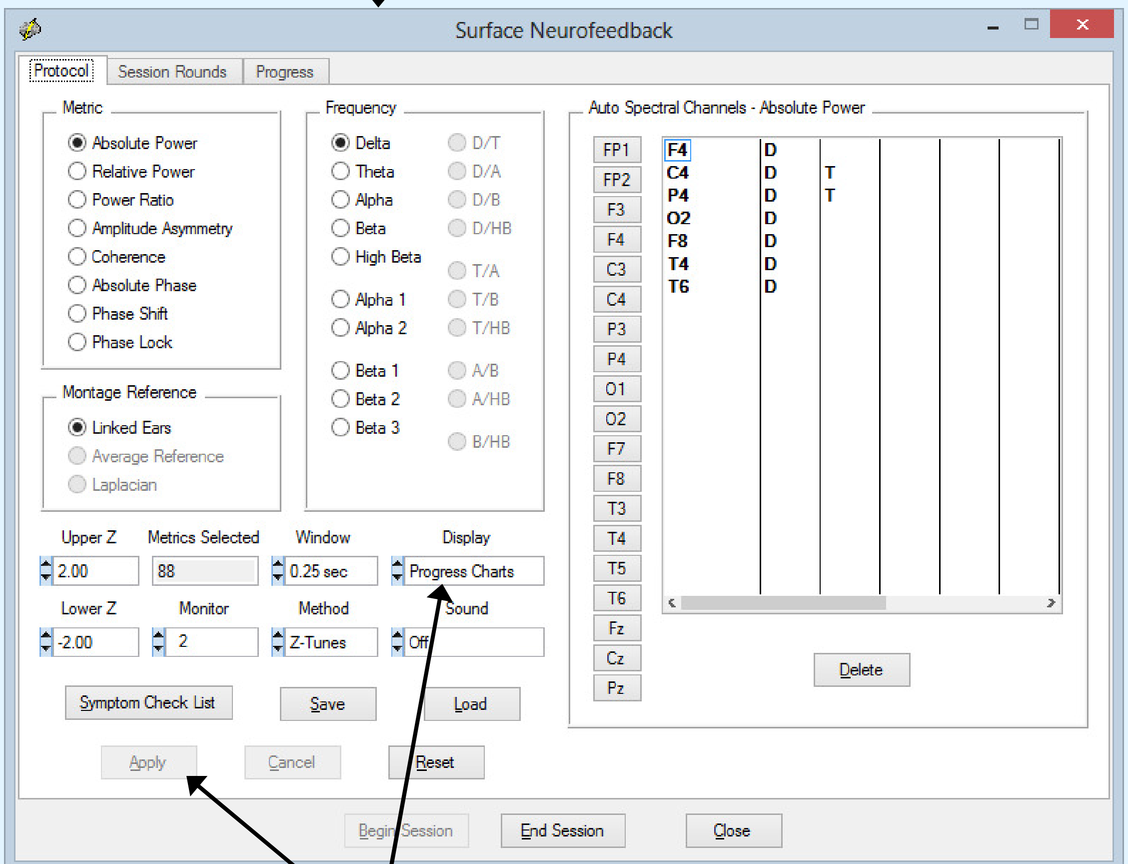
List of Symptoms

Anatomical Hypotheses

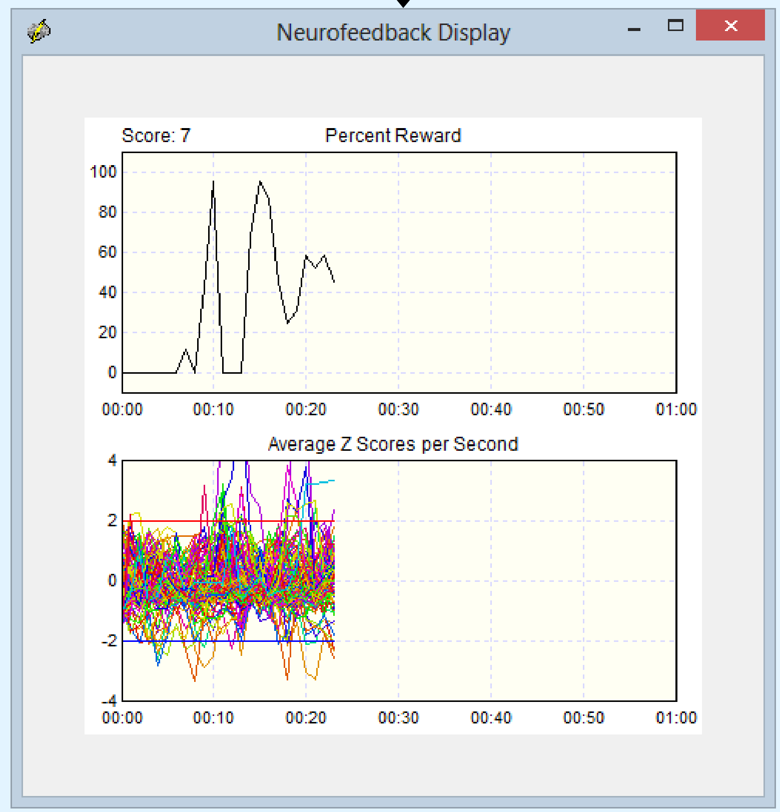


Use the Progress Chart as a Feedback Display

Neurofeedback Setup Panel



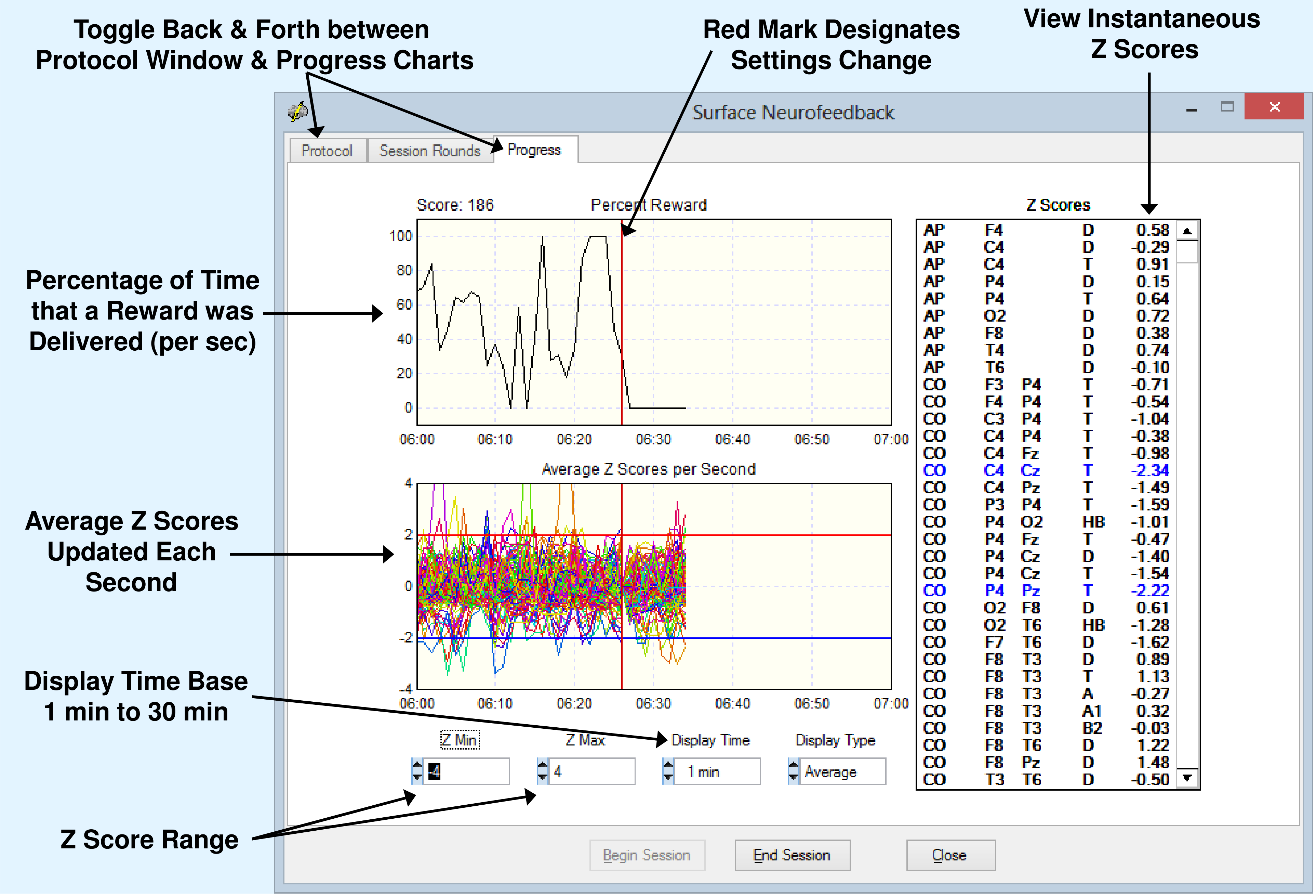
Move the Display to the Client's Monitor

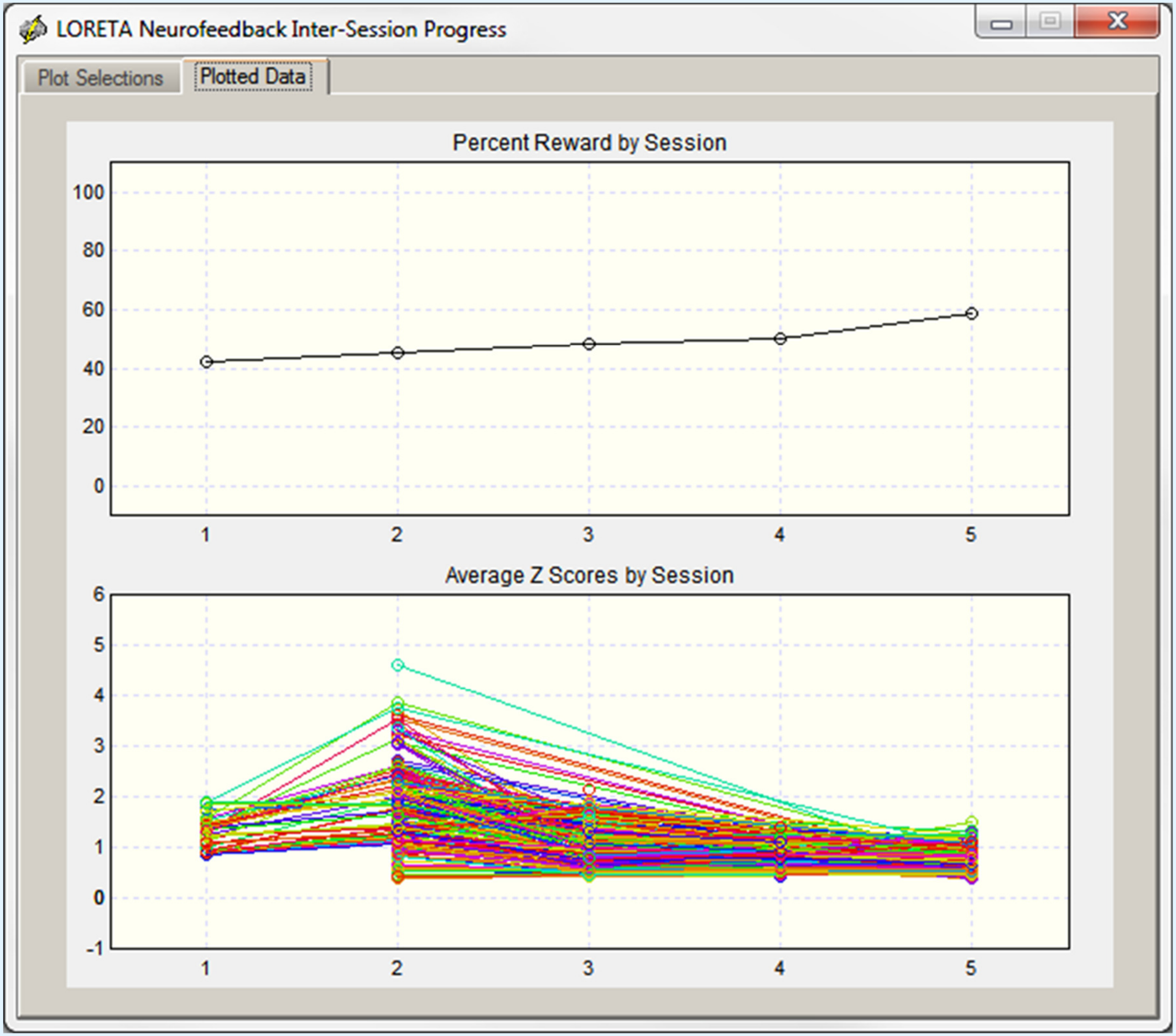


Select Progress Charts as Feedback to a Client and then Click Apply

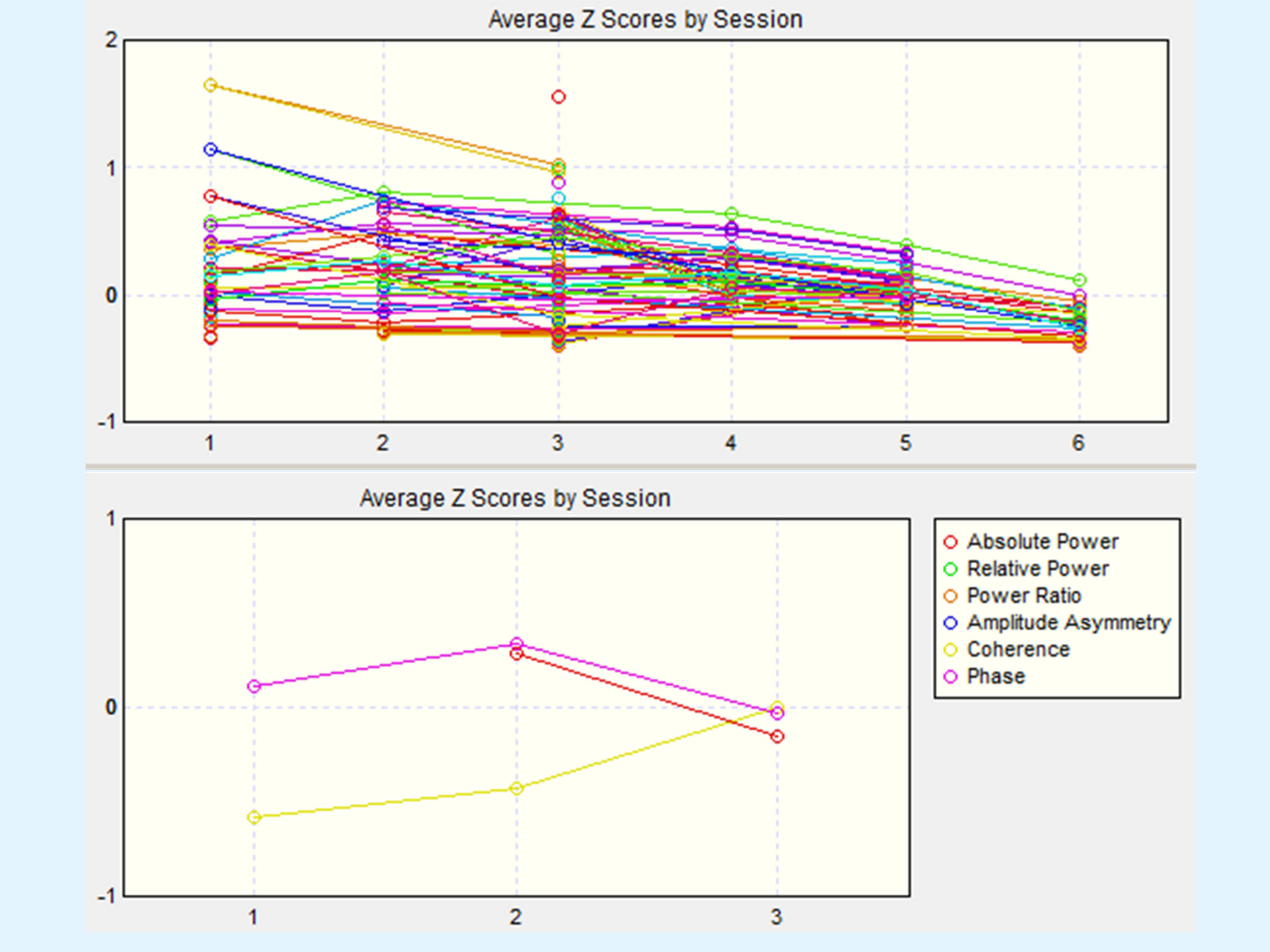
Move to the Client's Monitor

Progress Charts to be Monitored by the Clinician During Neurofeedback





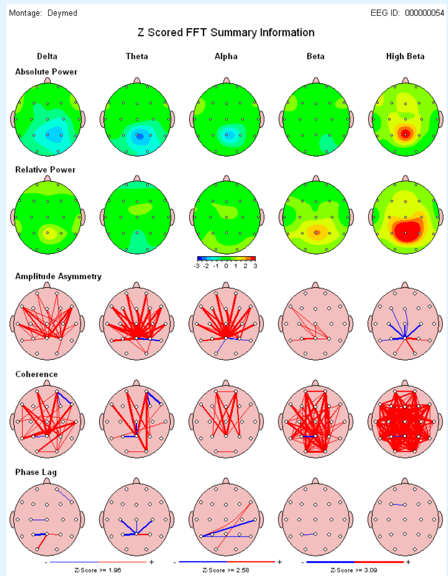
LORETA Neurofeedback Inter-Session Progress
Plot Selections
Plotted Data
Percent Reward by Session
100
80
60
40
20
0
1
2
3
4
5
Average Z Scores by Session
6
5
4
3
2
1
0
-1
1
2
3
4
5

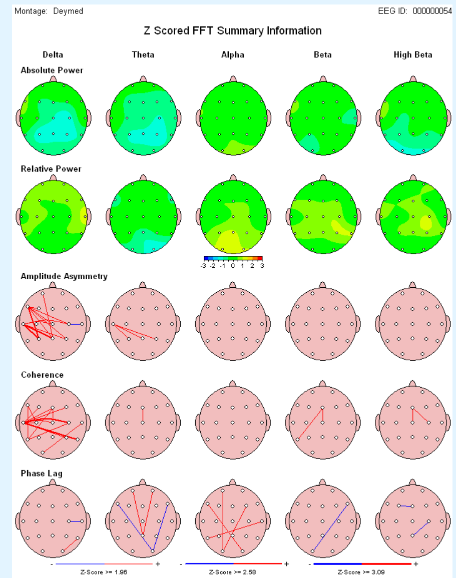

Average Z Scores by Session
2
1
0
-1
1
2
3
4
5
6
Average Z Scores by Session
1
0
-1
1
2
3
Absolute Power
Relative Power
Power Ratio
Amplitude Asymmetry
Coherence
Phase

Examples of Surface EEG Changes After EEG Neurofeedback

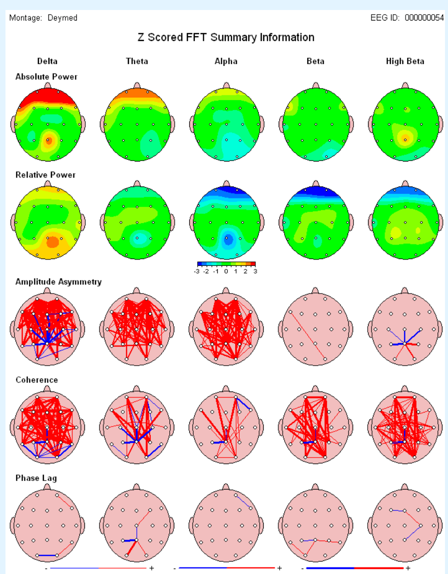
Pre-Treatment | Post – 10 Treatments

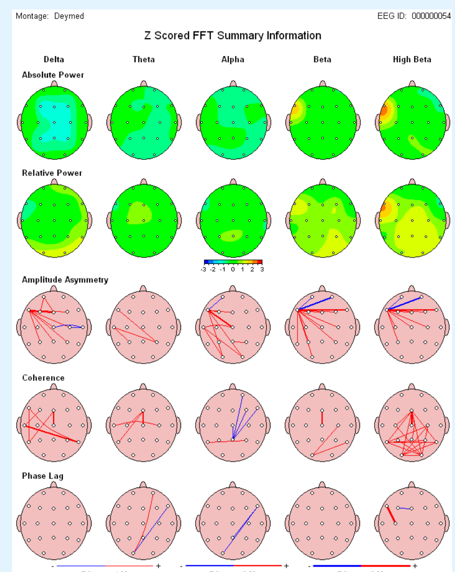
TBI Subject #1





TBI Subject #2

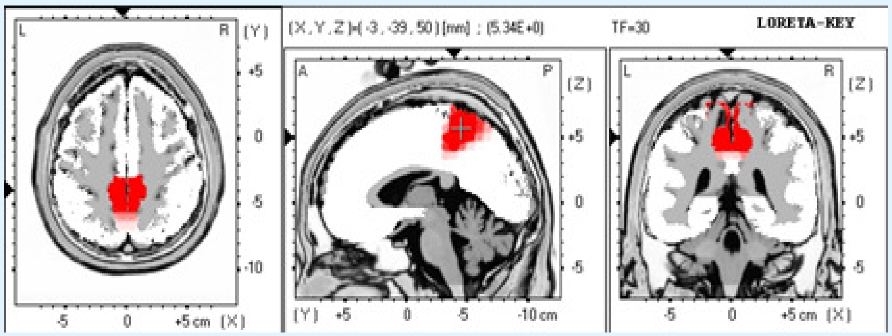


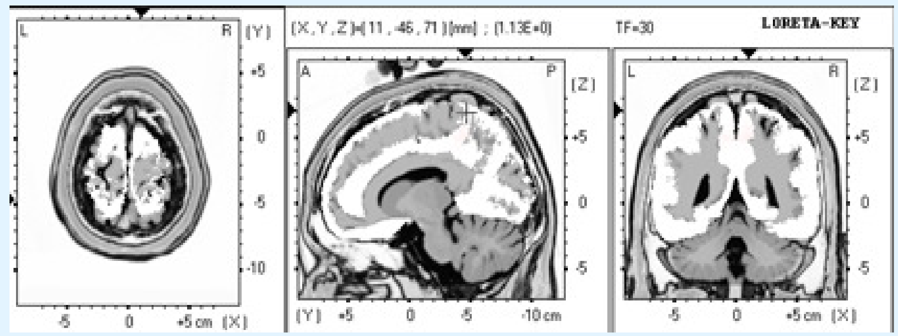


Examples of Electrical Neuroimaging After Neurofeedback

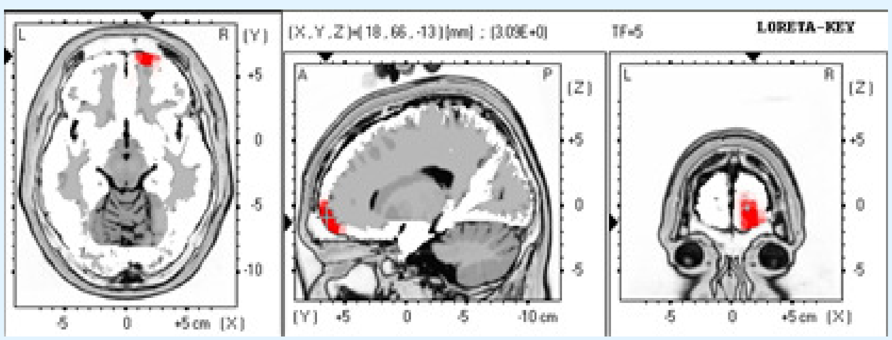
Pre-Treatment **Post – 10 Treatments**

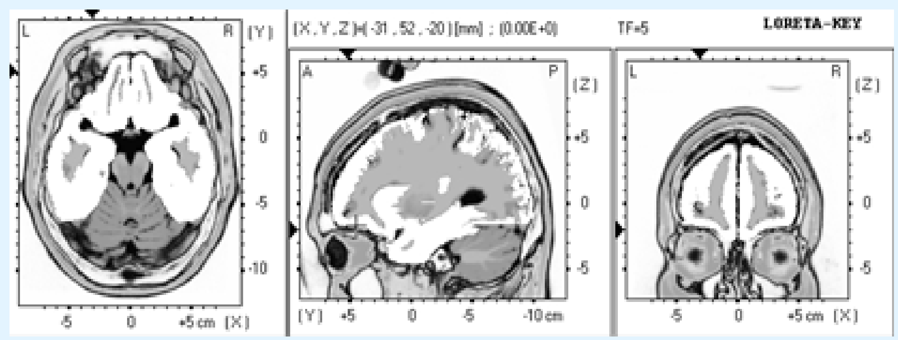
S #1

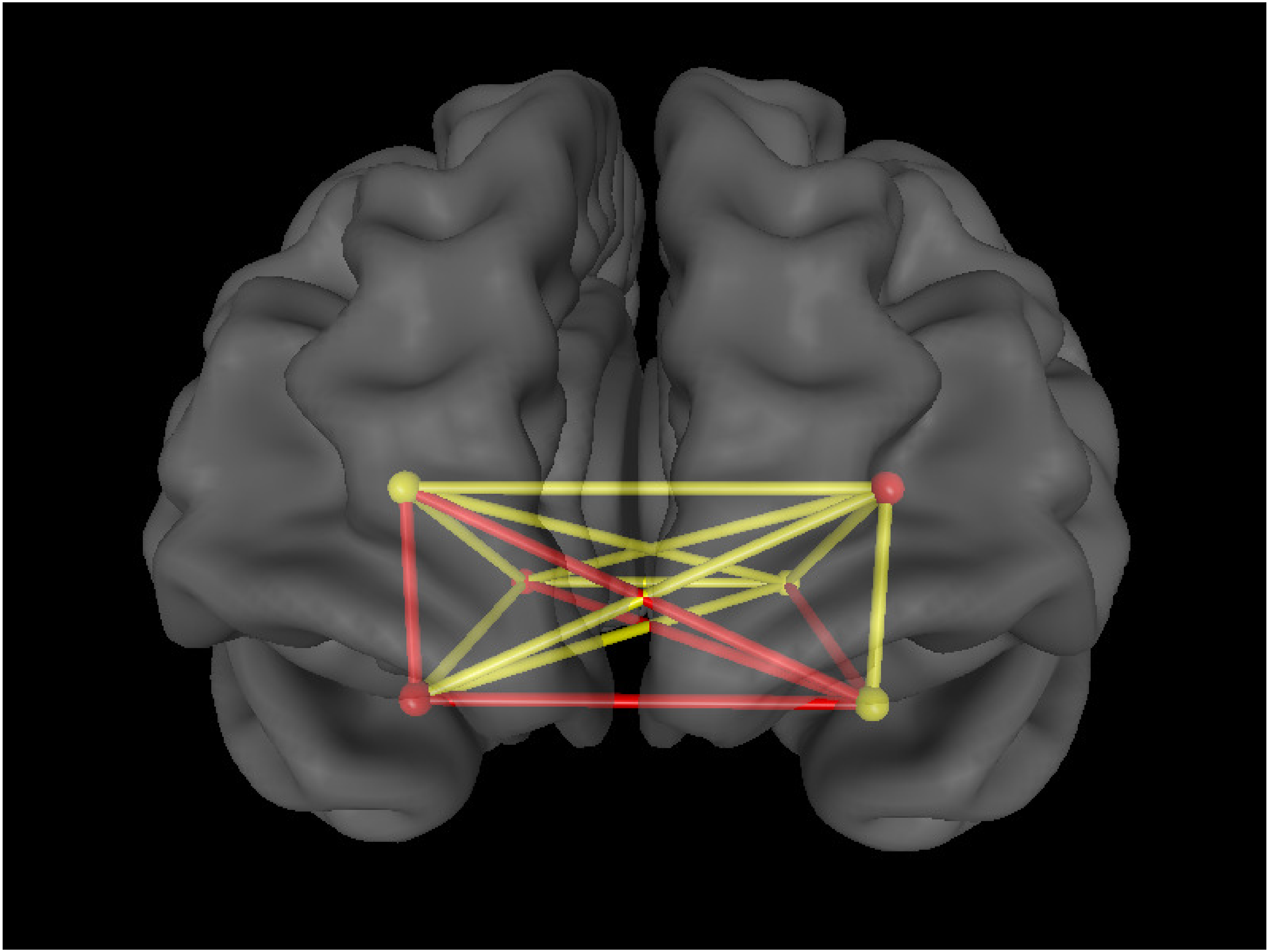


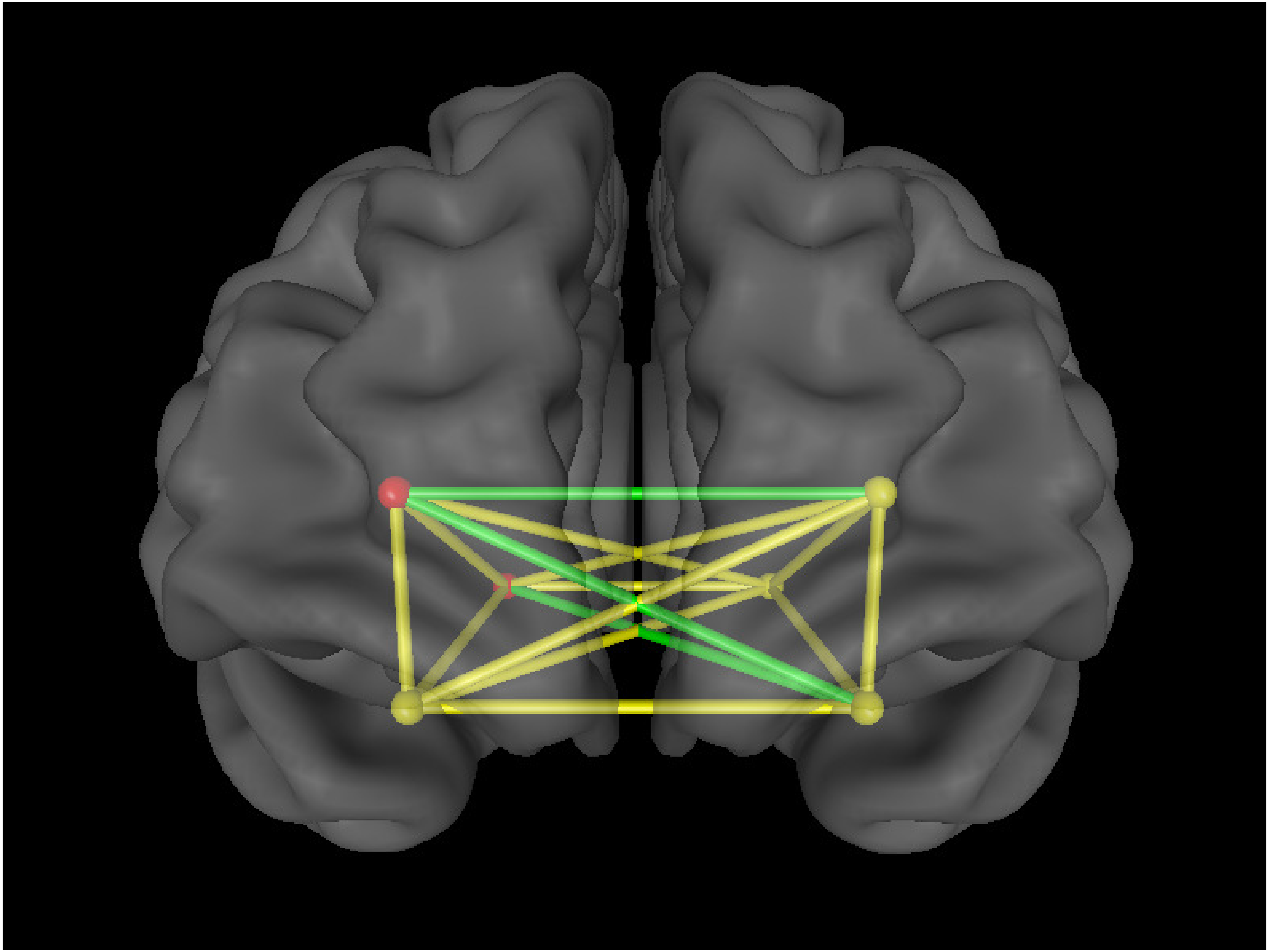


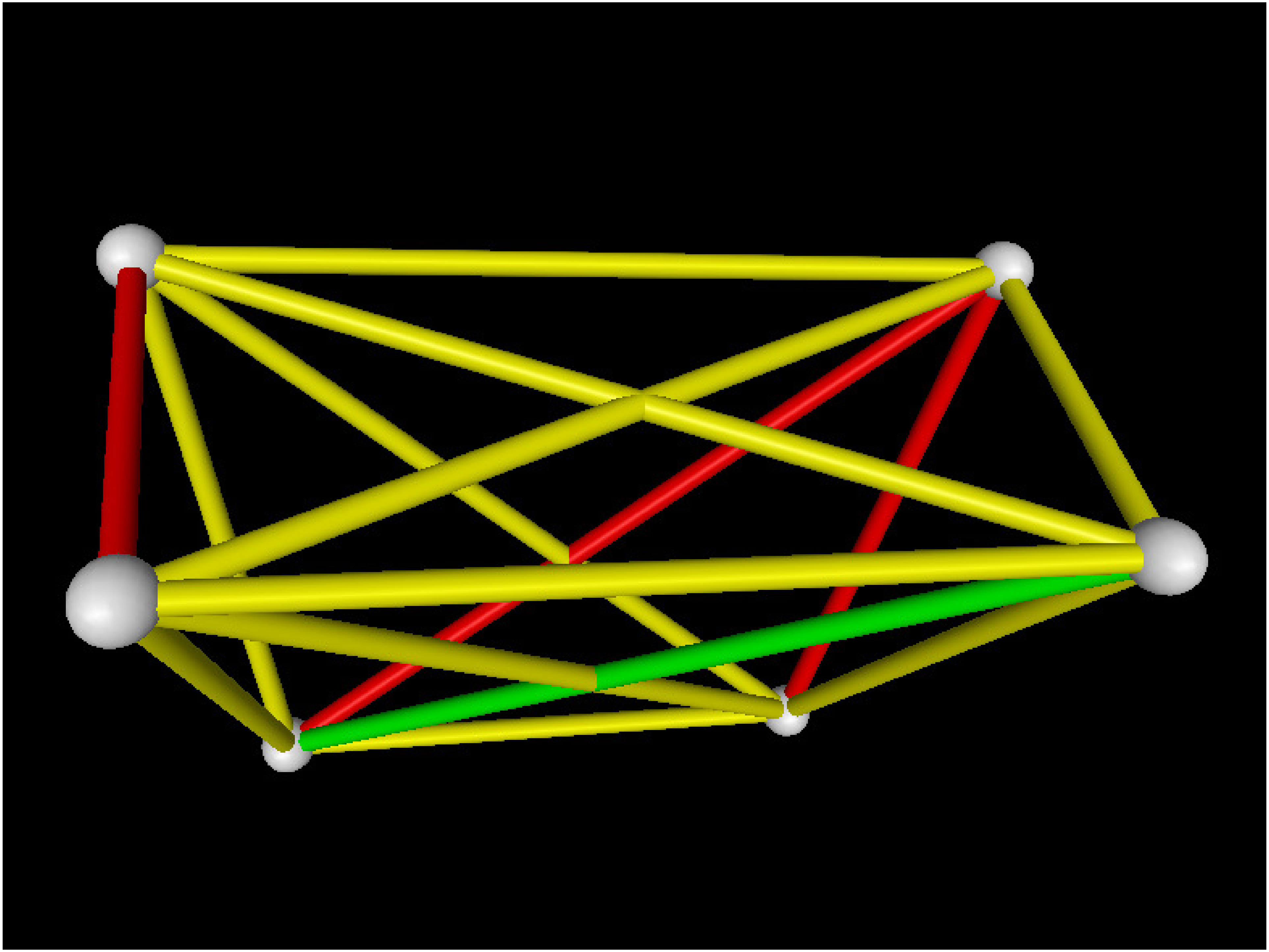
S #2

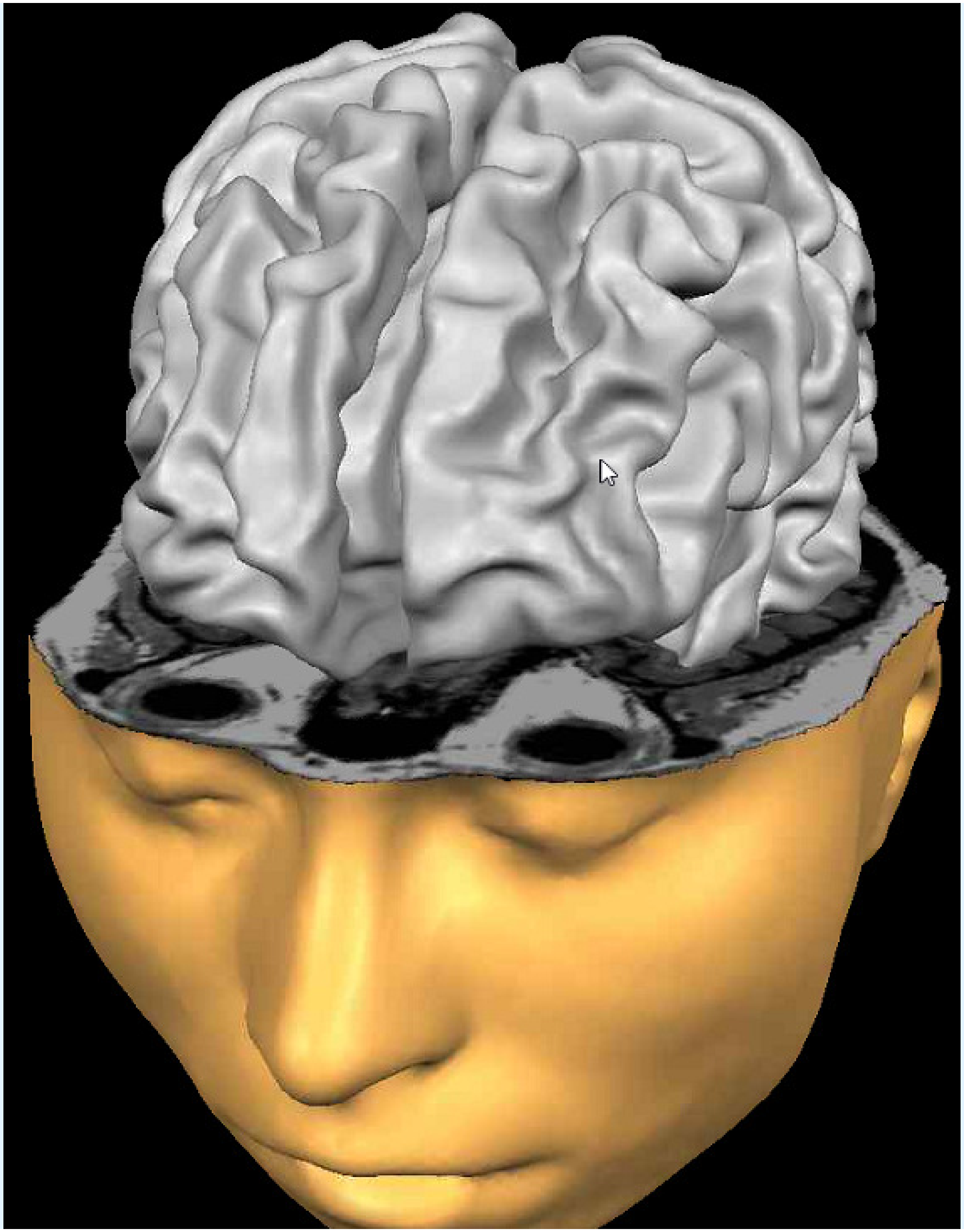


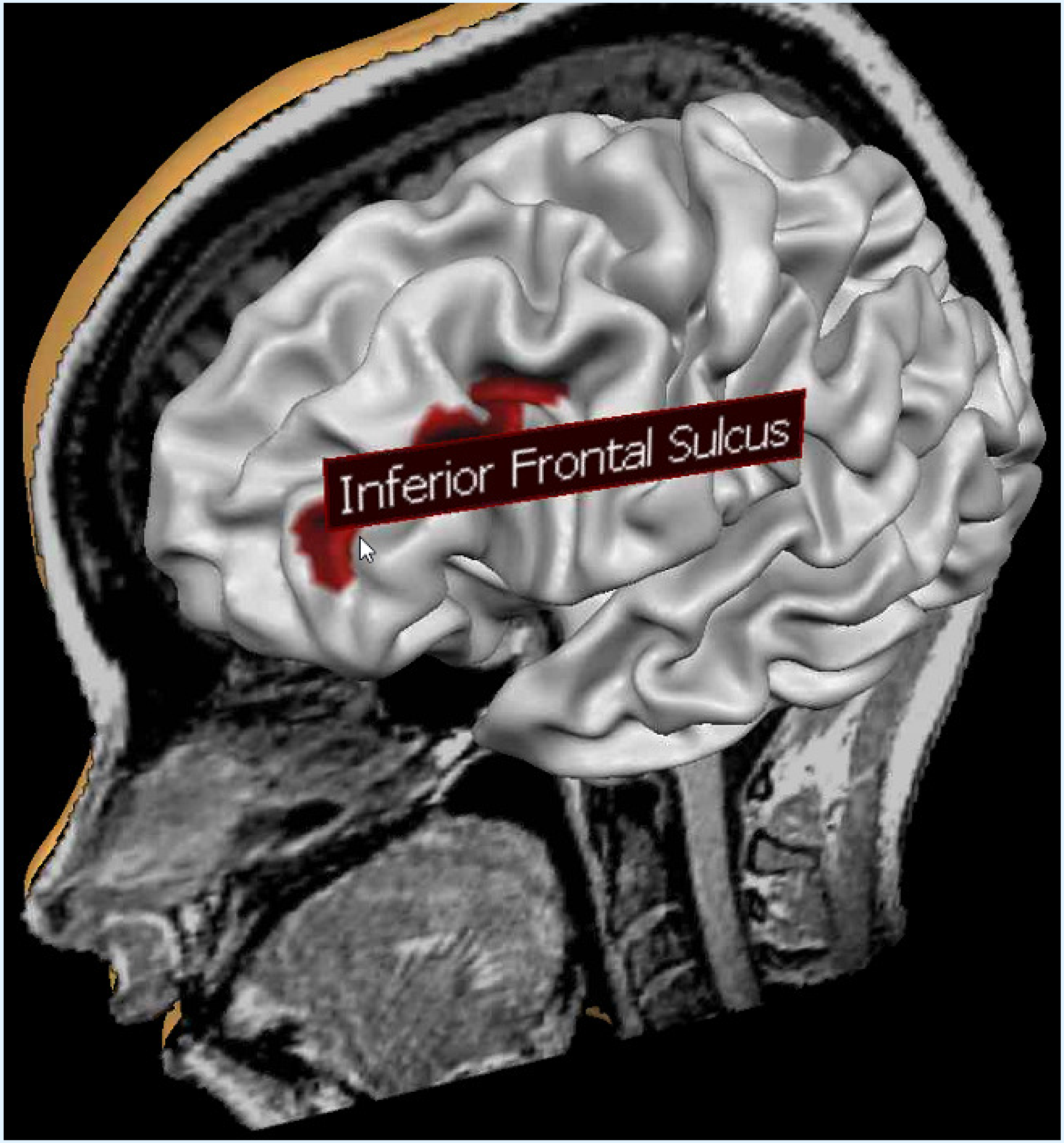











Inferior Frontal Sulcus

Advanced Concepts on EEG and QEEG Assessment and Human Performance

International Symposium on Clinical Neuroscience – Feb 3-5, 2017

Linking Symptoms to qEEG Biomarkers and Neurofeedback

Robert W. Thatcher, Ph.D.

Applied Neuroscience, Inc.
8200 Bryan Diary Rd., Suite 300
Largo, FL

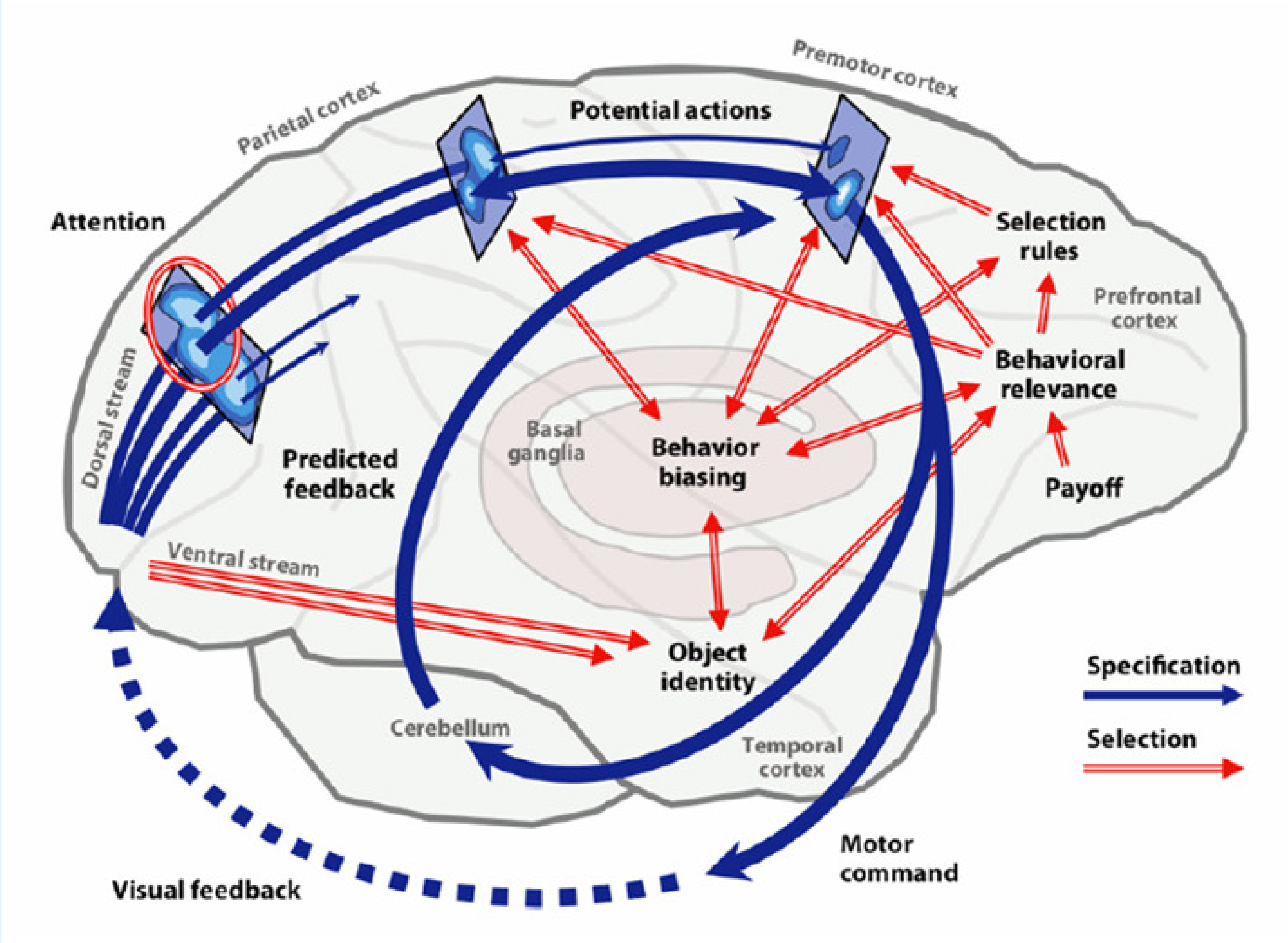
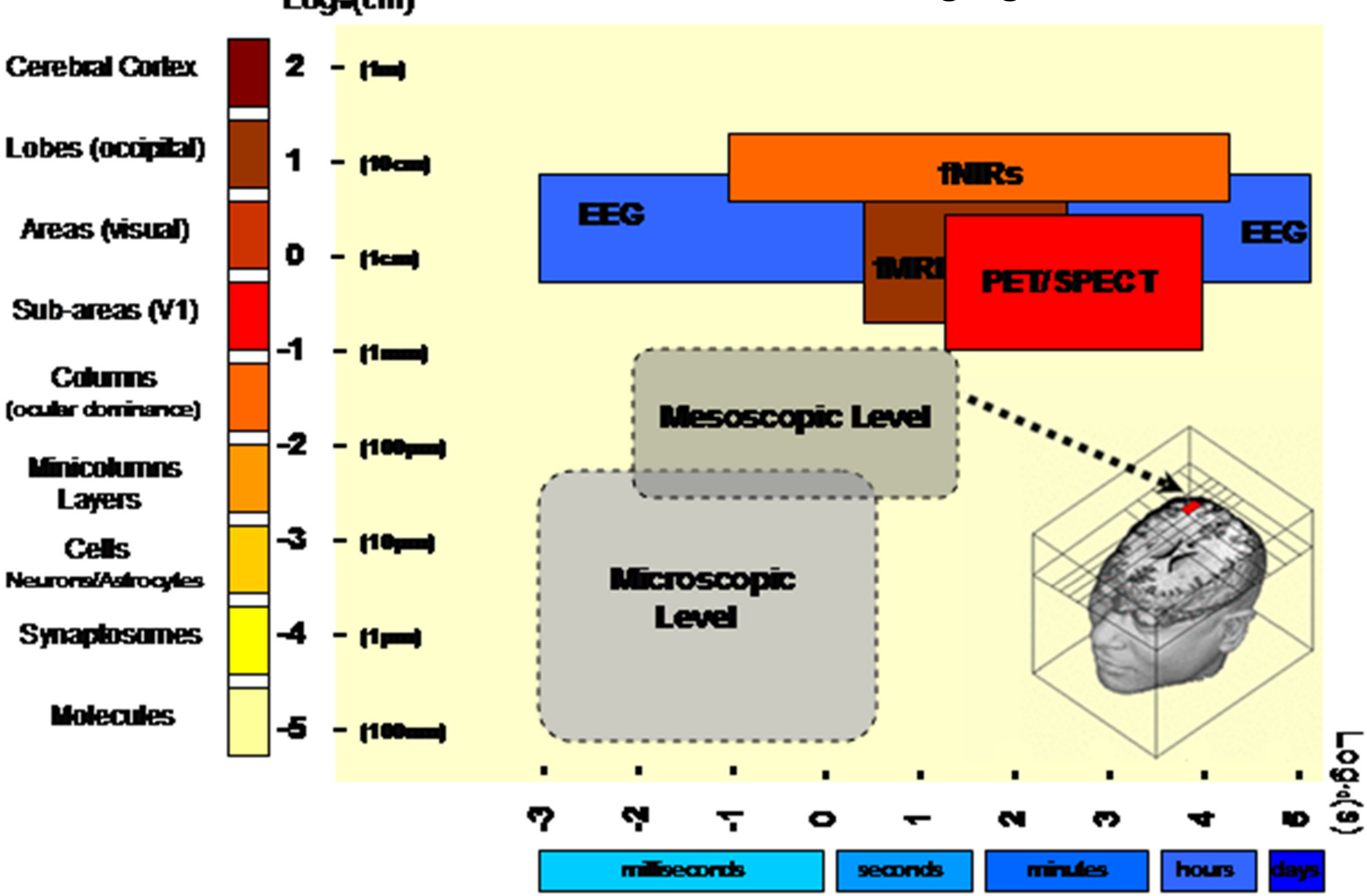
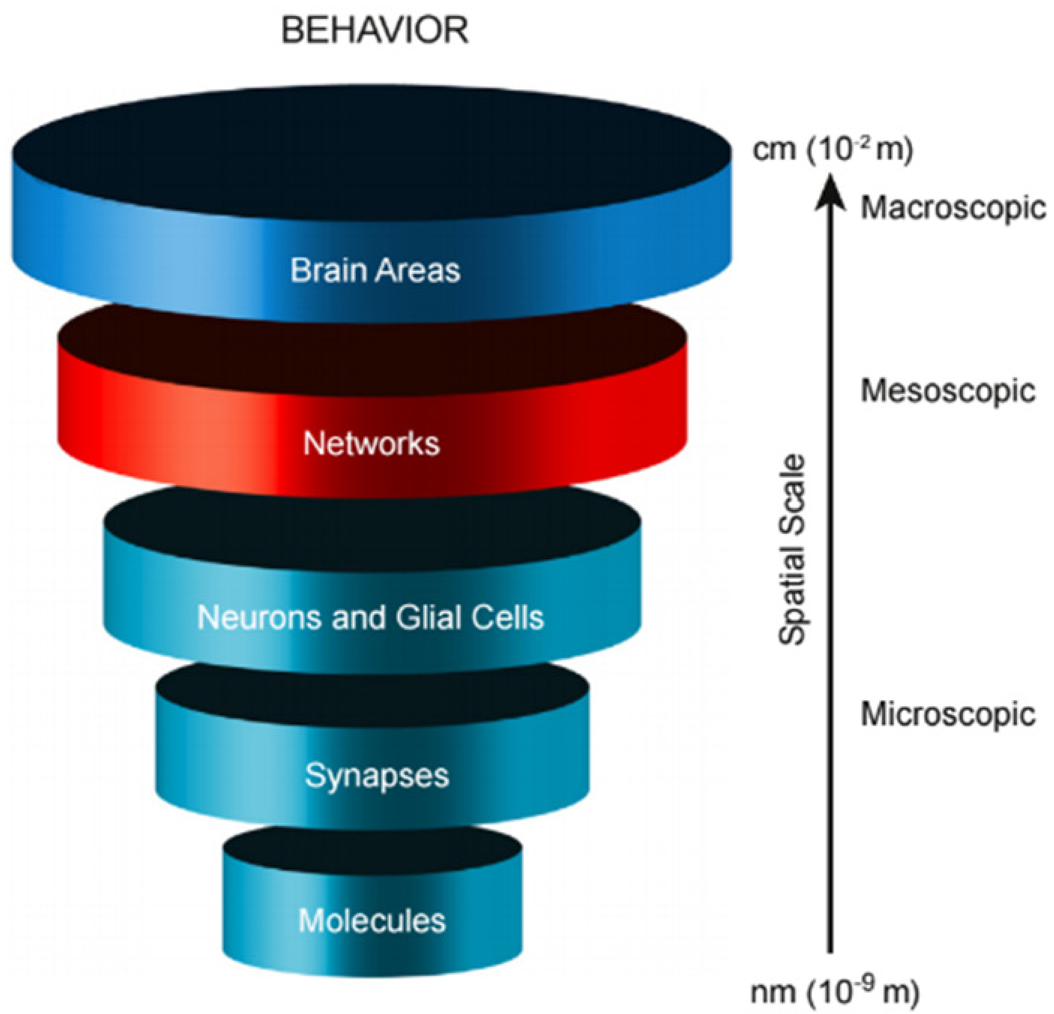


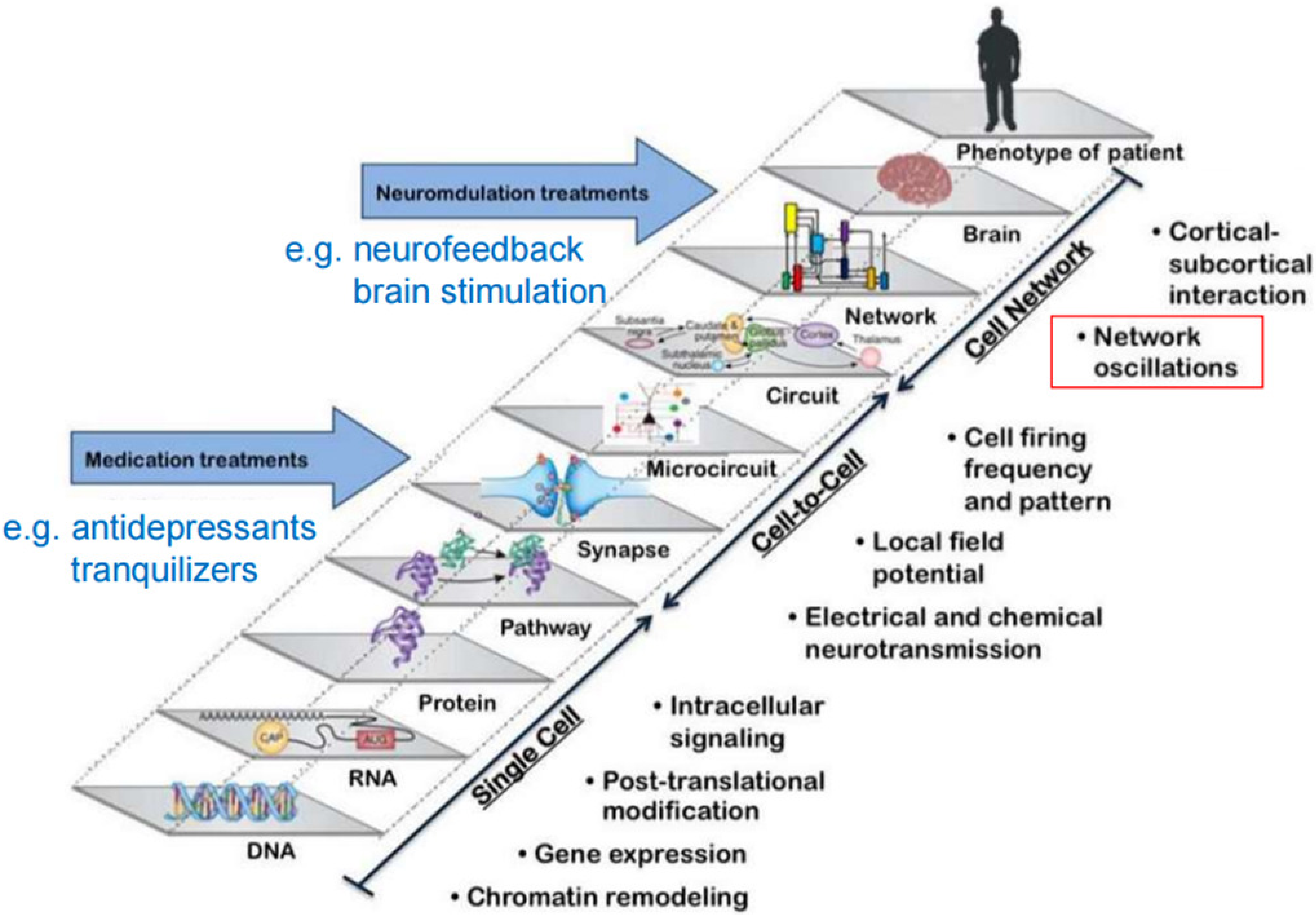
Illustration of brain information flow that can only be measured by the electroencephalogram using computers.
Information flow – Millisecond Match-Mismatch From Rabinovich et al, 2012

Functional Neuroimaging Modalities

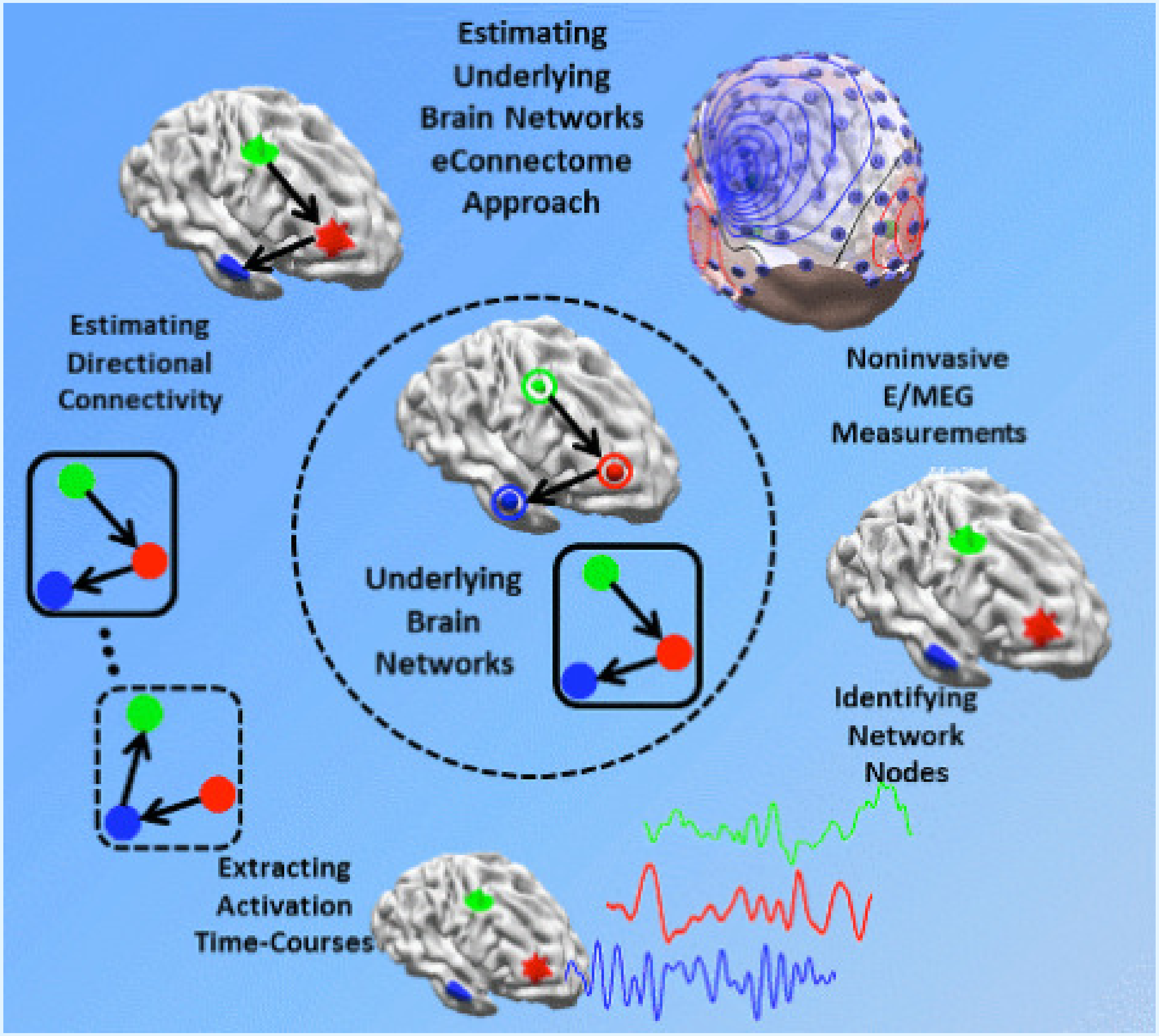




Frohlich, F., 2016. Network Neuroscience. Academic Press, NY



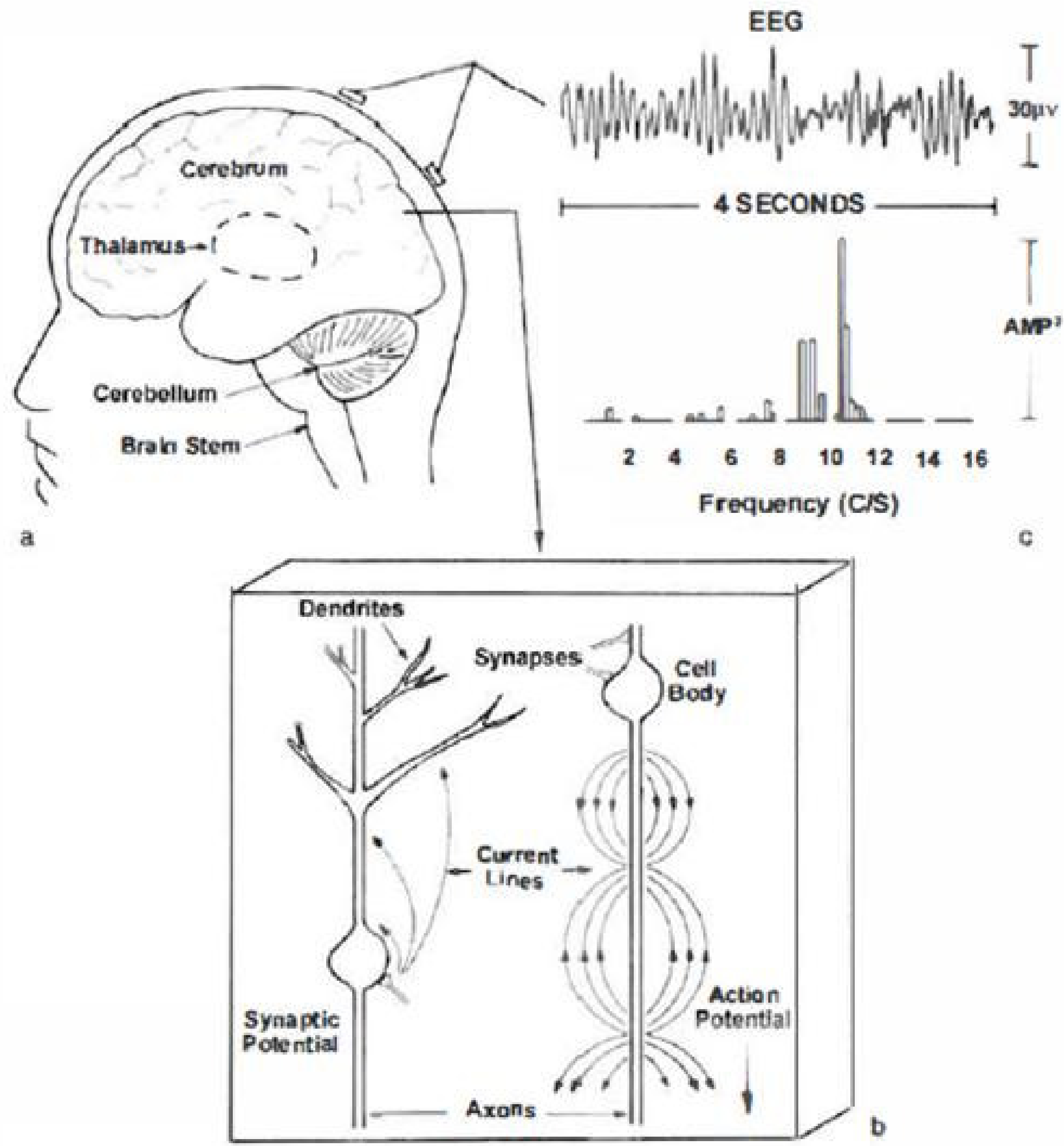
tuning-pathological-brain-oscillations-Thomas Ros-video -From Leuchter, 2015

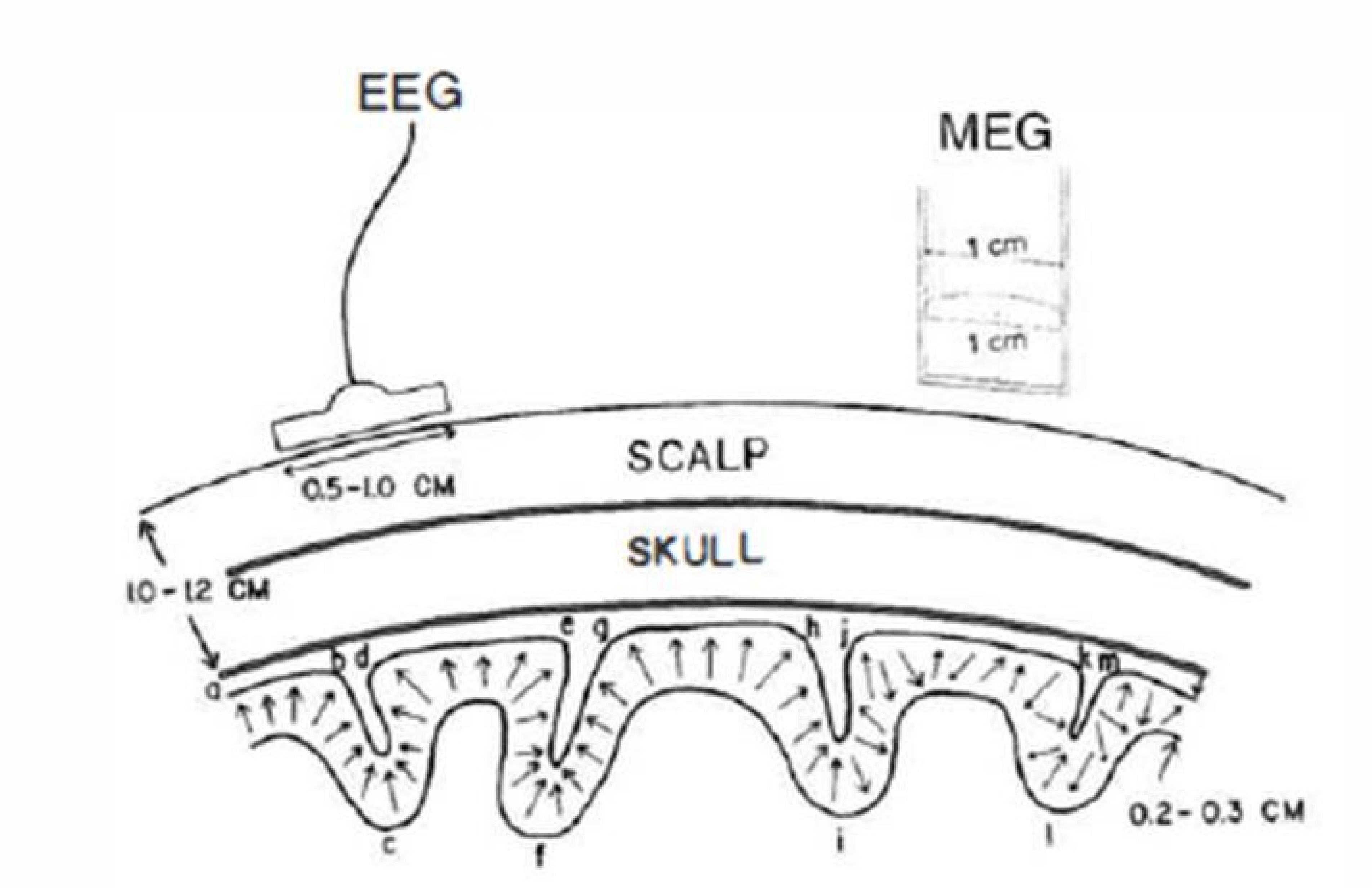


Noninvasive Electromagnetic Source Imaging and Granger Causality Analysis: An Electrophysiological Connectome (eConnectome) Approach ***Abbas Sohrabpour, Shuai Ye, Gregory Worrell, Wenbo Zhang, Bin He , University of Minnesota, USA,*** [*Volume: 63, Issue:12, Pages:2474-2487, 2016*]

Genesis of the Human Electroencephalogram - EEG

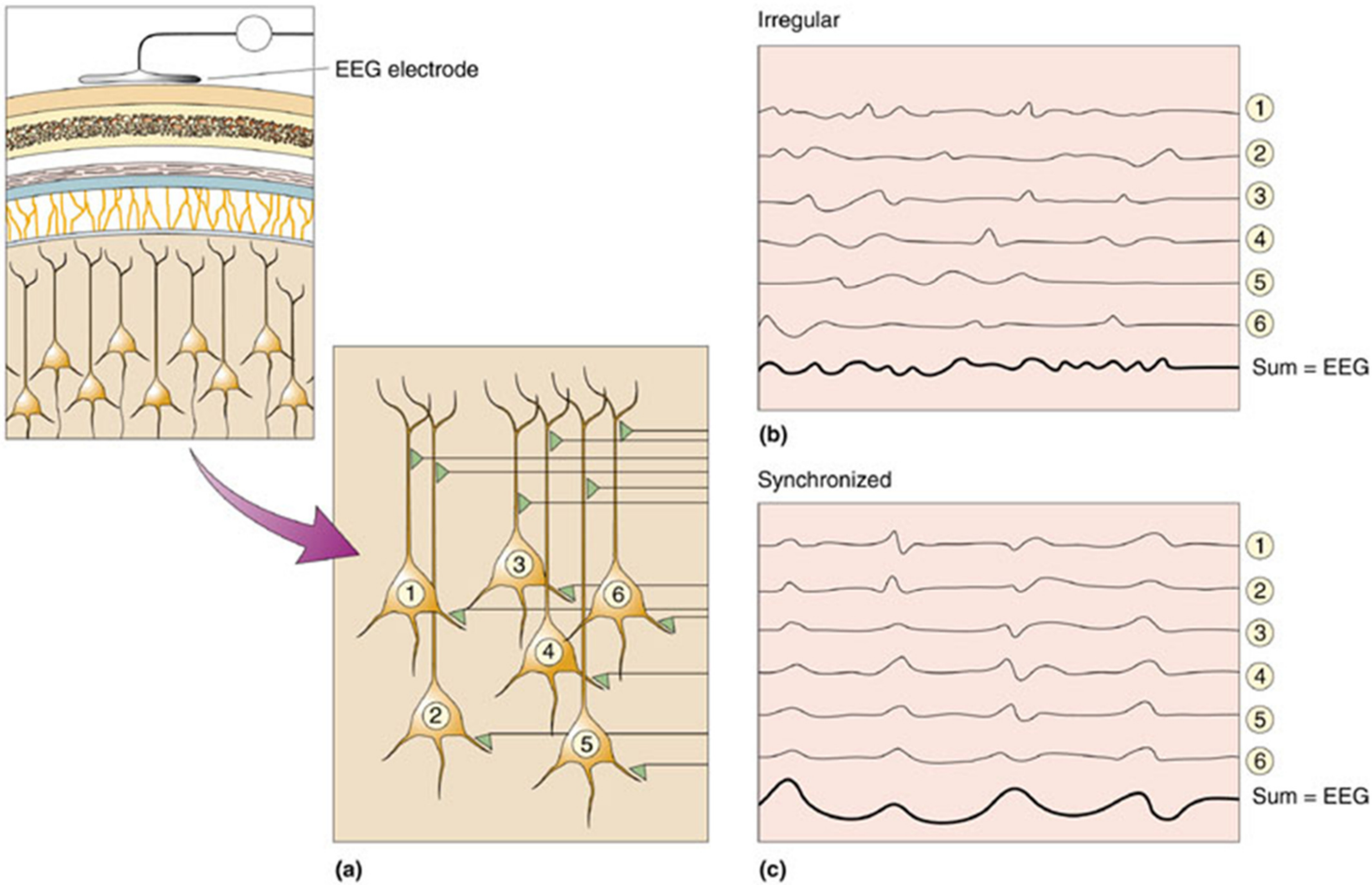
1- Pyramidal Neuron Dipoles
2- Oscillations In an Approx. 2mm thick sheet
3- Summated Local Field Potentials (LFP)
4- Amplitude = Proportion of Synchronous/Square Root of Proportion of Asynchronous Generators
5- Pacemakers and Resonance

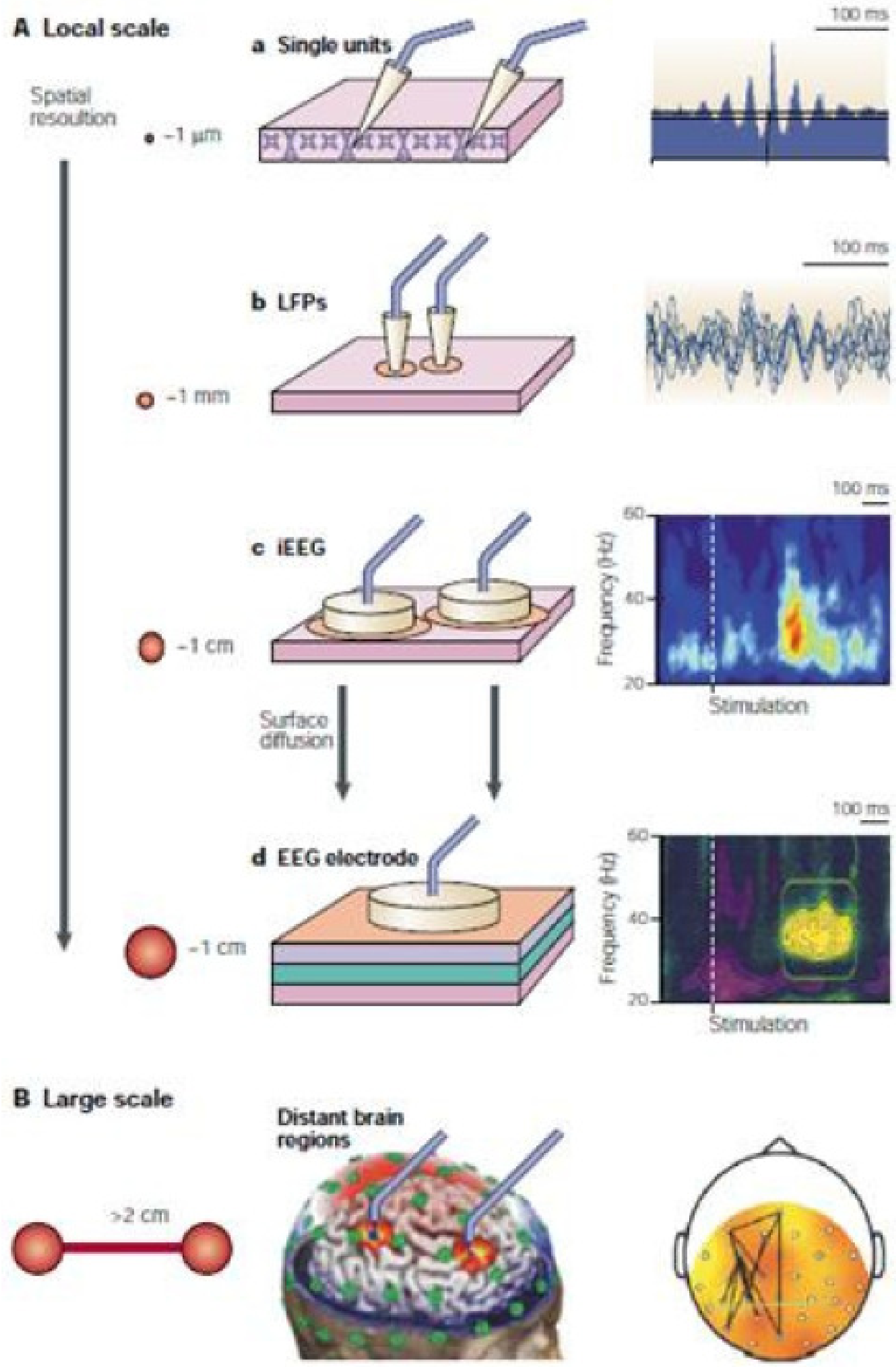

EEG
30µv
4 SECONDS
AMP²
2 4 6 8 10 12 14 16
Frequency (C/S)
Cerebrum
Thalamus
Cerebellum
Brain Stem
a
c
Dendrites
Synapses
Cell Body
Current Lines
Synaptic Potential
Action Potential
Axons
b



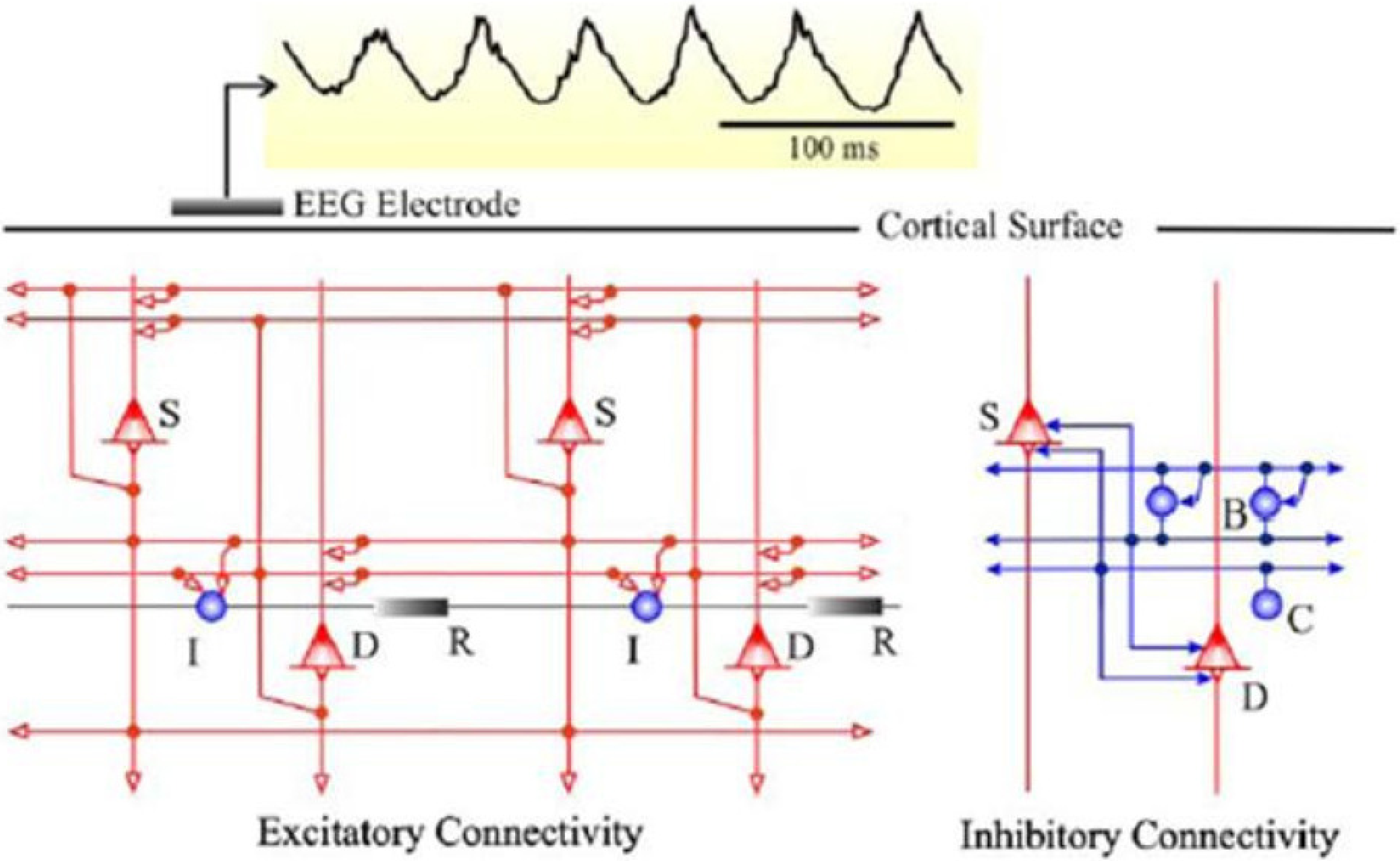
From Nunez, Electrical Fields of the Brain, Oxford Univ. Press, 1981

EEG = Summated Potentials at the Scalp





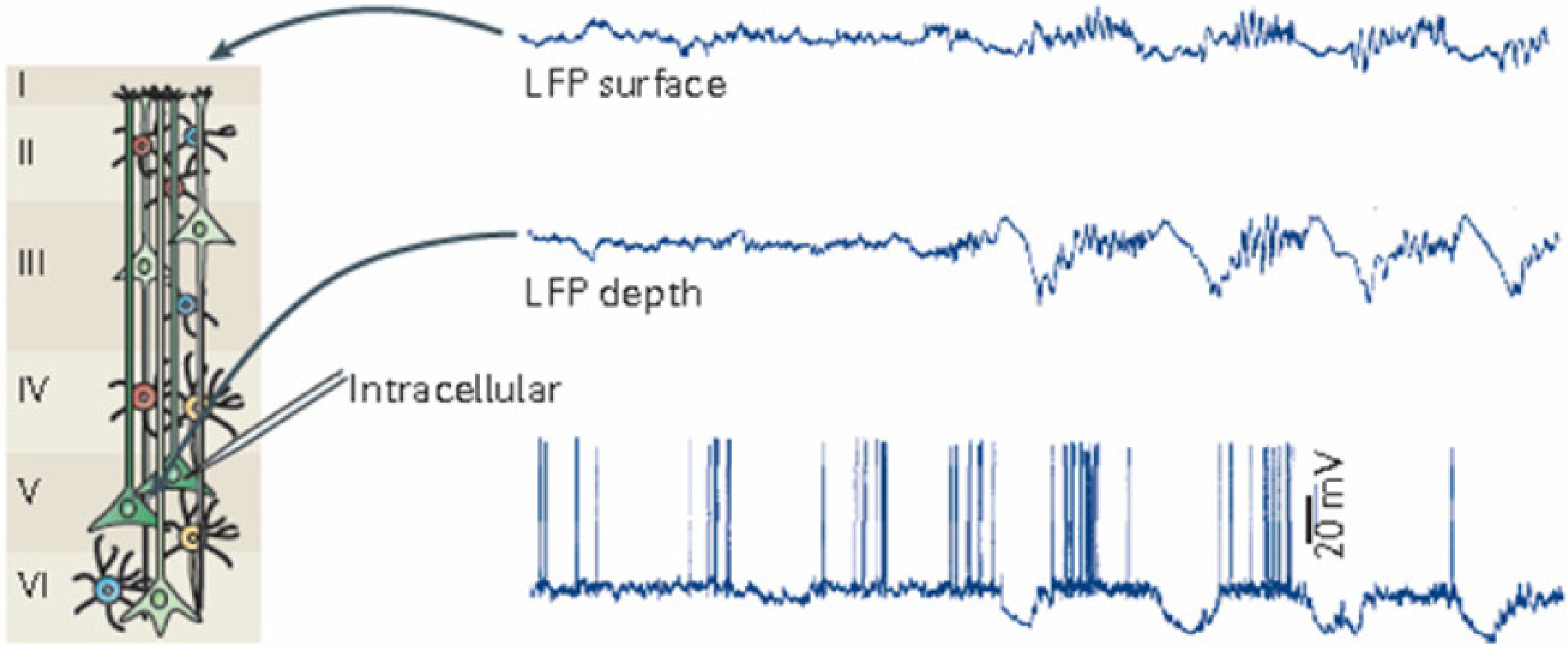
From Varela et al, 2001



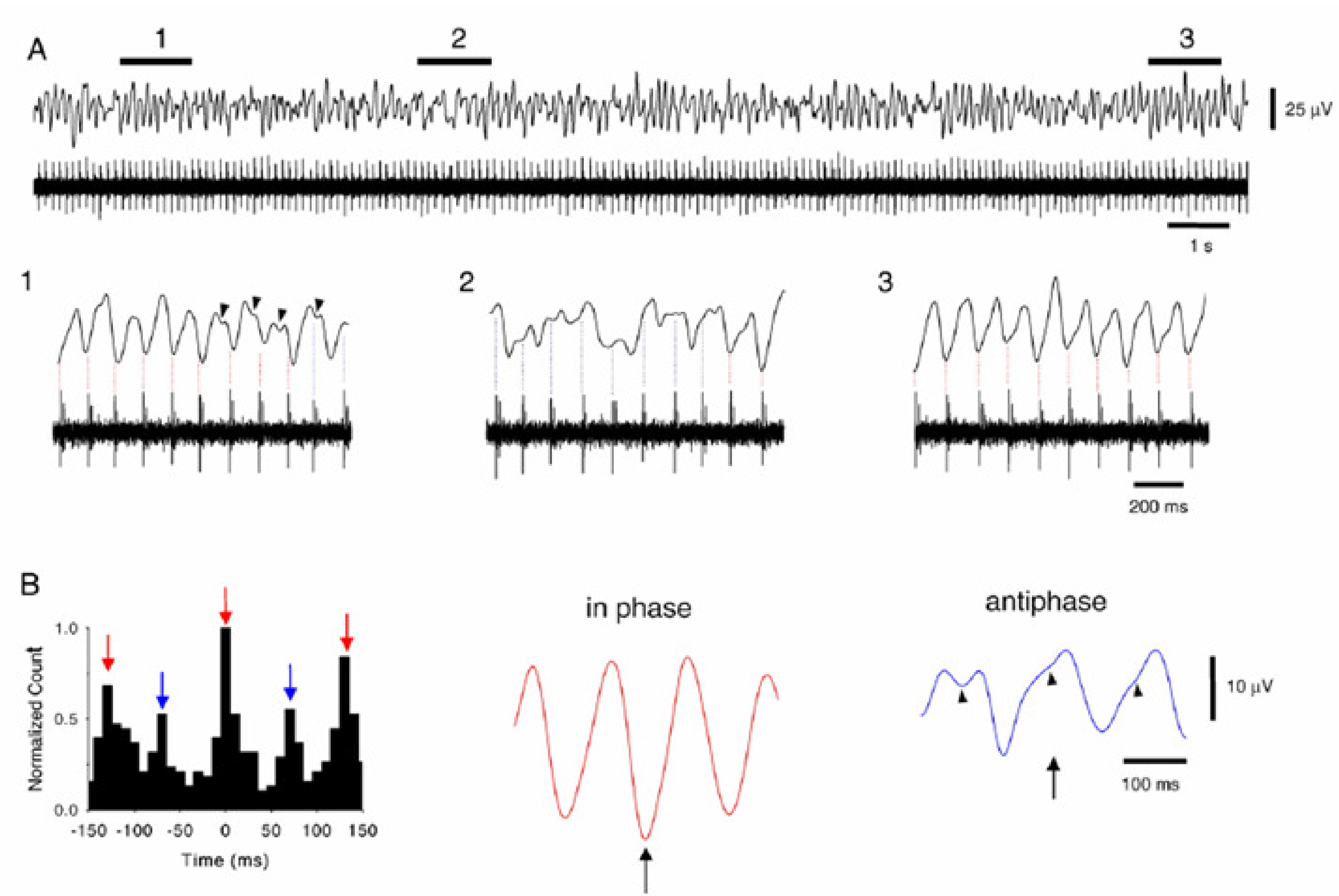
100 ms
EEG Electrode
Cortical Surface
S
S
S
I
D
R
I
D
R
B
C
D
Excitatory Connectivity
Inhibitory Connectivity

How Neurons are Selected For Brief Periods of Time

Shifting In-Phase vs Anti-Phase

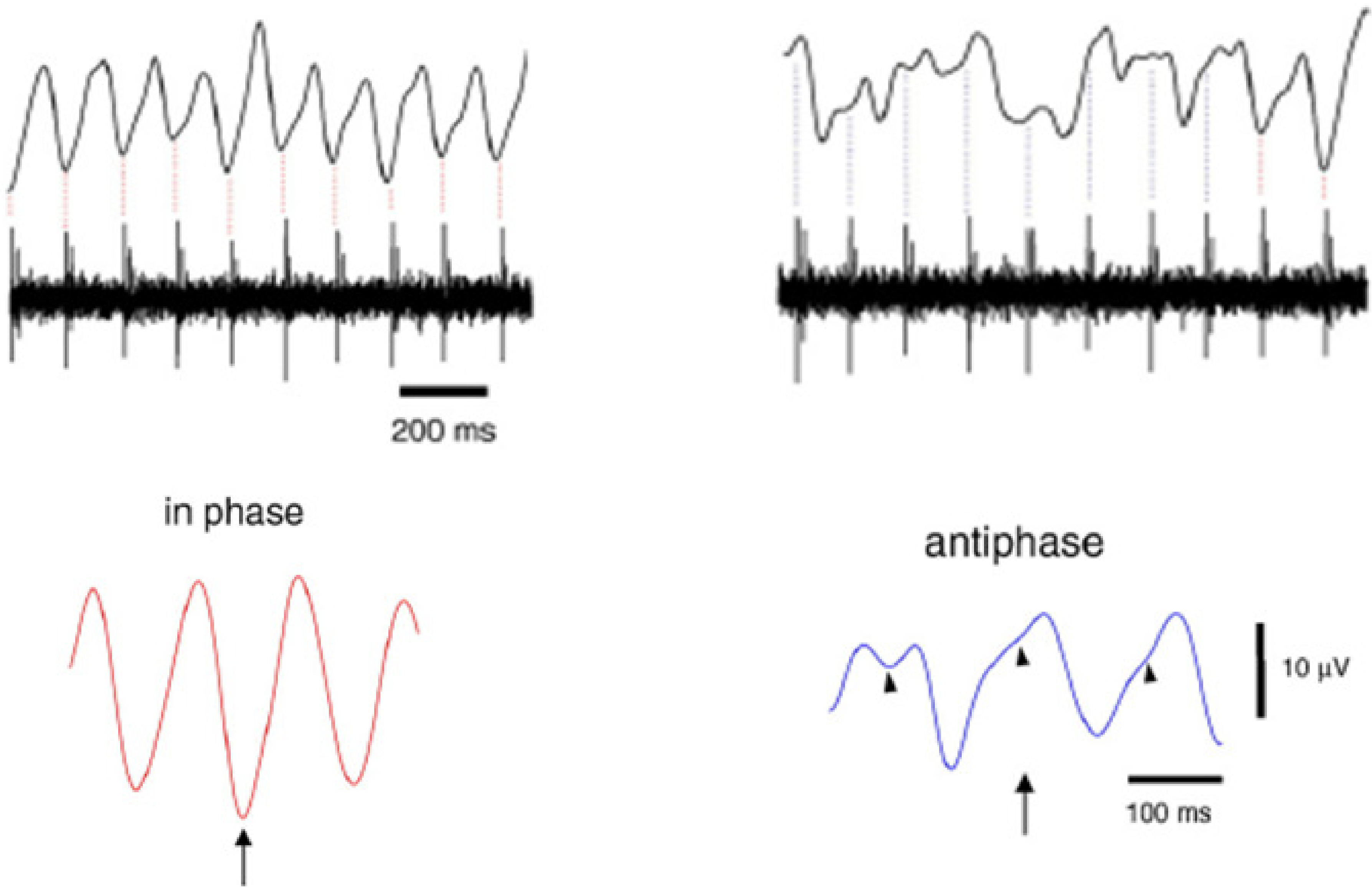


LFP surface
LFP depth
Intracellular
20 mV
I
II
III
IV
V
VI

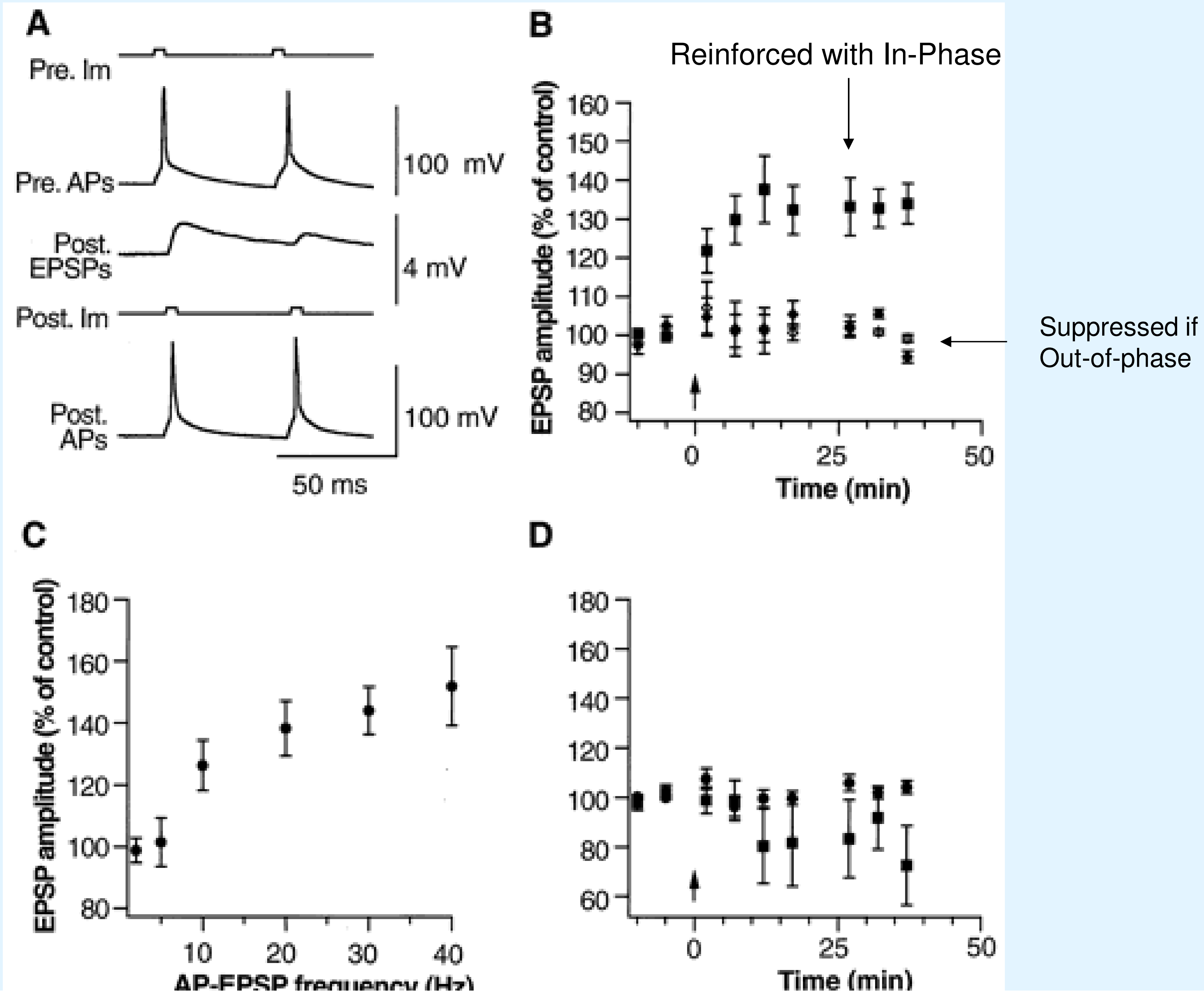


From Hughes et al, 2004

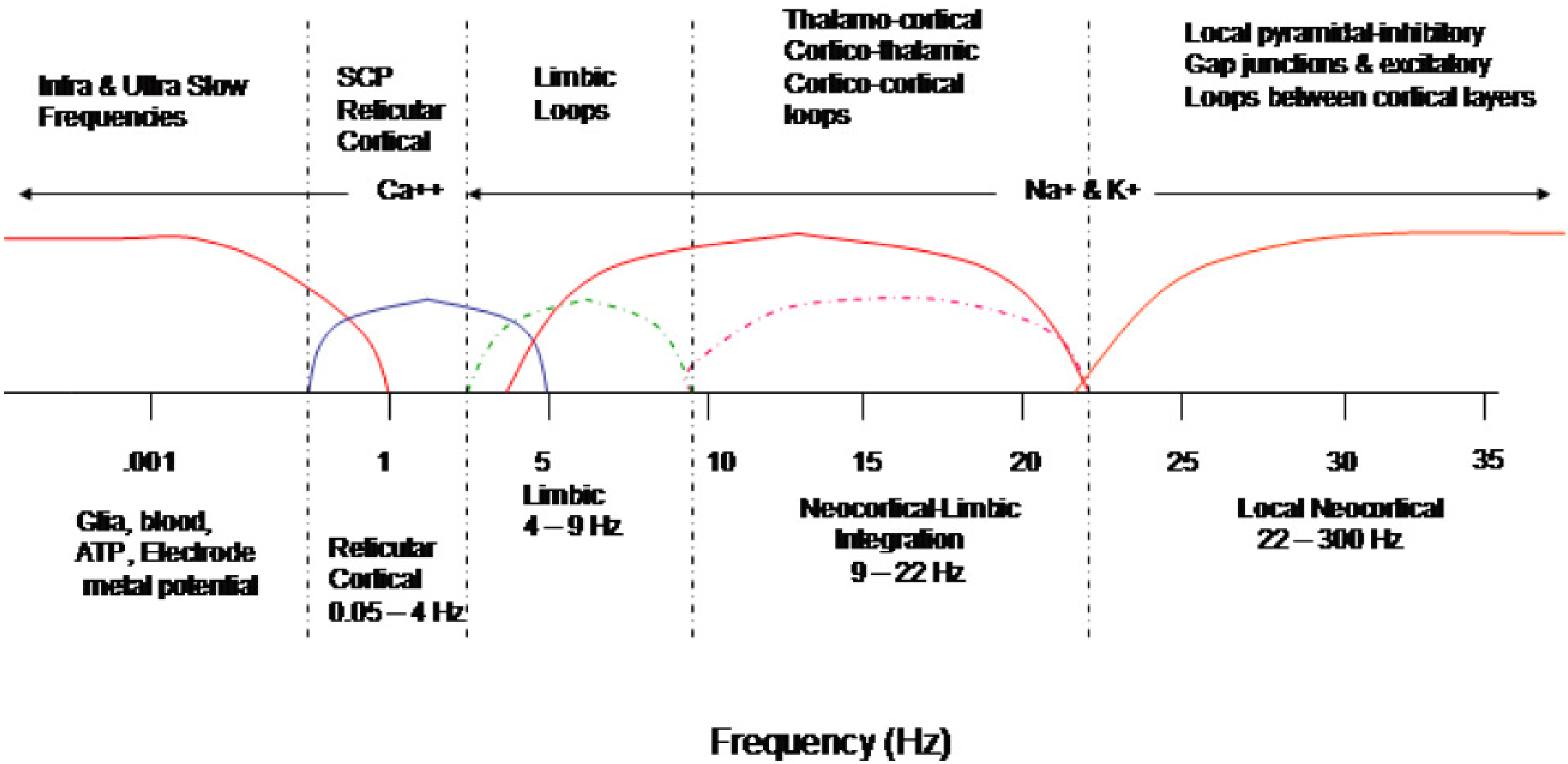
LFPs & In-Phase Action Potentials | **LFPs & Anti-Phase Action Potentials**

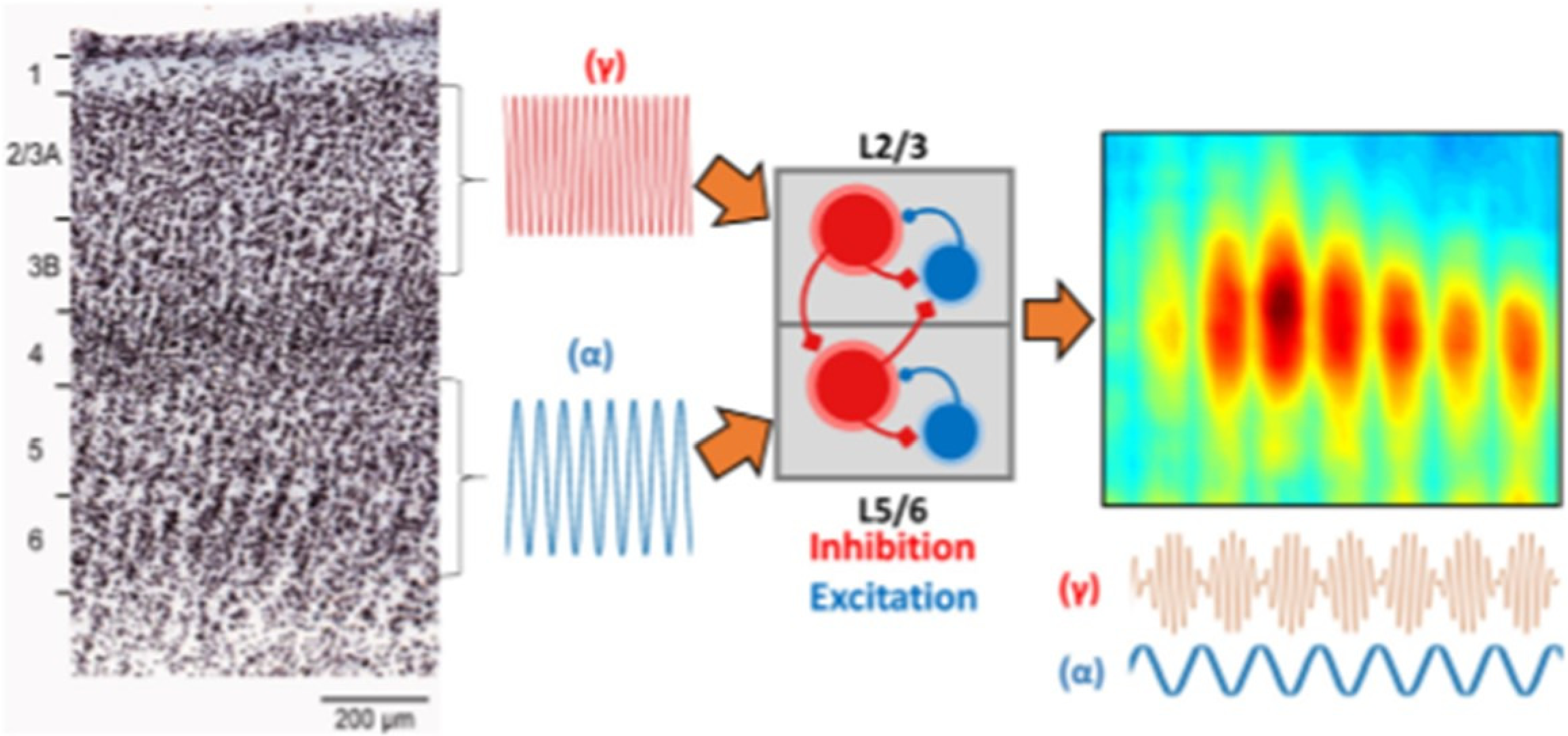


From Hughes et al, 2004

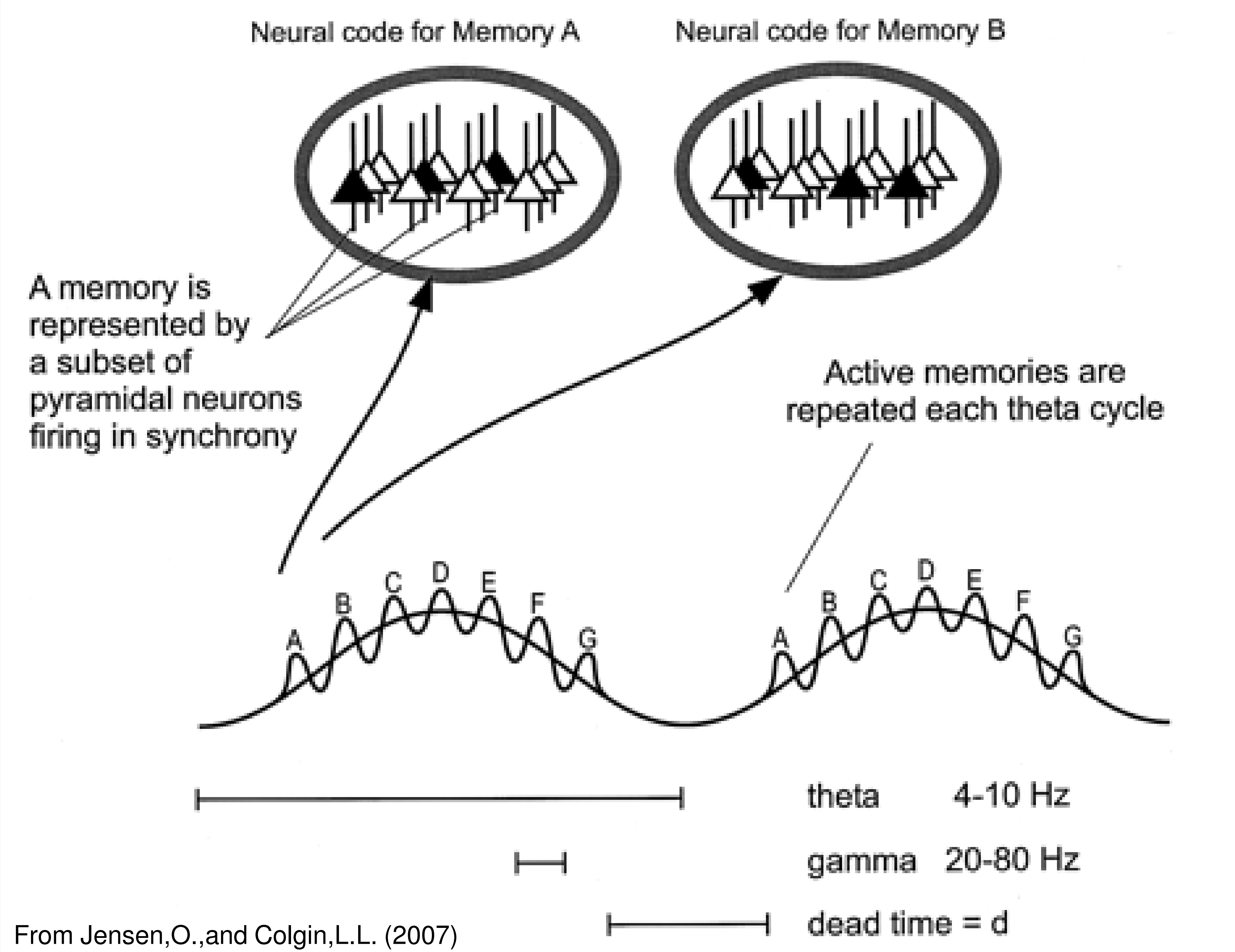

A
Pre. Im
Pre. APs
100 mV
Post. EPSPs
4 mV
Post. Im
Post. APs
100 mV
50 ms
B
Reinforced with In-Phase
EPSP amplitude (% of control)
Time (min)
Suppressed if Out-of-phase
C
EPSP amplitude (% of control)
AP-EPSP frequency (Hz)
D
Time (min)

Cross-Frequency Phase Lock and Phase Shift Spectrum

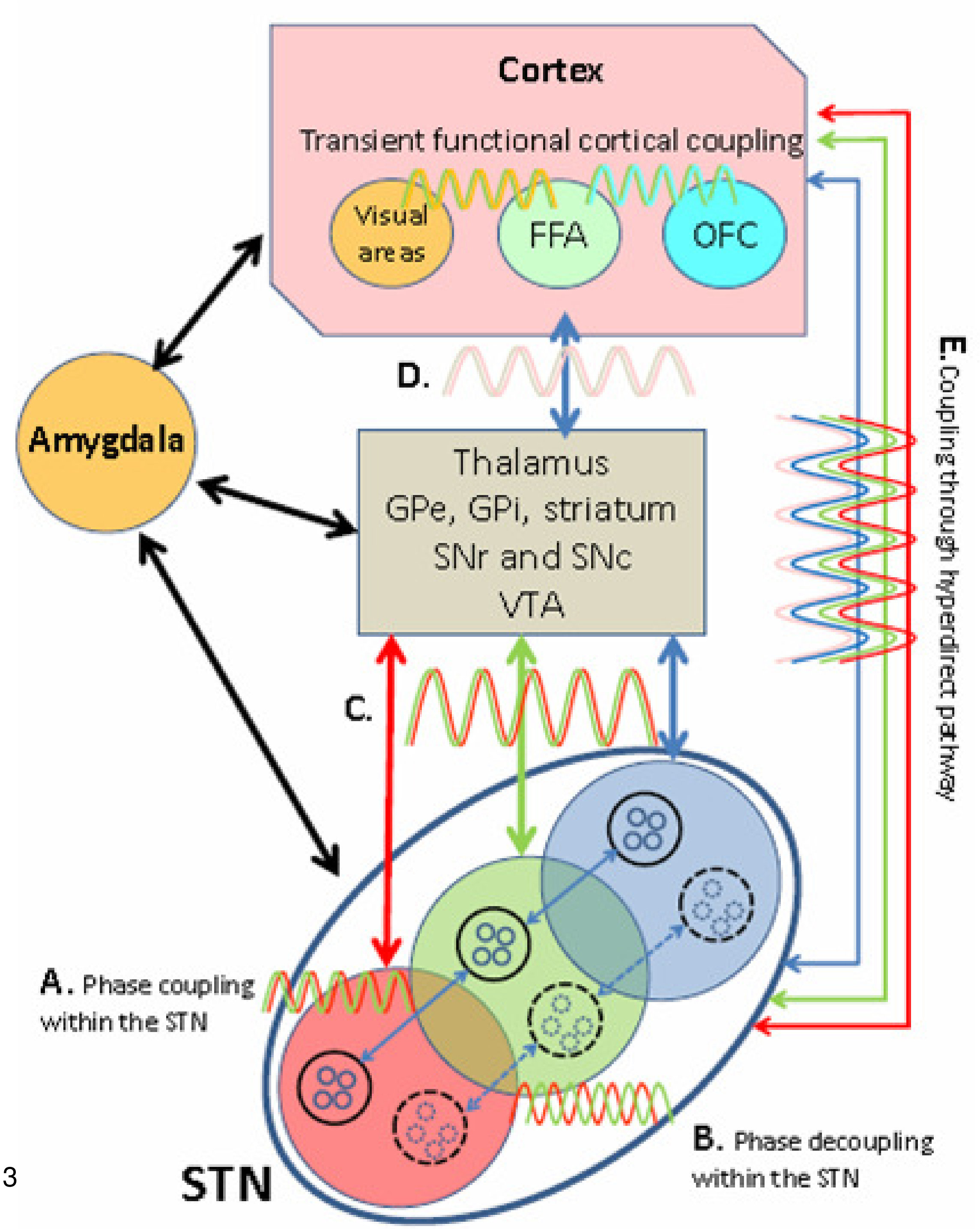




K. Kessler et al. J.; Neuroscience and Behavioral Reviews. 71(2016) 601-620



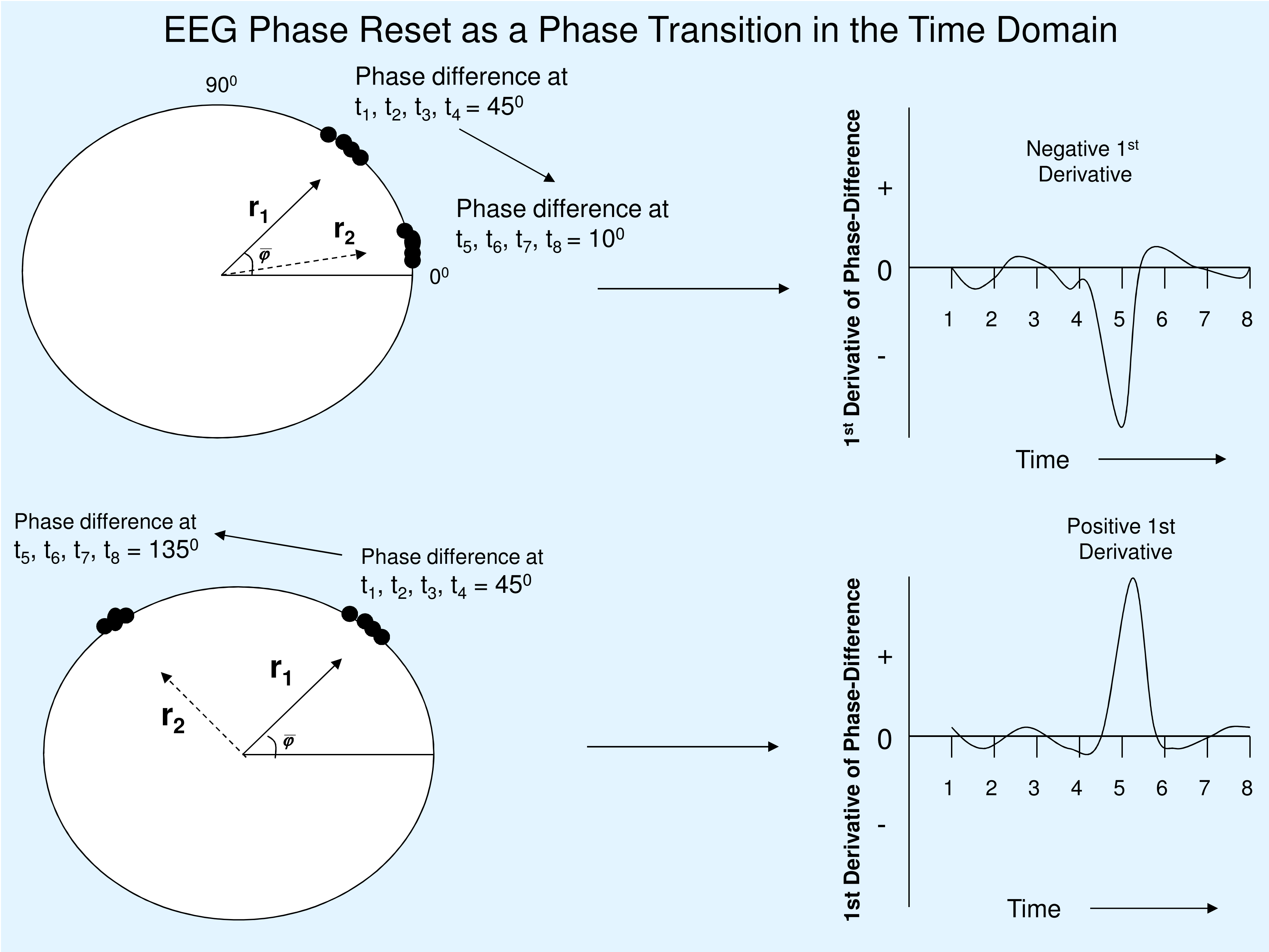
From Jensen,O.,and Colgin,L.L. (2007)



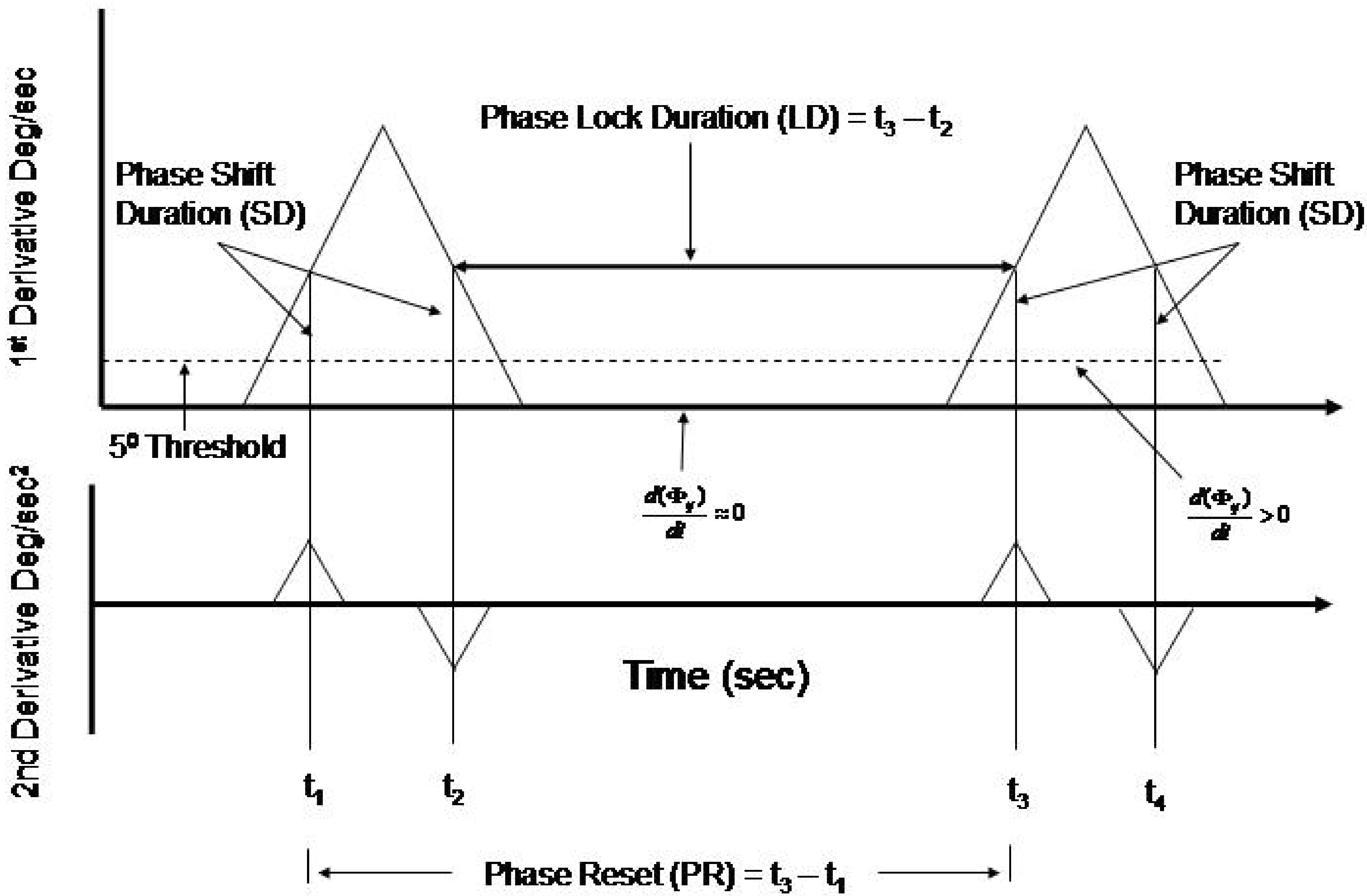
From Peron et al, 2013

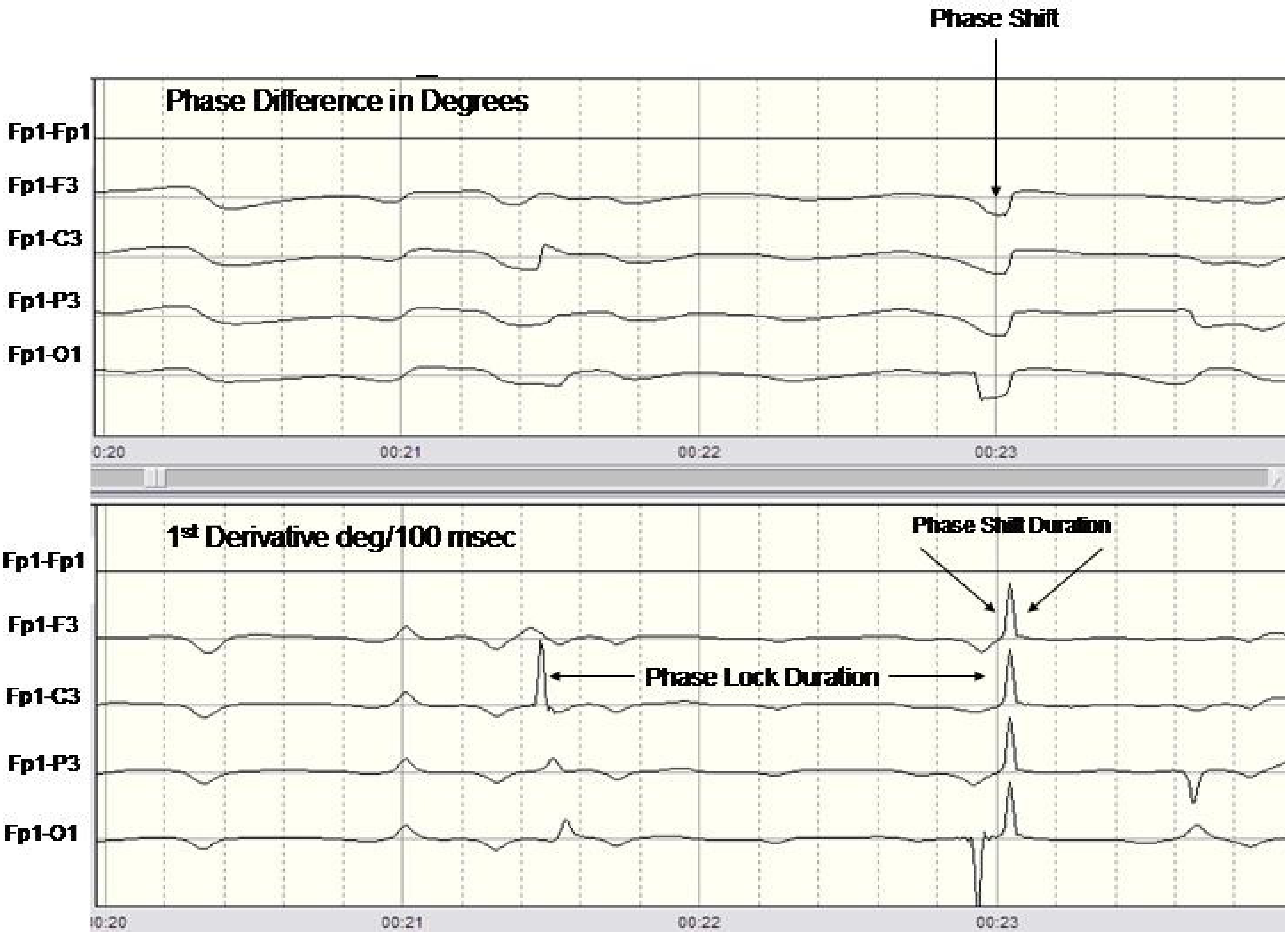
How to Measure Phase Shift and Phase Lock

Phase Reset and Neural Resource Selection and Allocation

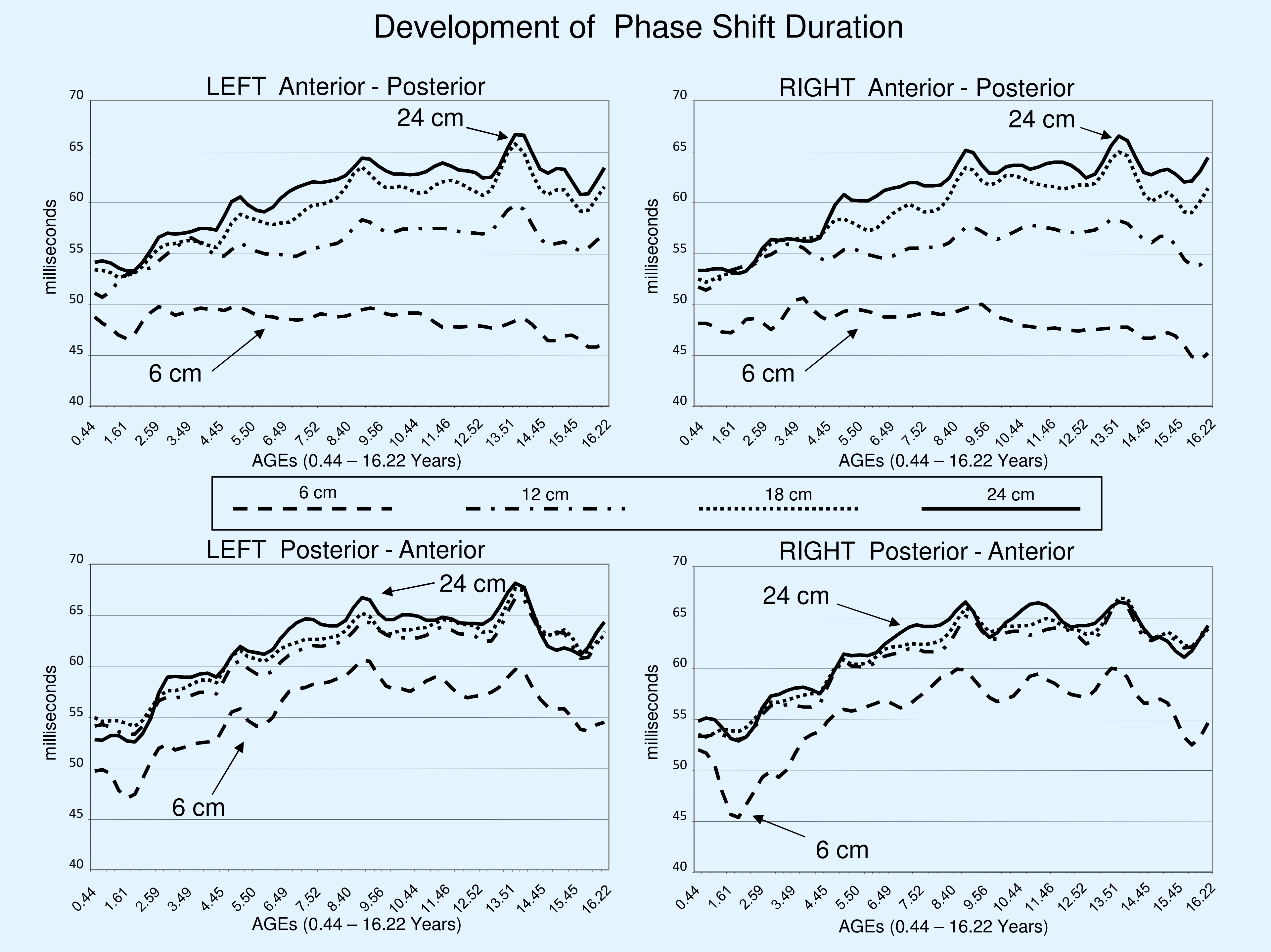

EEG Phase Reset as a Phase Transition in the Time Domain
90^0
Phase difference at
t_1, t_2, t_3, t_4 = 45^0
r_1
r_2
$\bar{\varphi}$
Phase difference at
t_5, t_6, t_7, t_8 = 10^0
0^0
1st Derivative of Phase-Difference
Negative 1st Derivative
+
0
-
1 2 3 4 5 6 7 8
Time
Phase difference at
t_5, t_6, t_7, t_8 = 135^0
Phase difference at
t_1, t_2, t_3, t_4 = 45^0
r_1
r_2
$\bar{\varphi}$
1st Derivative of Phase-Difference
Positive 1st Derivative
+
0
-
1 2 3 4 5 6 7 8
Time

Phase Reset Metrics

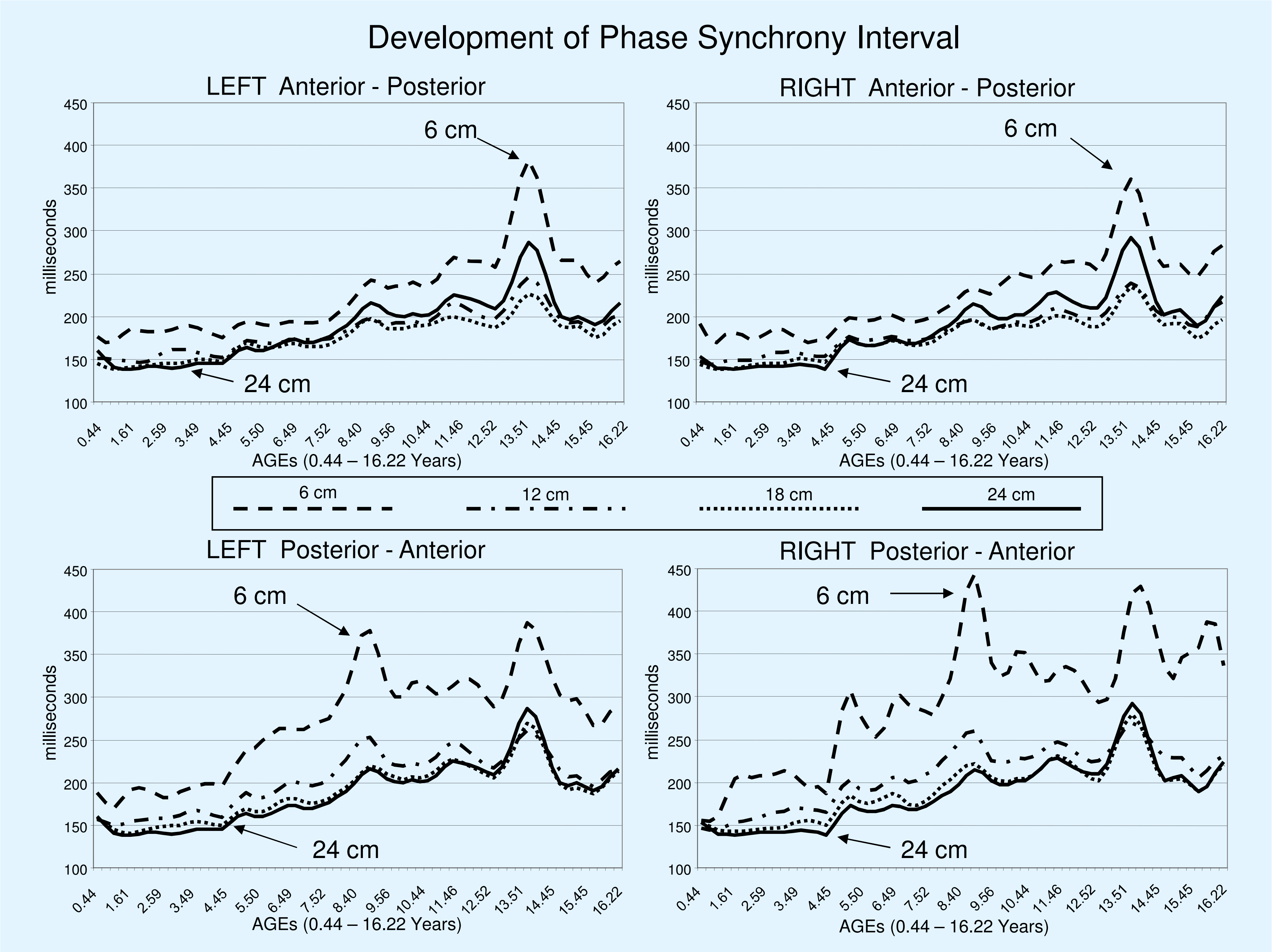




Phase Shift
Phase Difference in Degrees
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23
1st Derivative deg/100 msec
Phase Shift Duration
Fp1-Fp1
Fp1-F3
Phase Lock Duration
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23



Development of Phase Shift Duration
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
24 cm
6 cm
milliseconds
70
65
60
55
50
45
40
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22
AGEs (0.44 – 16.22 Years)
6 cm
12 cm
18 cm
24 cm



Development of Phase Synchrony Interval
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
milliseconds
AGEs (0.44 – 16.22 Years)
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22
100
150
200
250
300
350
400
450
6 cm
24 cm
6 cm
12 cm
18 cm
24 cm

Published in NeuroImage – NeuroImage, 42(4): 1639-1653, 2008.

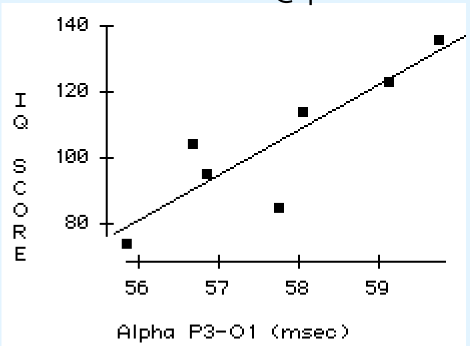
INTELLIGENCE AND EEG PHASE RESET:
A TWO COMPARTMENTAL MODEL OF PHASE SHIFT AND LOCK

Thatcher, R. W. 1,2, North, D. M.1, and Biver, C. J.1

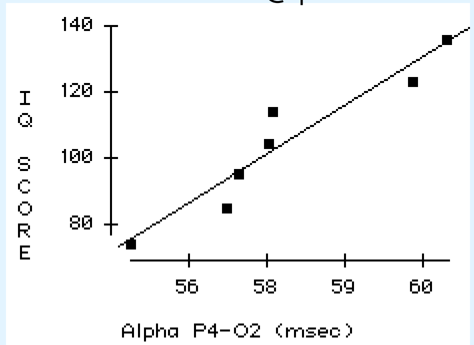
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute.
St. Petersburg, Fl1 and Department of Neurology, University of South Florida
College of Medicine, Tampa, Fl.2

Regressions & Correlations of Phase Shift Duration Short Distances (6 cm)

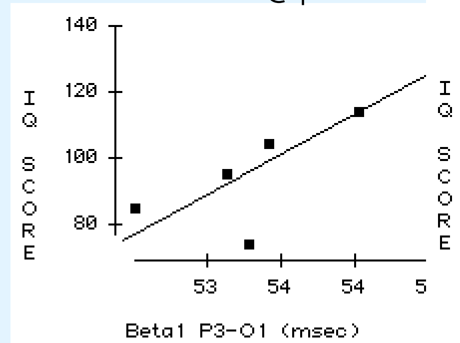
IQ = 78 + 13.78 x (msec)
r = .876 @ p< .01



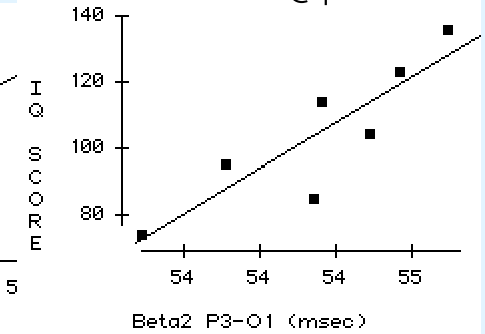
IQ = 70 +11.85 x (msec)
r = .954 @ p< .0001



IQ = 75 + 24.45 x (msec)
r = .868 @ p< .01

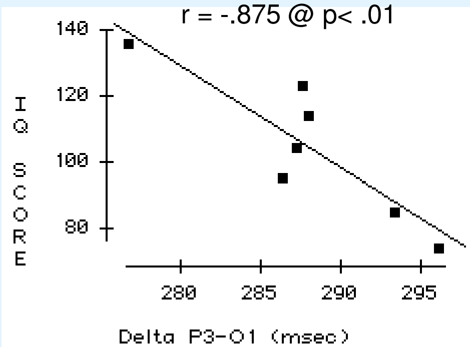


IQ = 68 + 34.40 x (msec)
r = .874 @ p< .01

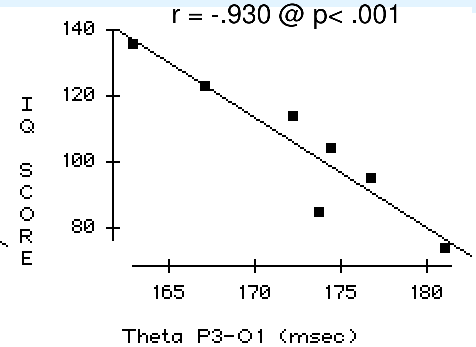


Regressions & Correlations of Phase Locking Interval Short Distances (6 cm)

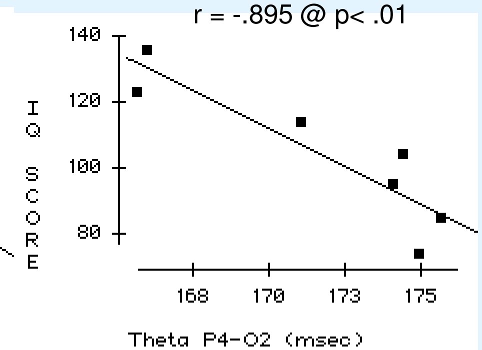
IQ = 143 - 3.11 x (msec)
r = -.875 @ p< .01



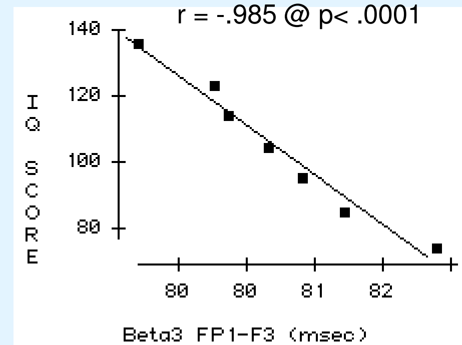
IQ = 142 - 3.36 x (msec)
r = -.930 @ p< .001



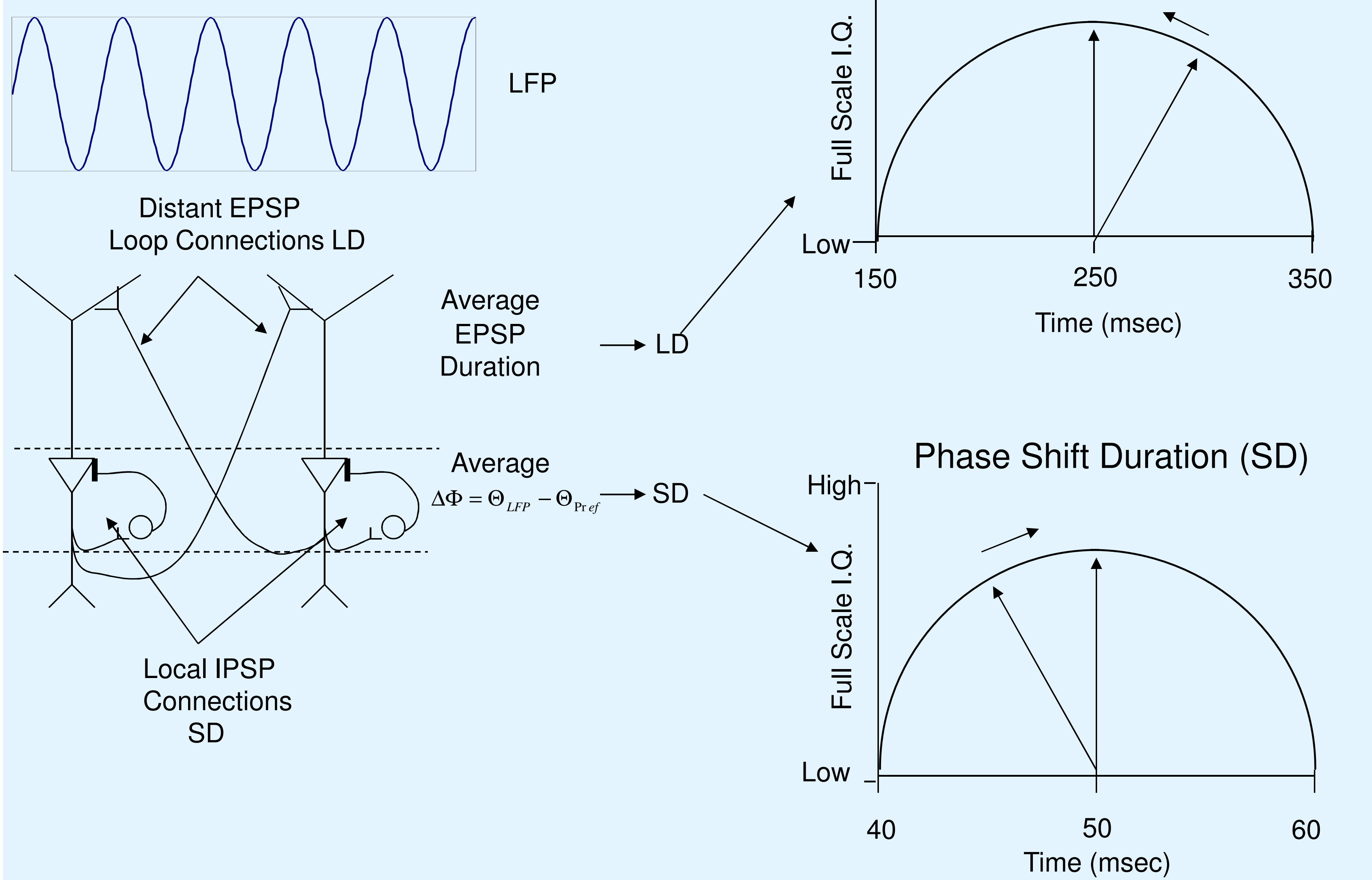
IQ = 132 - 4.57 x (msec)
r = -.895 @ p< .01



IQ = 140 - 20.08 x (msec)
r = -.985 @ p< .0001



Pyramidal Cell Model of EEG Phase Reset and Full Scale I.Q.



SCIENTIFIC REPORTS

OPEN

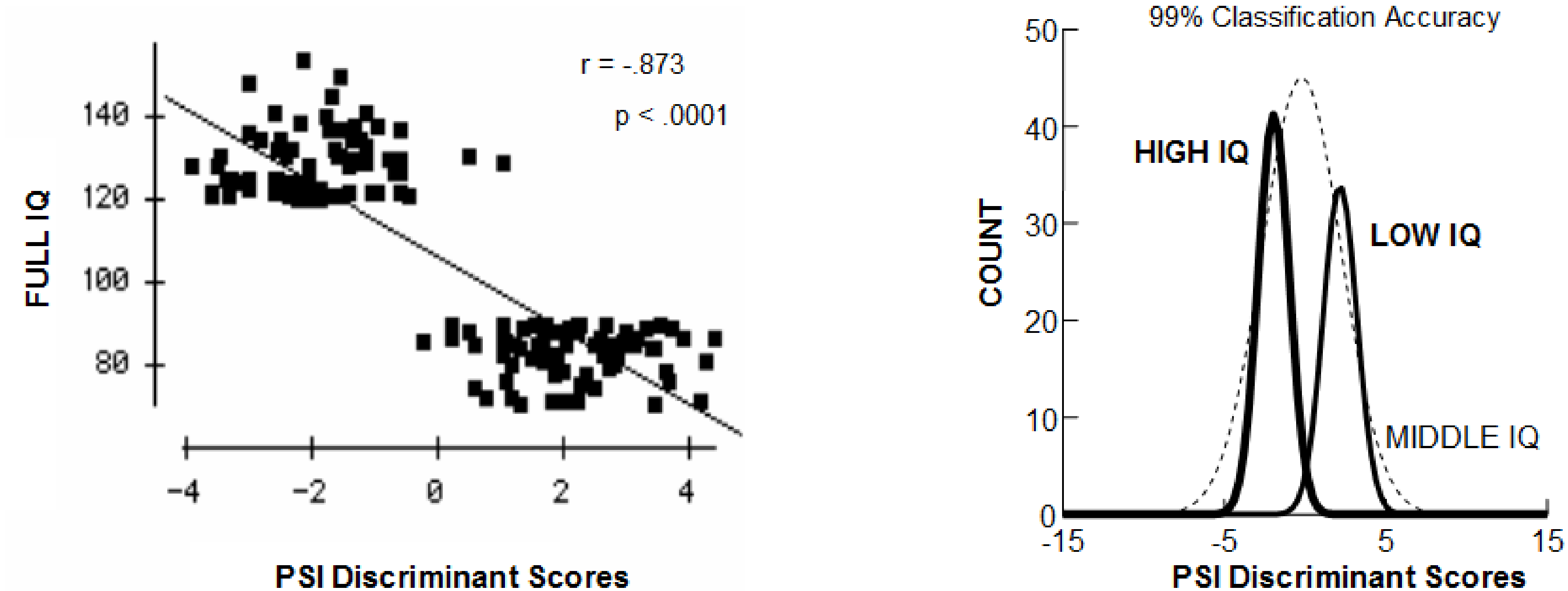
Intelligence and eeg measures of information flow: efficiency and homeostatic neuroplasticity

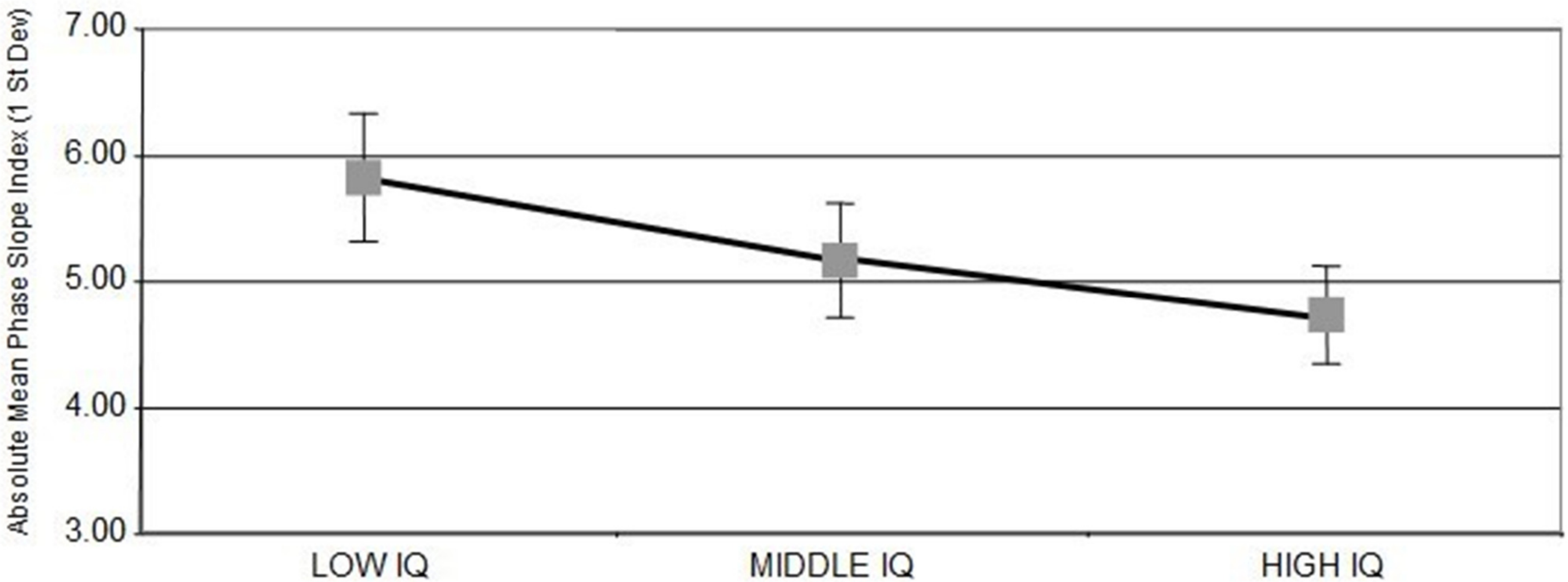
Received: 25 July 2016
Accepted: 14 November 2016
Published: 20 December 2016

R. W. Thatcher, E. Palmero-Soler, D. M. North & C. J. Biver

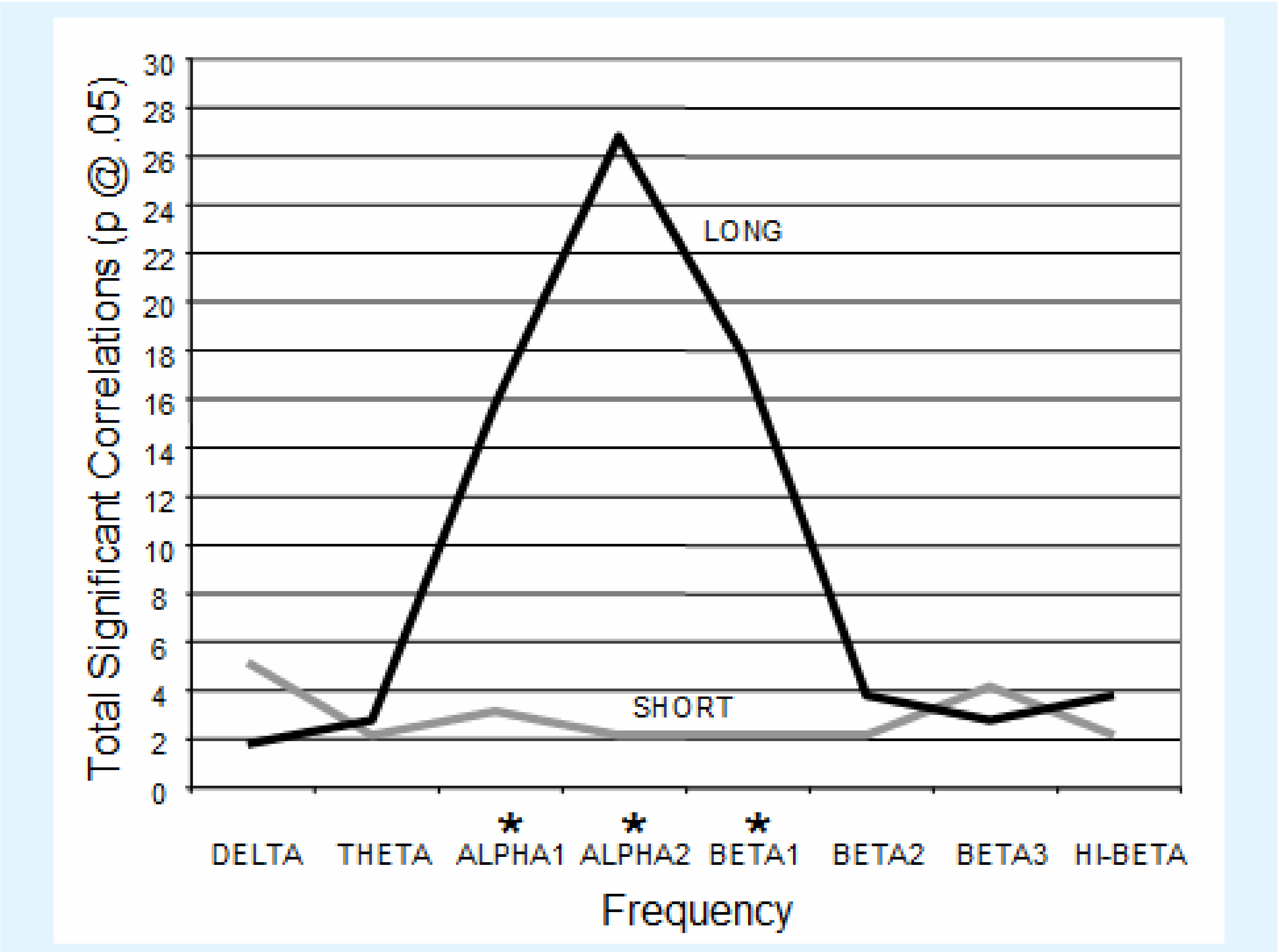
The purpose of this study was to explore the relationship between the magnitude of EEG information flow and intelligence. The electroencephalogram (EEG) was recorded from 19 scalp locations from 371 subjects ranging in age from 5 years to 17.6 years. The Wechler Intelligence Scale for Children (WISC-R) was administered for individuals between 5 years of age and 16 years and the Weschler Adult Intelligence Scale revised (WAIS-R) was administered to subjects older than 16 years to estimate I.Q. The phase slope index estimated the magnitude of information flow between all electrode combinations for difference frequency bands. Discriminant analyses were performed between high I.Q. (>120) and low I.Q. groups (<90). The magnitude of information flow was inversely related to I.Q. especially in the alpha and beta frequency bands. Long distance inter-electrode distances exhibited greater information flow than short inter-electrode distances. Frontal-parietal correlations were the most significant. It is concluded that higher I.Q. is related to increased efficiency of local information processing and reduced long distance compensatory dynamics that supports a small-world model of intelligence.

Discriminant Scores of the Magnitude of Phase Slope Index (PSI) with Full Scale IQ

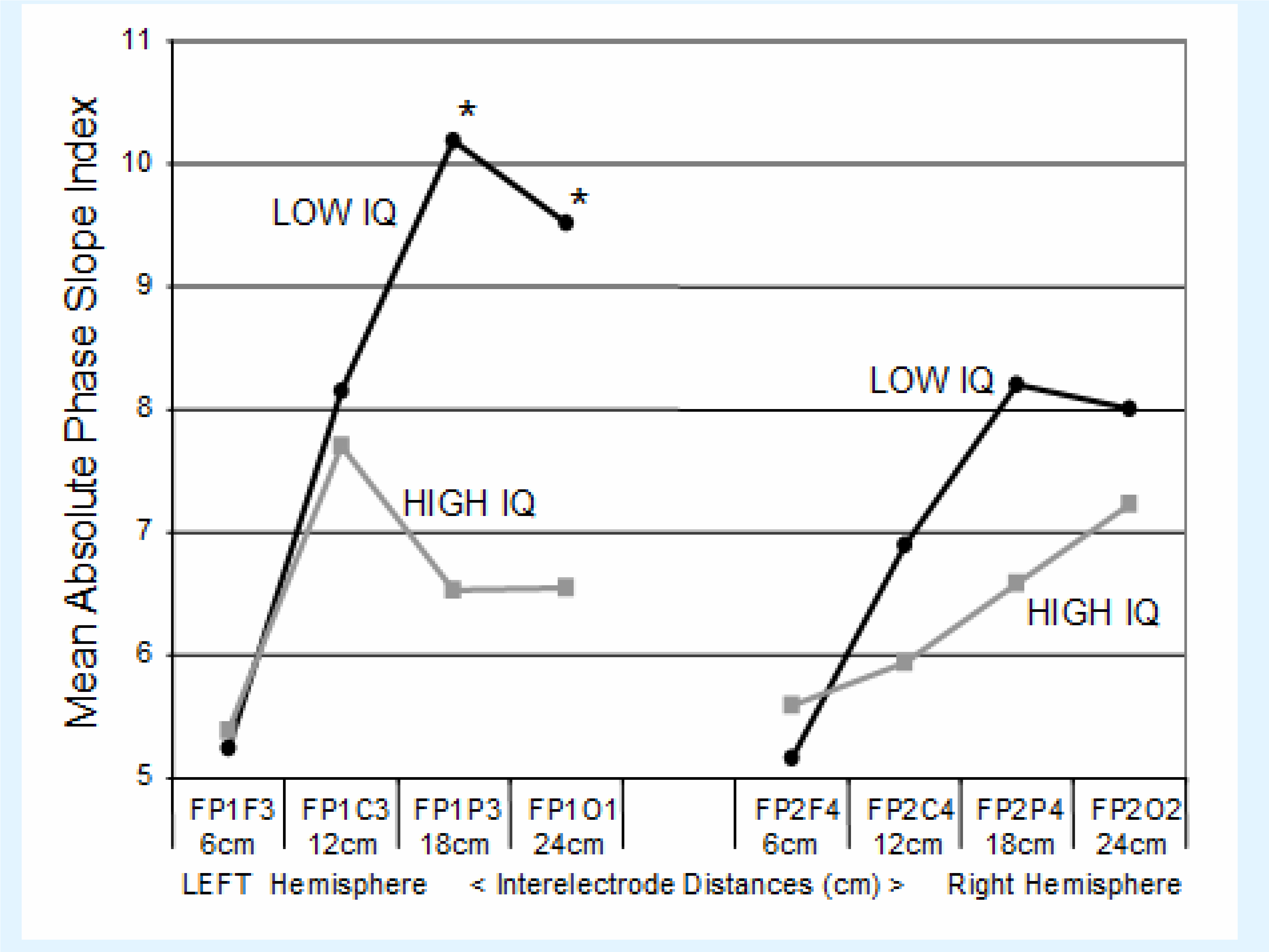


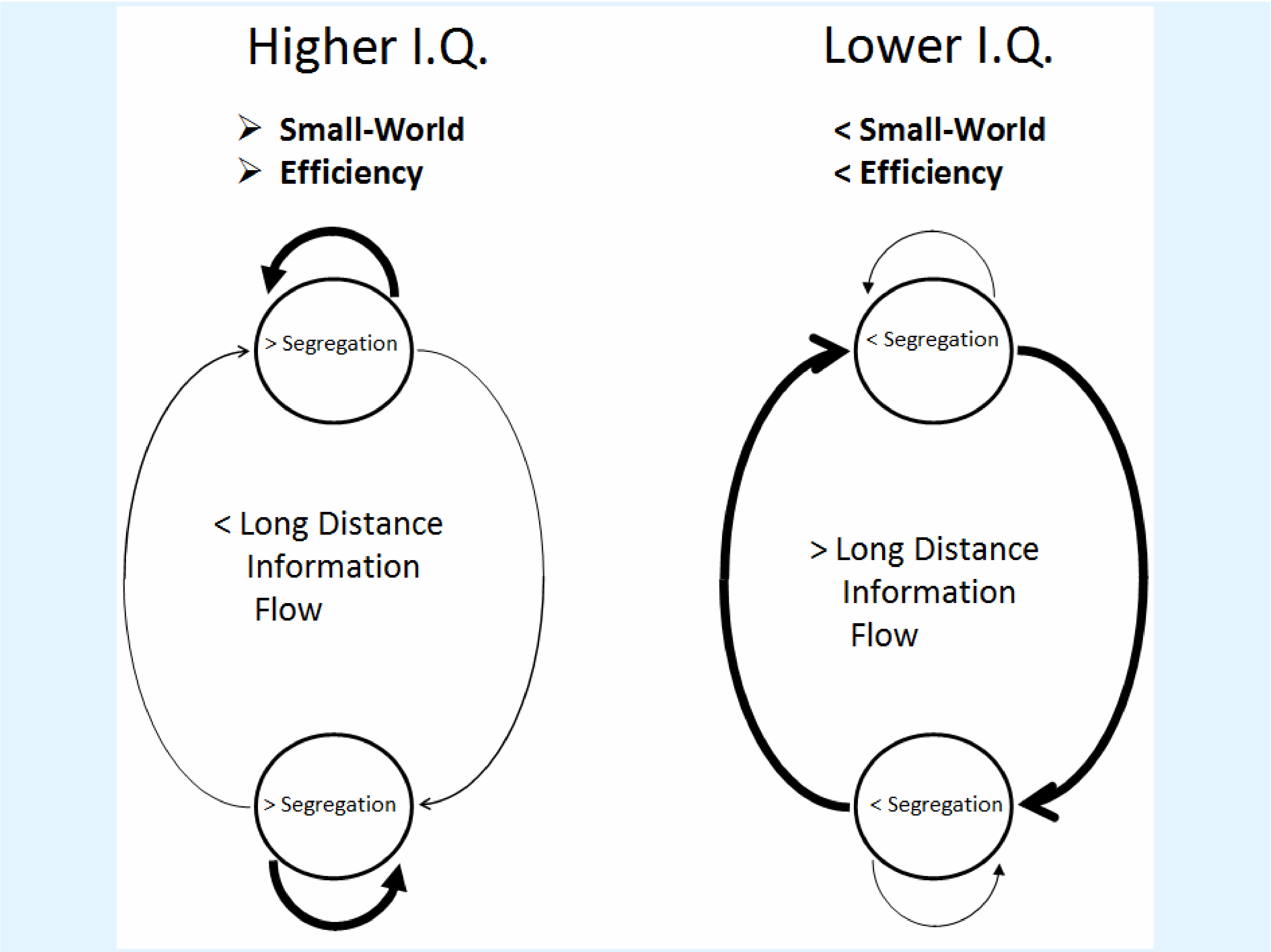


Absolute Mean Phase Slope Index (1 St Dev)
7.00
6.00
5.00
4.00
3.00
LOW IQ
MIDDLE IQ
HIGH IQ



Total Significant Correlations (p @ .05)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
LONG
SHORT
*
*
*
DELTA
THETA
ALPHA1
ALPHA2
BETA1
BETA2
BETA3
HI-BETA
Frequency

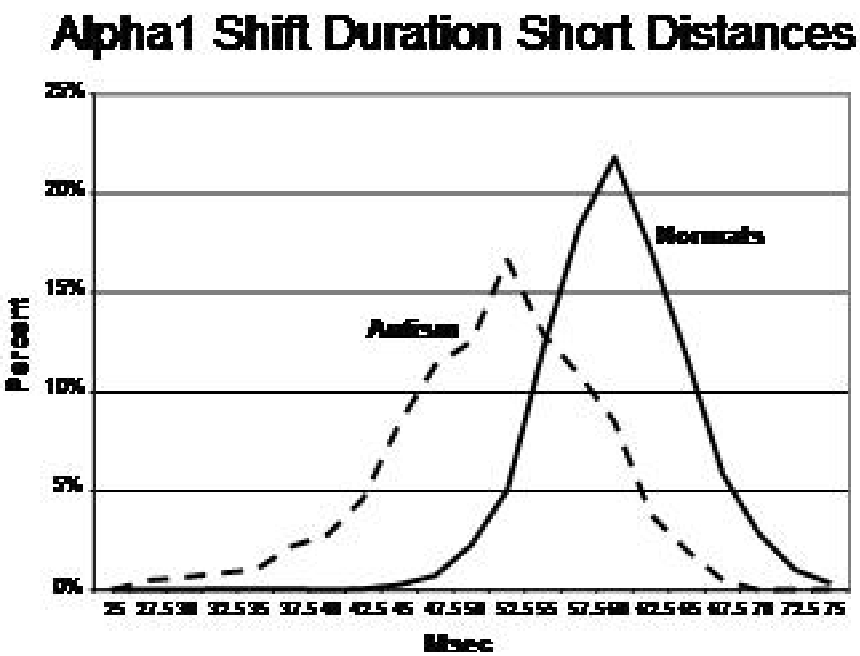

Mean Absolute Phase Slope Index
11
10
9
8
7
6
5
LOW IQ
HIGH IQ
*
*
LOW IQ
HIGH IQ
FP1F3 6cm
FP1C3 12cm
FP1P3 18cm
FP1O1 24cm
FP2F4 6cm
FP2C4 12cm
FP2P4 18cm
FP2O2 24cm
LEFT Hemisphere
< Interelectrode Distances (cm) >
Right Hemisphere


Higher I.Q.
➢ Small-World
➢ Efficiency
> Segregation
< Long Distance Information Flow
> Segregation
Lower I.Q.
< Small-World
< Efficiency
< Segregation
> Long Distance Information Flow
< Segregation

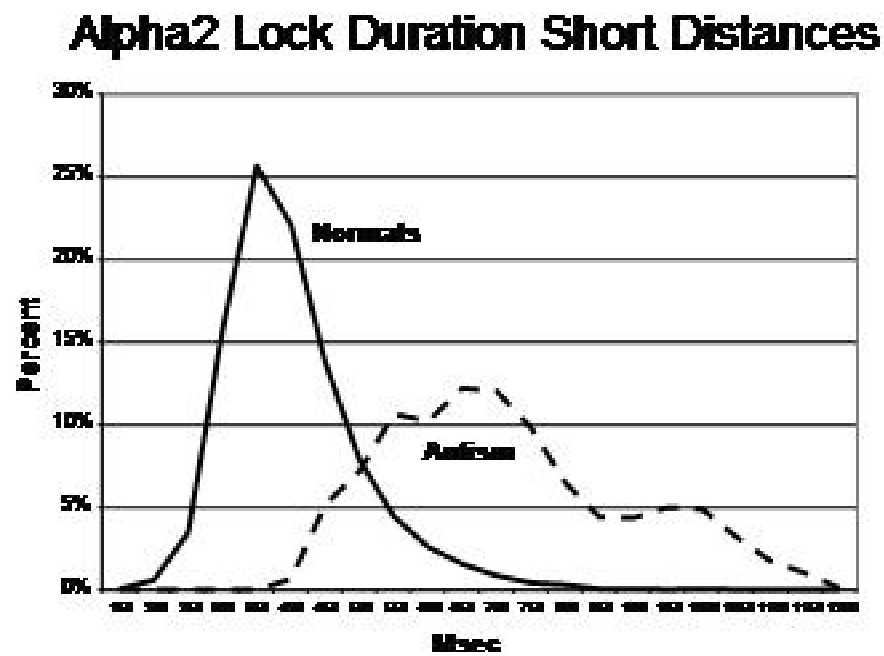
AUTISM AND EEG PHASE RESET:
A UNIFIED THEORY OF DEFICIENT GABA MEDIATED INHIBITION IN THALAMO-CORTICAL CONNECTIONS

Thatcher, R. W. 1,2, Phillip DeFina2, James Neurbrander2, North, D. M.1, and Biver, C. J.1

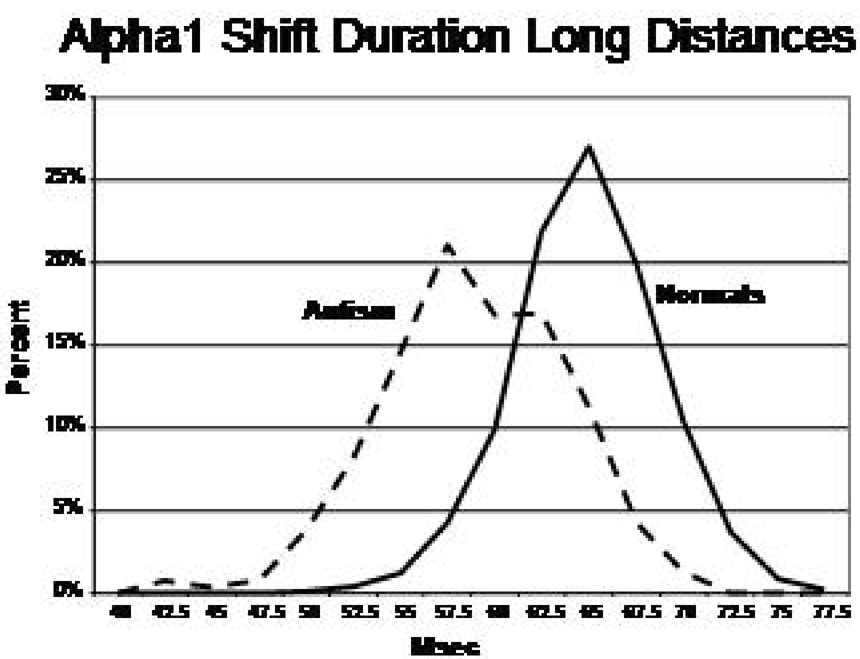
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute., St. Petersburg, Fl1 and the International Brain Research Foundation, Menlo Park, NJ2



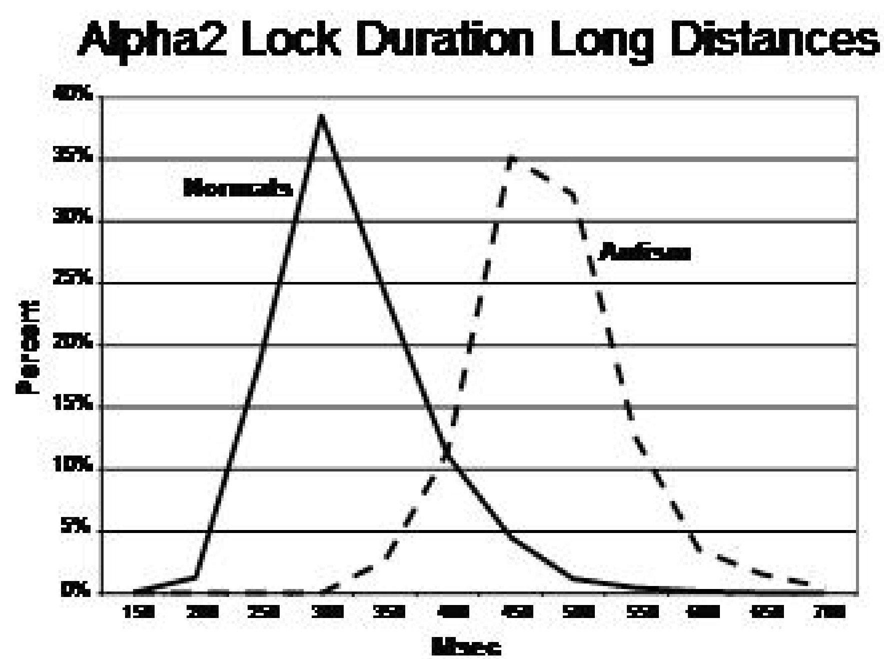
Alpha1 Shift Duration Short Distances
Percent
Msec
Normals
Autism
25%
20%
15%
10%
5%
0%



Alpha2 Lock Duration Short Distances
Percent
Msec
Normals
Autism
30%
25%
20%
15%
10%
5%
0%



Alpha1 Shift Duration Long Distances
Percent
Msec
Normals
Autism
30%
25%
20%
15%
10%
5%
0%
40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65 67.5 70 72.5 75 77.5



Alpha2 Lock Duration Long Distances
Percent
Msec
Normals
Autism
40%
35%
30%
25%
20%
15%
10%
5%
0%
150 200 250 300 350 400 450 500 550 600 650 700

Electrical NeuroImaging of Functional Modules and Hubs as Measured by fMRI and PET

Phase Shift and Phase Lock Switch Dynamics that "Animate" Information Flow Within and Between Modules and Hubs

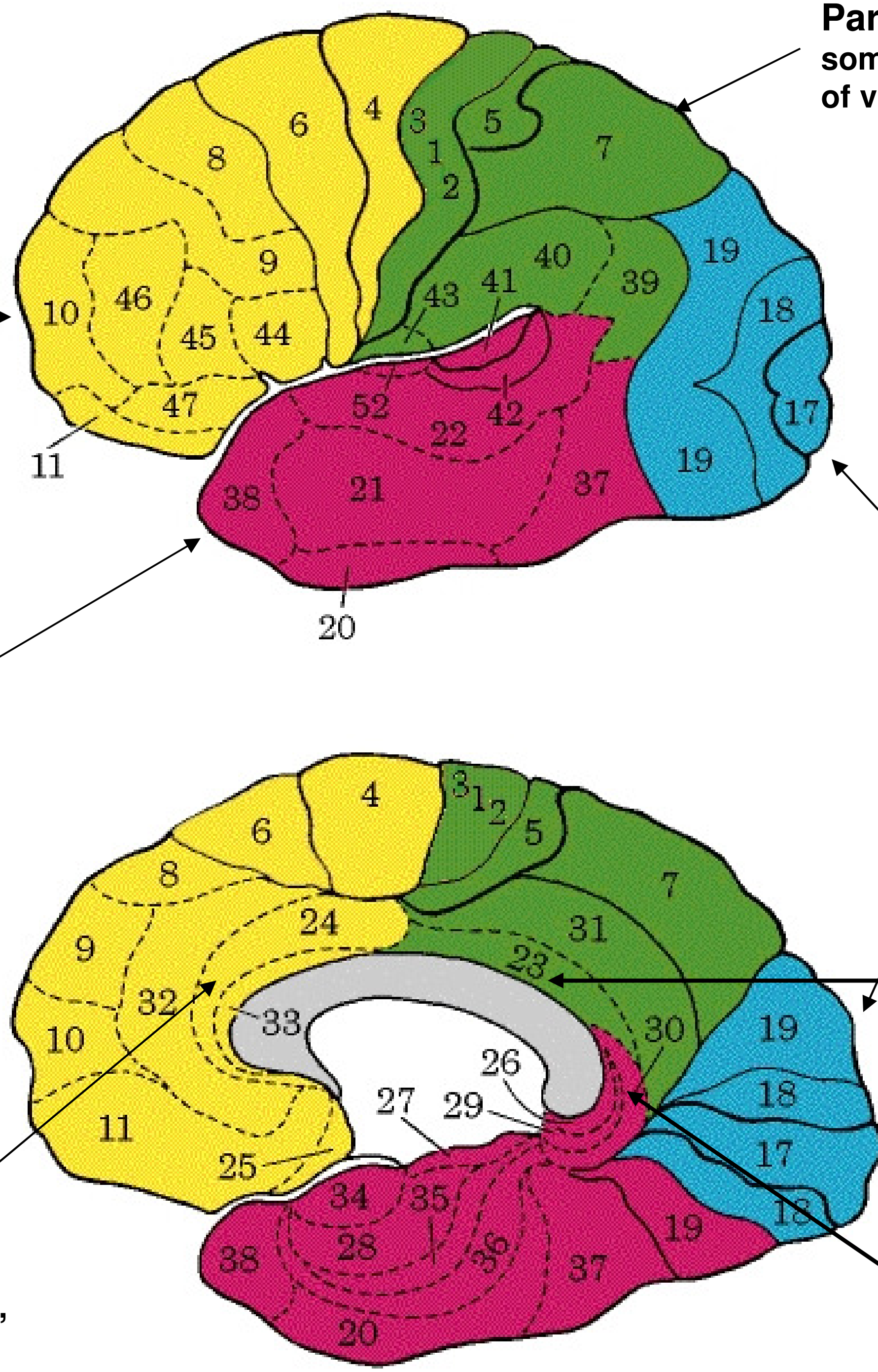
Brodmann Areas

Parietal Lobe
somatosensory perception integration of visual & somatospatial information

Frontal Lobe
Thinking, Planning, Motor execution, Executive Functions, Mood Control

Temporal Lobe
language function and auditory perception involved in long term memory and emotion

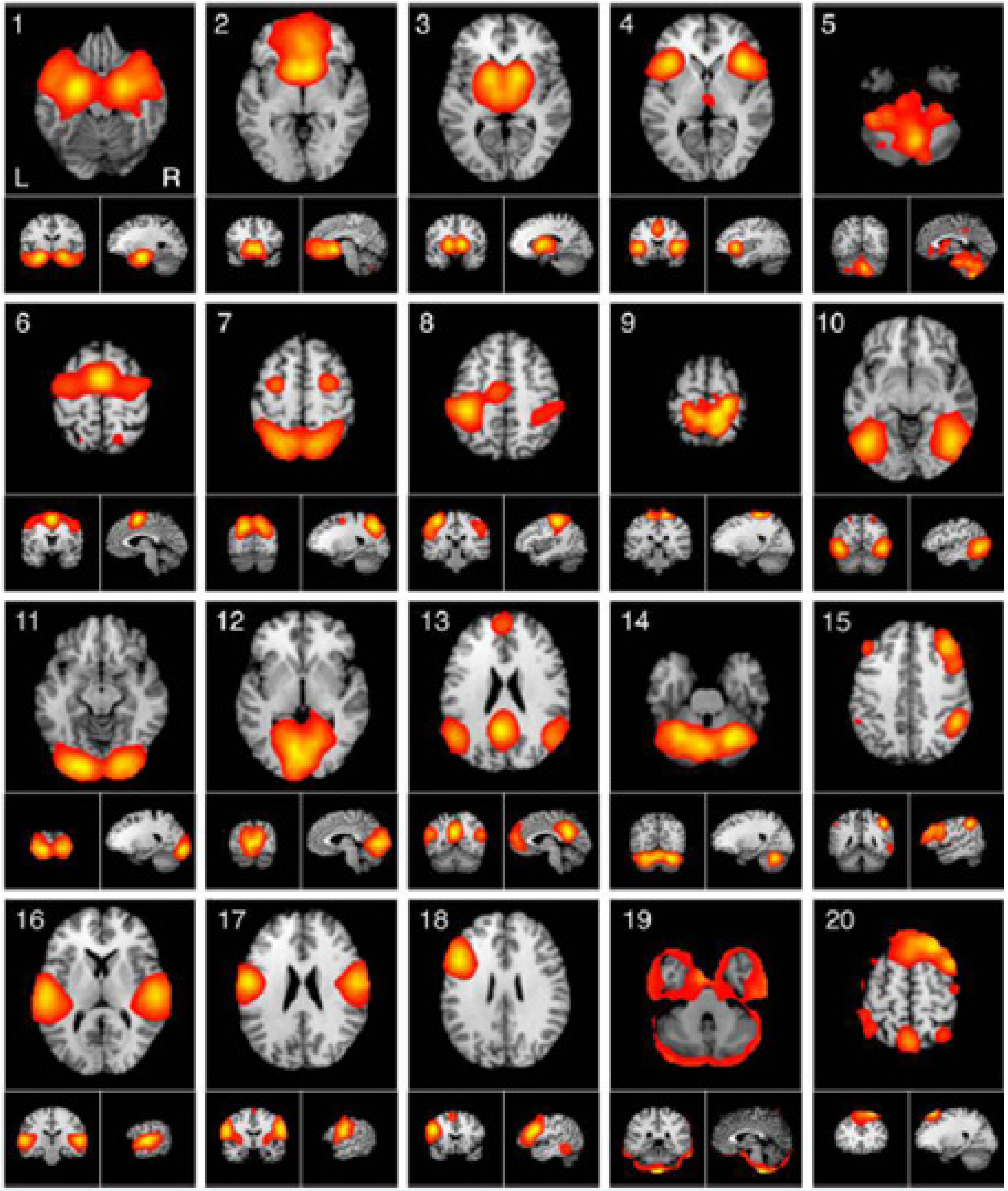
Occipital Lobe
Visual perception & Spatial processing



Posterior Cingulate
attention, long-term memory

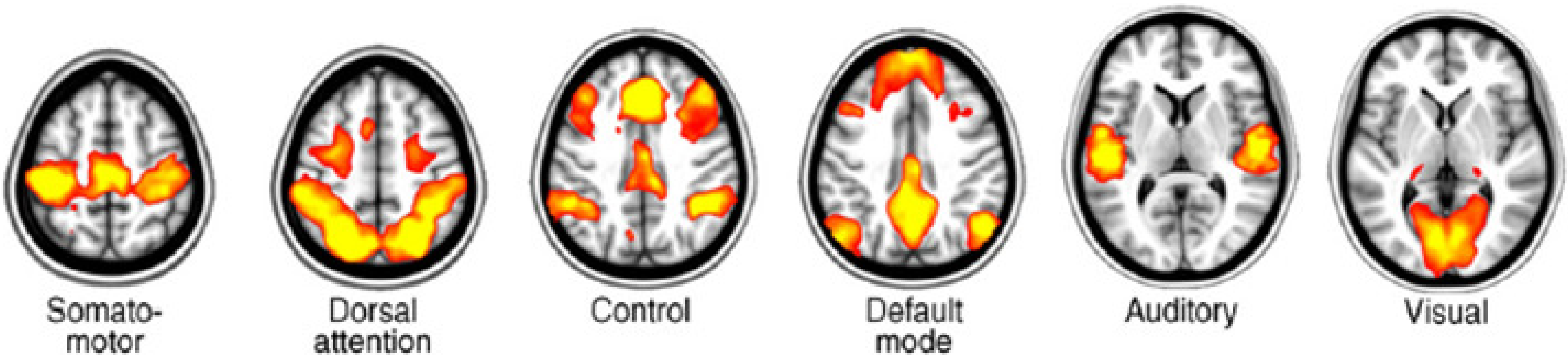
Anterior Cingulate Gyrus
Volitional movement, attention, long term memory

Parahippocampal Gyrus
Short-term memory, attention



Laird et al (2011) summarized the various "intrinsic connectivity networks" or ICNs into eighteen specific groupings based upon 30,000 fMRI and PET studies

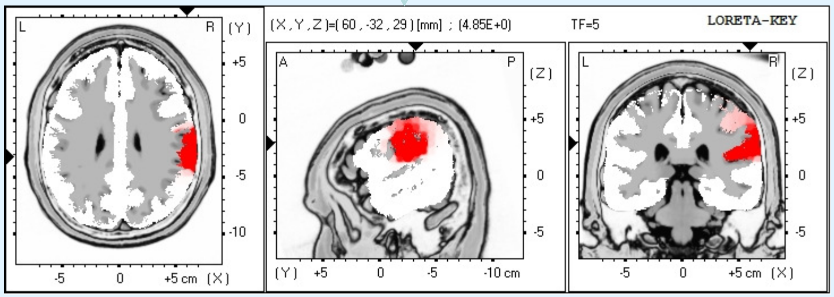
Six Functional Modules as Measured by fMRI



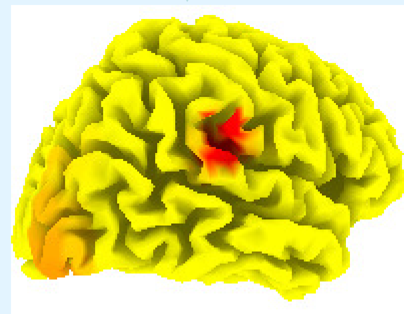
From Raichle, 2010

Electrical Neuroimaging and Cortical Source Localization

Horizontal, Sagital & Coronal Views of a Single Slice



Cortical Surface Projection



Tomographic Slice Display

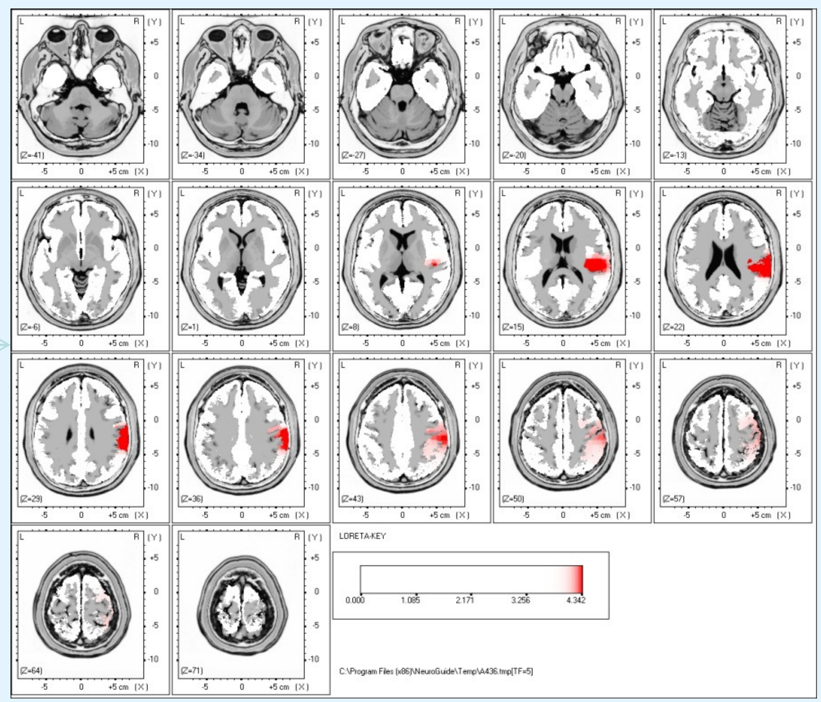


Table 5: Error measure ED1 for the four inverse algorithms, with regularization, under four different noise levels: 25 dB, 15 dB, 10 dB and 5 dB. Each cell value gives the mean and standard deviation.

		ED1			
		Regularised			
	SNR/dB	5	10	15	25
	Layer				
WMN	Surface	3.46 ± 0.42	2.10 ± 0.28	1.34 ± 0.11	1.13 ± 0.03
	Middle	5.08 ± 0.50	3.94 ± 0.38	2.95 ± 0.21	2.40 ± 0.03
	Deep	5.91 ± 0.39	5.31 ± 0.36	4.61 ± 0.24	3.89 ± 0.15
sLORETA	Surface	0.99 ± 0.1	0.49 ± 0.08	0.11 ± 0.04	0.00 ± 0.00
	Middle	1.61 ± 0.13	0.84 ± 0.11	0.25 ± 0.07	0.00 ± 0.00
	Deep	1.79 ± 0.25	0.95 ± 0.16	0.39 ± 0.13	0.00 ± 0.00
LORETA	Surface	2.32 ± 0.08	2.18 ± 0.04	2.16 ± 0.03	2.21 ± 0.02
	Middle	1.51 ± 0.13	1.15 ± 0.08	0.95 ± 0.07	1.05 ± 0.06
	Deep	2.30 ± 0.21	1.81 ± 0.13	1.59 ± 0.11	1.53 ± 0.09
SLF	Surface	5.27 ± 0.30	4.50 ± 0.28	3.81 ± 0.20	2.98 ± 0.13
	Middle	4.53 ± 0.39	4.09 ± 0.35	3.50 ± 0.31	2.51 ± 0.15
	Deep	3.89 ± 0.55	3.70 ± 0.45	3.27 ± 0.48	1.73 ± 0.30

Electrical Neuroimaging – Assessment and Treatment

Advantages of Electrical Neuroimaging

1- Spatial Resolution – 1 cm to 3 cm

2- Temporal Resolution – 1 msec

3- Imaging of Current Sources

4- Imaging of Network Connections

5- Integration with DTI & fMRI (Brodmann Areas)

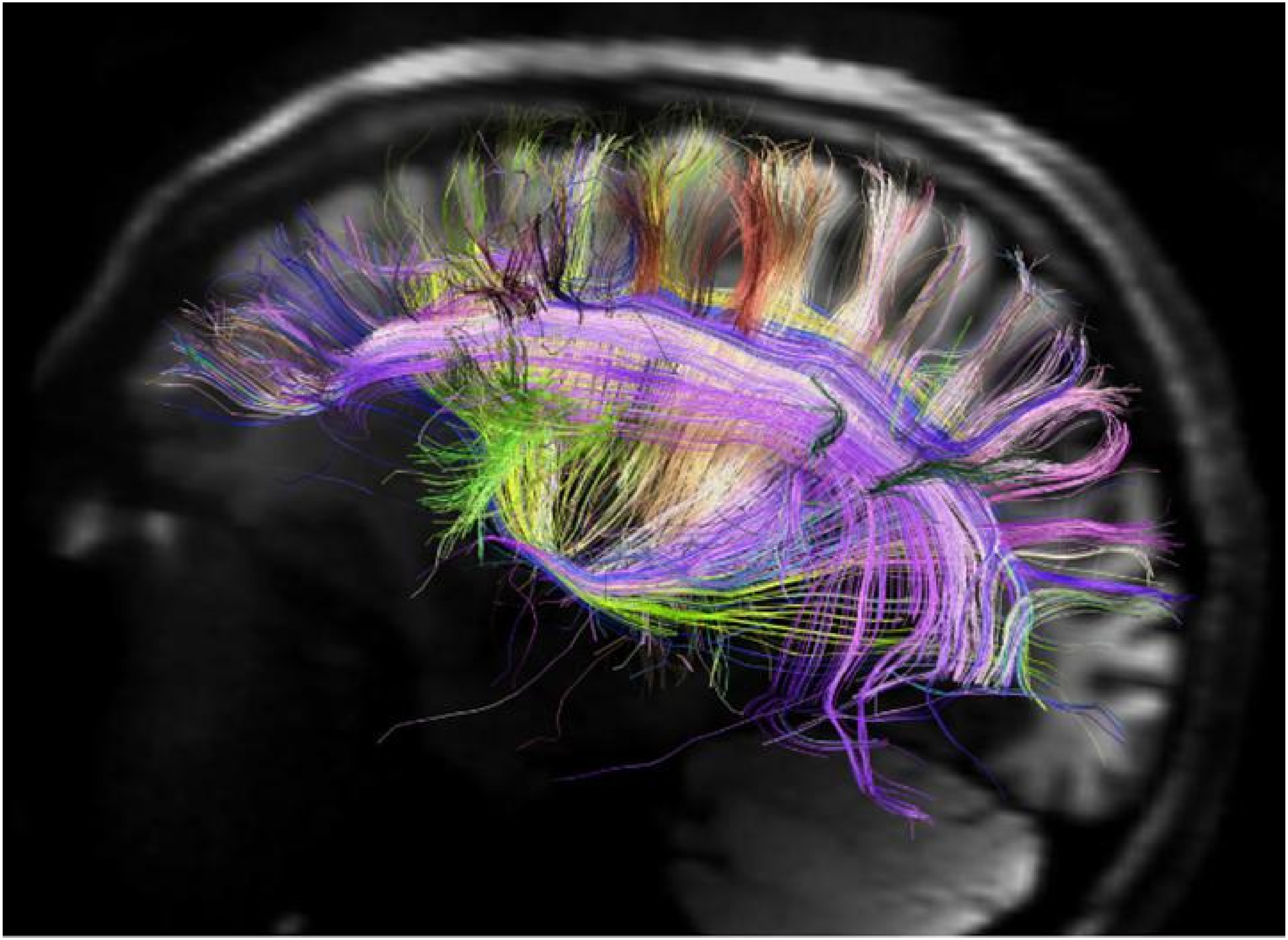
6- Inexpensive ($10,000 vs $3,000,000)

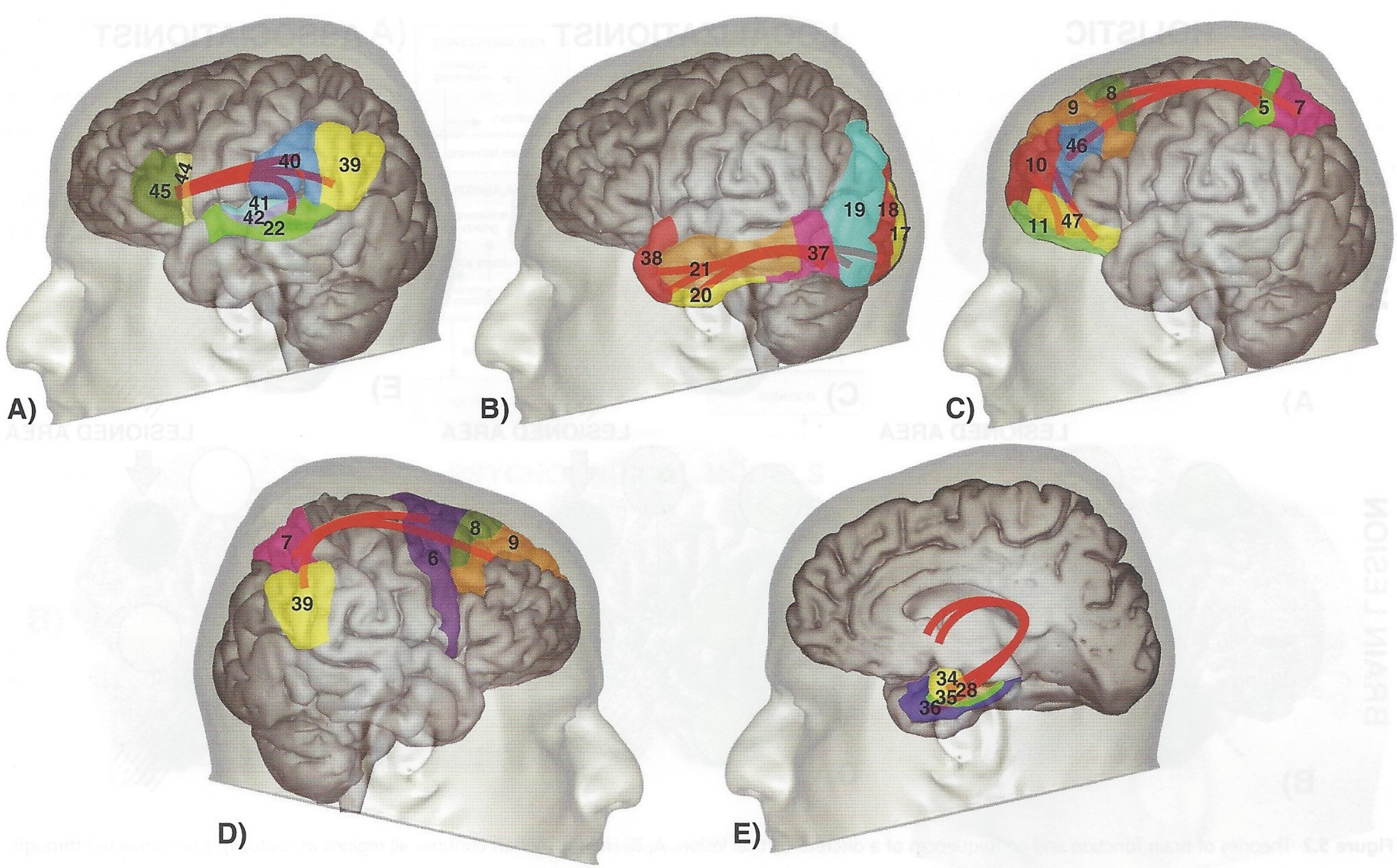
7- Dry Electrodes & Wireless Caps

8- Portable

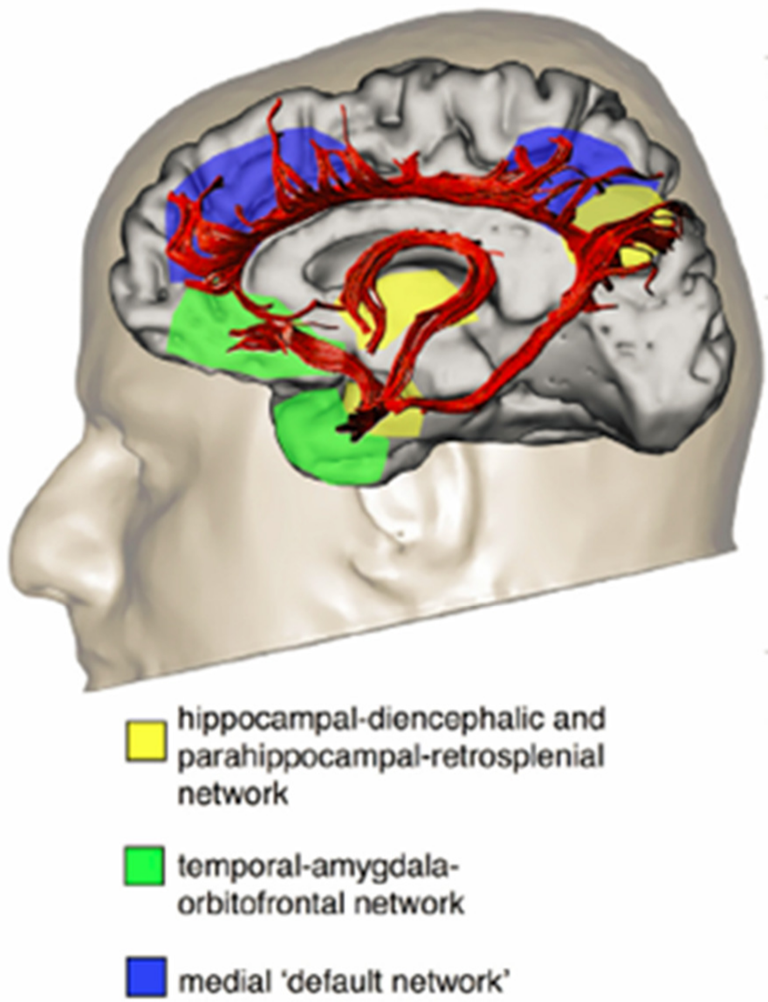
9- Integration with Smart Phones & Tablets

10- Can Assess & Treat in Real-Time1



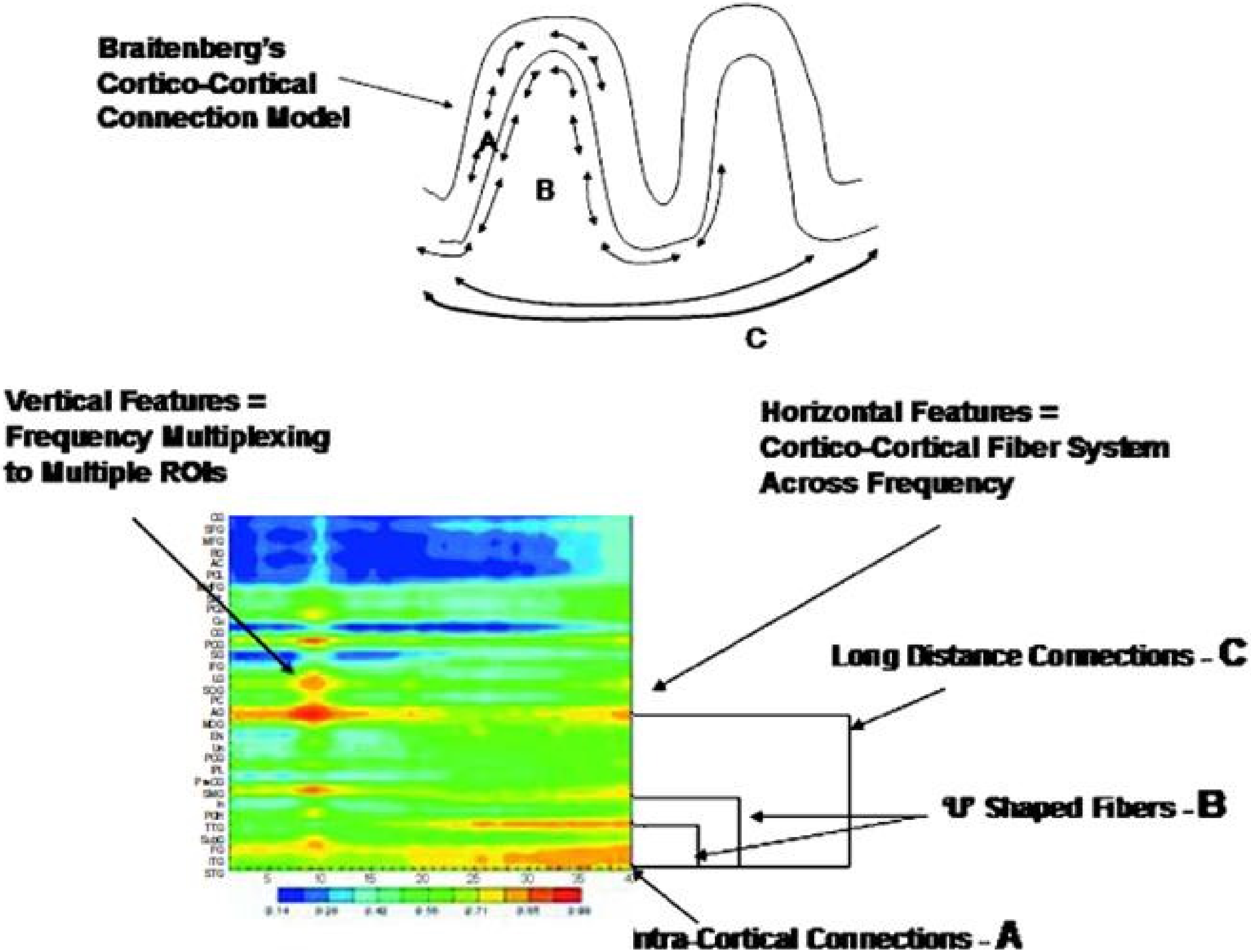


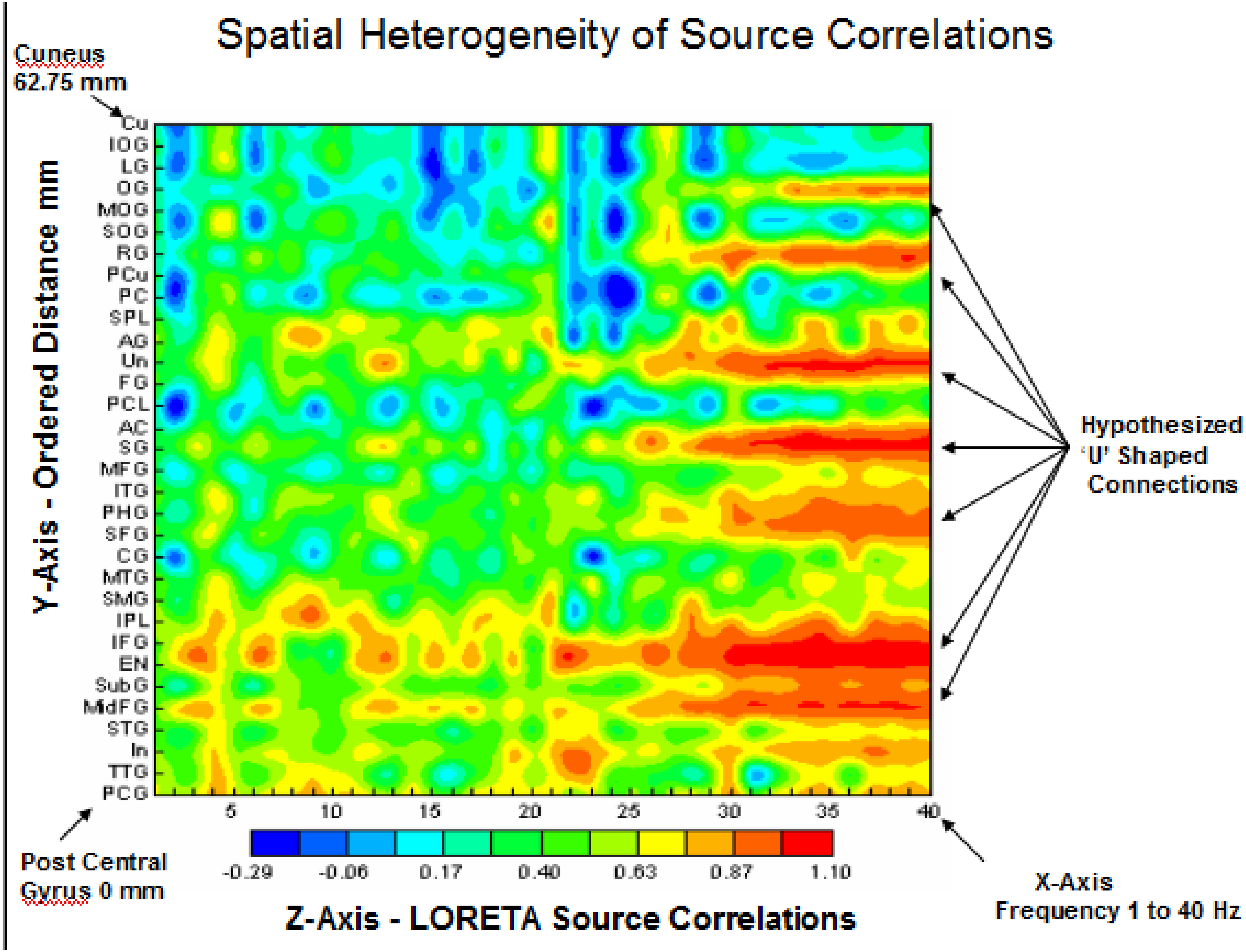
From Catani and deShotten, 2012



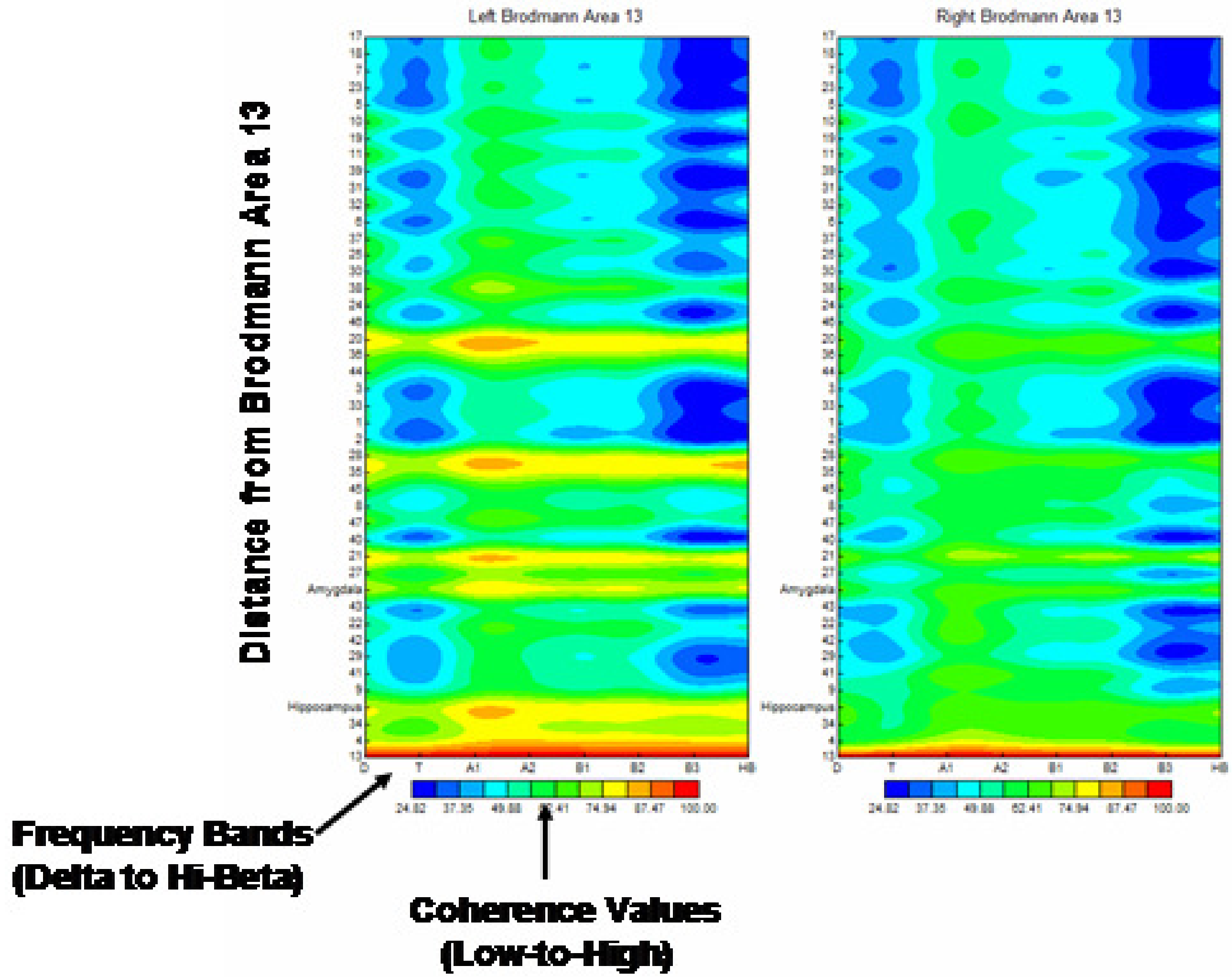
Network	Function	Disorder
Hippocampal-diencephalic and parahippocampal-retrosplenial	•memory •spatial orientation	•Amnesias •Korsakoff's syndrome •Mild Cognitive impairment •Alzheimer's disease (early) •Balint syndrome
Temporo-amydgala-orbitofrontal	•Behavioural inhibition •Memory for temporally complex visual information •Olfactory-gustatory-visceral functions •Multimodal sensory integration •Object-reward association learning •Outcome monitoring	•Alzheimer's Disease (advanced) •Semantic dementia •Klüver-Bucy syndrome •Temporal lobe epilepsy •Geschwind's syndromes •Psychopathy •Bipolar affective disorders
Dorsomedial default network	•Pain perception •Self-knowledge •Attention •Mentalizing •Empathy •Response selection and action monitoring •Autobiographical memory •Person perception	•Depression •Autism •Schizophrenia •Obsessive compulsive disorder •Mild Cognitive Impairmentt •Alzheimer's Disease (early) •Attention Deficit Hyperactivity Disorder •Anxiety

From Catani and deShotten, 2012

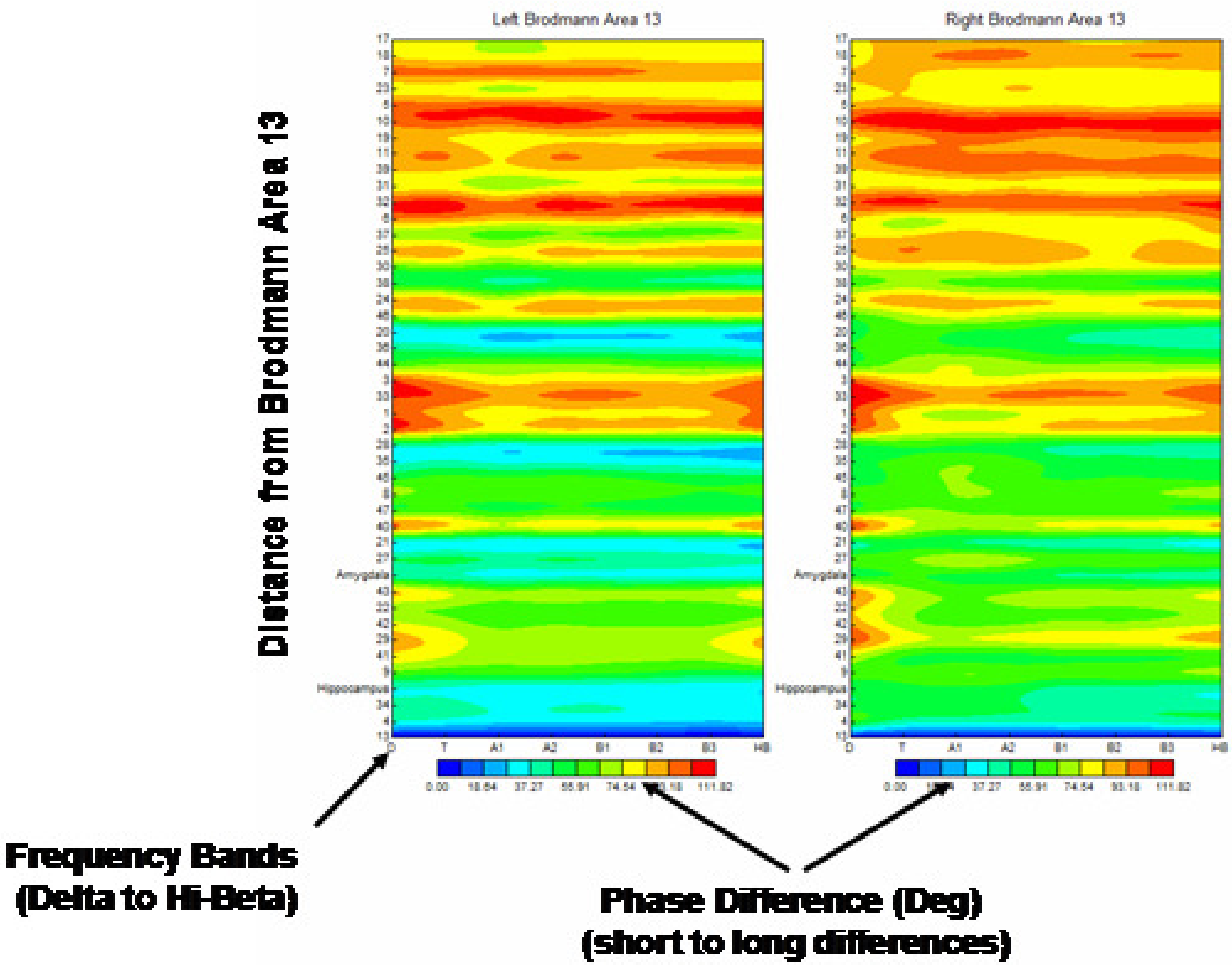

Braitenberg's Cortico-Cortical Connection Model
A
B
C
Vertical Features = Frequency Multiplexing to Multiple ROIs
Horizontal Features = Cortico-Cortical Fiber System Across Frequency
Long Distance Connections - C
'U' Shaped Fibers - B
ntra-Cortical Connections - A


Spatial Heterogeneity of Source Correlations
Cuneus
62.75 mm
Cu
IOG
LG
OG
MOG
SOG
RG
PCu
PC
SPL
AG
Un
FG
PCL
AC
SG
MFG
ITG
PHG
SFG
CG
MTG
SMG
IPL
IFG
EN
SubG
MidFG
STG
In
TTG
PCG
Y-Axis - Ordered Distance mm
5
10
15
20
25
30
35
40
-0.29
-0.06
0.17
0.40
0.63
0.87
1.10
Hypothesized
'U' Shaped
Connections
Post Central
Gyrus 0 mm
Z-Axis - LORETA Source Correlations
X-Axis
Frequency 1 to 40 Hz

LORETA Coherence



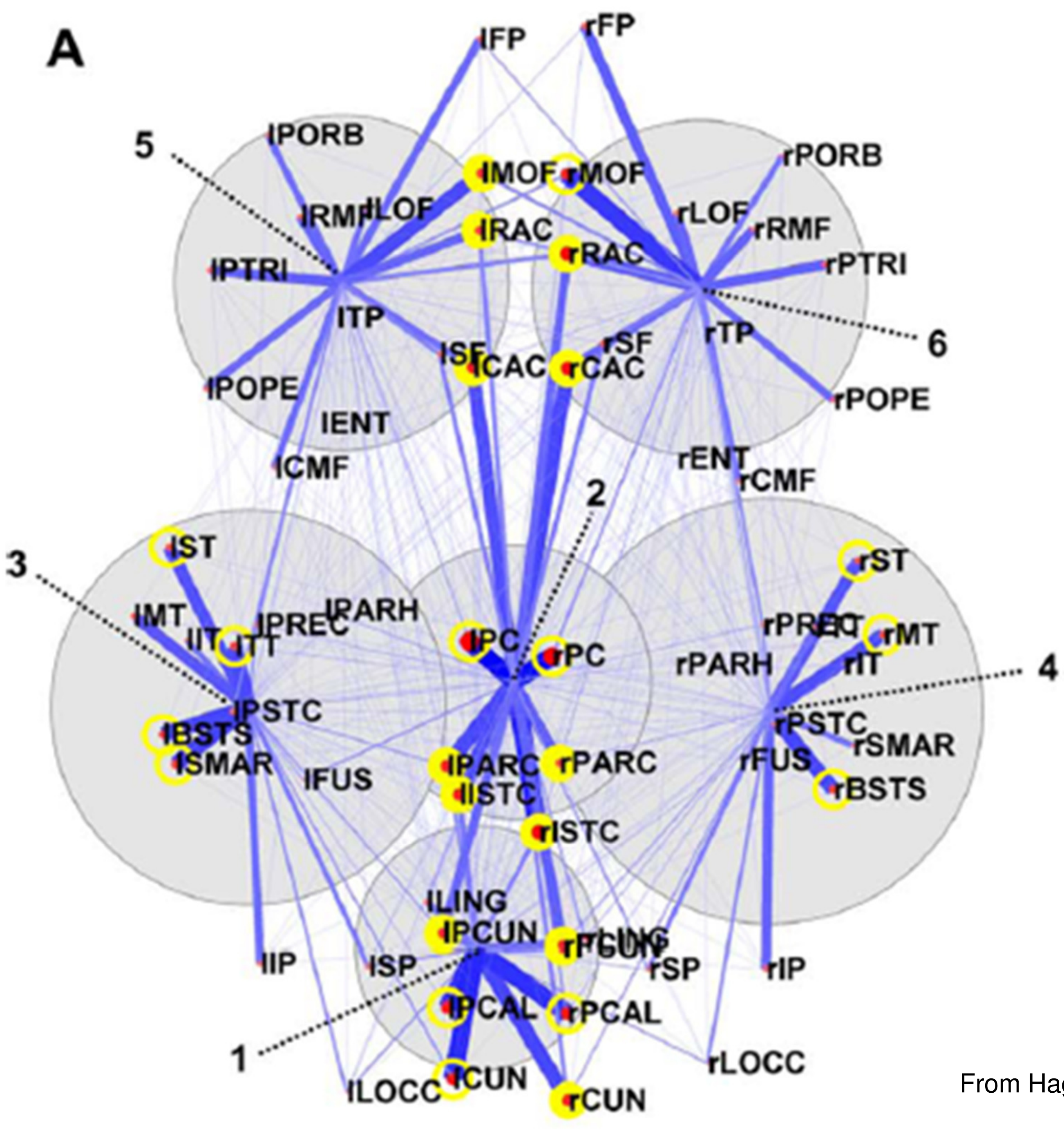
LORETA Absolute Phase



• Human Brain Mapping 33:1062–1075 (2012) •

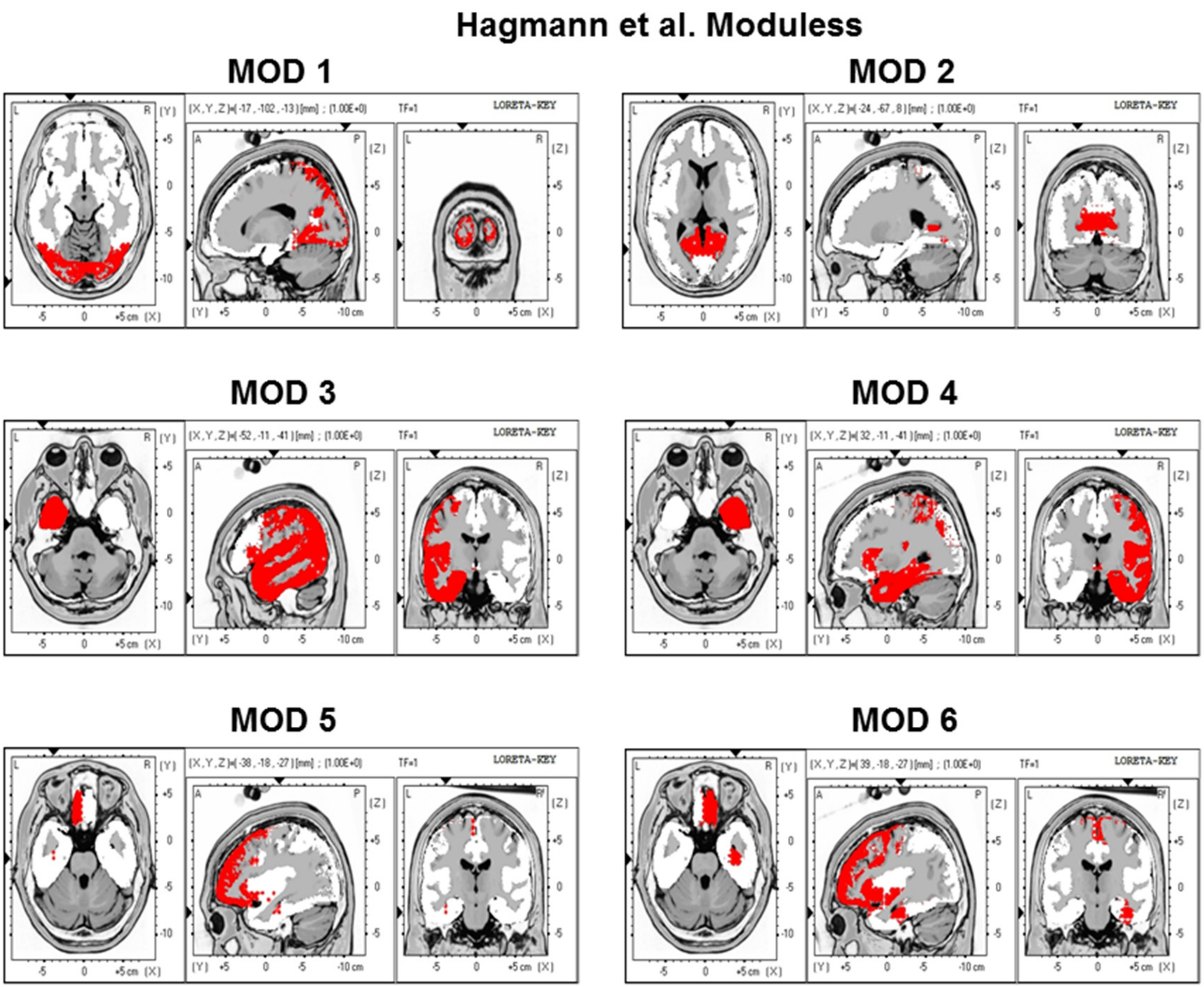
Diffusion Spectral Imaging Modules Correlate With EEG LORETA Neuroimaging Modules

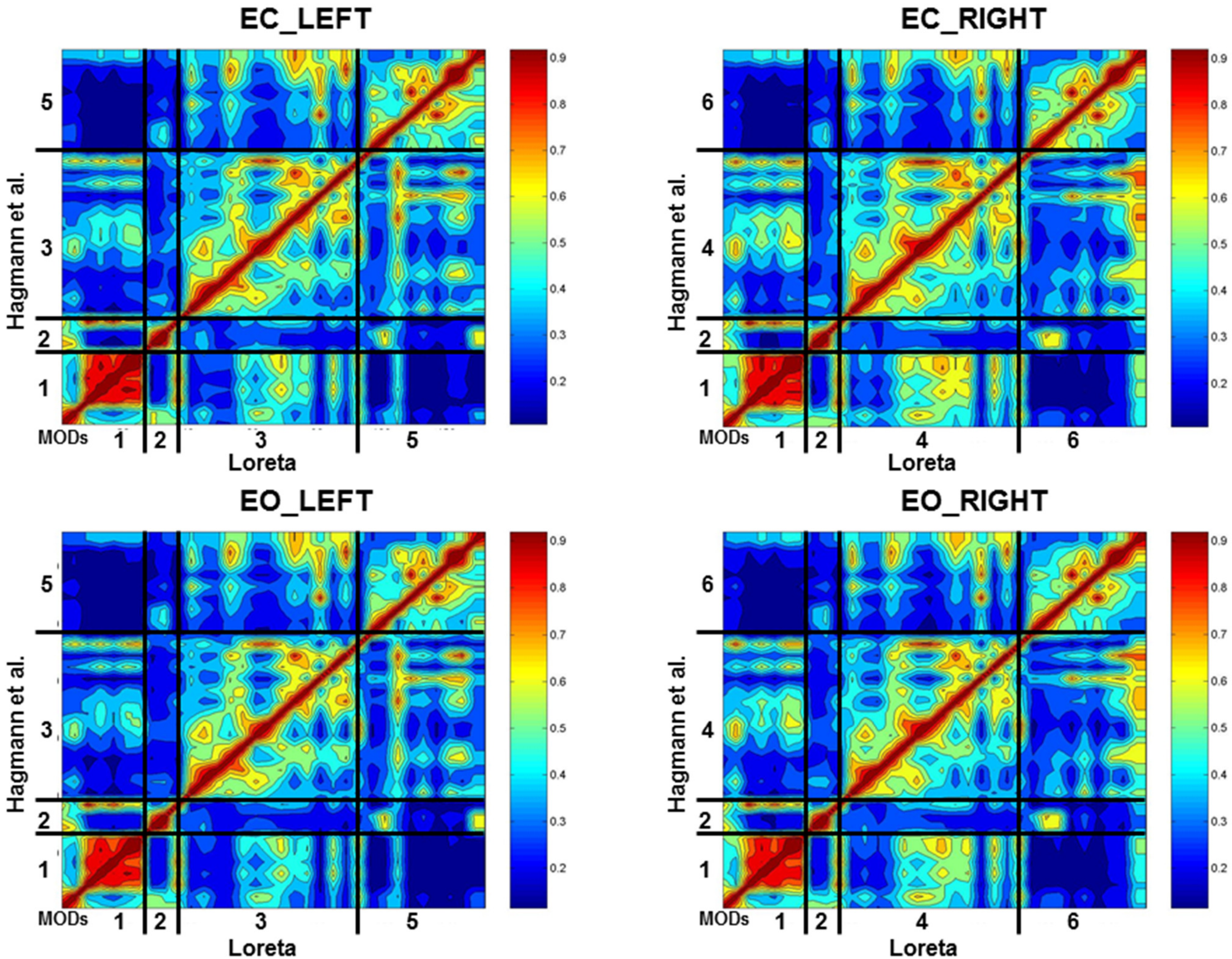
Robert W. Thatcher,* Duane M. North, and Carl J. Biver



From Hagmann et al, 2008

Correlations Between EEG Neuroimaging and Diffusion Spectral Imaging (DTI)




EC_LEFT
EC_RIGHT
EO_LEFT
EO_RIGHT
Hagmann et al.
Loreta
MODs
1
2
3
4
5
6
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

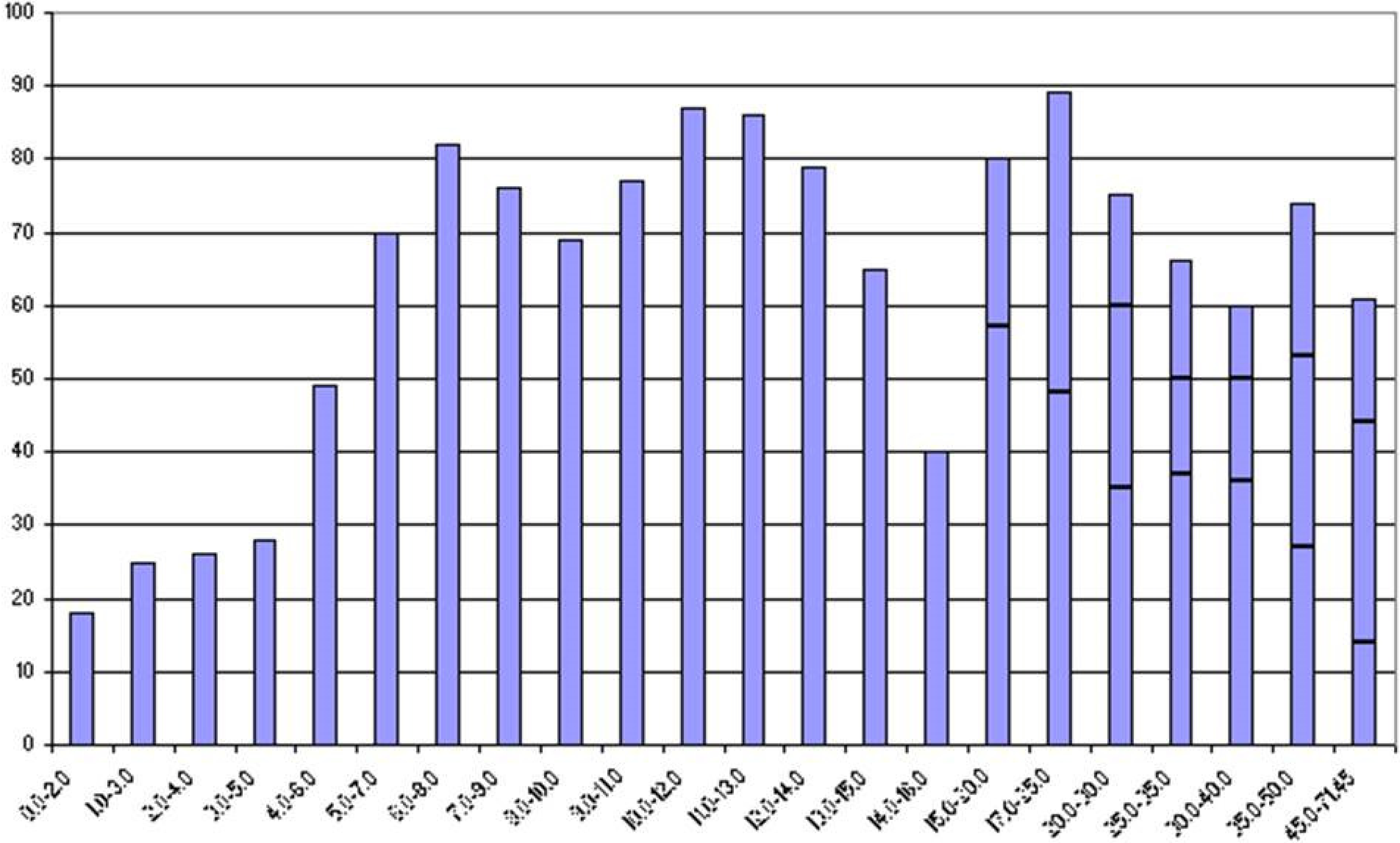
Published as a chapter in "Introduction to QEEG and Neurofeedback: Advanced Theory and Applications" Thomas Budzinsky, H. Budzinski, J. Evans and A. Abarbanel editors, Academic Press, San Diego, Calif, 2008.

HISTORY OF THE SCIENTIFIC STANDARDS OF QEEG NORMATIVE DATABASES

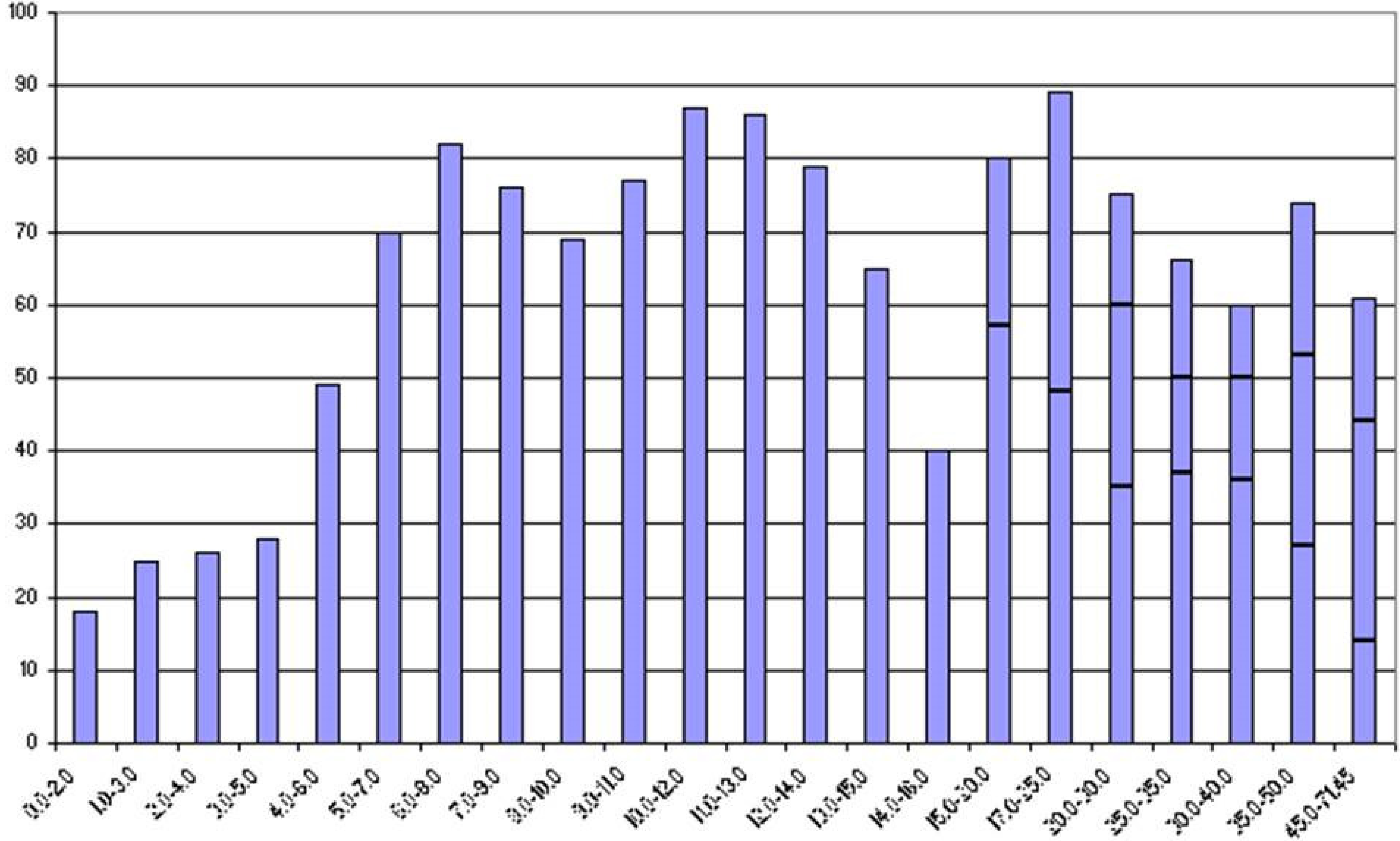
Thatcher, R.W. [1,2] and Lubar, J.F.[3]

Department of Neurology, University of South Florida College of Medicine, Tampa, Fl.[1] and EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, Fl[2] , Brain Research and Neuropsychology Lab, University of Tennessee, Knoxville, TN[3].

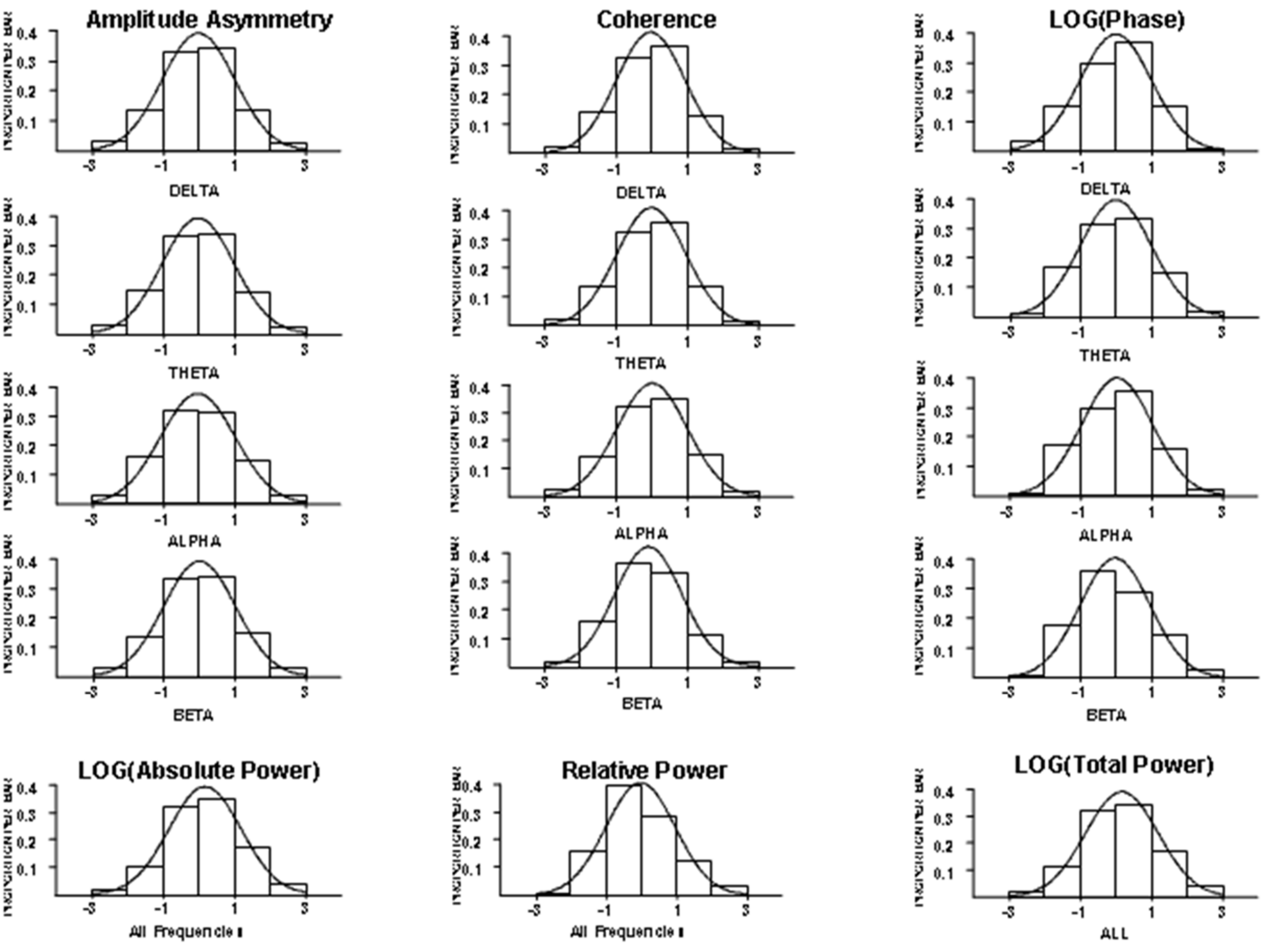
NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011



NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011

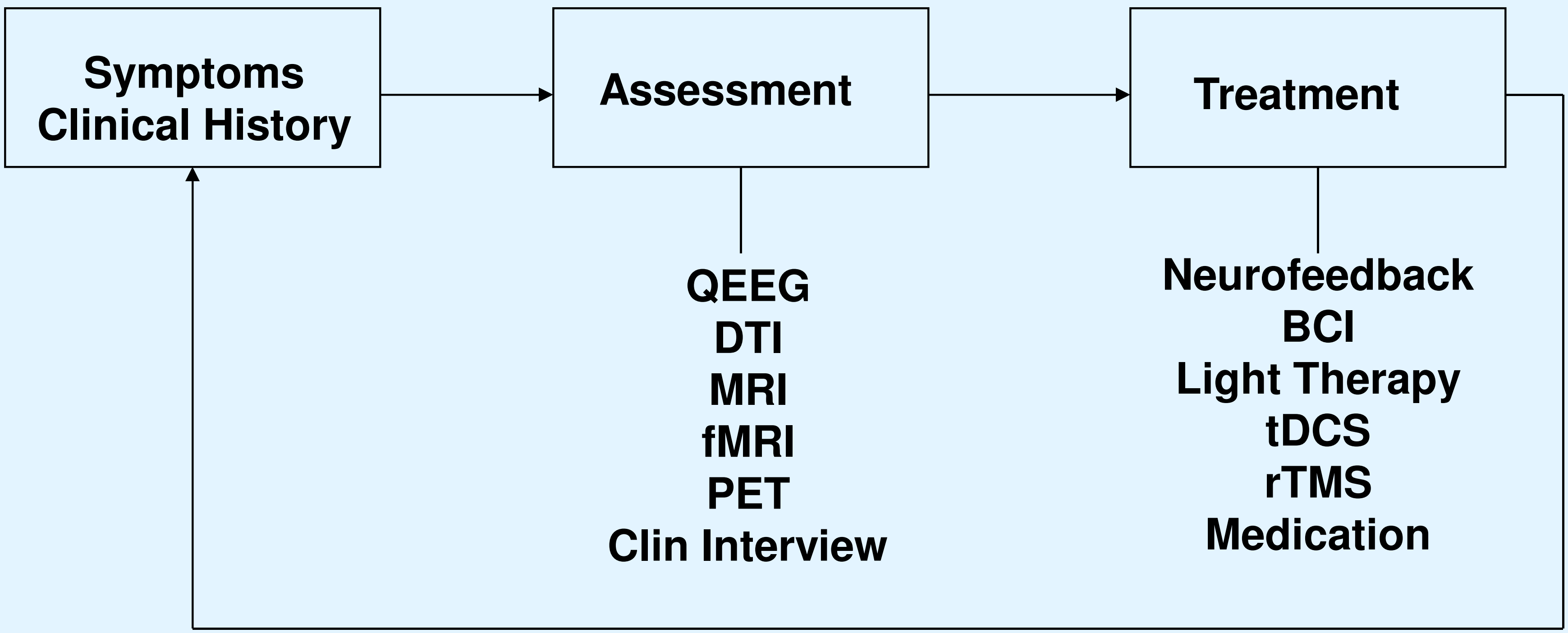


Cross-Validation Birth to 82 Year EEG Normative Database

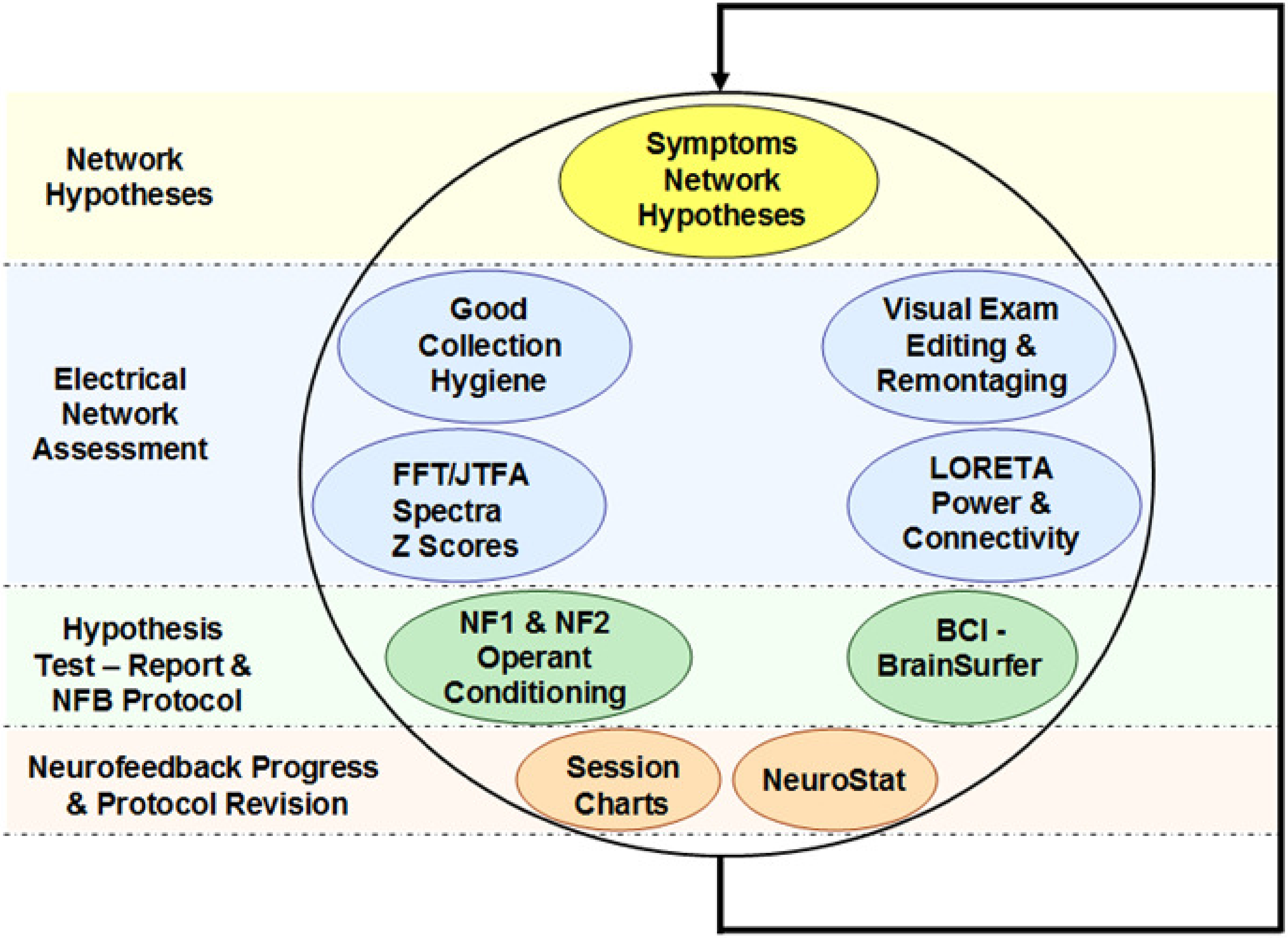


Essential Steps in Helping Patients with Neurological/Psychological Problems

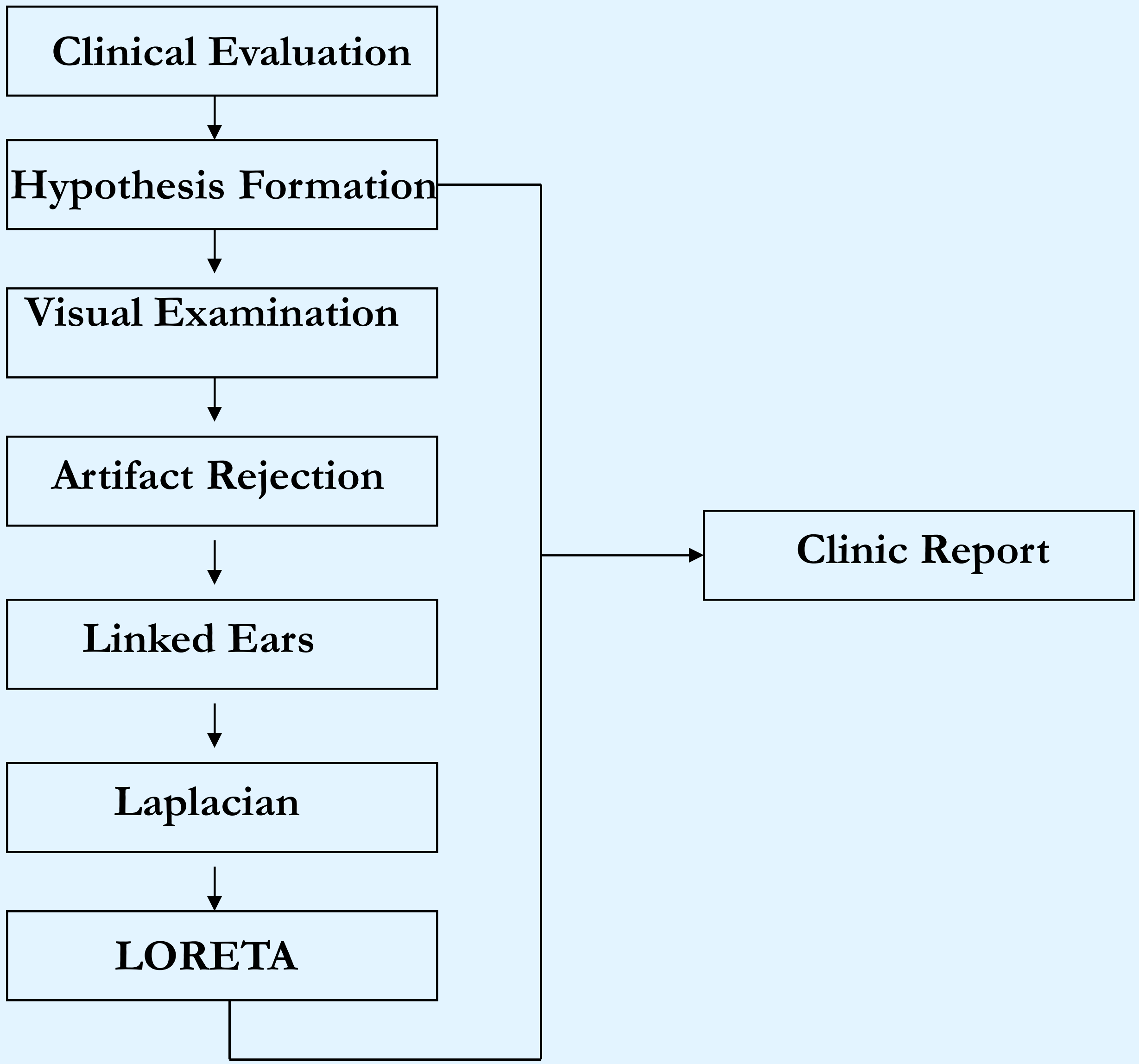
Assess, Address, Reassess …



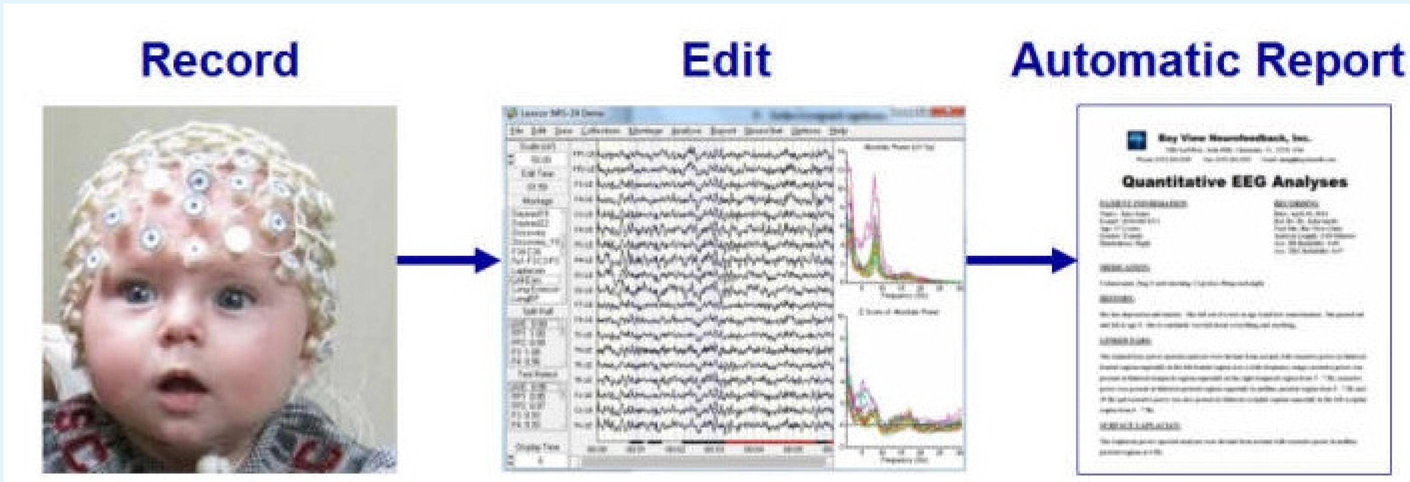
Linking Patient's Symptoms to Patient's Brain



QEEG Report Generation Sequence



Automatic Clinical Report Writer (ACR)



•No Delays with Minimal Expense for a Professional Quality In-House QEEG Clinical Report

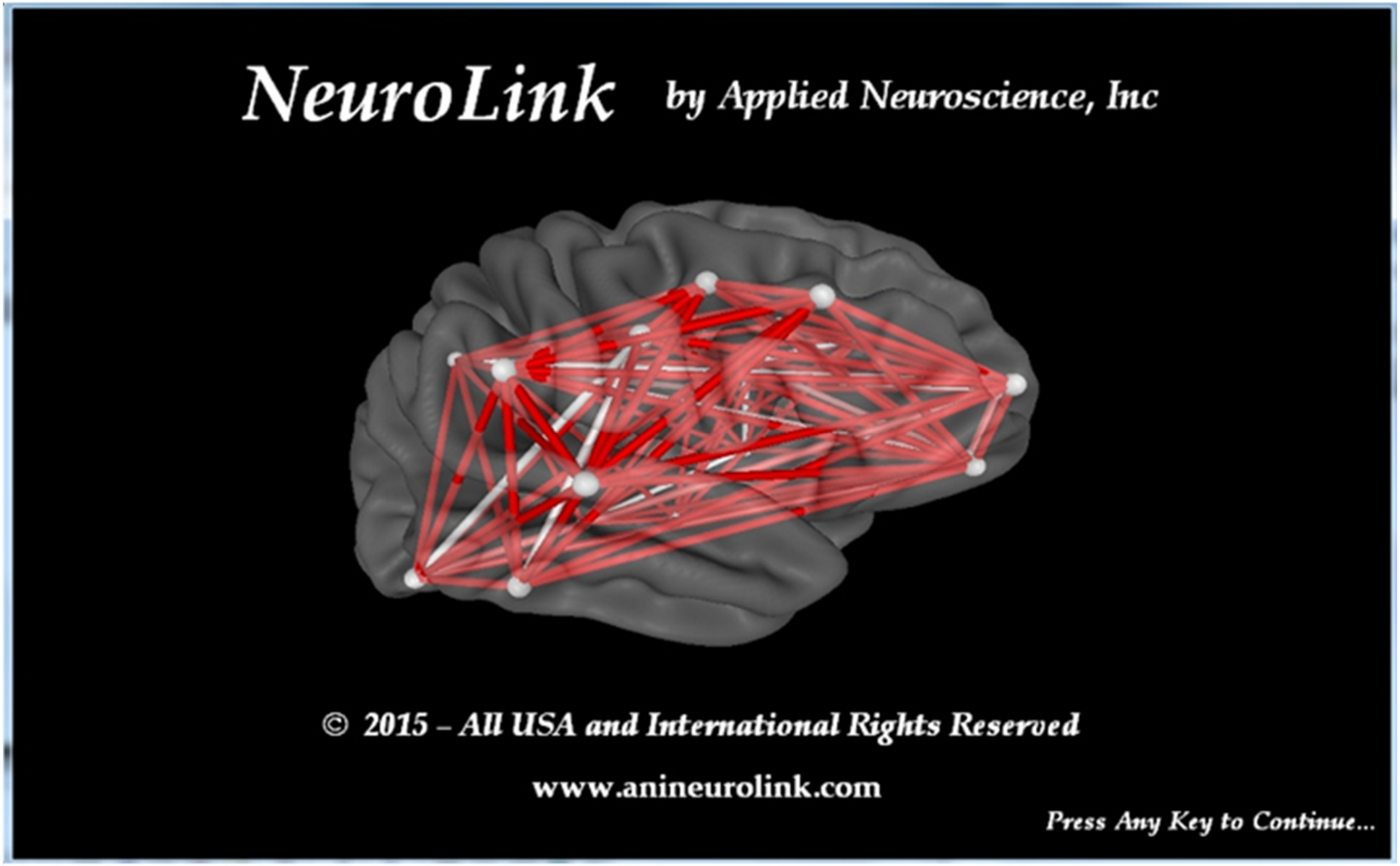
•Less than One Minute to Produce a Professional QEEG Clinical Report, in Microsoft Word format

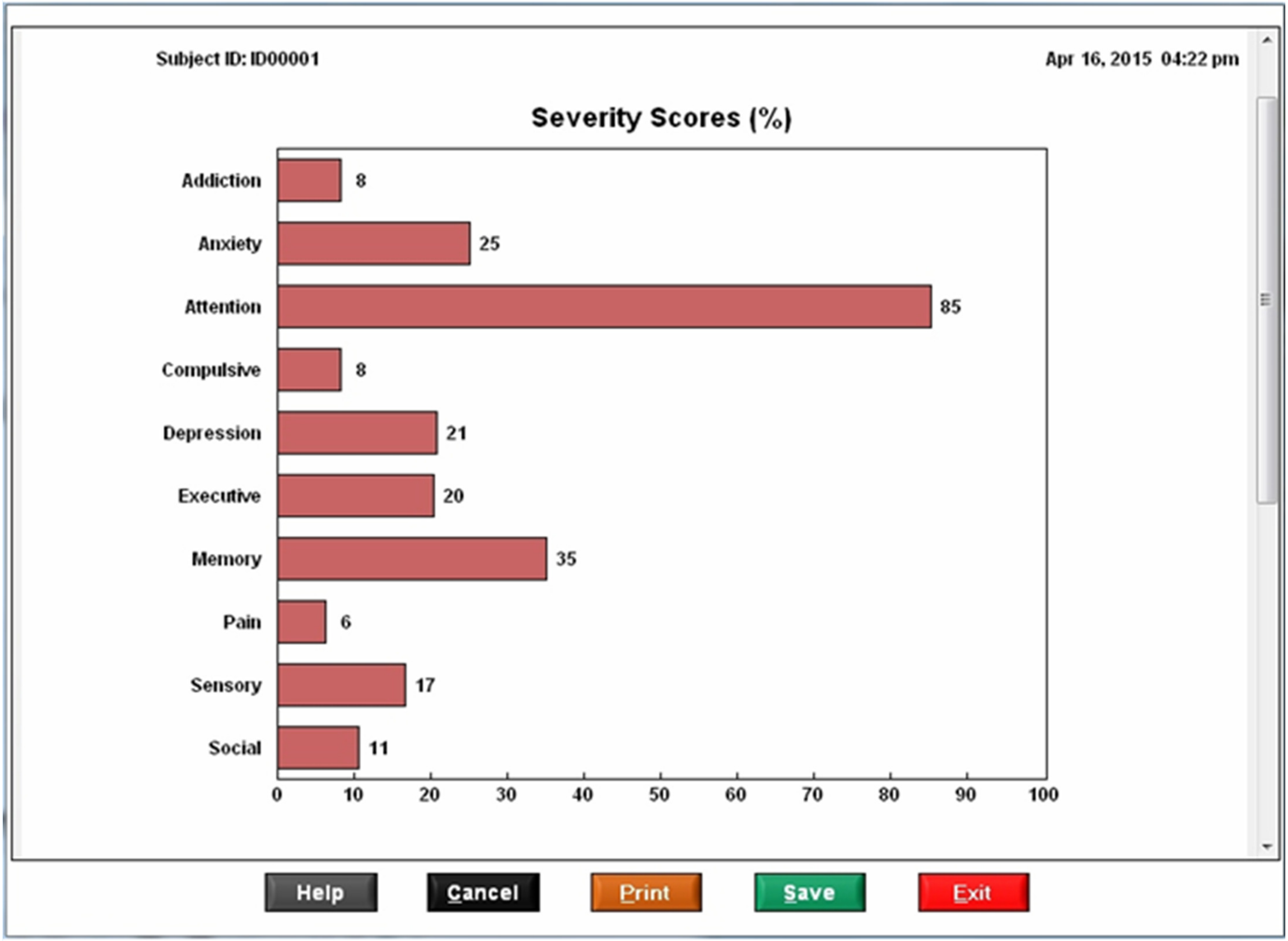
•ACR Provides: Empowerment, Simplicity, Accuracy & Efficiency!

•Get Valid Normative Database Comparisons using without Depending on Internet Q-EEG Report Services!

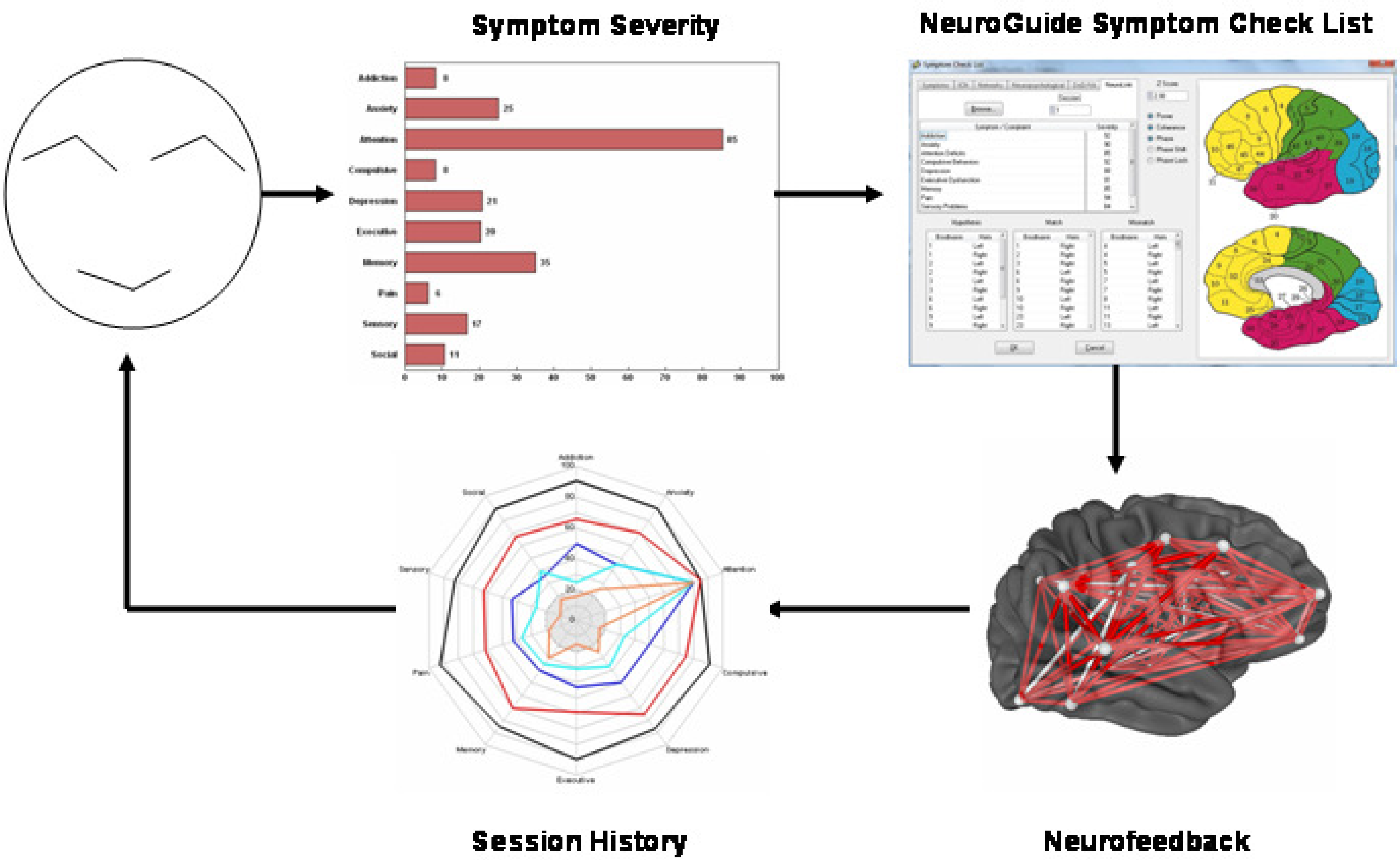
•Get Relevant Content and Displays, plus Helpful NFB Recommendations in Less than a Minute.

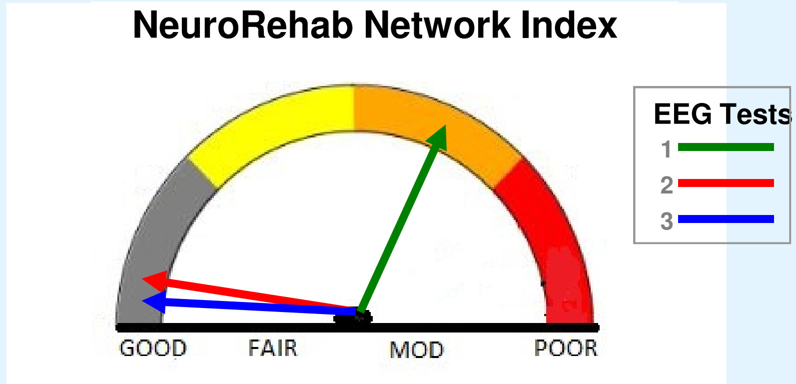
•Increased Productivity by at Least 10 Fold, e.g. Ten Reports in an Hour!


NeuroLink
by Applied Neuroscience, Inc
© 2015 – All USA and International Rights Reserved
www.anineurolink.com
Press Any Key to Continue...

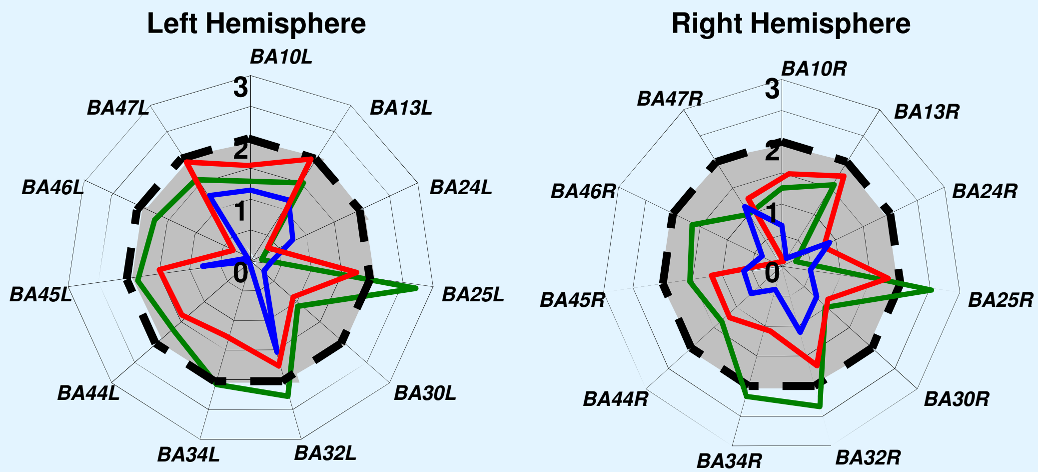

Subject ID: ID00001
Apr 16, 2015 04:22 pm
Severity Scores (%)
Addiction 8
Anxiety 25
Attention 85
Compulsive 8
Depression 21
Executive 20
Memory 35
Pain 6
Sensory 17
Social 11
0 10 20 30 40 50 60 70 80 90 100
Help
Cancel
Print
Save
Exit

NeuroLink and NeuroGuide Integration – Linking Symptoms to the Brain

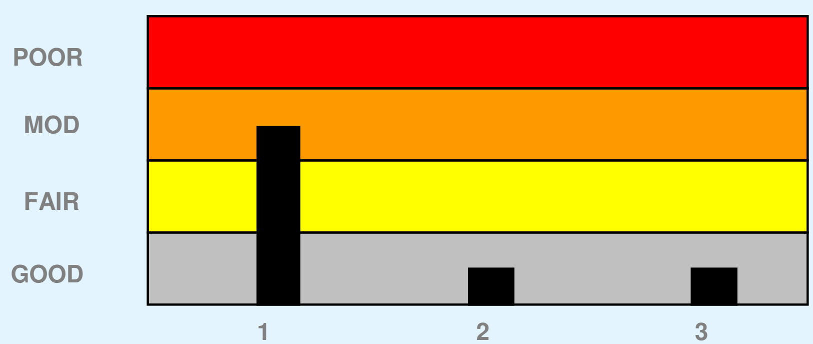


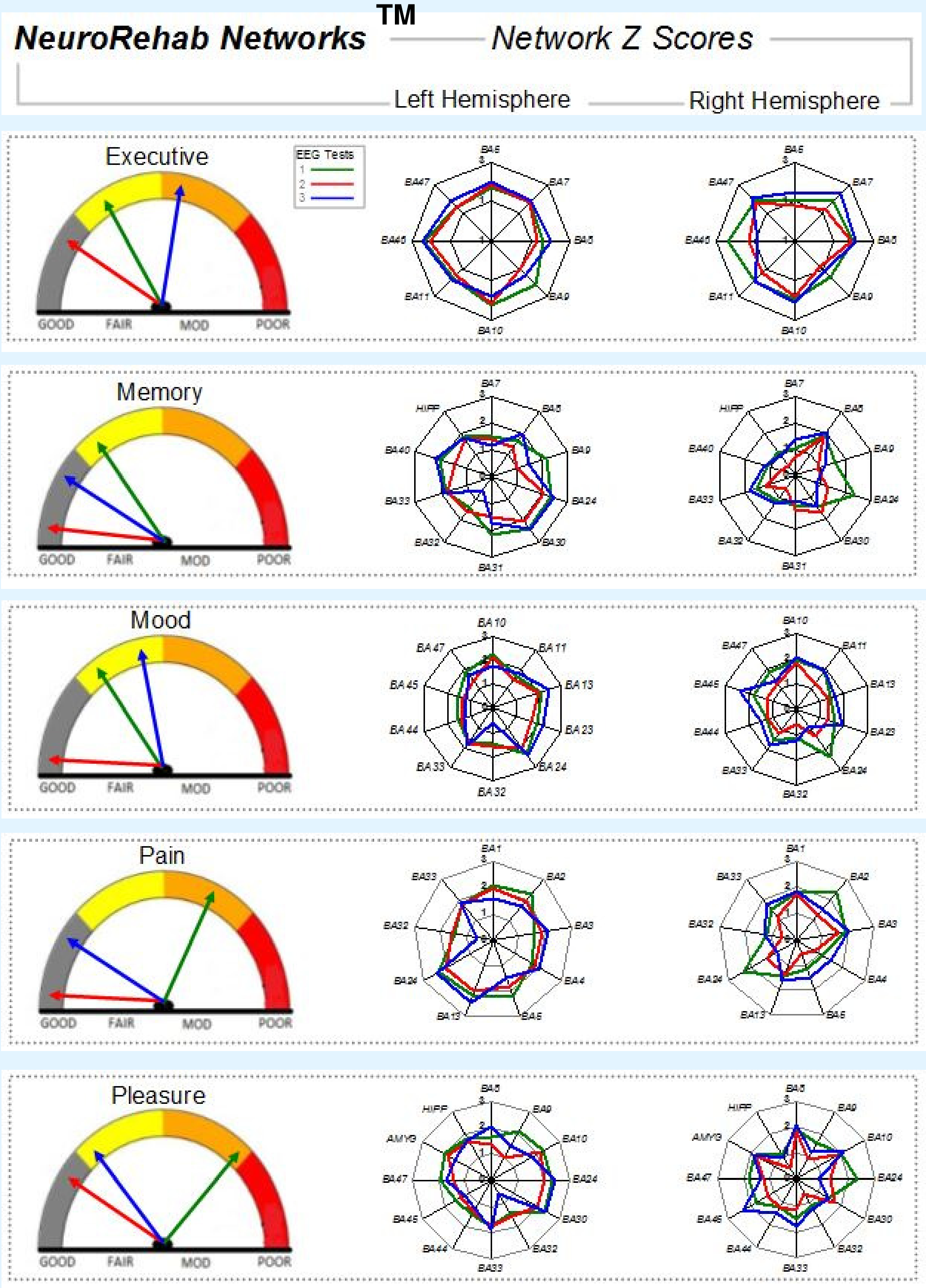


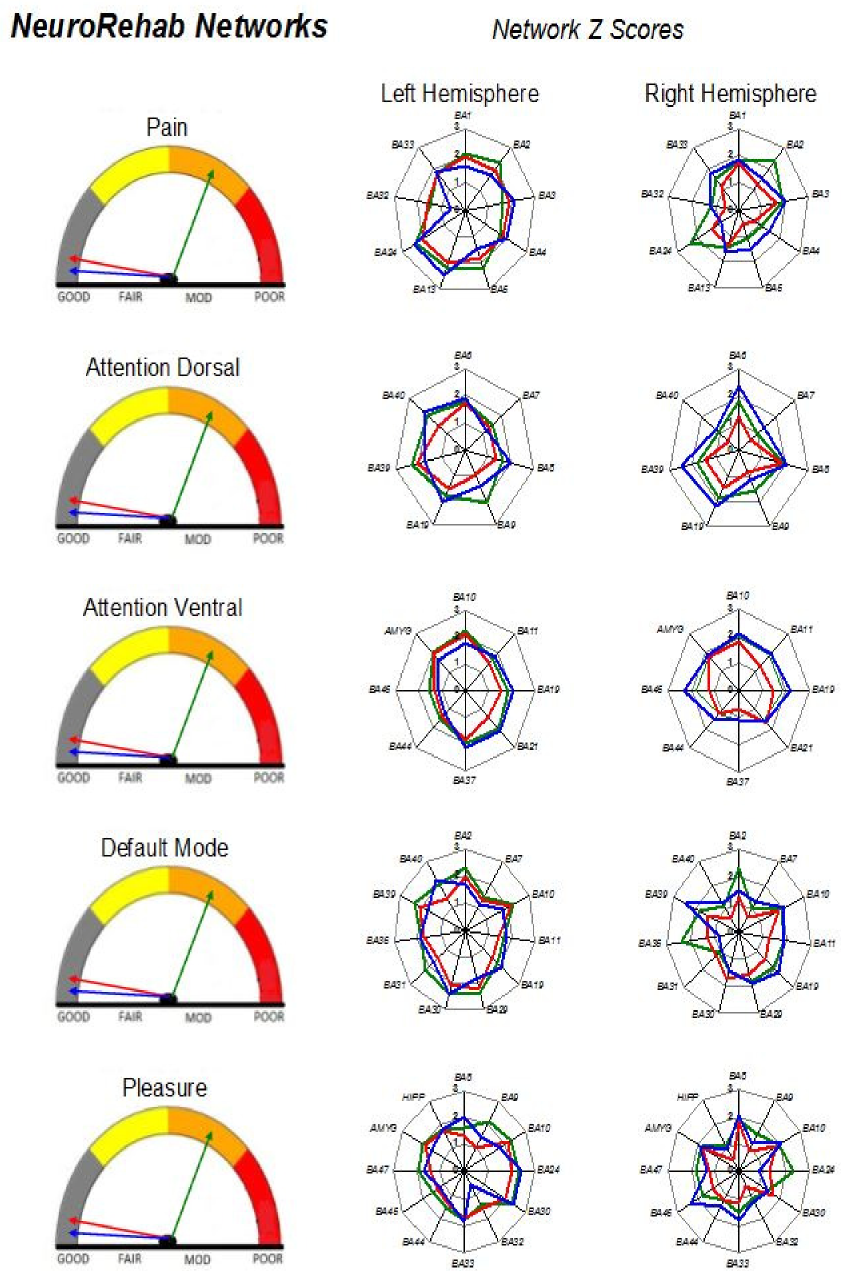
Addiction Network Z Scores



Rehabilitation History

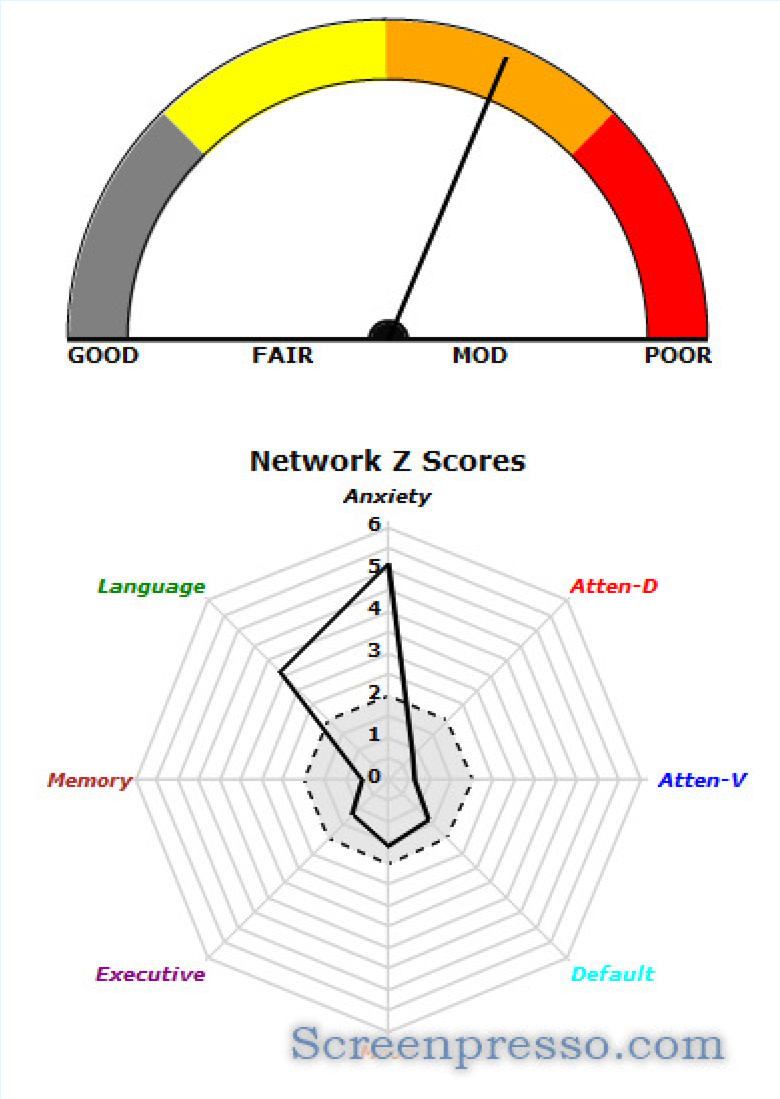


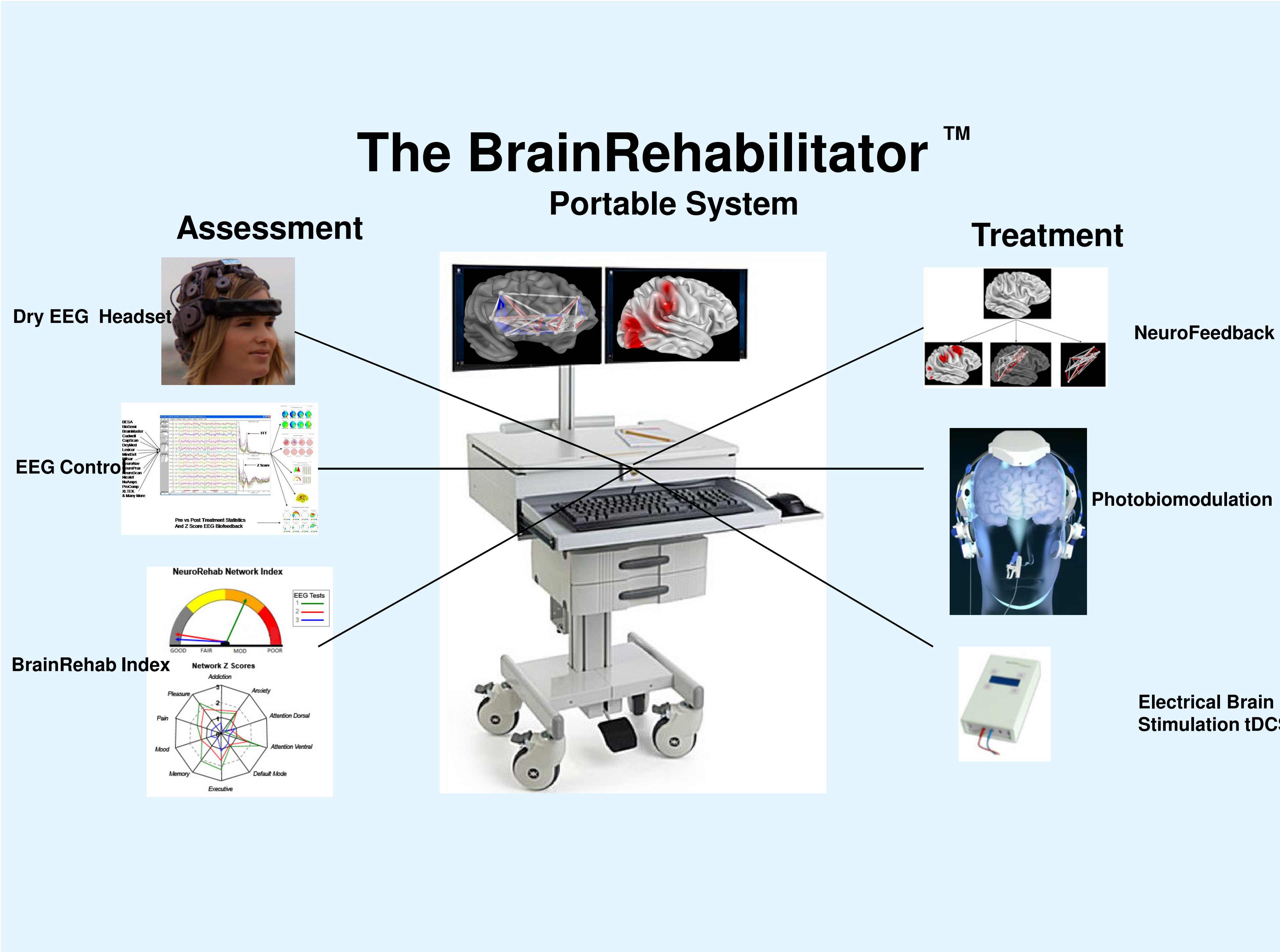

NeuroRehab Networks TM
Network Z Scores
Left Hemisphere
Right Hemisphere
Executive
EEG Tests
Memory
Mood
Pain
Pleasure
GOOD
FAIR
MOD
POOR



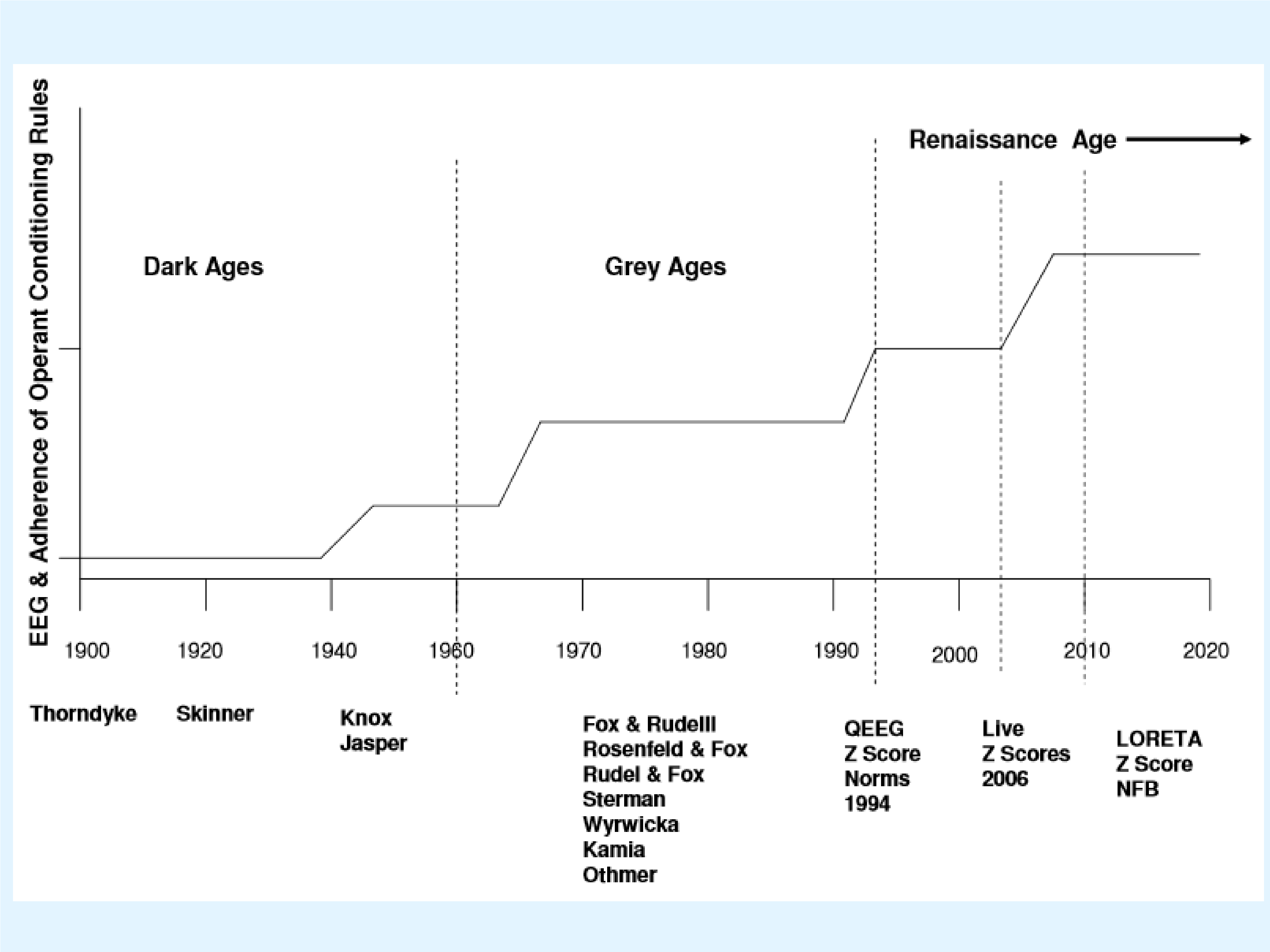
NeuroRehab Networks
Network Z Scores
Left Hemisphere
Right Hemisphere
Pain
Attention Dorsal
Attention Ventral
Default Mode
Pleasure
GOOD
FAIR
MOD
POOR

The BrainRehab Index





The BrainRehabilitator ™
Portable System
Assessment
Treatment
Dry EEG Headset
EEG Control
Pre vs Post Treatment Statistics
And Z Score EEG Biofeedback
FFT
Z Score
BrainRehab Index
NeuroRehab Network Index
EEG Tests
1
2
3
GOOD
FAIR
MOD
POOR
Network Z Scores
Addiction
Anxiety
Attention Dorsal
Attention Ventral
Default Mode
Executive
Memory
Mood
Pain
Pleasure
NeuroFeedback
Photobiomodulation
Electrical Brain
Stimulation tDCS



EEG & Adherence of Operant Conditioning Rules
Renaissance Age
Dark Ages
Grey Ages
1900
1920
1940
1960
1970
1980
1990
2000
2010
2020
Thorndyke
Skinner
Knox
Jasper
Fox & Rudelll
Rosenfeld & Fox
Rudel & Fox
Sterman
Wyrwicka
Kamia
Othmer
QEEG
Z Score
Norms
1994
Live
Z Scores
2006
LORETA
Z Score
NFB

What is the Future for Z Score Neurofeedback?

1- Expanding Number or Clinicians Using Z Score NFB

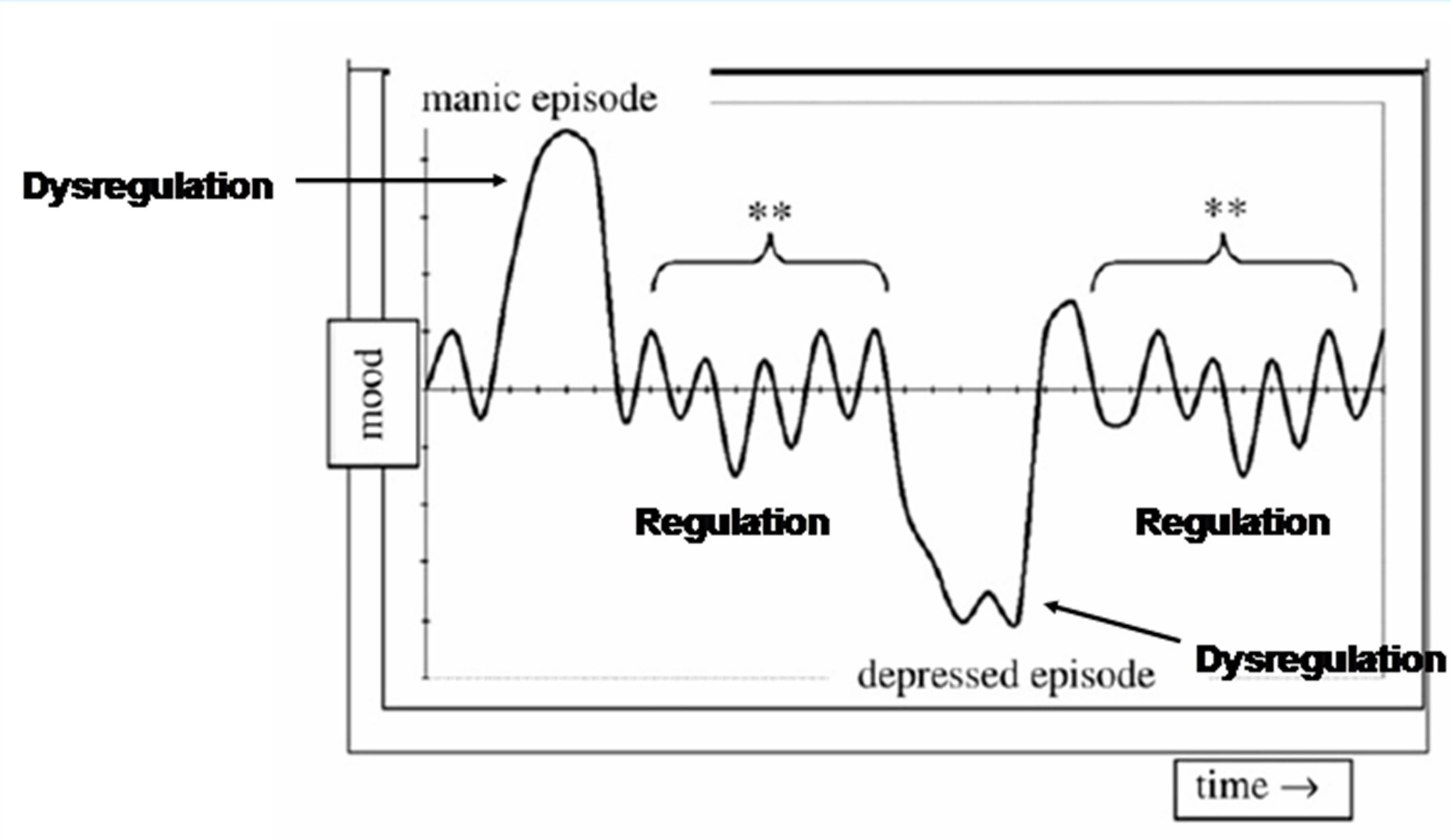
2- Expanding Number of Metrics:

- a- Effective Connectivity
- b- Cross-Frequency Coherence
- c- Cross-Frequency Effective Connectivity
- d- Phase Amplitude Cross-Frequency Coupling
- e- swLORETA – Individualized MRI & NFB

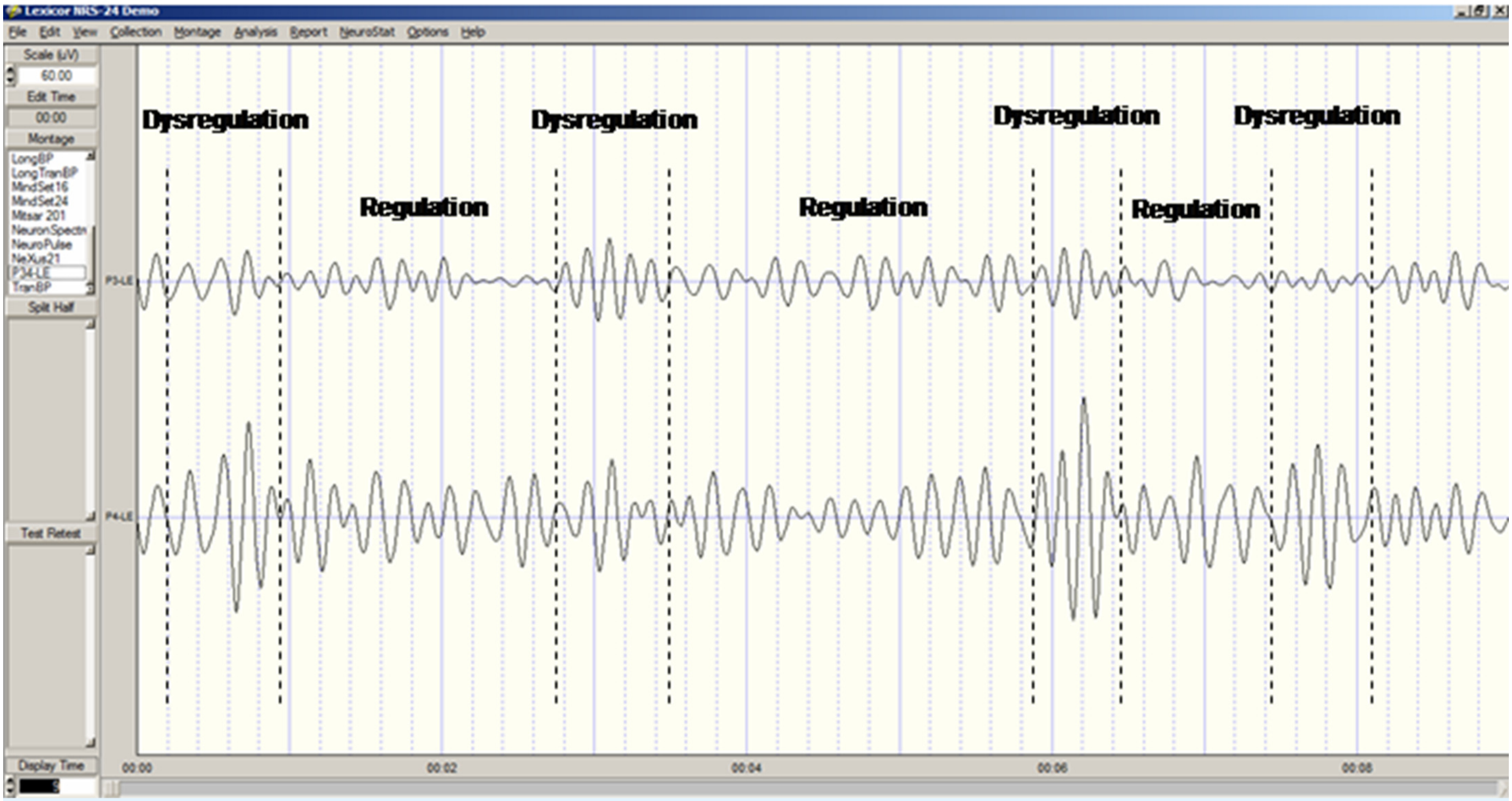
3- New Brain Imaging Technology

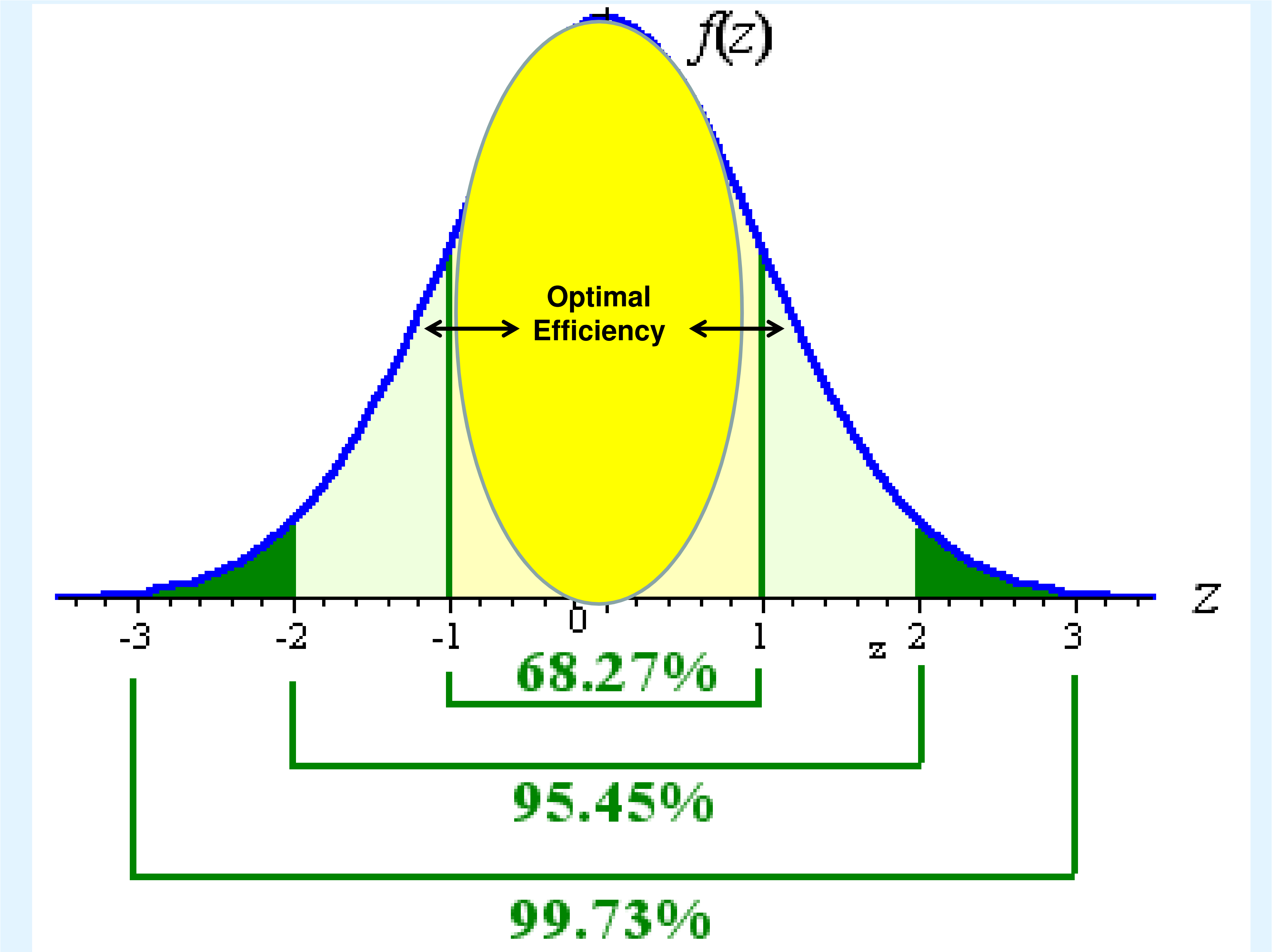
4- Smart Phone and Tablet Techology

Moment-to-Moment “Regulation” and “Dysregulation”



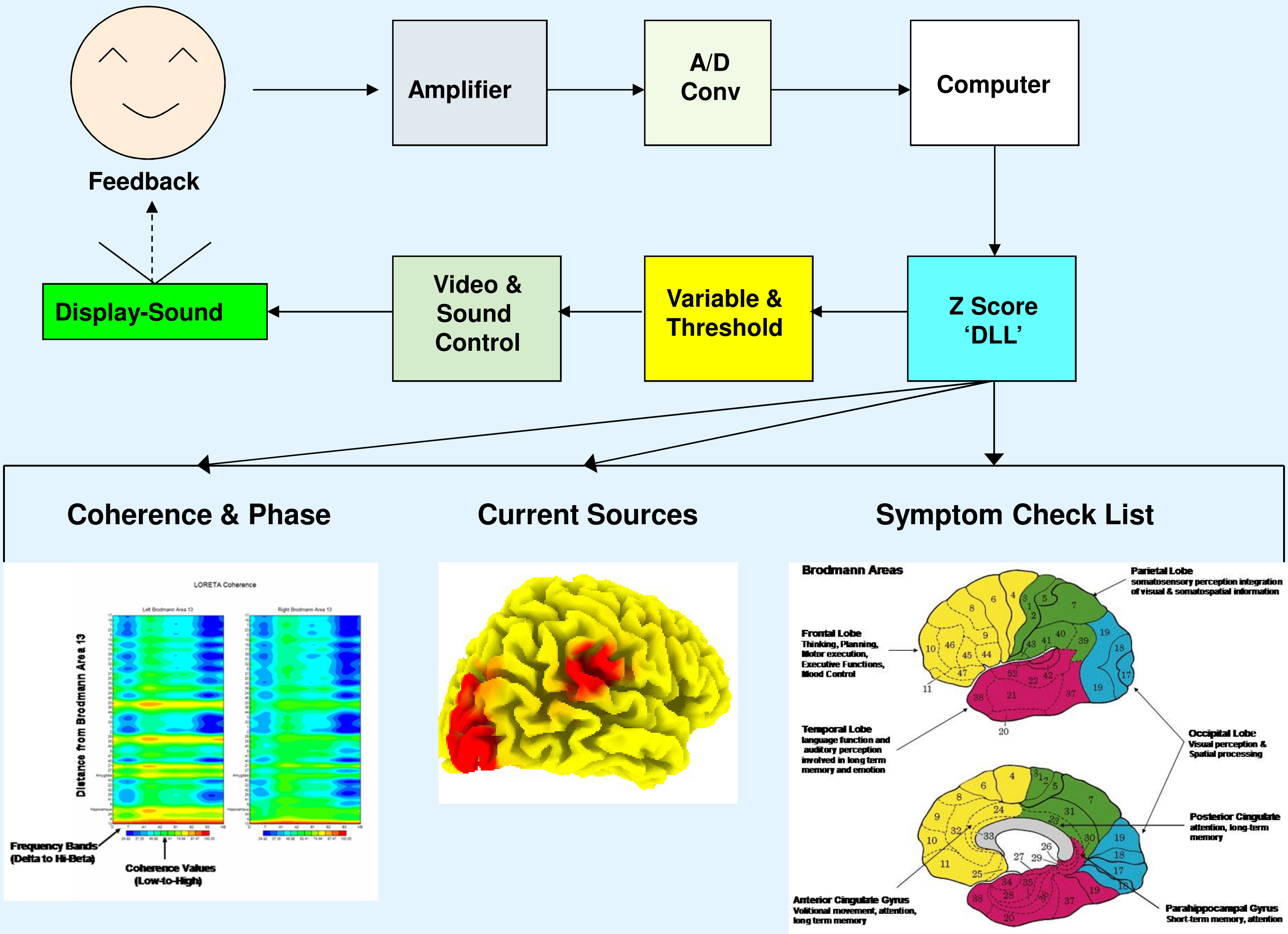
TBI Demo Right Parietal Lobe Alternating Degrees of Regulation Biofeedback's Goal is to Reduce the Frequency, Duration and Intensity of Dysregulation





f(z)
Optimal
Efficiency
Z
-3
-2
-1
0
1
z
2
3
68.27%
95.45%
99.73%

Neuroimaging Neurofeedback - Fort Campbell



LMU

KLINIKUM
DER UNIVERSITÄT MÜNCHEN

DEPARTMENT OF PSYCHIATRY

INSTITUTE OF CLINICAL RADIOLOGY

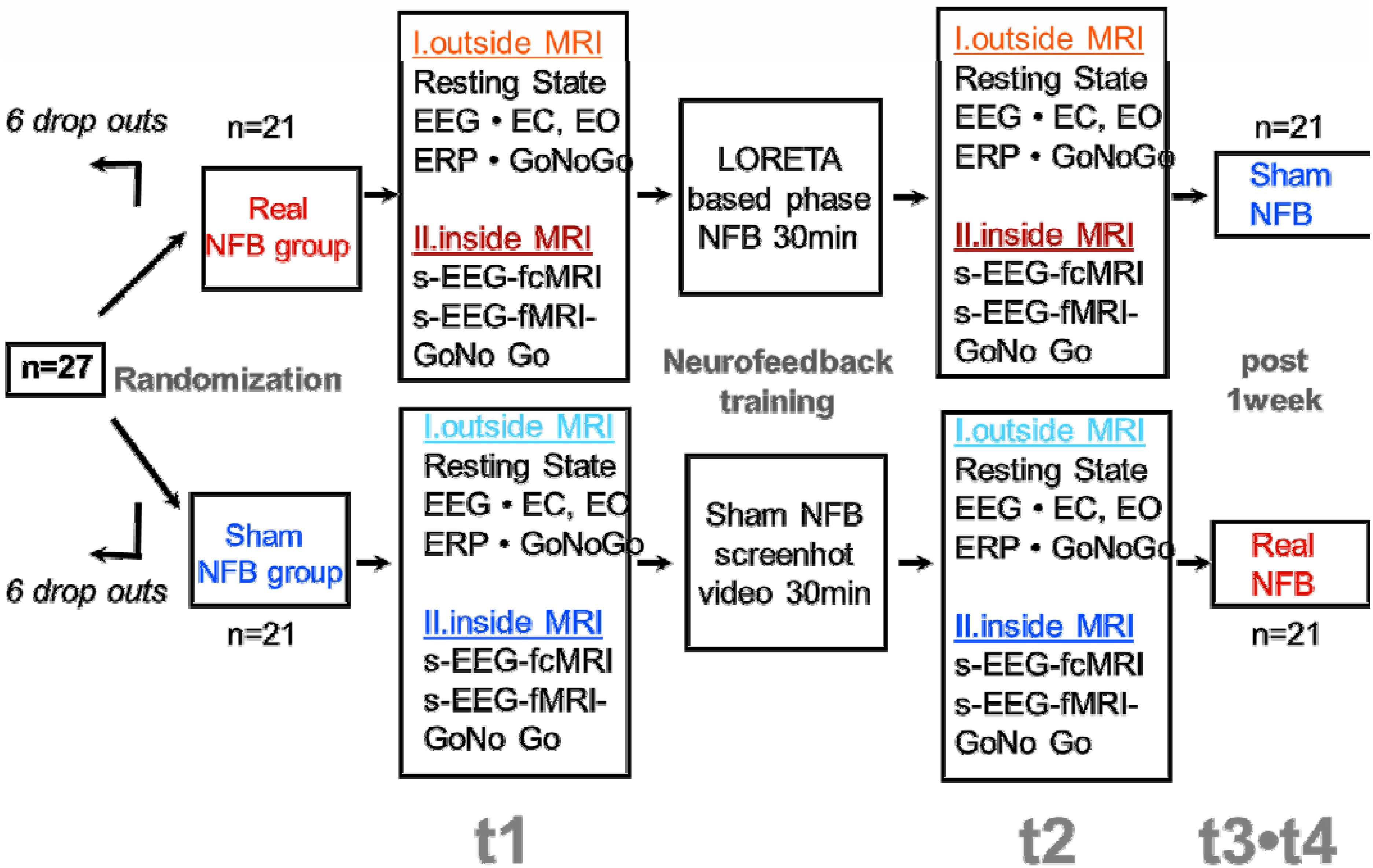
The impact of source-localized EEG phase neurofeedback on brain activity

A double-blinded placebo-controlled study using simultaneously EEG-fMRI – preliminary results

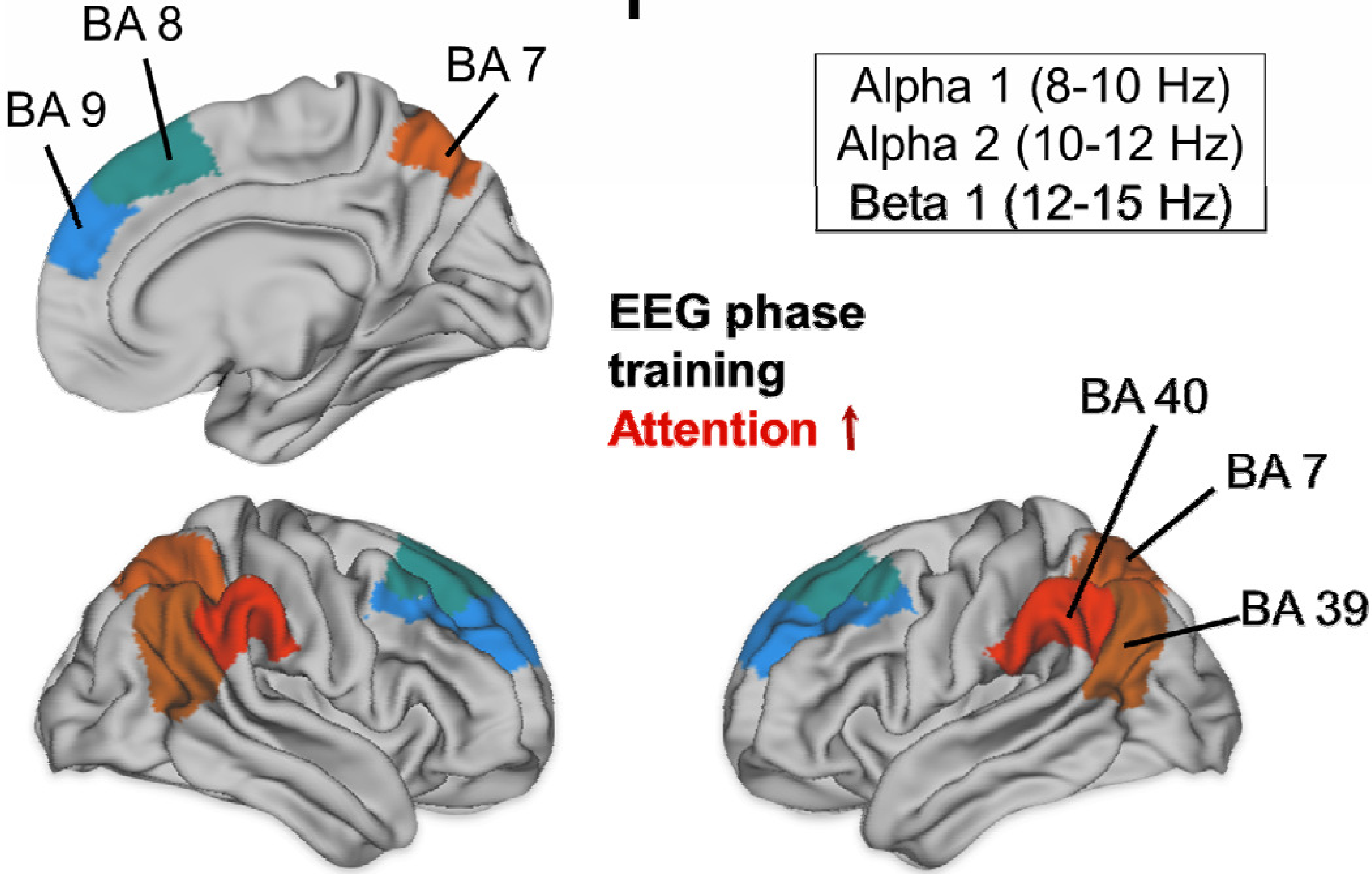
Daniel Keeser

Valerie Kirsch, Boris Rauchmann, Brian Stamm, Paul Reidler, Robert Thatcher, Susanne Karch, Oliver Pogarell, Birgit Ertl-Wagner

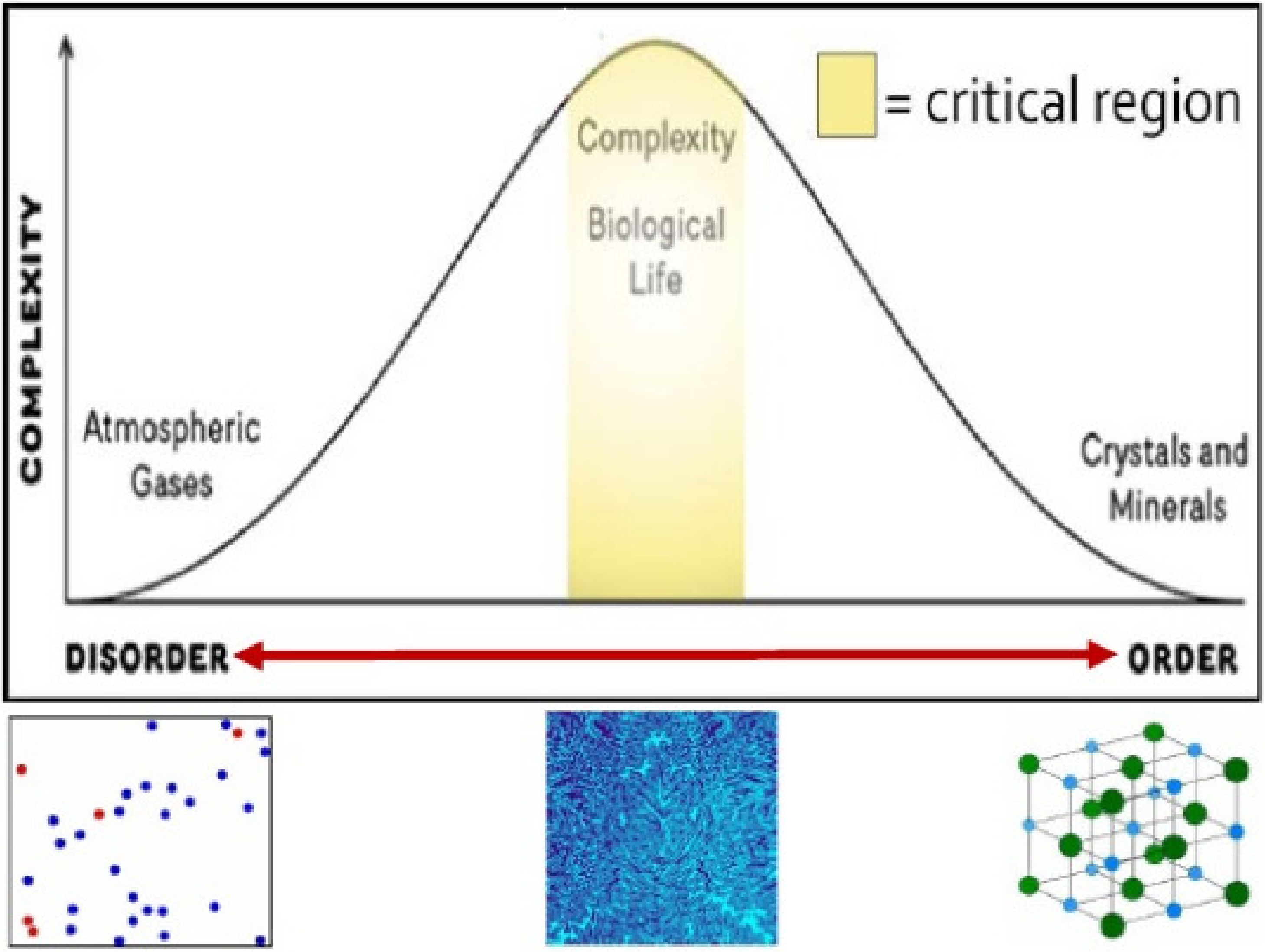
s-EEG-fcMRI neurofeedback study design



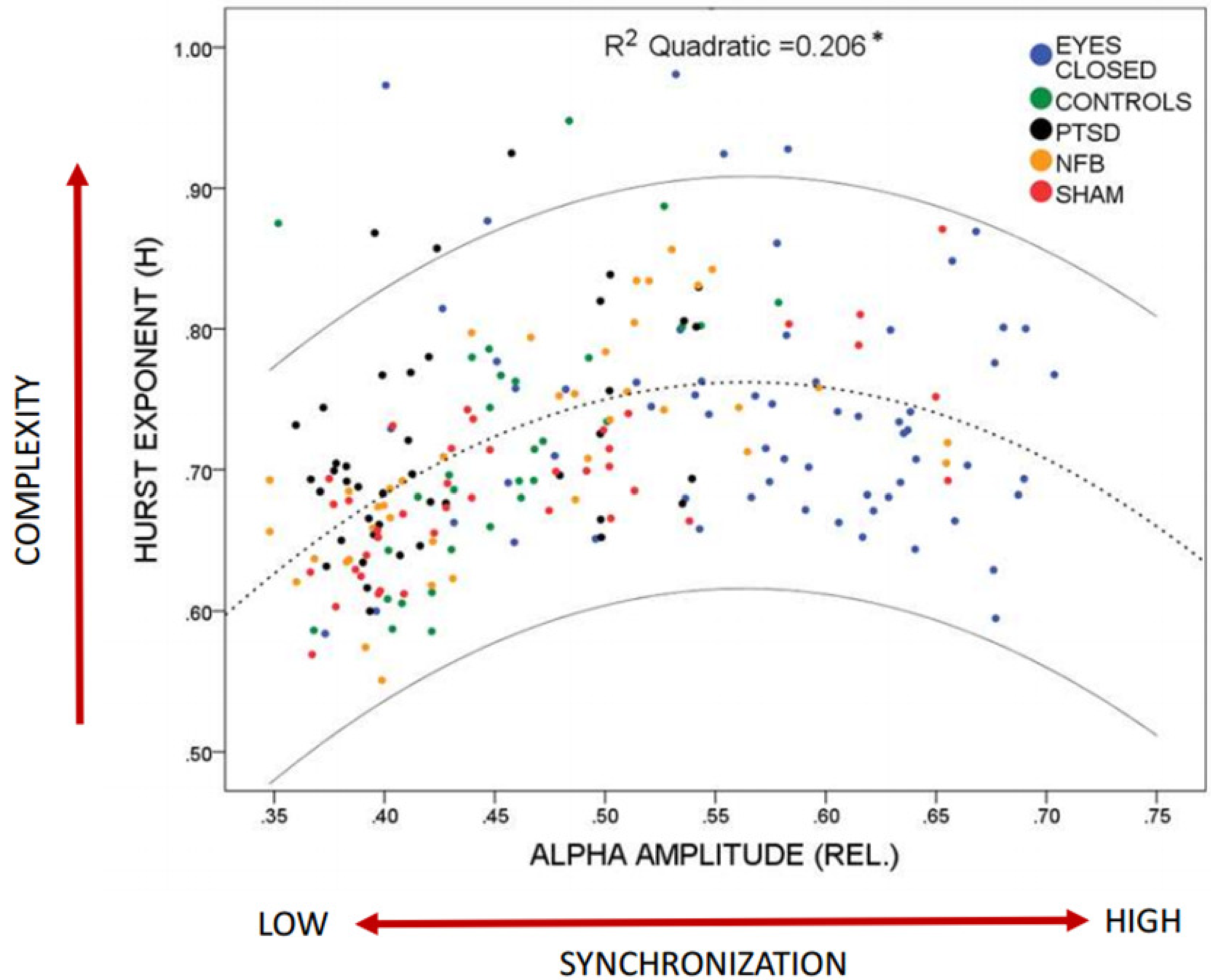
NFB protocol



The Theory of Self-Organised Criticality

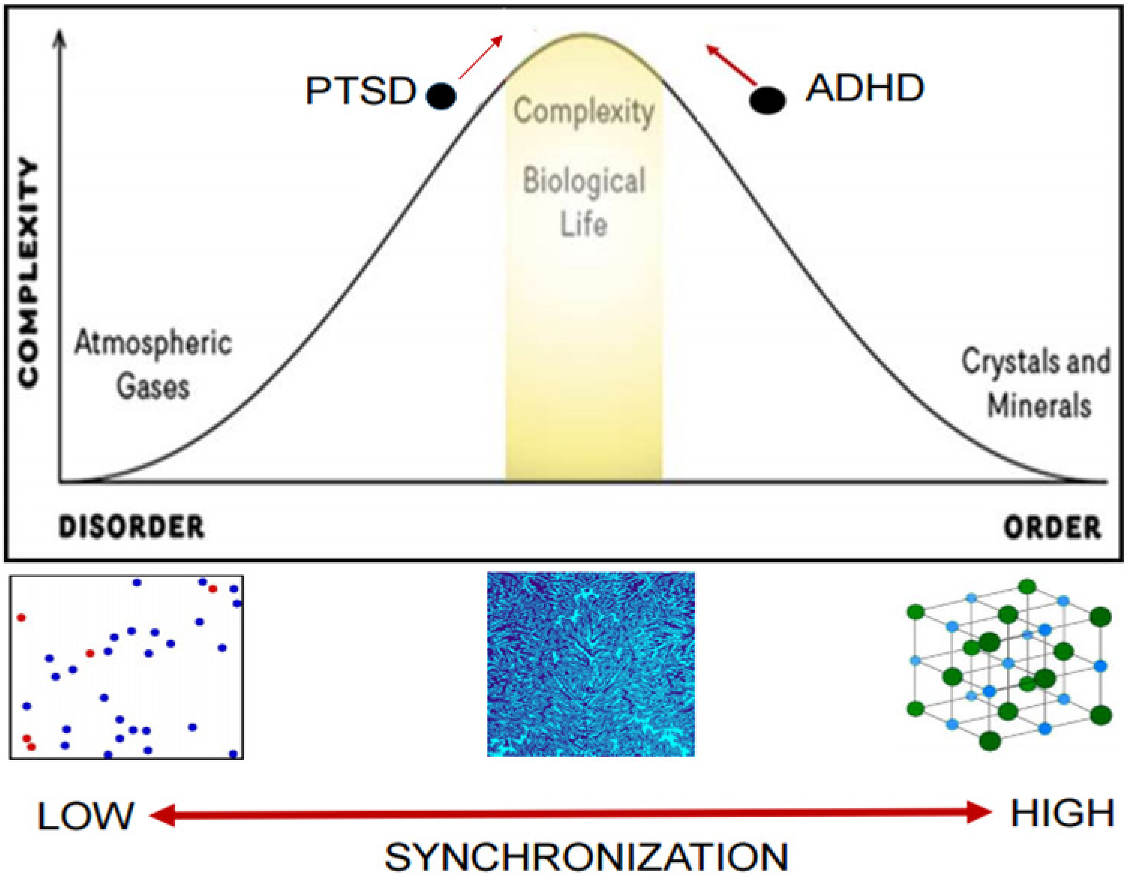


Tuning-pathological-brain-oscillations-Thomas Ros- 2016



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

Self-Organised Criticality: a potential mechanism?



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

frontiers in
HUMAN NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE
published: 18 December 2014
doi: 10.3389/fnhum.2014.01008

Tuning pathological brain oscillations with neurofeedback: a systems neuroscience framework

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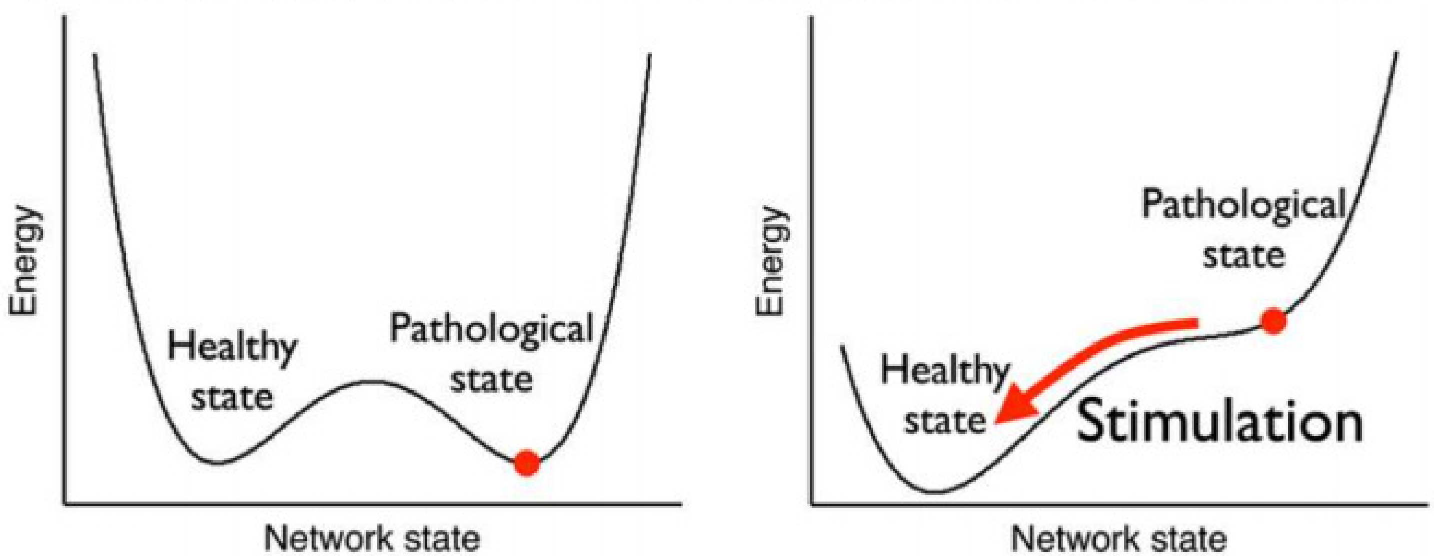


Select a Network or Symptoms, Frequency and Metric

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Network	Severity
Addiction	0
Anxiety	0
Attention - Dorsal	0
Attention - Ventral	0
Attention - Emotional	0
Default Mode	0
Executive Function	0
Face, Object Recognition	0
Language	0
Memory - Emotion	0
Mirror Neuron	0
Mood	0
Pain	0
Pleasure	0
Salience	0
Schizophrenia	0
Working Memory	0
DTI - Frontal Limbic	0
DTI - Frontal Occipital	0
DTI - Frontal Parietal	0
DTI - Frontal Temporal	0
DTI - Local Frontal	0
DTI - Local Limbic	0
DTI - Local Occipital	0
DTI - Local Parietal	0
DTI - Local Temporal	0
Hagmann Module 1 (Vision)	0
Hagmann Module 2 (Attention, Working Memory)	0
Hagmann Module 3 (Auditory, Language, Memory)	0
Hagmann Module 4 (Auditory, Language, Memory)	0
Hagmann Module 5 (Executive, Sequential Planning)	0
Hagmann Module 6 (Executive, Social Skills)	0
Isocortex Hippocampocentric	0
Isocortex Olfactocentric	0
Mesocortex Hippocampocentric	0
Mesocortex Olfactocentric	0
Mesulam - Emotional Memory	0
Mesulam - Executive Function	0
Mesulam - Face/Object Indentification	0
Mesulam - Language	0
Mesulam - Spatial Attention	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Intrinsic Connectivity Network	Severity
ICN 1 (Limbic, Medial-Temporal, Emotion)	0
ICN 2 (Reward, Emotion)	0
ICN 4 (Language, Executive)	0
ICN 6 (Premotor, Supplemental Motor)	0
ICN 7 (Visual-Spatial Processing)	0
ICN 8, 17 (Primary Sensory Motor)	0
ICN 9 (Parietal)	0
ICN 10 (Picture Naming, Visual Tracking)	0
ICN 11, 12 (Visual System)	0
ICN 13 (Default Mode Network)	0
ICN 15 (Right Hemisphere, Attention, Reasoning, Memory)	0
ICN 16 (Auditory, Music)	0
ICN 18 (Left Hemisphere, Language)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Neuropsychological Diagnosis	Severity
Agnosia of Action Apperceptive	0
Agnosia of Action Associative	0
Agnosia Auditory Apperceptive	0
Agnosia Auditory Associative	0
Agnosia Auditory Space	0
Agnosia Prosopagnosia (Face)	0
Agnosia Social Emotional	0
Agnosia Social of Action - Theory of Mind	0
Agnosia Somatosensory Autotopagnosia	0
Agnosia Somatosensory Finger	0

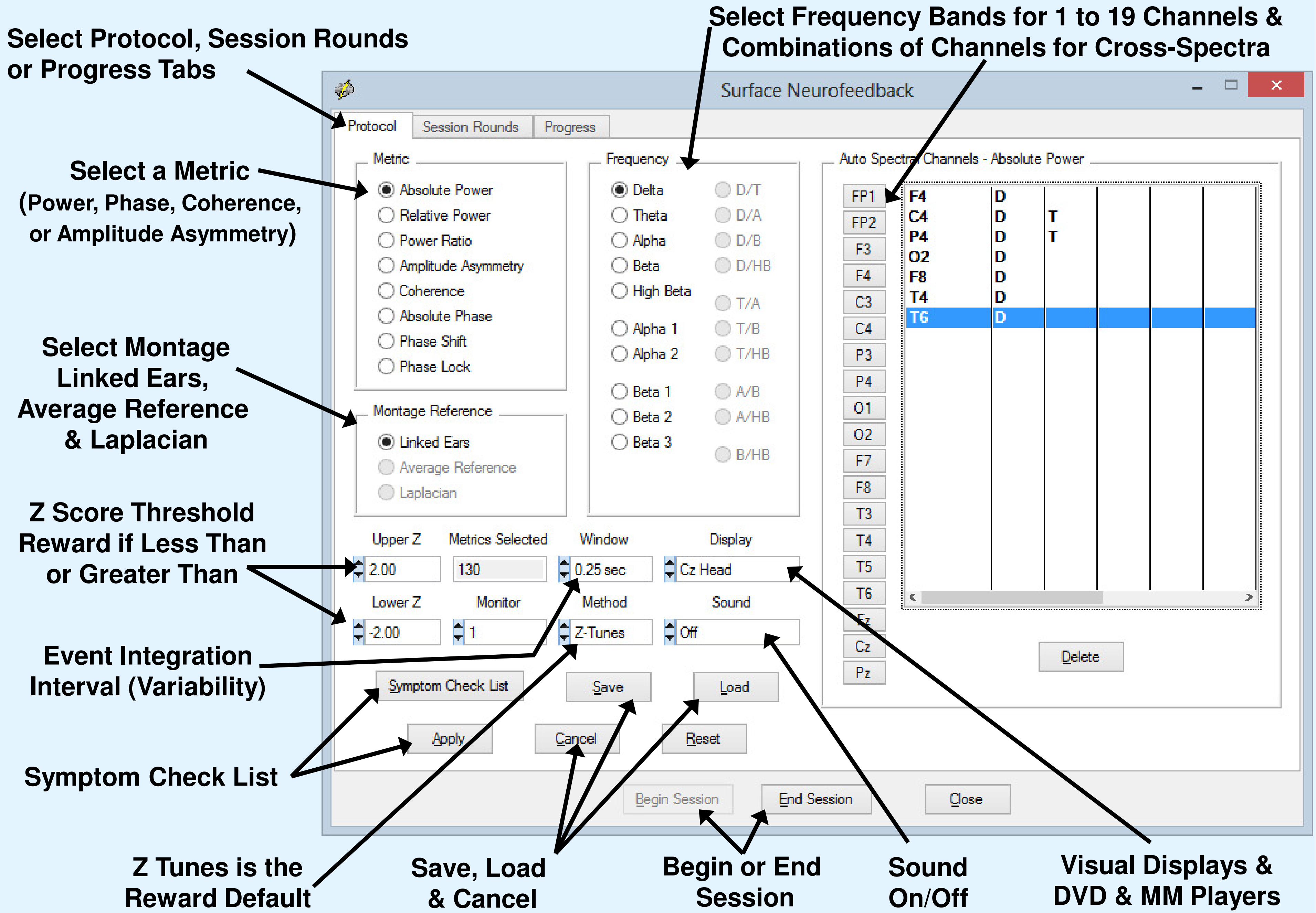
Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Attention - Re-Experiences Intrusive Memories	0
Attention - Emotional Numbing	0
Attention - Distracting Pain	0
Attention - Difficulty Multi-Tasking	0
Attention - Worsens with Emotional Stress	0
Attention - Dissociative Episodes	0
Attention - Worsens With Withdrawl Symptoms	0
Chronic Pain - Neuropathic	0
Chronic Pain - Musculoskeletal	0
Chronic Pain - Diffuse Pain (Entire Body)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Anosognosia - Denial of a Problem	0
Anxiety	0
Attention Deficits - Easily Distractible	0
Auditory Sequencing Problems	0
Balance Problems	0
Blurred Vision	0
Chronic Pain	0
Compulsive Behaviors and/or Thoughts	0
Concentration Problems	0
Decreased Tactile or Skin Sensitivity	0
Delusional	0
Depression (Sad & Blue)	0
Difficulty Comprehending Social Cues	0
Dyscalculia - Problems Calculating	0
Dyslexia - Letter Reversal	0
Executive Function Problems	0
Face Recognition Problems	0
Failure to Initiate Actions	0
Hyperactive and/or Agitation	0
Impulsive Behaviors	0
Insensitive to Others Emotional Expressions	0
Insensitive to Other's Feelings	0
Low Motivation	0
Low Threshold for Anger & Loss of Control	0
Migrane Headaches	0
Mood Swings	0
Multi-Tasking Problems	0
Obsessive Thoughts about Self	0
Obsessive Thoughts and/or Hyper Focused	0
Oppositional Defiant Conduct	0
Orientation in Space Problems	0
Perception of Letters Problems	0
Poor Judgement	0
Poor Skilled Motor Movements	0
Poor Social Skills	0
Receptive Language Problems	0
Recognizing Objects by Touch Problems	0
Self-Esteem Problems	0
Sequential Planning Problems	0
Short-Term Memory Problems	0
Slow Reader	0
Slowness of Thought - Easily Confused	0
Spatial Perception Problems	0
Speech Articulation Problems	0
Substance Abuse	0
Symptoms of Fibromyalgia	0
Word Finding Problems	0

Z Score Neurofeedback Panel



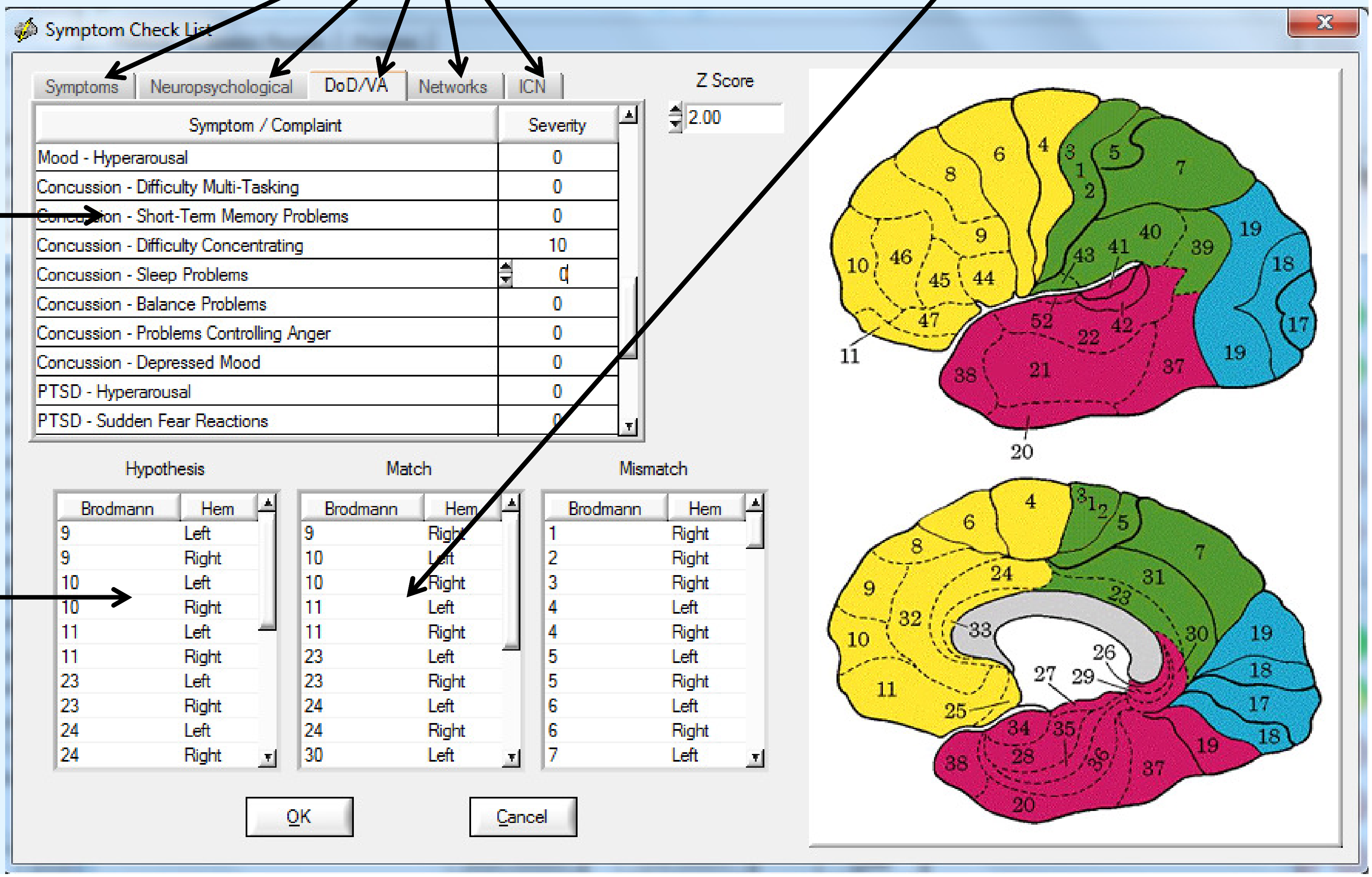
Neuroimaging Neurofeedback Symptom Check List

Click Symptoms or Neuropsychological Diagnoses or DoD/VA List or Networks & Severity

List of Matching Brodmann Areas

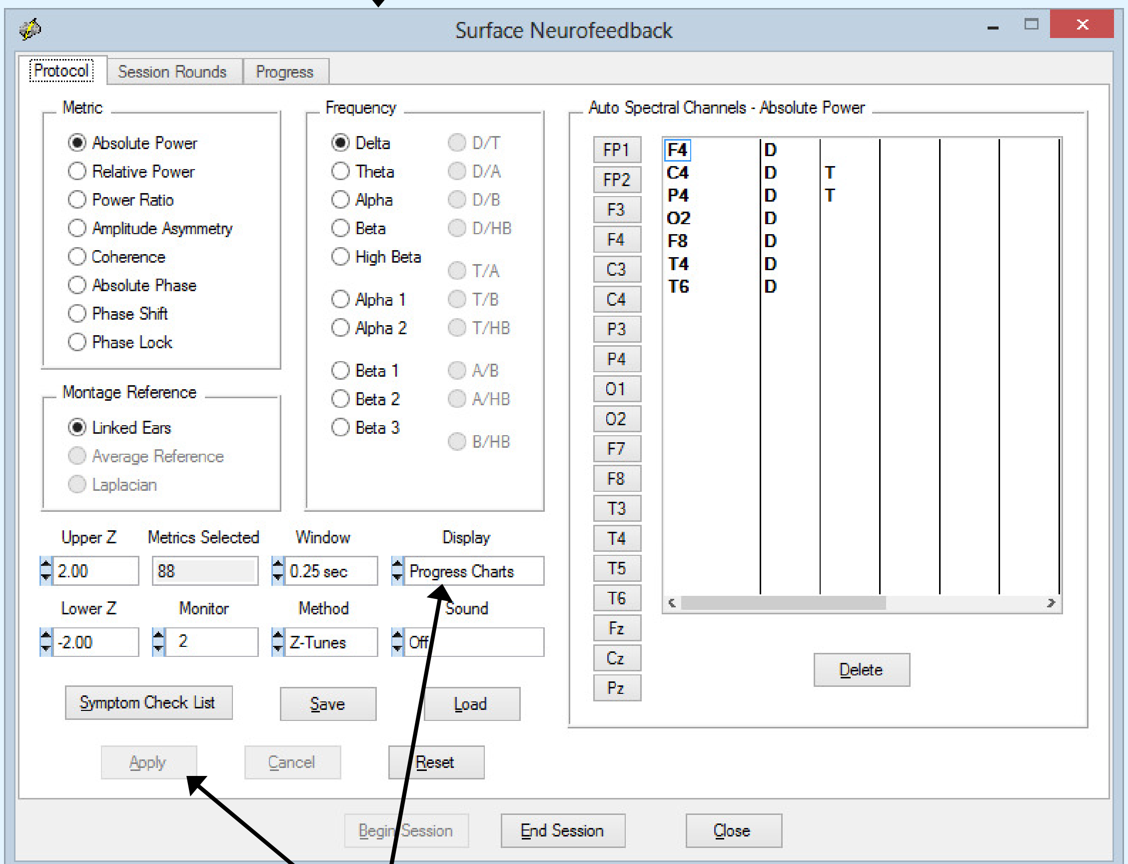
List of Symptoms

Anatomical Hypotheses

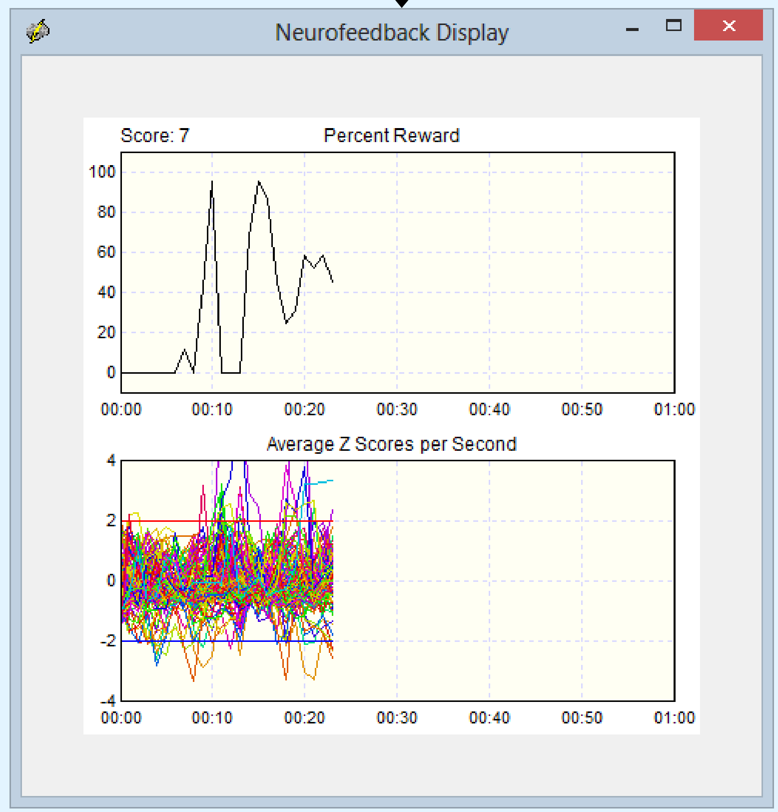


Use the Progress Chart as a Feedback Display

Neurofeedback Setup Panel



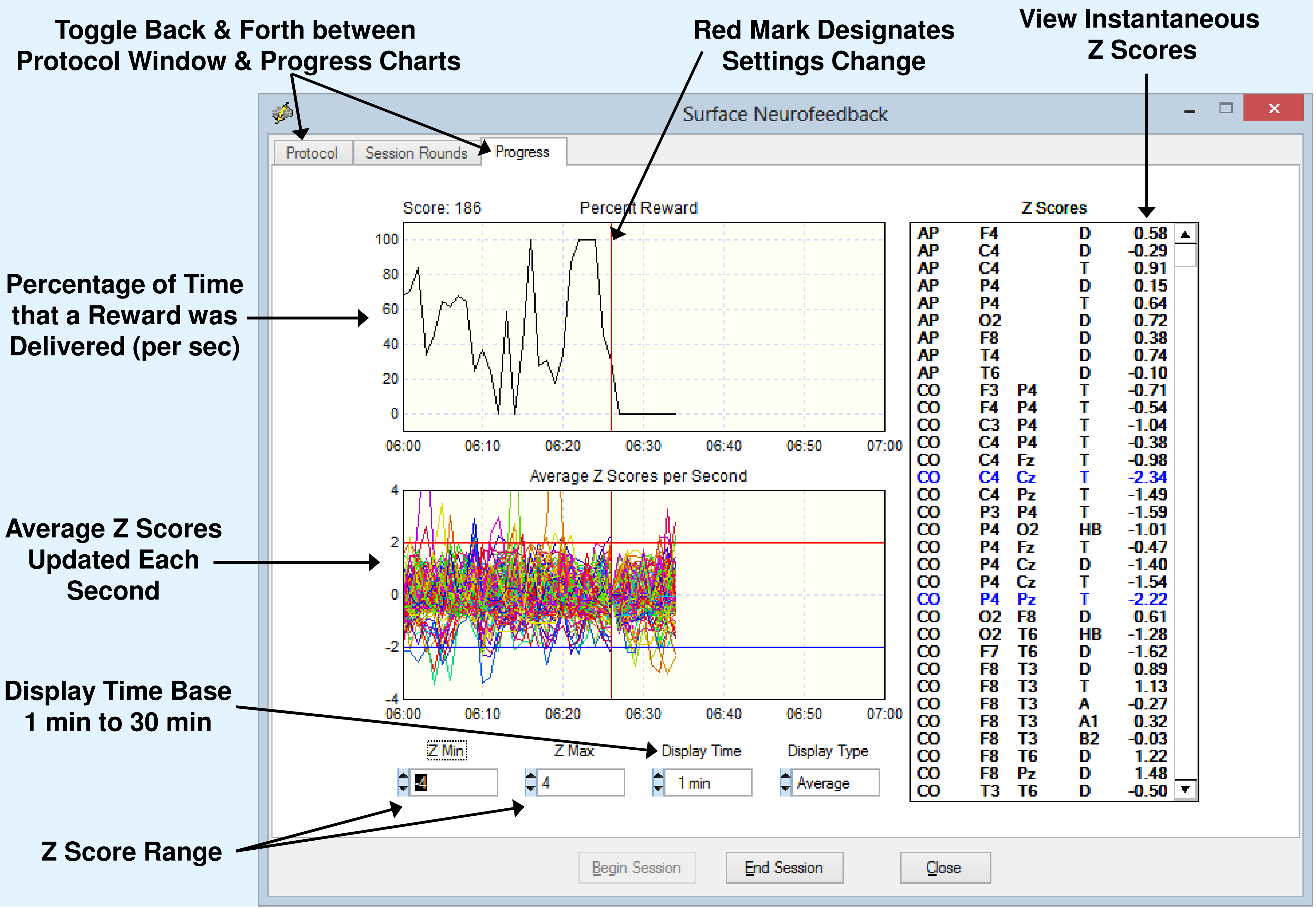
Move the Display to the Client's Monitor

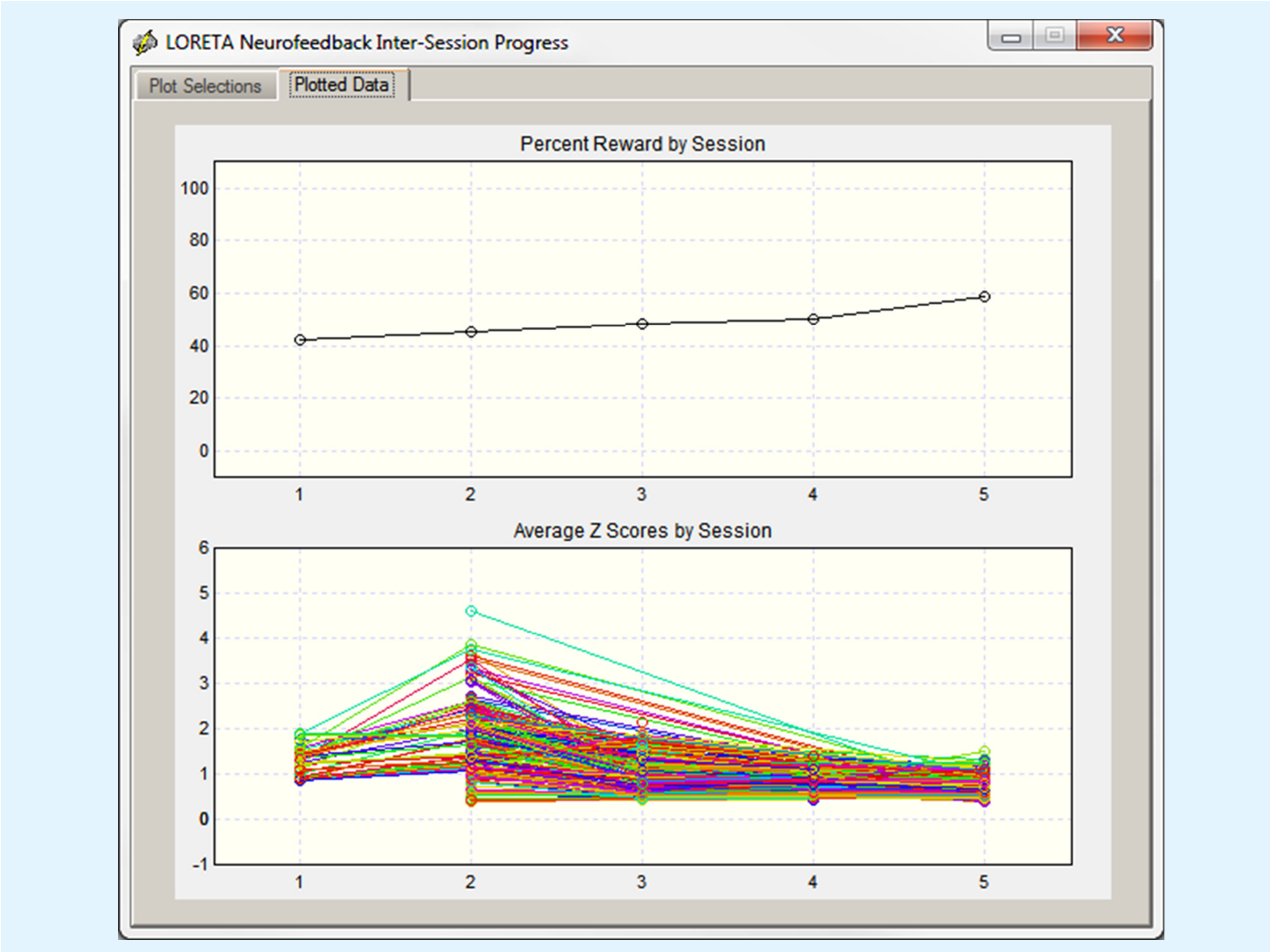


Select Progress Charts as Feedback to a Client and then Click Apply

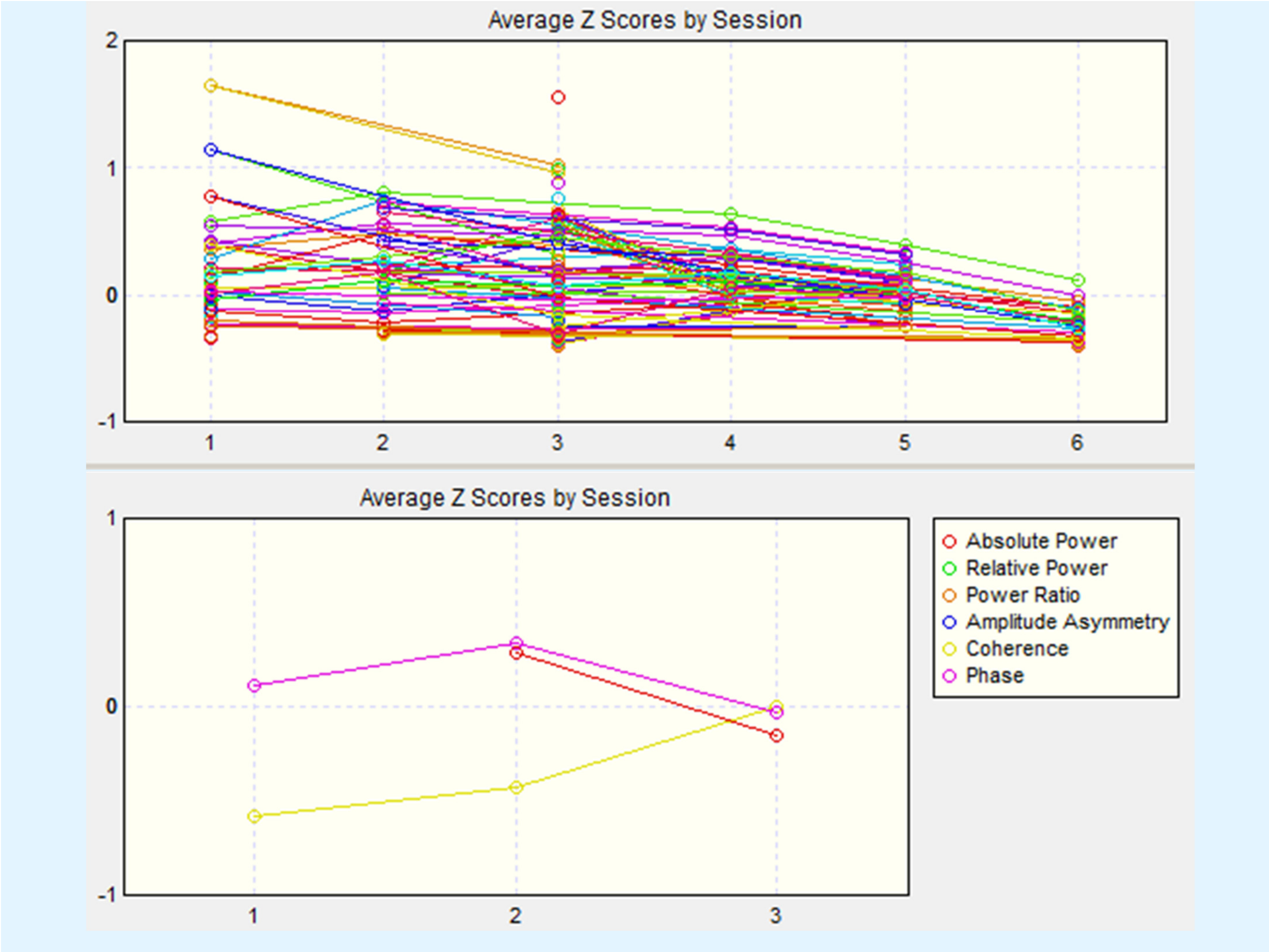
Move to the Client's Monitor

Progress Charts to be Monitored by the Clinician During Neurofeedback





LORETA Neurofeedback Inter-Session Progress
Plot Selections
Plotted Data
Percent Reward by Session
100
80
60
40
20
0
1
2
3
4
5
Average Z Scores by Session
6
5
4
3
2
1
0
-1
1
2
3
4
5



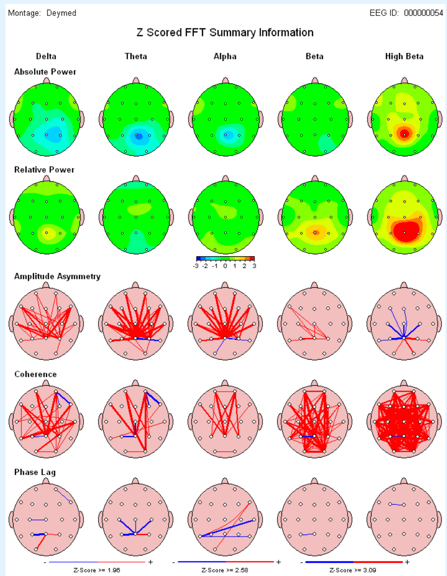
Average Z Scores by Session
2
1
0
-1
1
2
3
4
5
6
Average Z Scores by Session
1
0
-1
1
2
3
Absolute Power
Relative Power
Power Ratio
Amplitude Asymmetry
Coherence
Phase

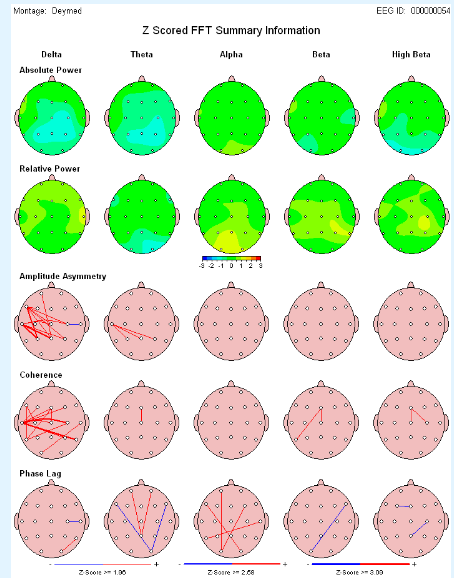
Examples of Surface EEG Changes After EEG Neurofeedback

Pre-Treatment

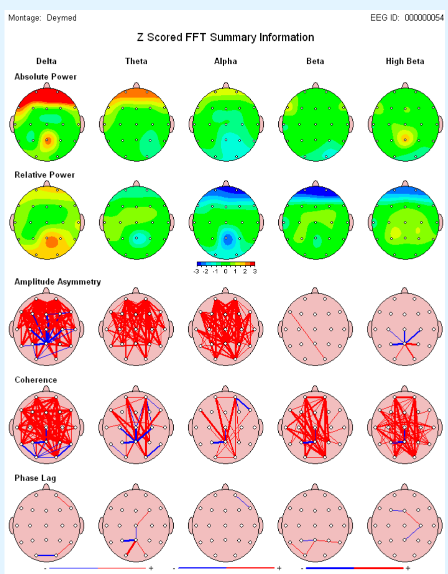
Post – 10 Treatments

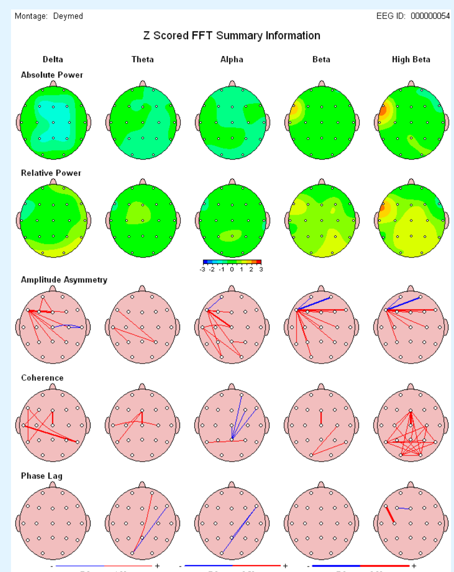
TBI Subject #1





TBI Subject #2

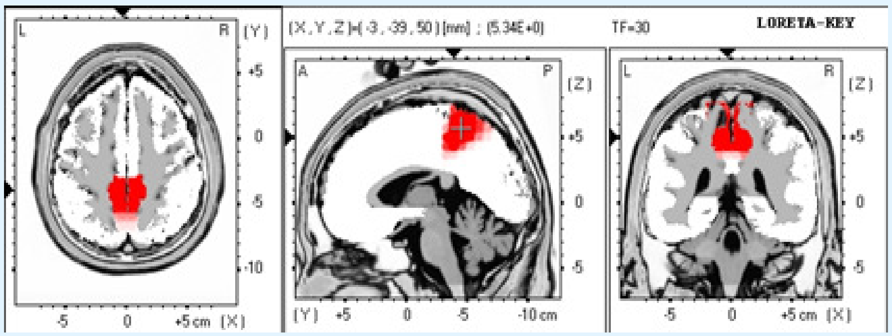


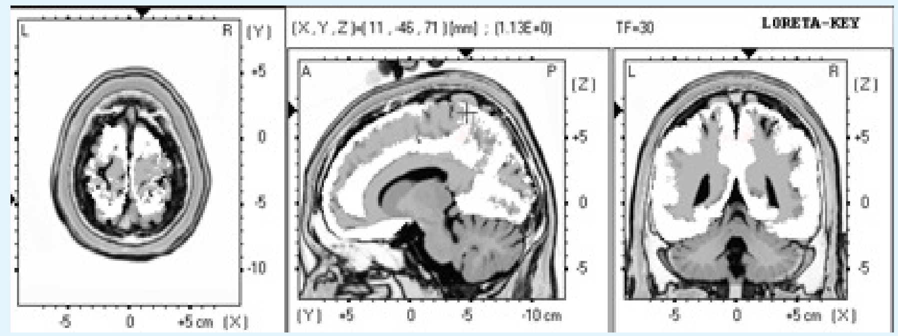


Examples of Electrical Neuroimaging After Neurofeedback

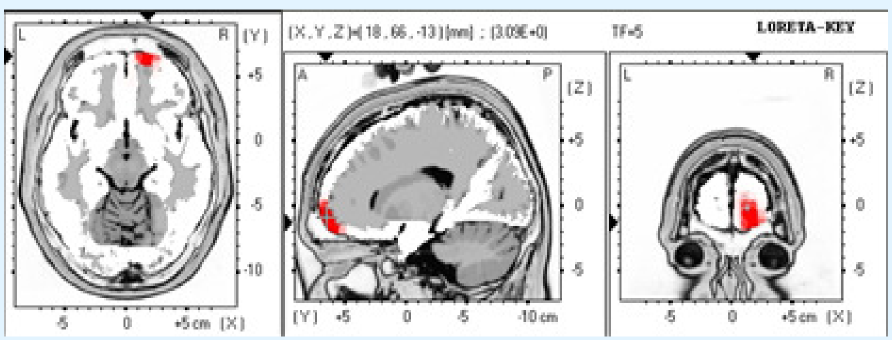
Pre-Treatment | **Post – 10 Treatments**

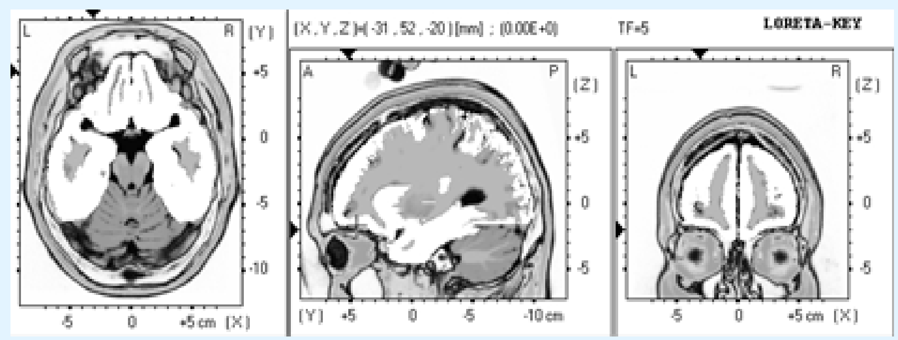
S #1

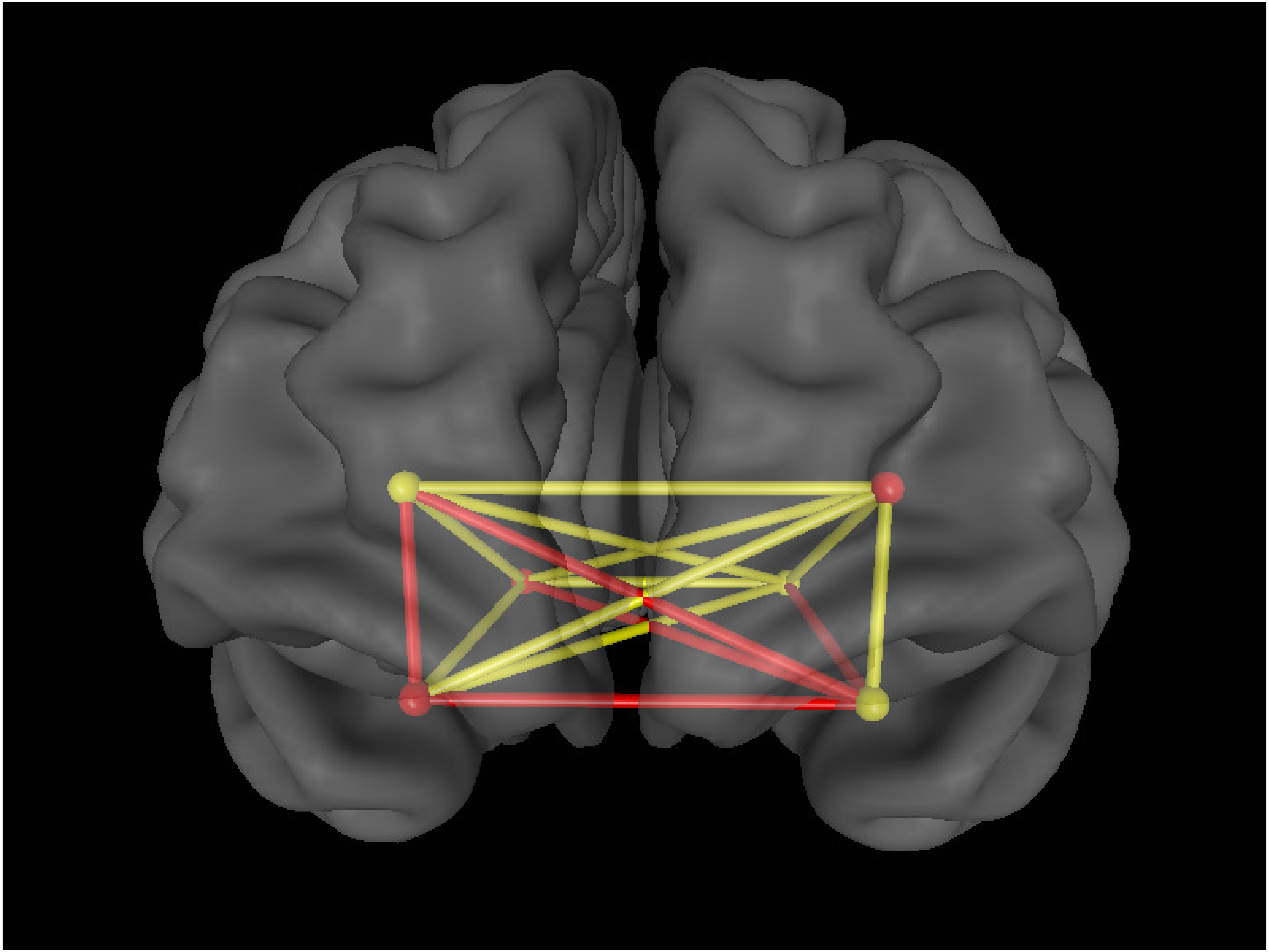


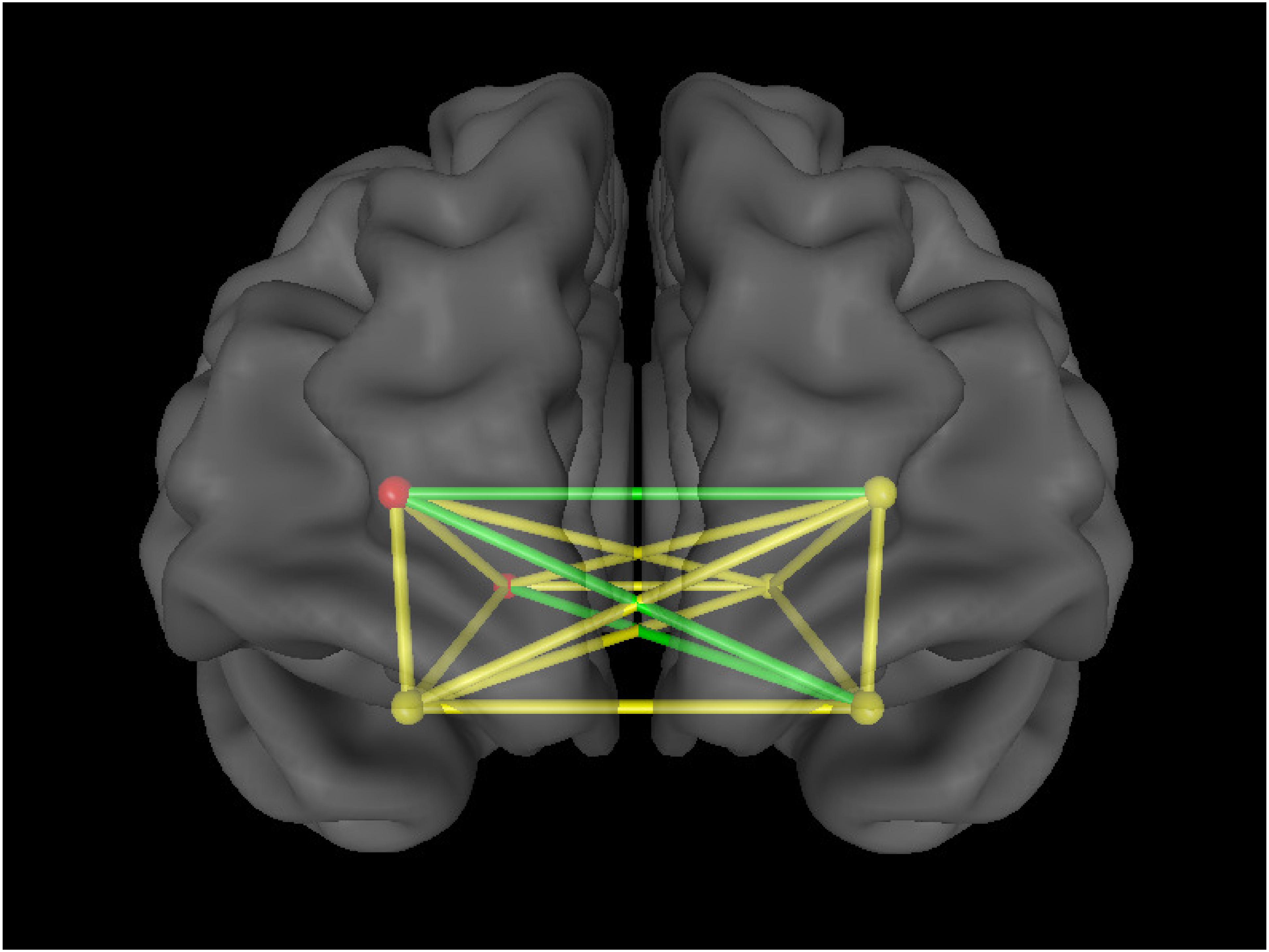


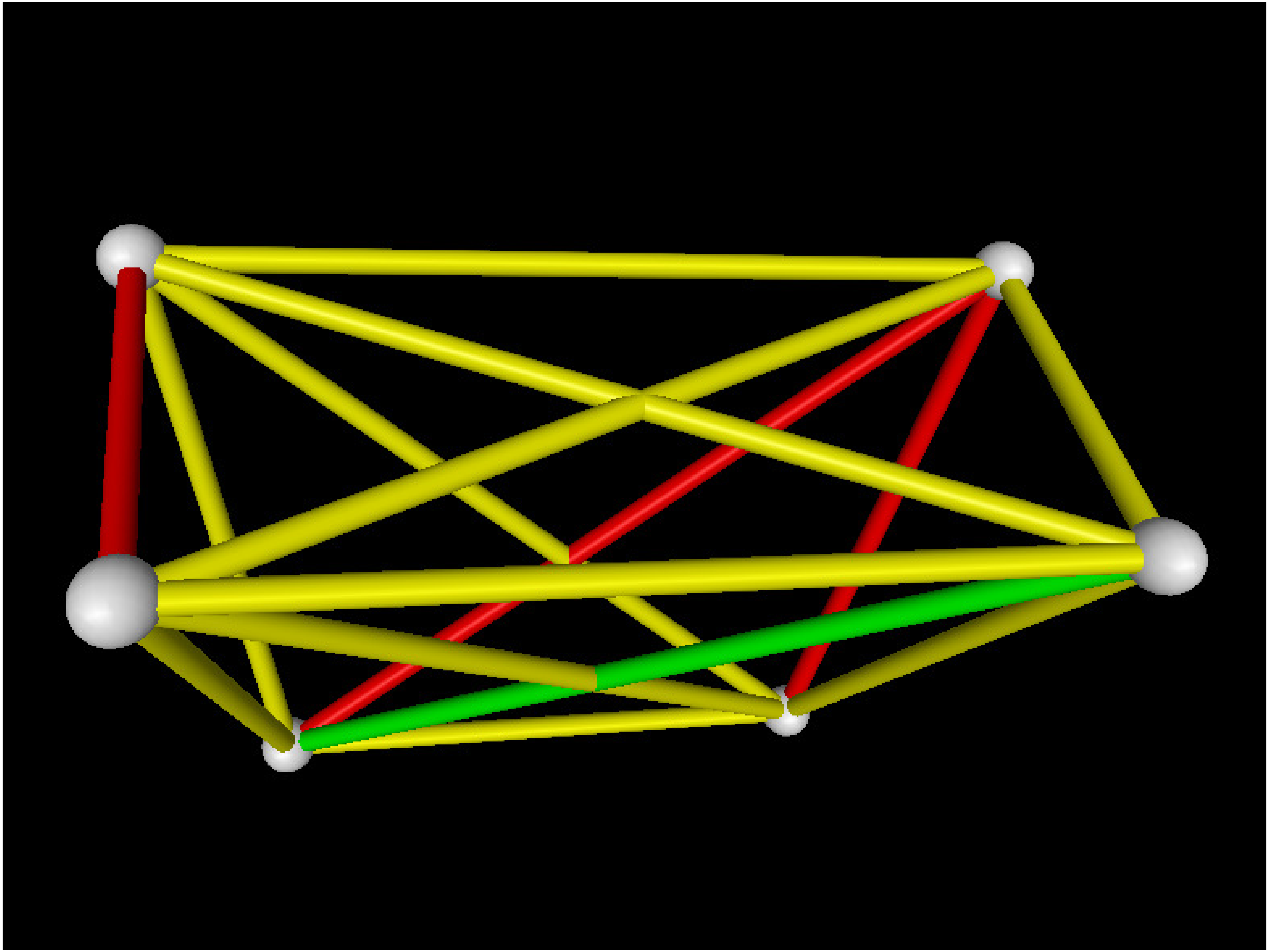
S #2

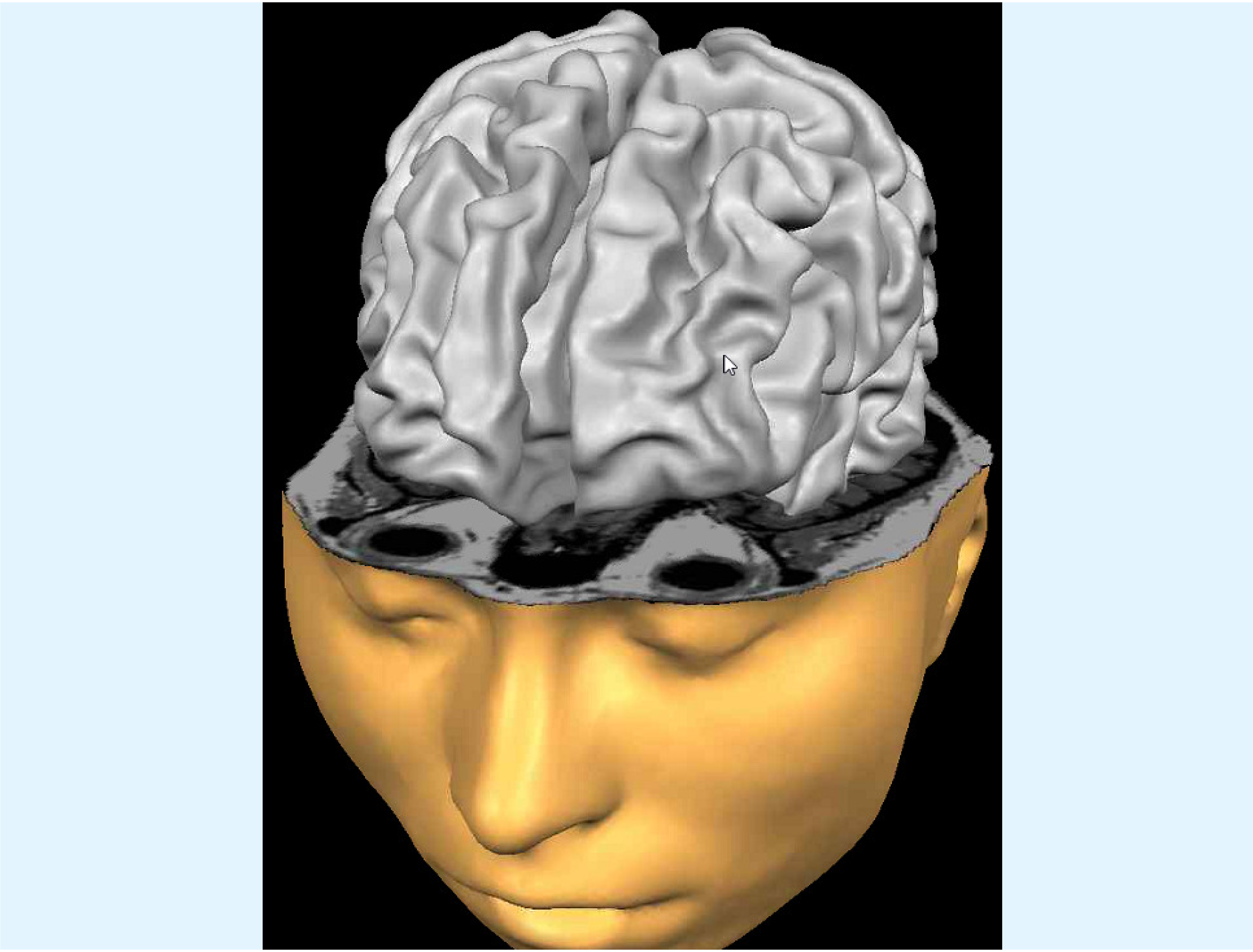


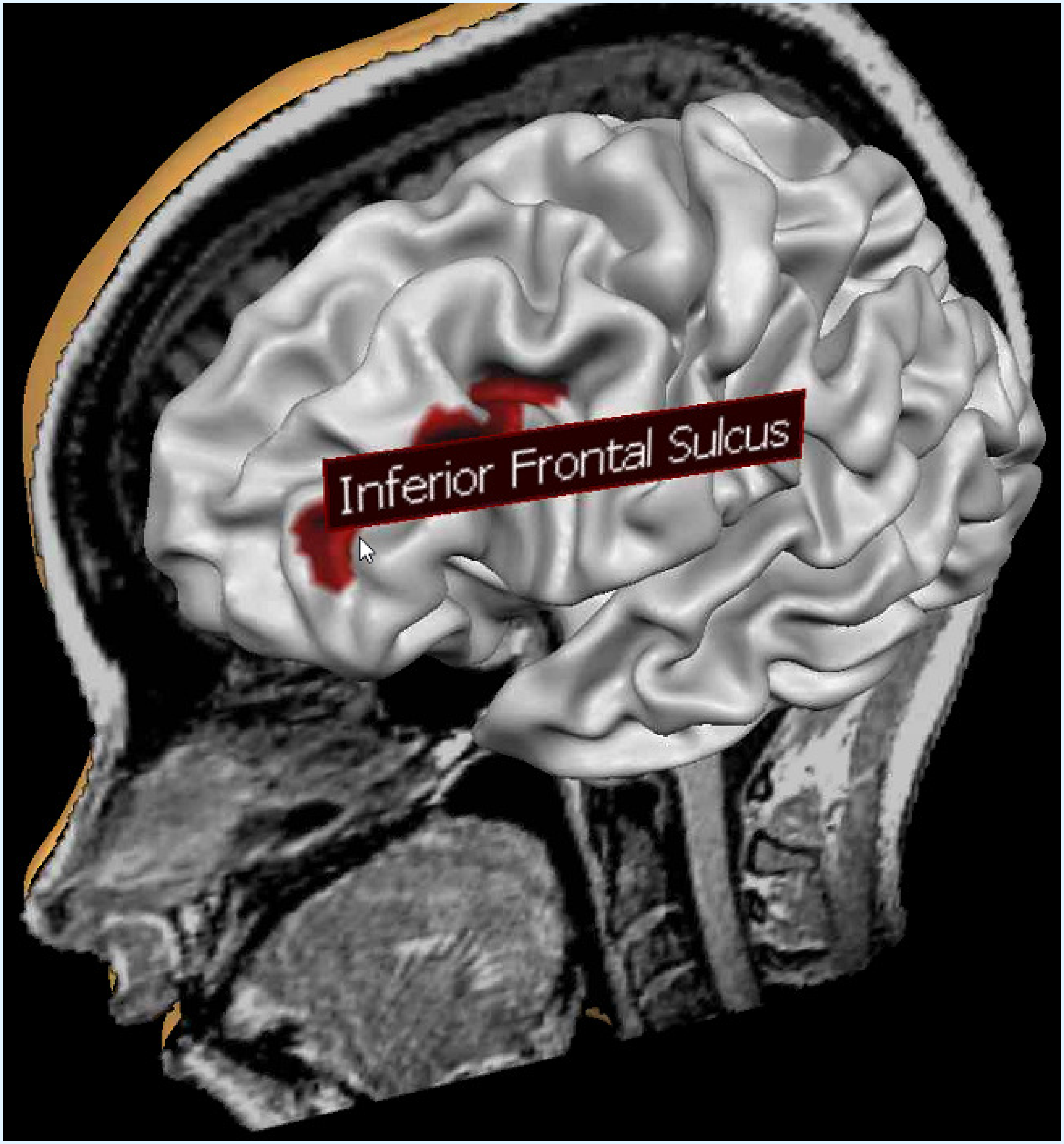











Inferior Frontal Sulcus

Advanced Concepts on EEG and QEEG Assessment and Human Performance

International Symposium on Clinical Neuroscience – Feb 3-5, 2017

Linking Symptoms to qEEG Biomarkers and Neurofeedback

Robert W. Thatcher, Ph.D.

Applied Neuroscience, Inc.
8200 Bryan Diary Rd., Suite 300
Largo, FL

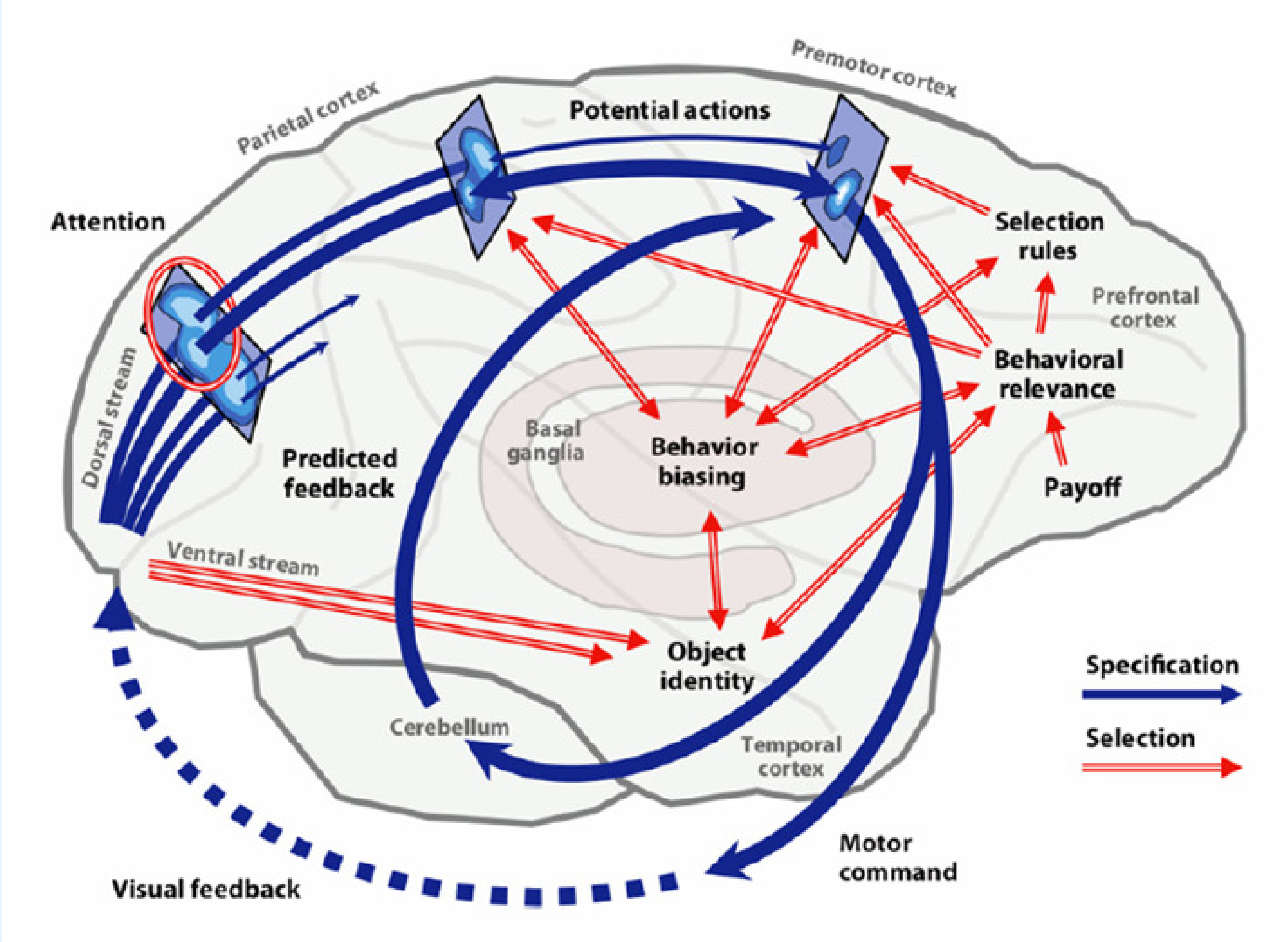
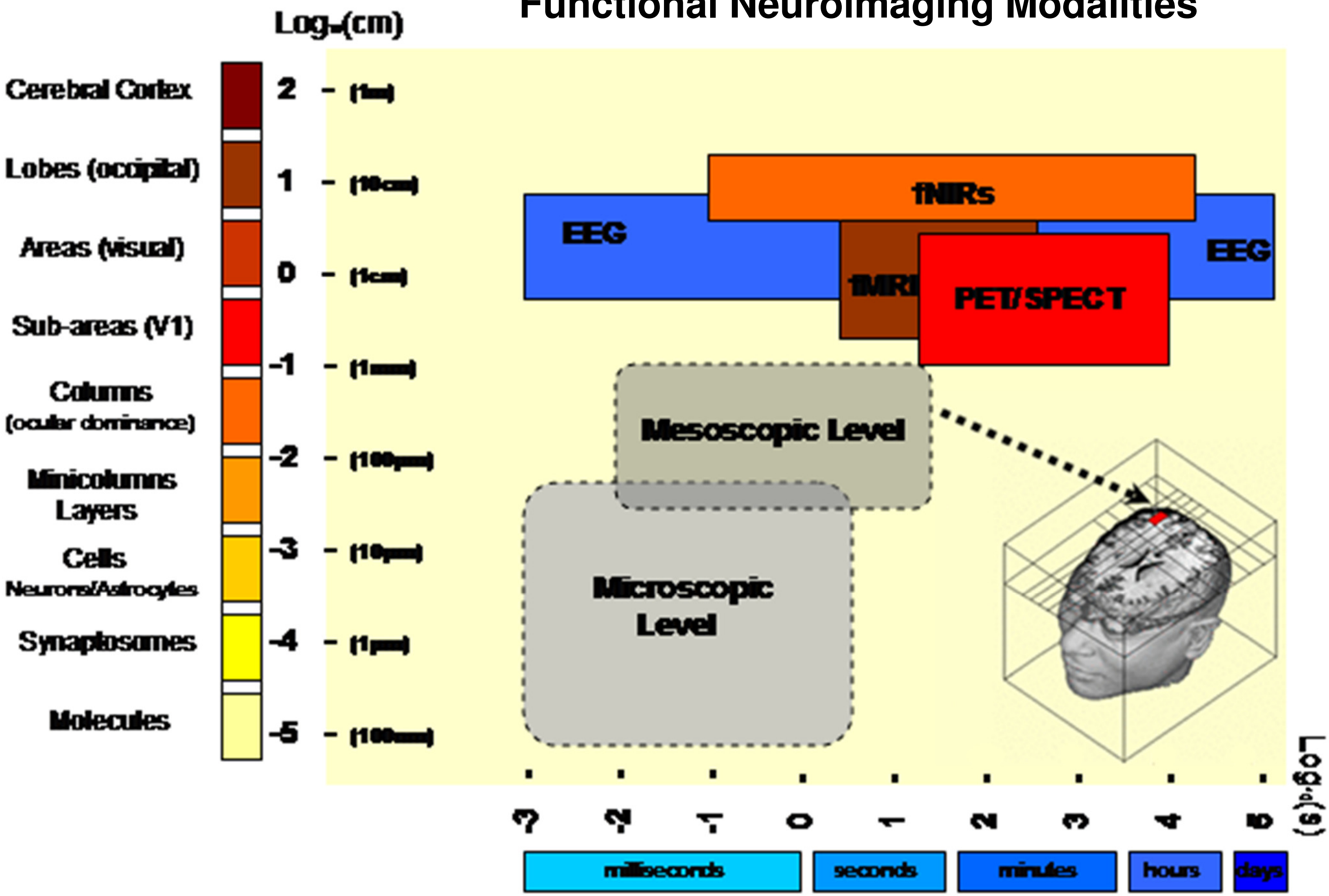
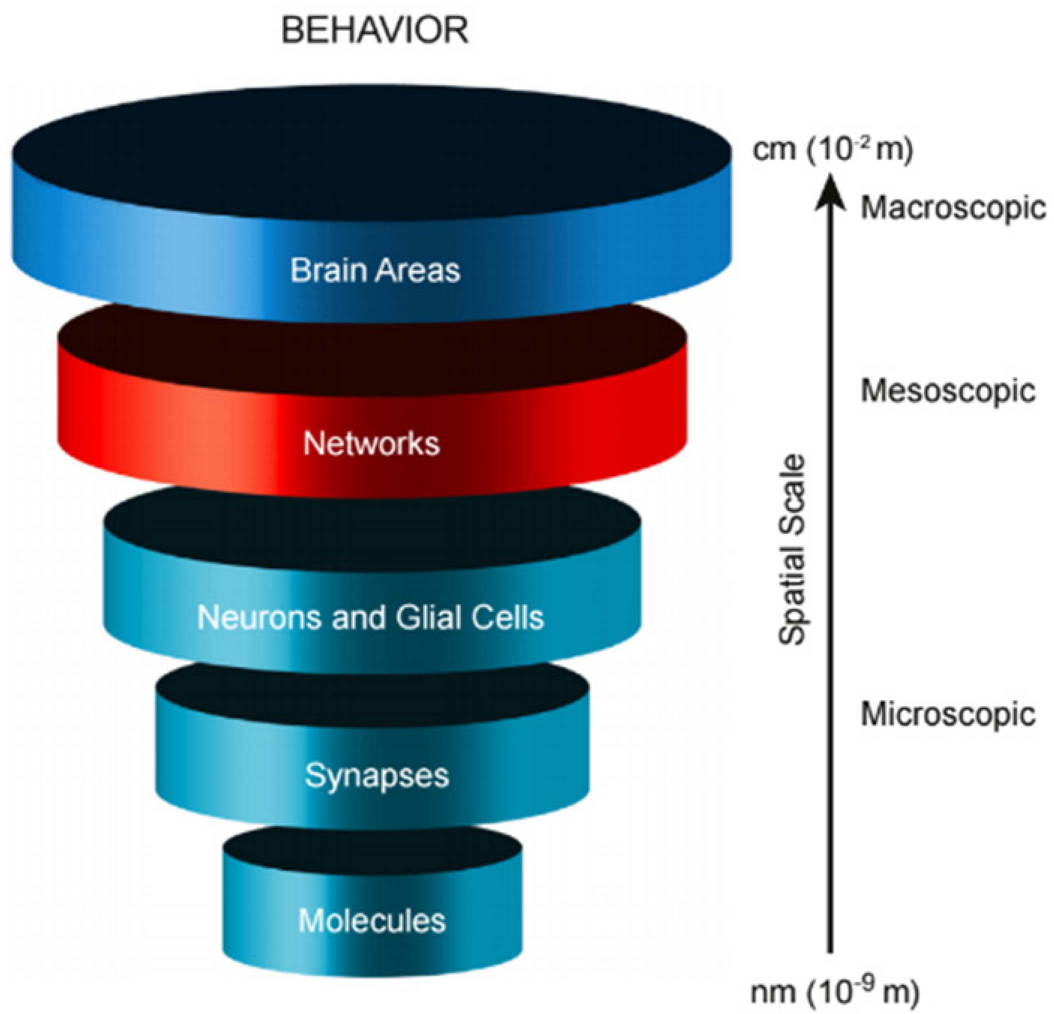


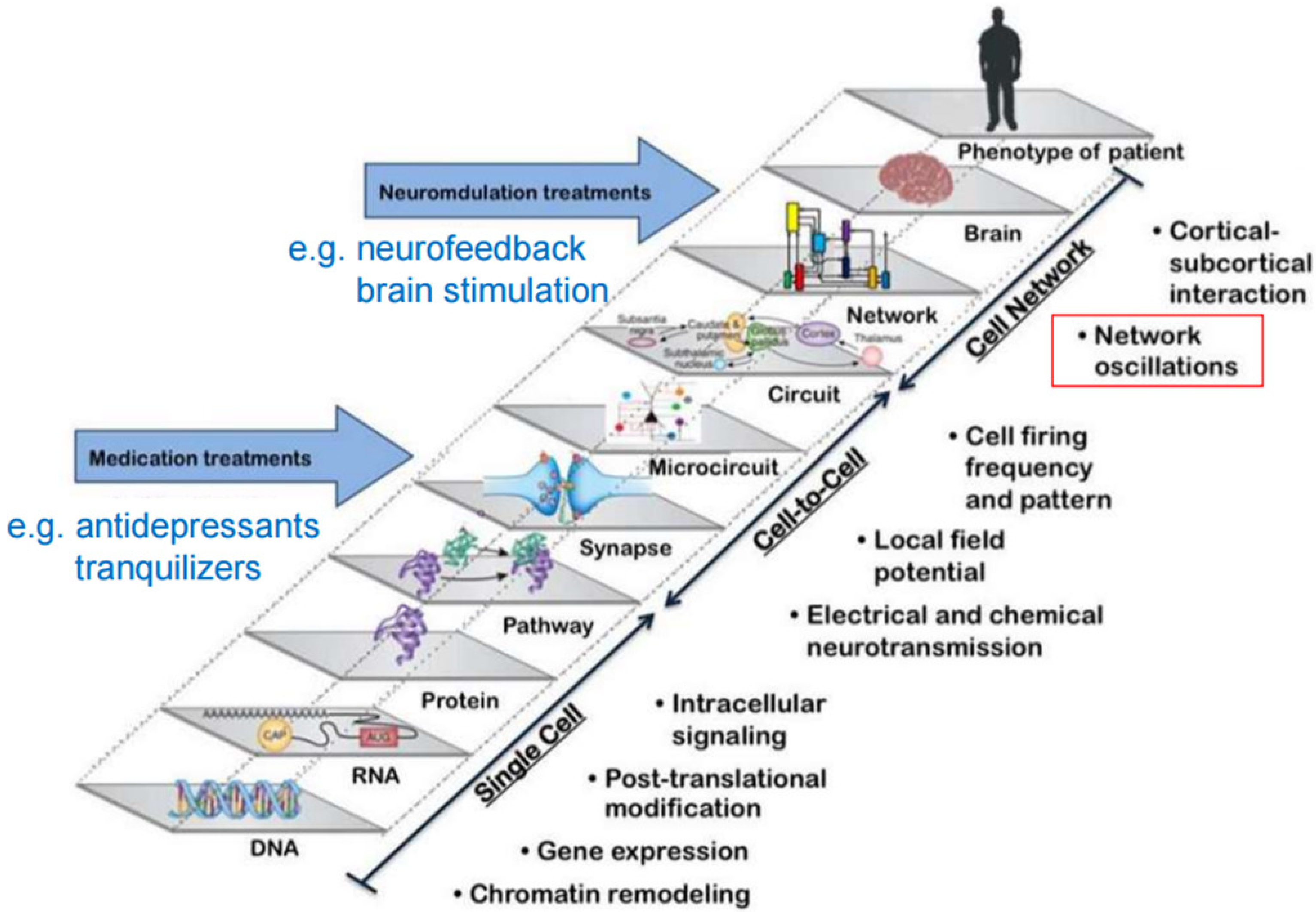
Illustration of brain information flow that can only be measured by the electroencephalogram using computers.
Information flow – Millisecond Match-Mismatch From Rabinovich et al, 2012

Functional Neuroimaging Modalities

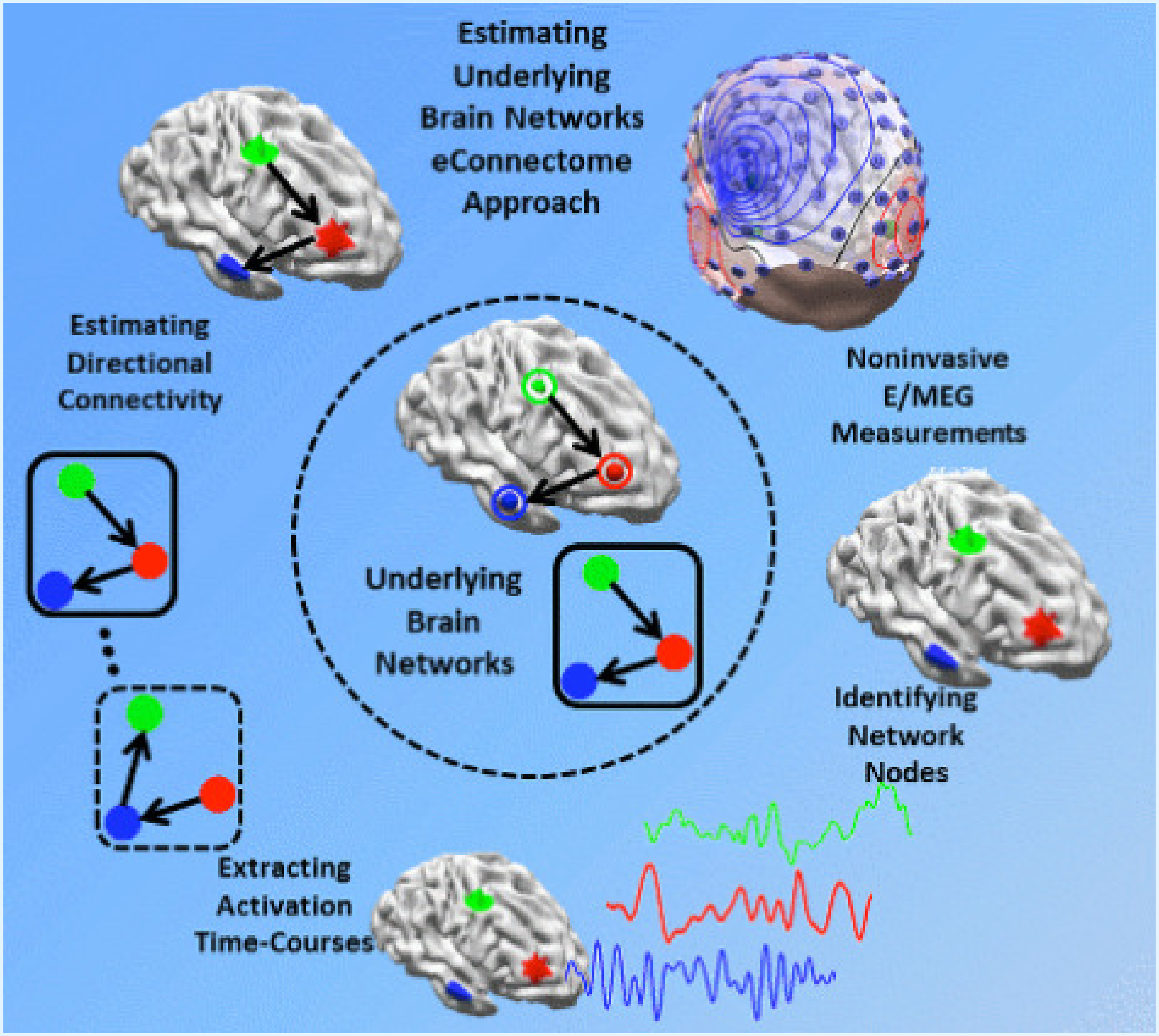




Frohlich, F., 2016. Network Neuroscience. Academic Press, NY



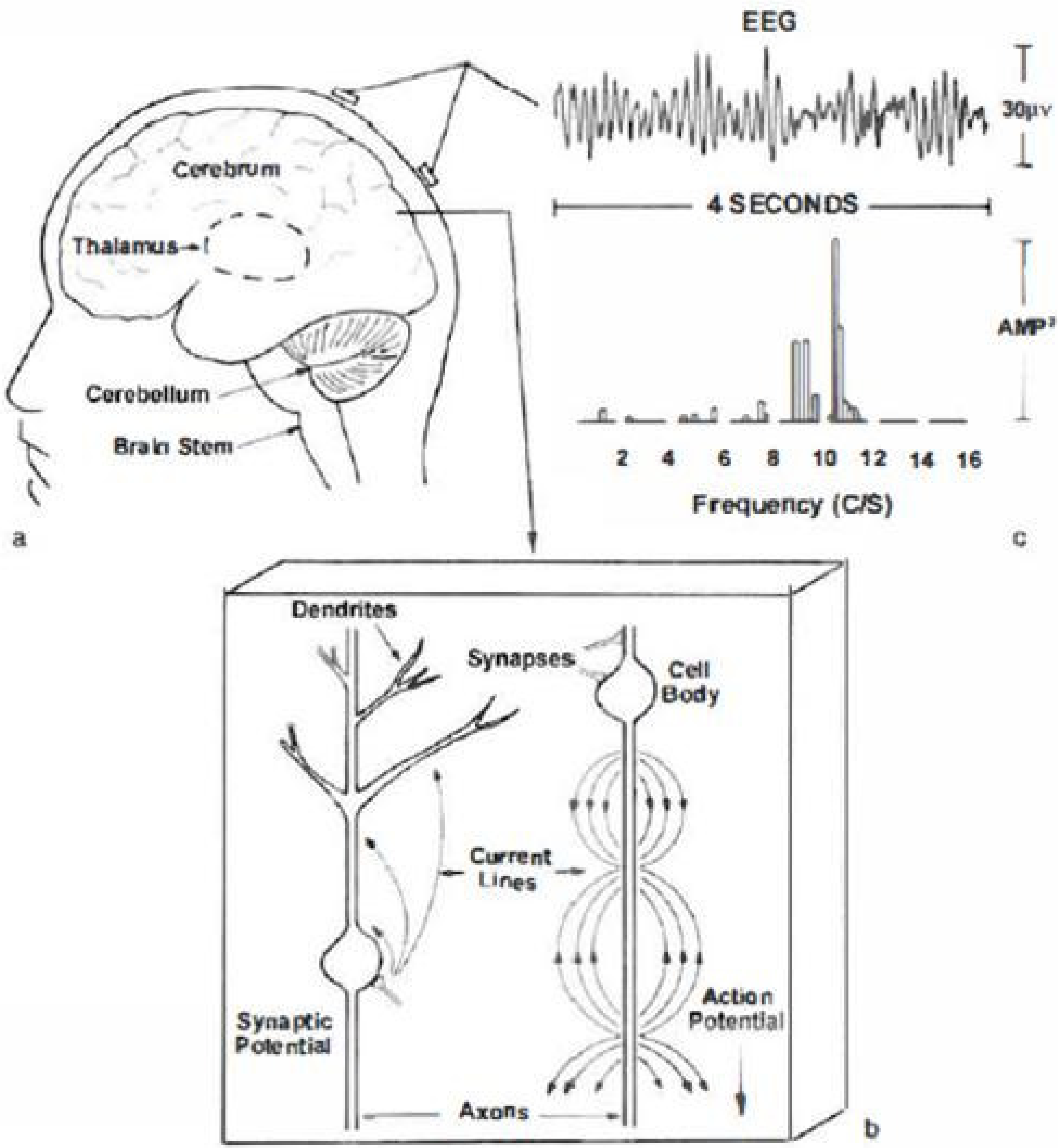
tuning-pathological-brain-oscillations-Thomas Ros-video -From Leuchter, 2015

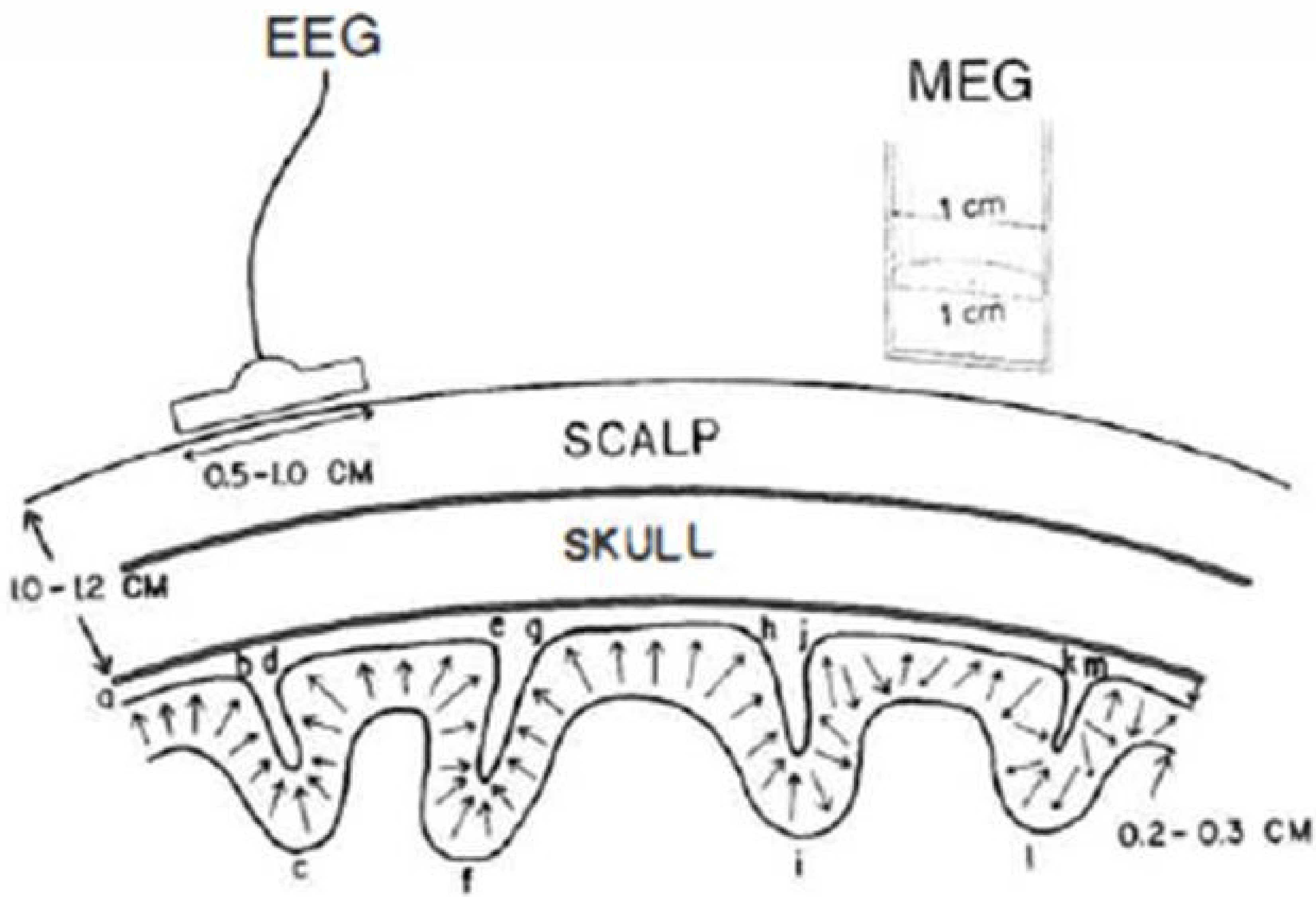


Noninvasive Electromagnetic Source Imaging and Granger Causality Analysis: An Electrophysiological Connectome (eConnectome) Approach ***Abbas Sohrabpour, Shuai Ye, Gregory Worrell, Wenbo Zhang, Bin He , University of Minnesota, USA,*** *Volume: 63, Issue:12, Pages:2474-2487, 2016*

Genesis of the Human Electroencephalogram - EEG

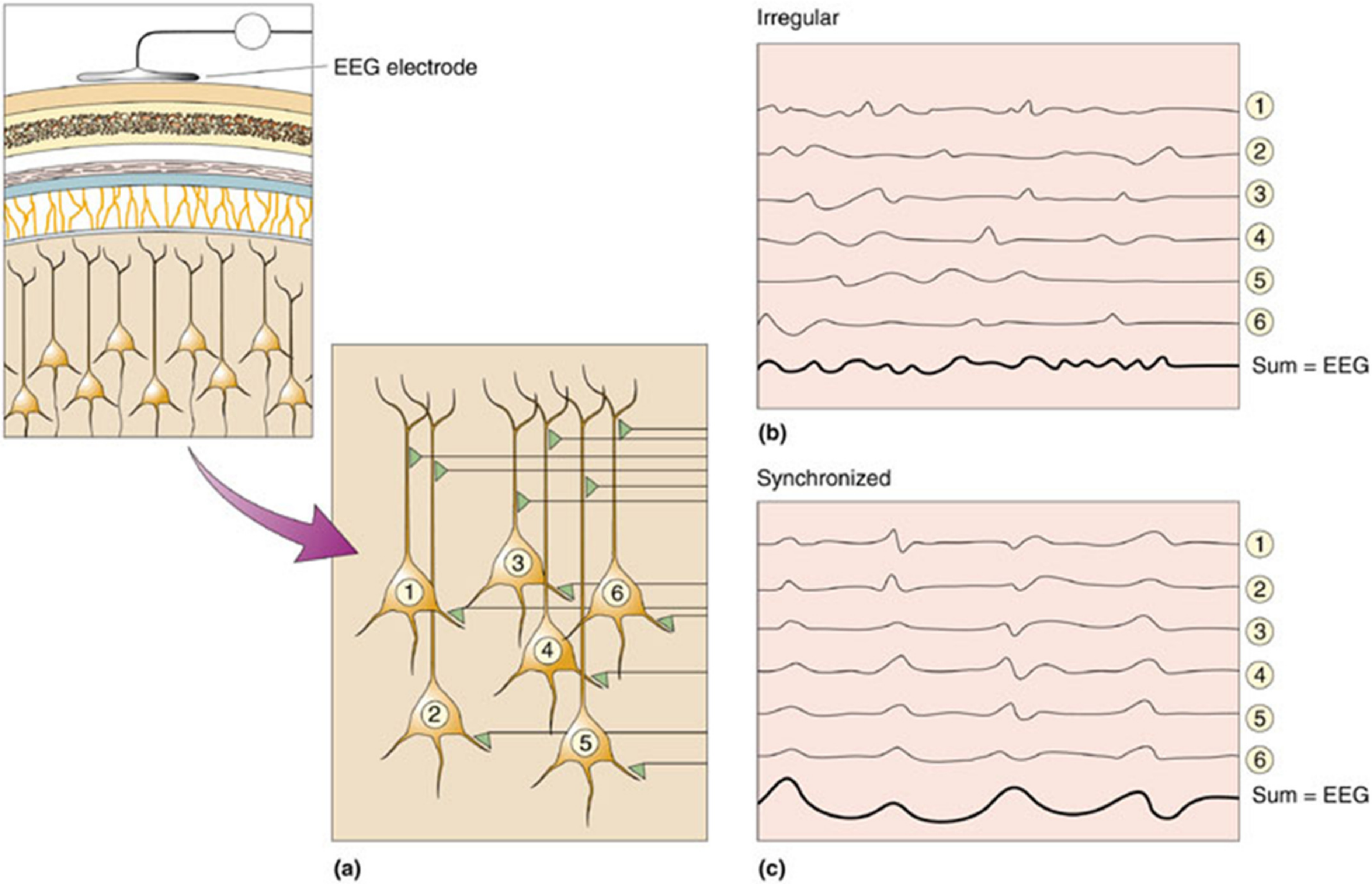
1- Pyramidal Neuron Dipoles
2- Oscillations In an Approx. 2mm thick sheet
3- Summated Local Field Potentials (LFP)
4- Amplitude = Proportion of Synchronous/Square Root of Proportion of Asynchronous Generators
5- Pacemakers and Resonance

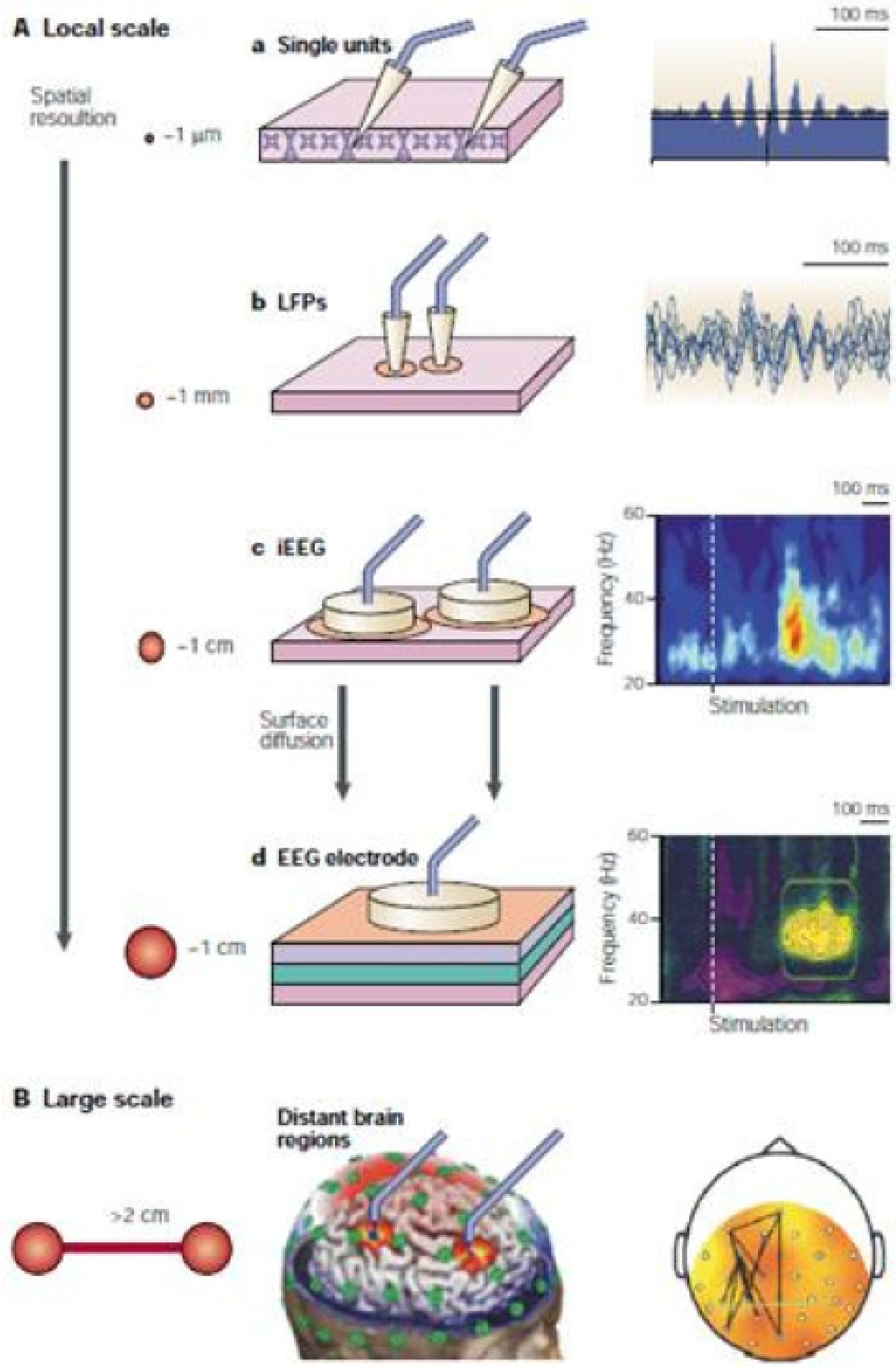

EEG
30µv
4 SECONDS
AMP²
2 4 6 8 10 12 14 16
Frequency (C/S)
Cerebrum
Thalamus
Cerebellum
Brain Stem
a
c
Dendrites
Synapses
Cell Body
Current Lines
Action Potential
Synaptic Potential
Axons
b



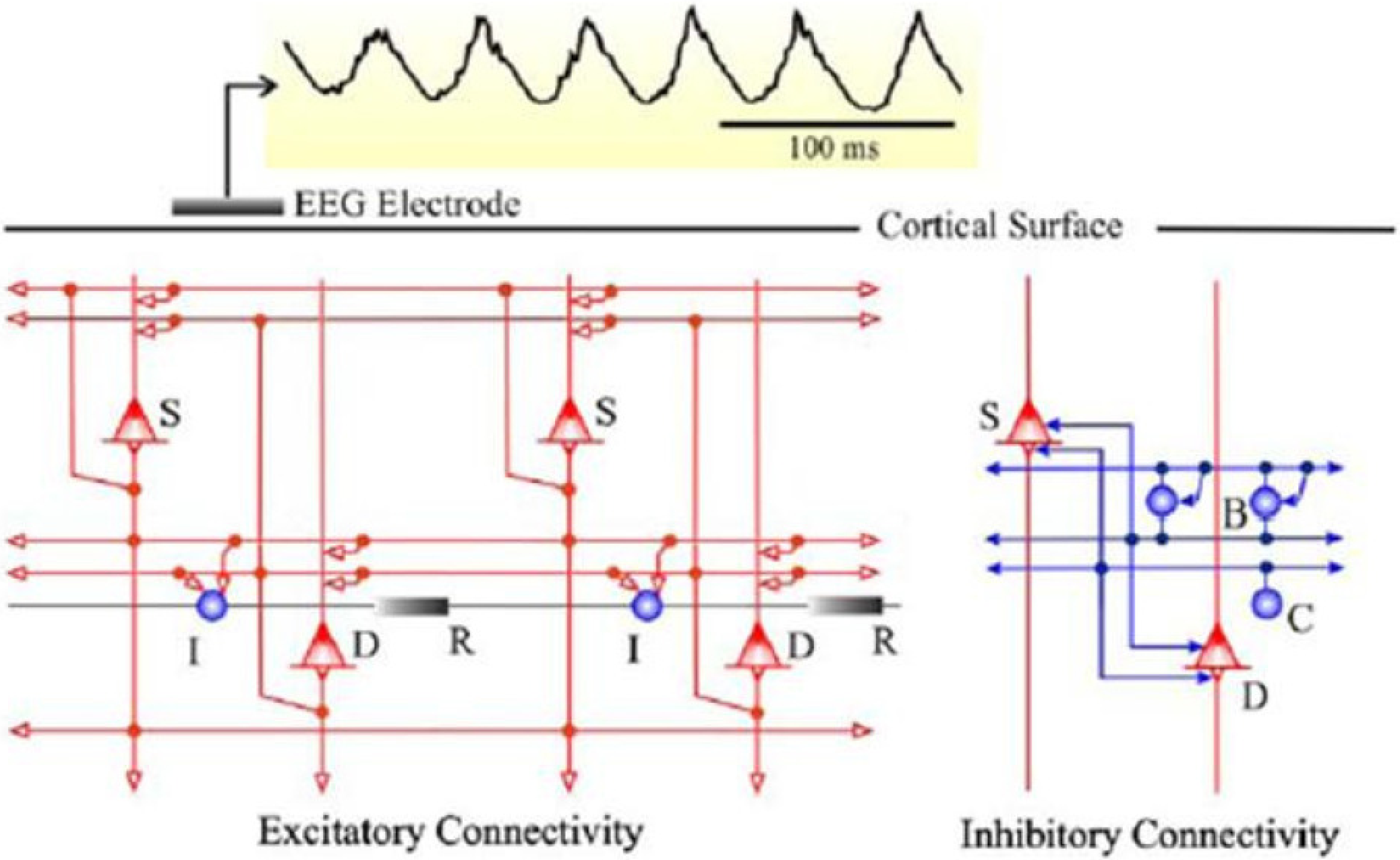
From Nunez, Electrical Fields of the Brain, Oxford Univ. Press, 1981

EEG = Summated Potentials at the Scalp





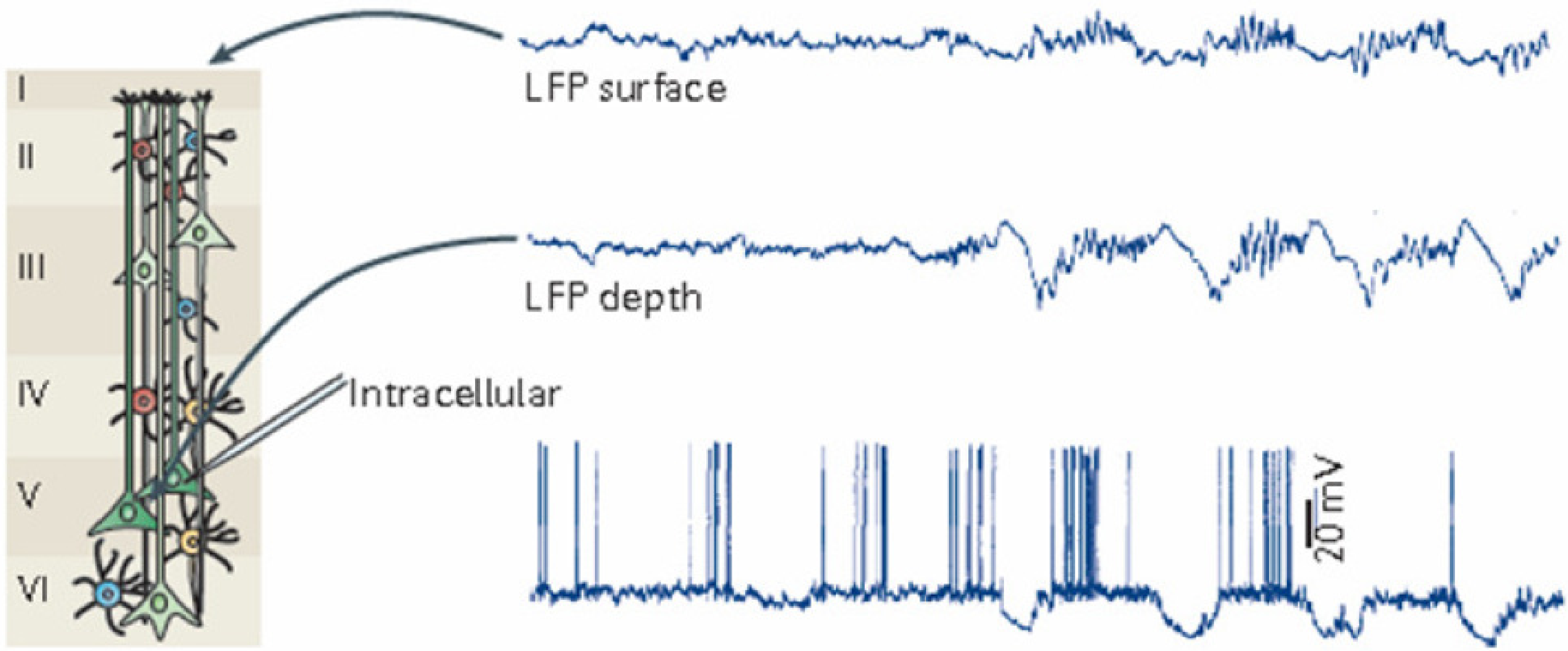
From Varela et al, 2001



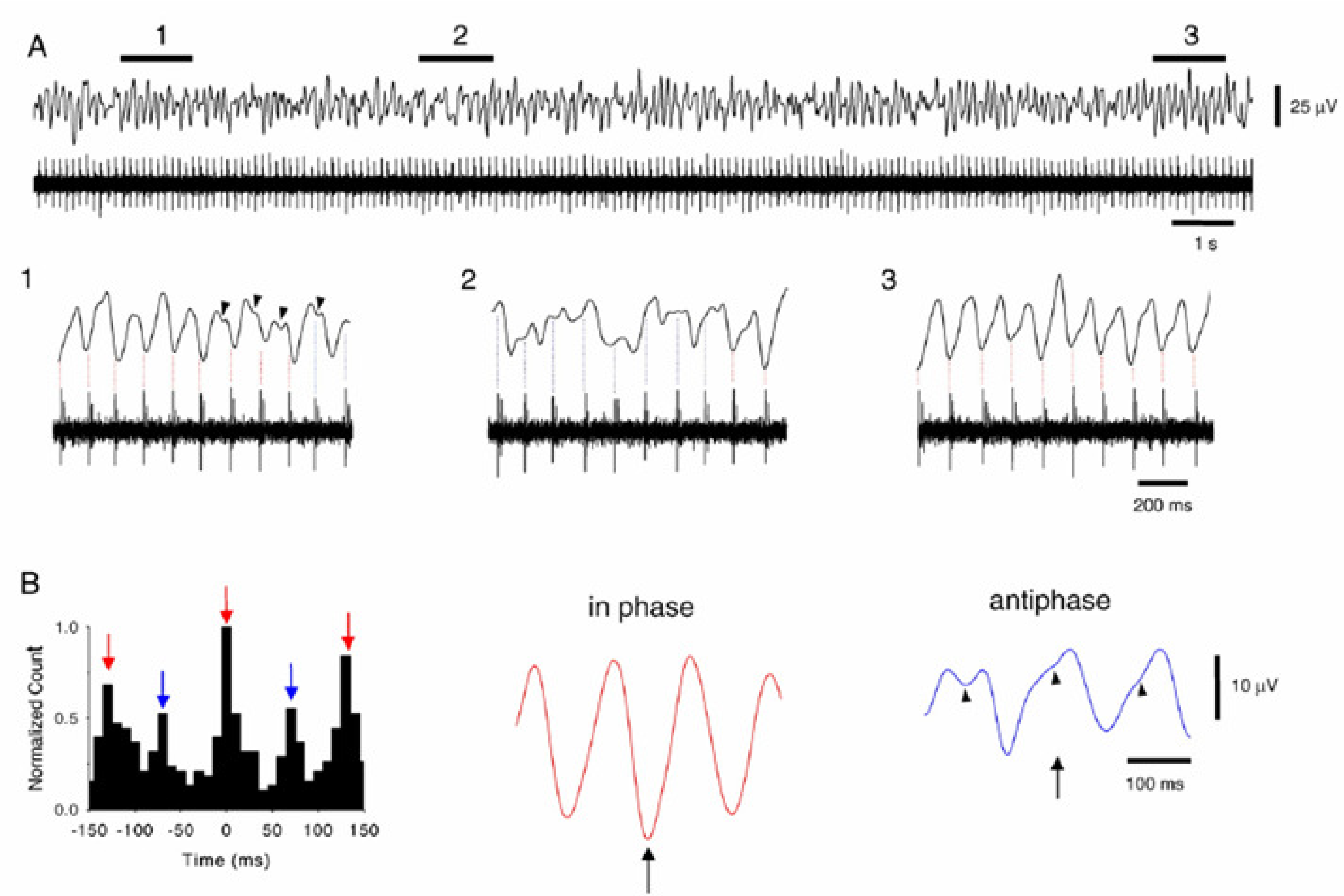
100 ms
EEG Electrode
Cortical Surface
S
S
I
D
R
I
D
R
S
B
C
D
Excitatory Connectivity
Inhibitory Connectivity

How Neurons are Selected For Brief Periods of Time

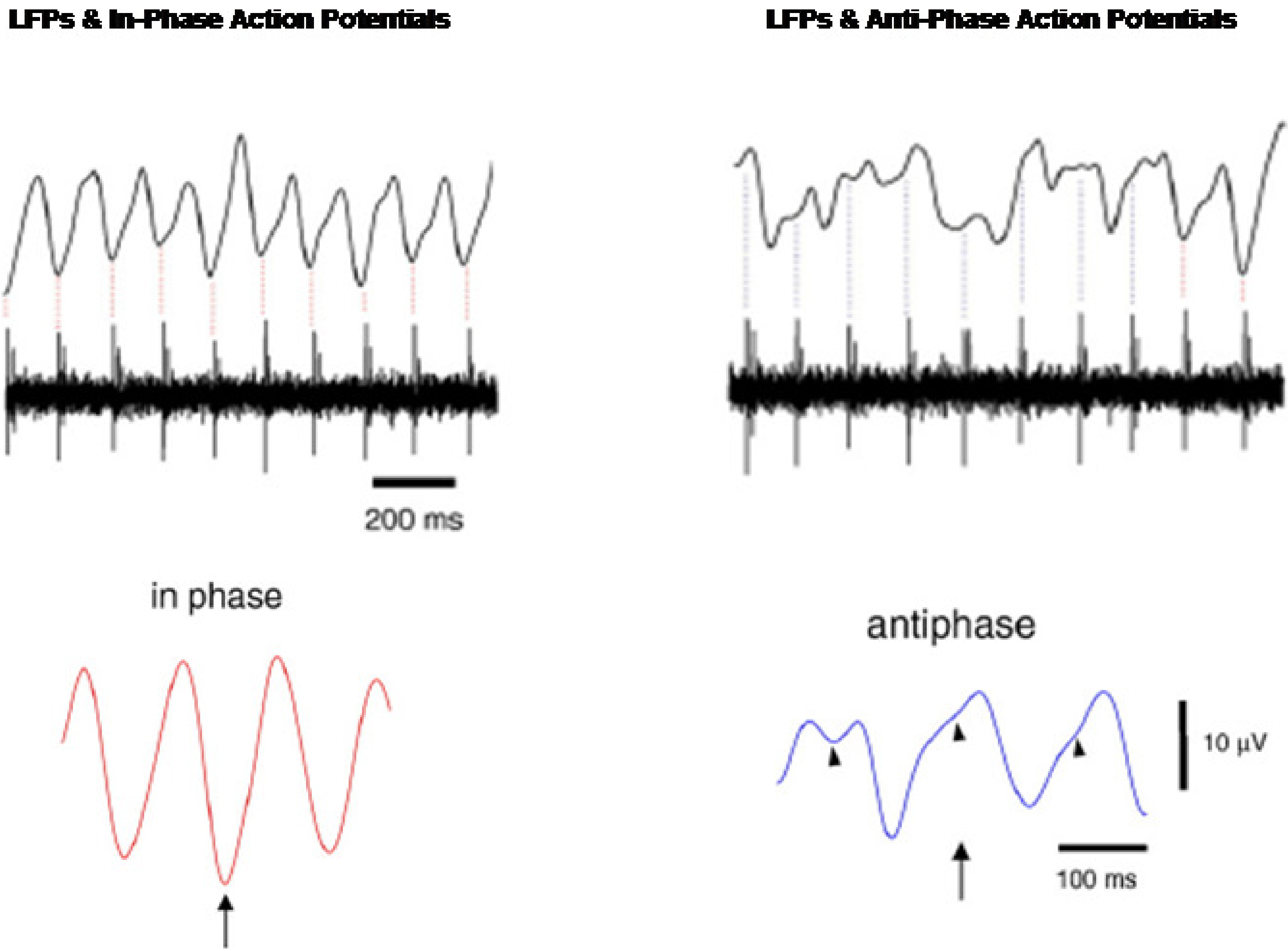
Shifting In-Phase vs Anti-Phase



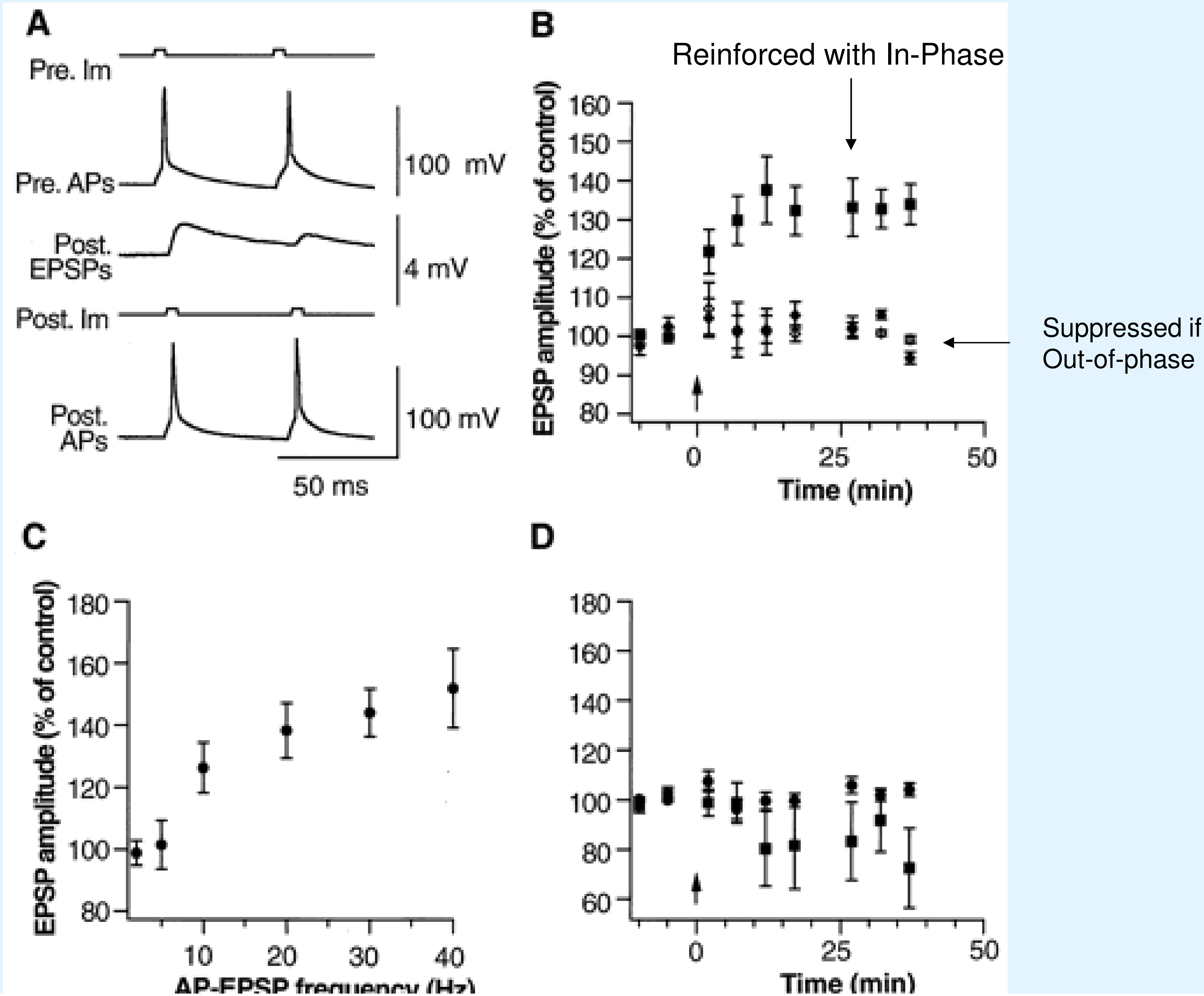
LFP surface
LFP depth
Intracellular
20 mV
I
II
III
IV
V
VI



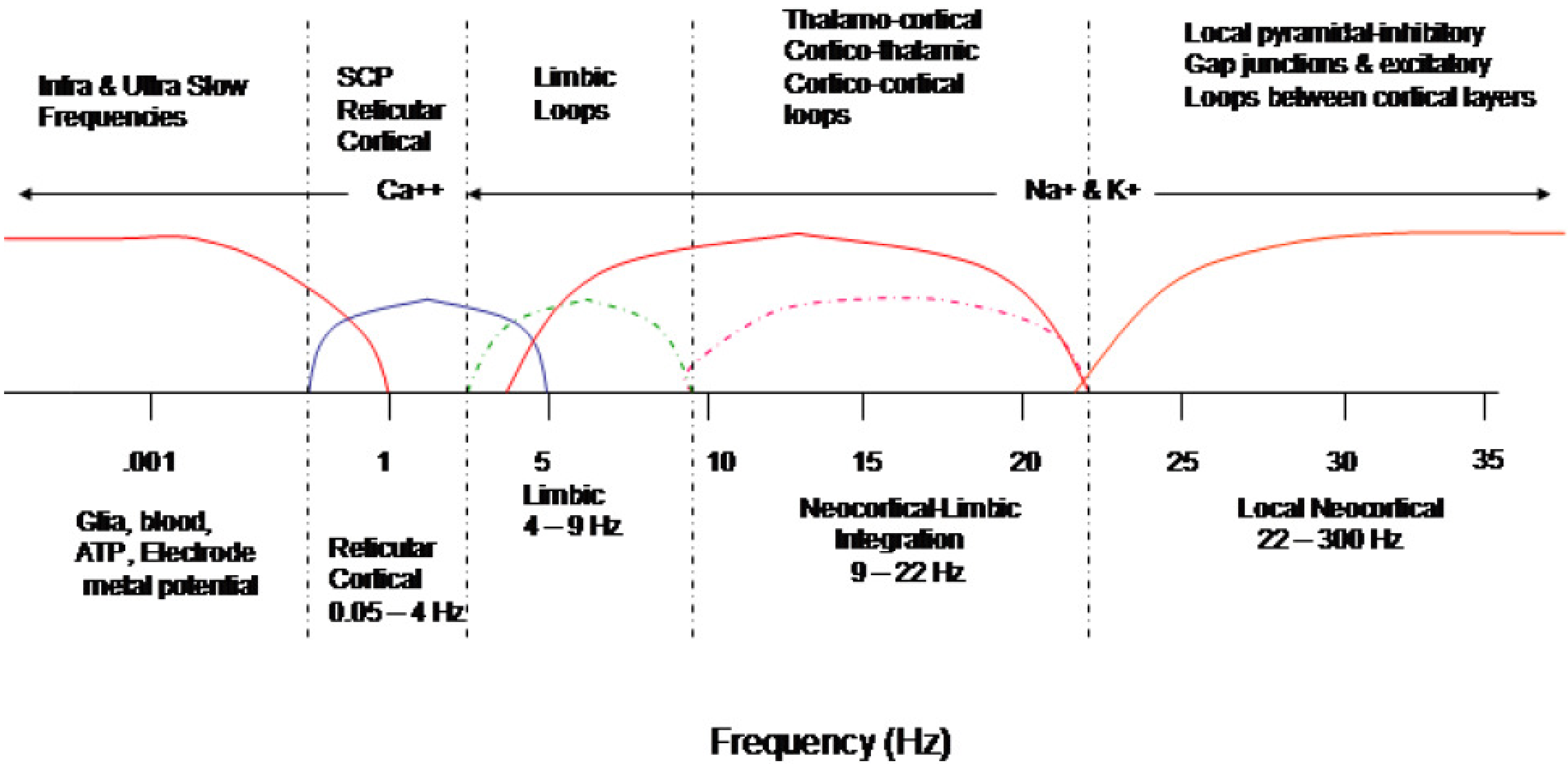
From Hughes et al, 2004

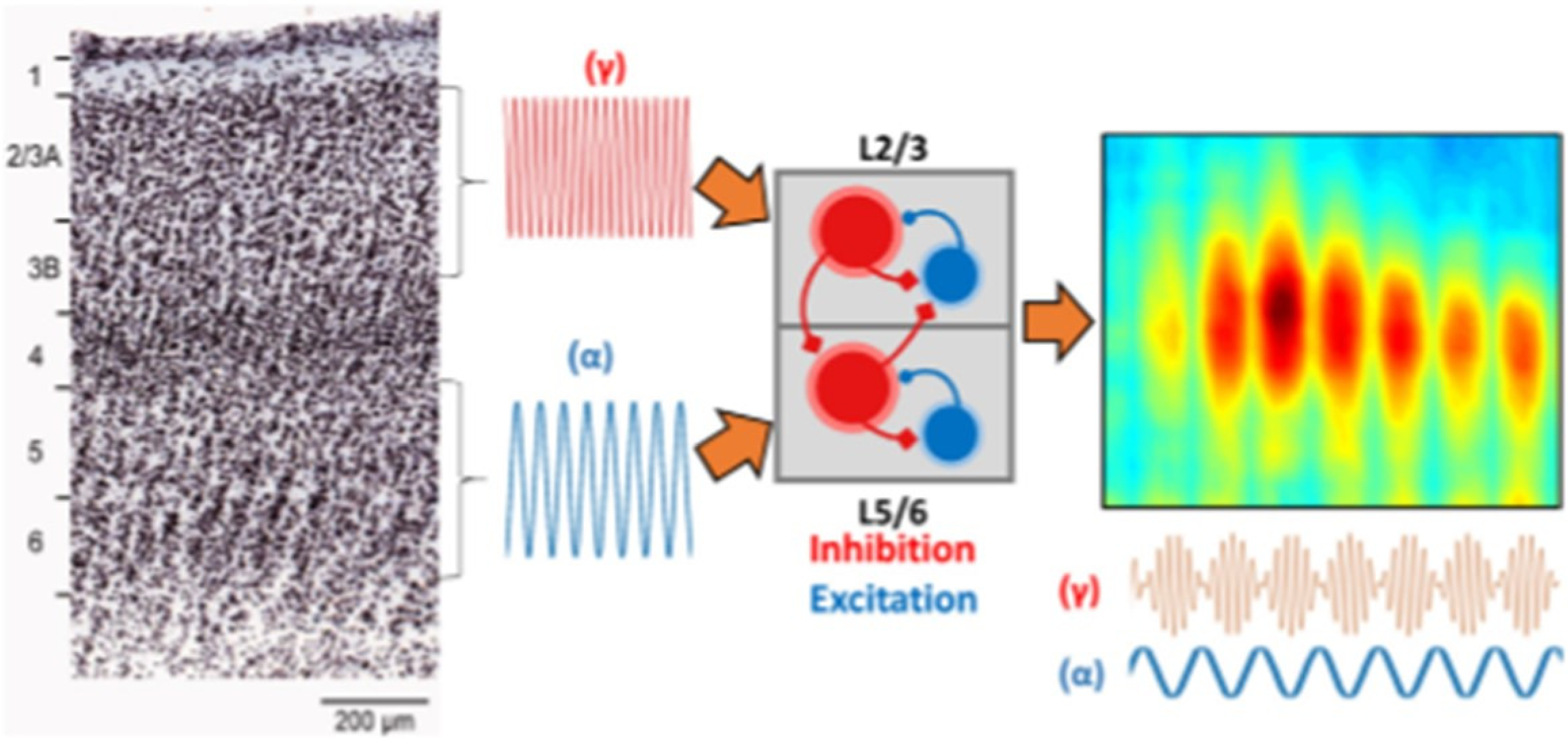


From Hughes et al, 2004

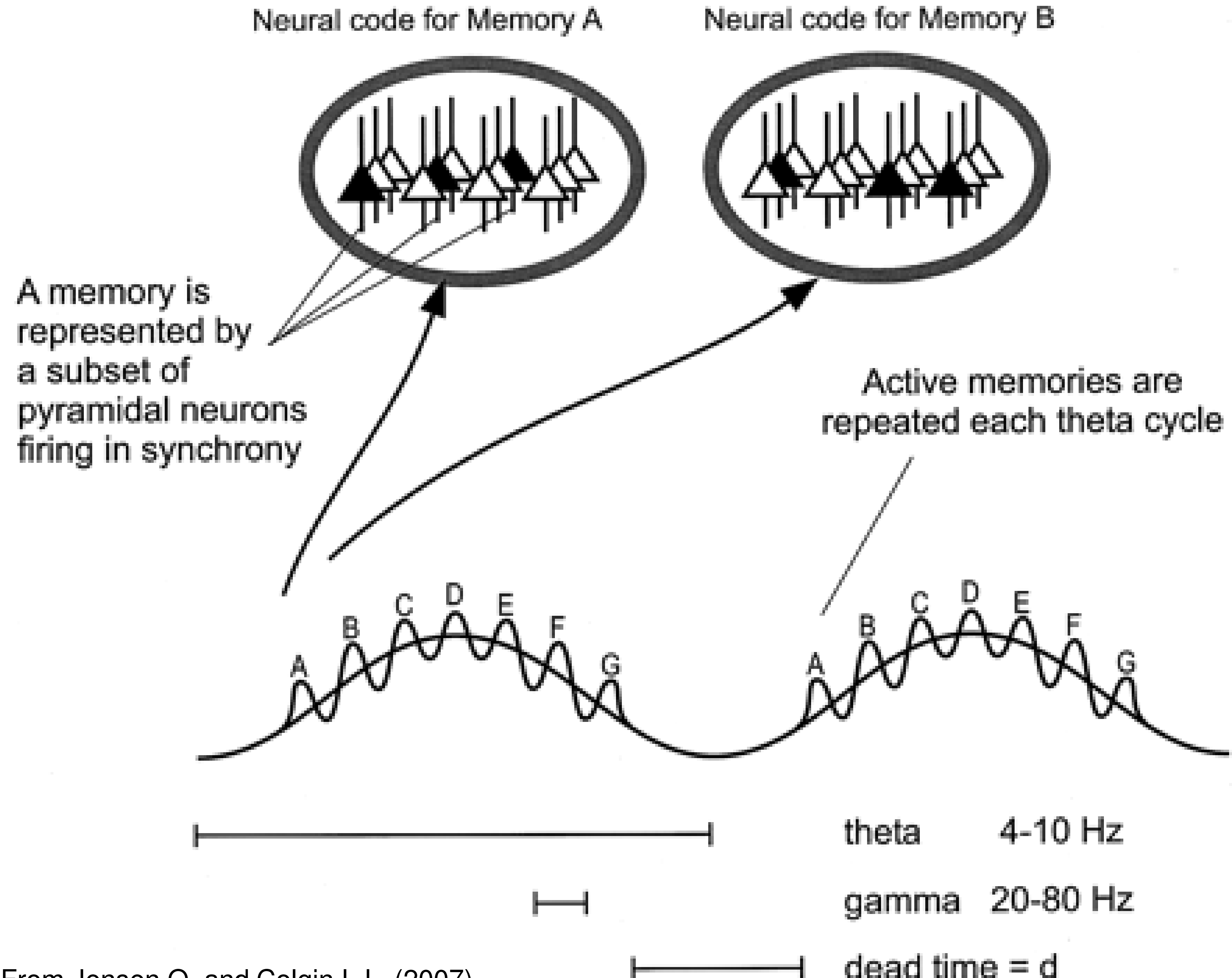

A
Pre. Im
Pre. APs
100 mV
Post. EPSPs
4 mV
Post. Im
Post. APs
100 mV
50 ms
B
Reinforced with In-Phase
EPSP amplitude (% of control)
160
150
140
130
120
110
100
90
80
0
25
50
Time (min)
Suppressed if Out-of-phase
C
EPSP amplitude (% of control)
180
160
140
120
100
80
10
20
30
40
AP-EPSP frequency (Hz)
D
180
160
140
120
100
80
60
0
25
50
Time (min)

Cross-Frequency Phase Lock and Phase Shift Spectrum

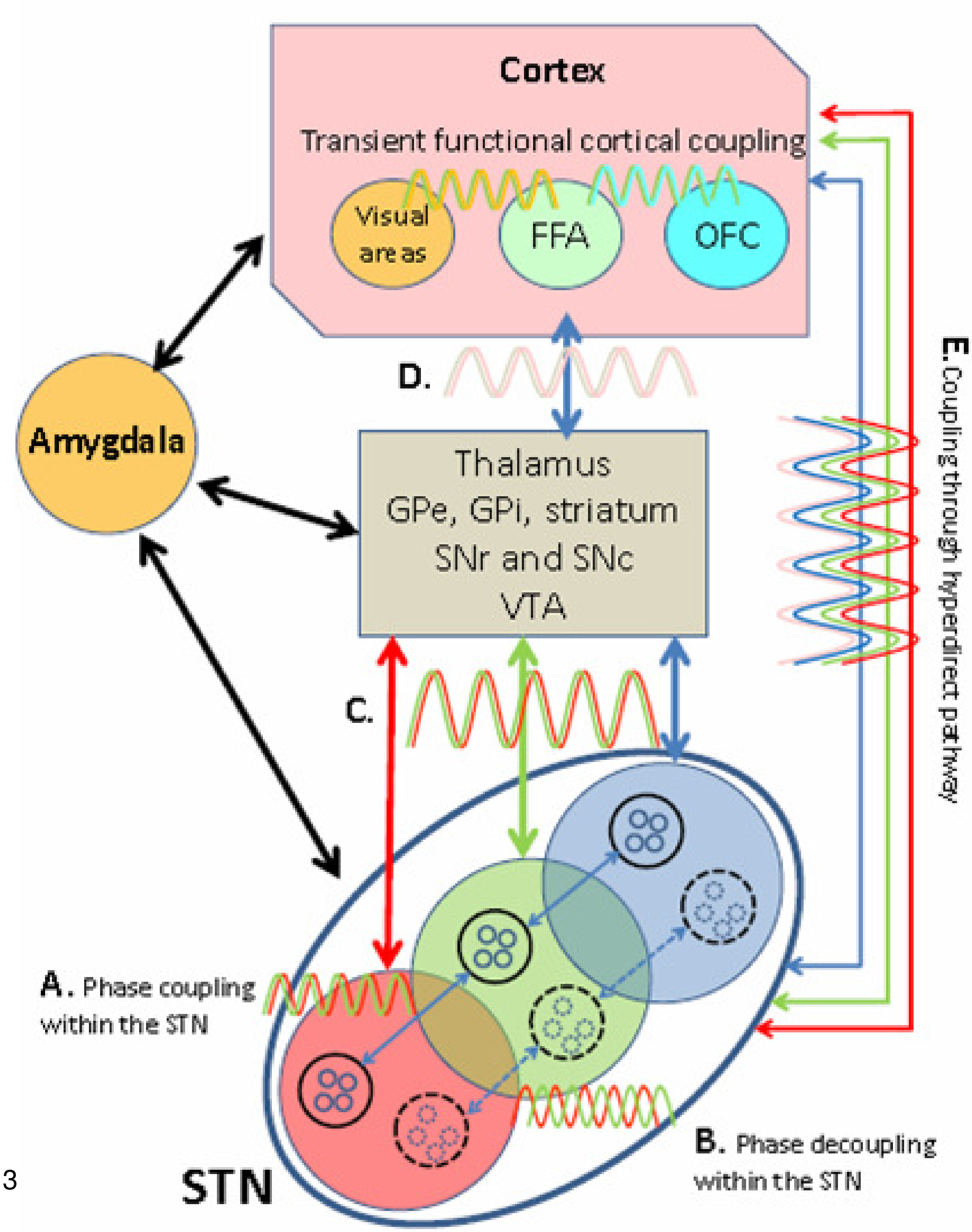




K. Kessler et al. J.; Neuroscience and Behavioral Reviews. 71(2016) 601-620



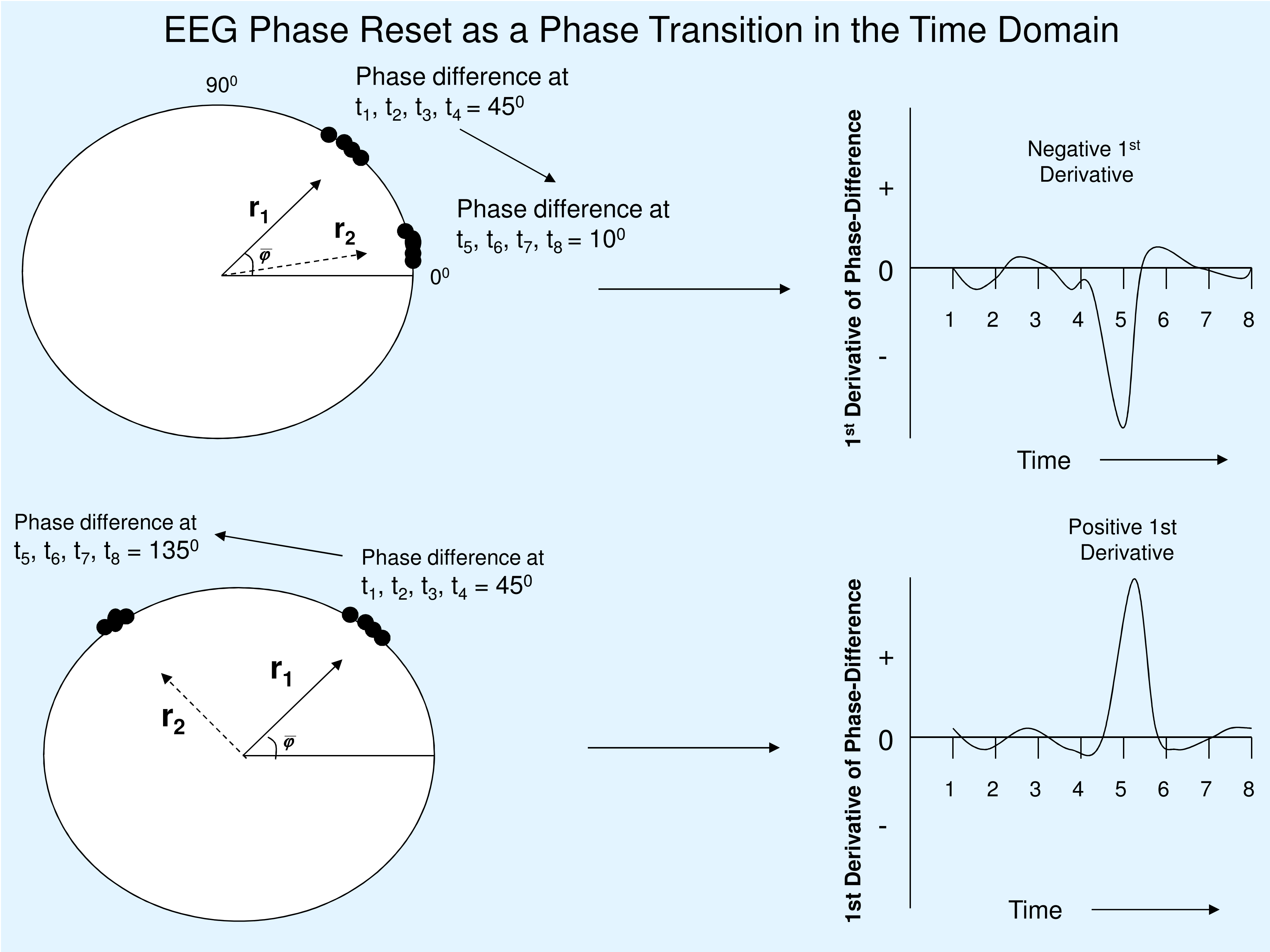
From Jensen,O.,and Colgin,L.L. (2007)



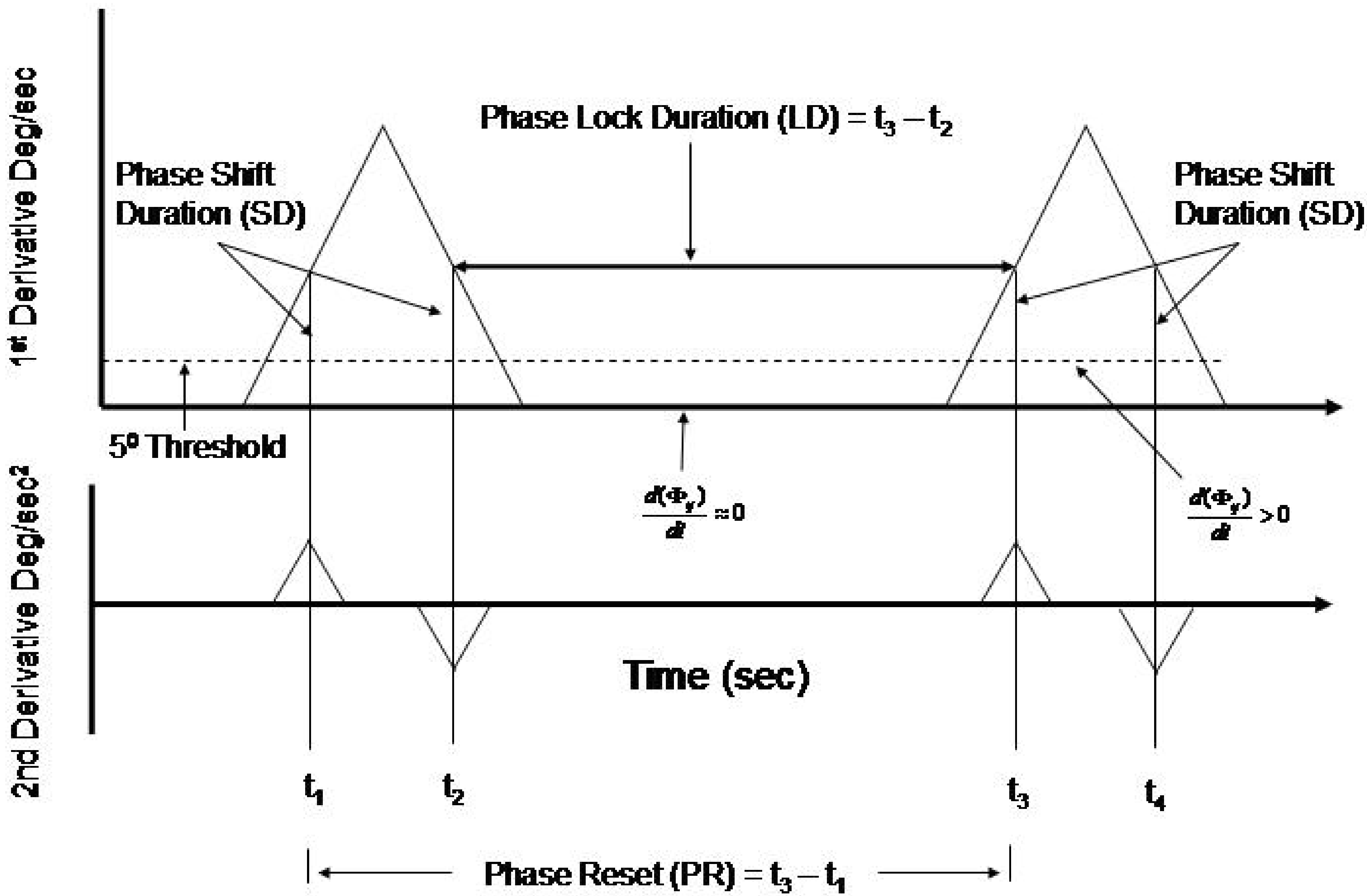
From Peron et al, 2013

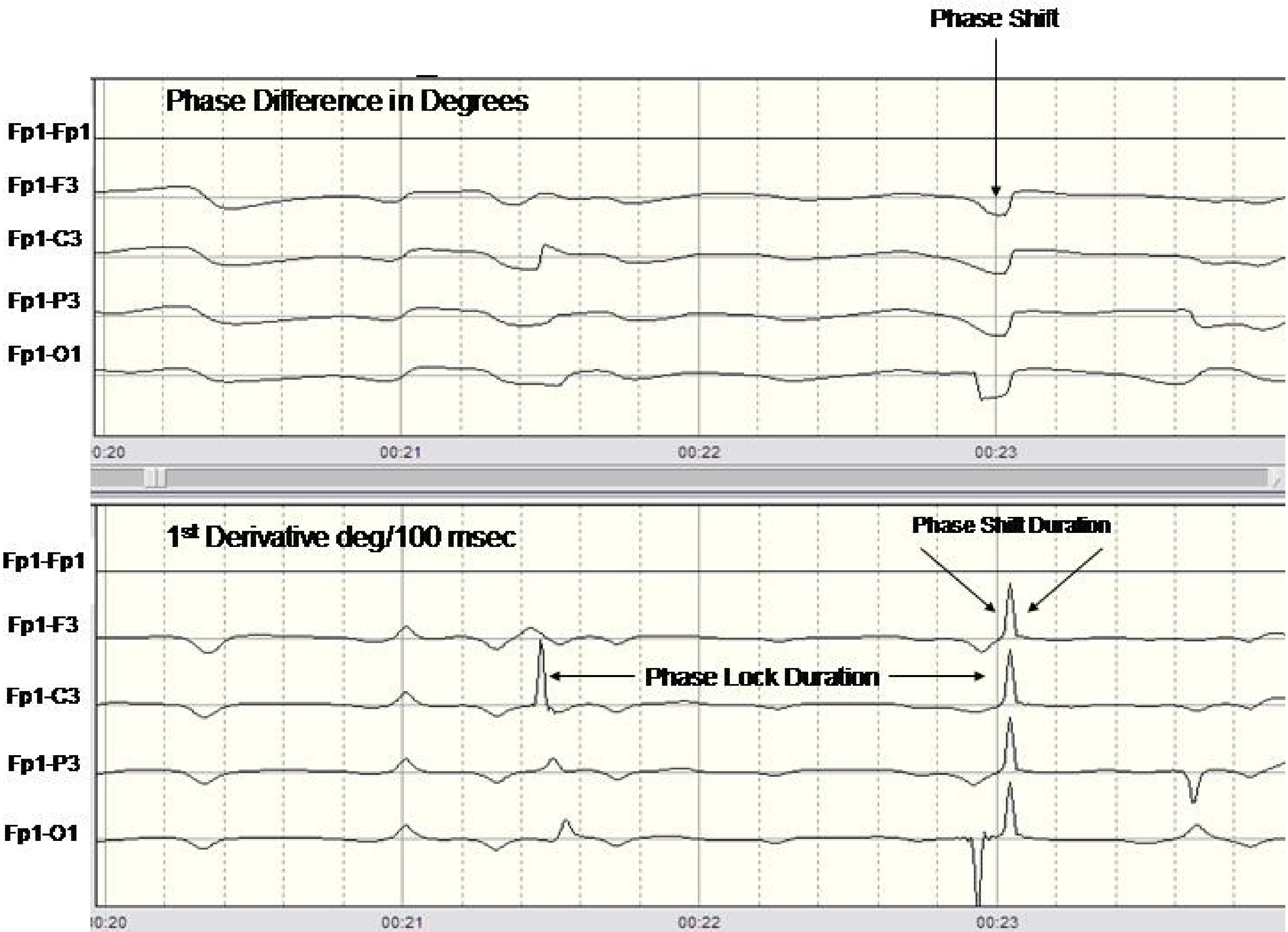
How to Measure Phase Shift and Phase Lock

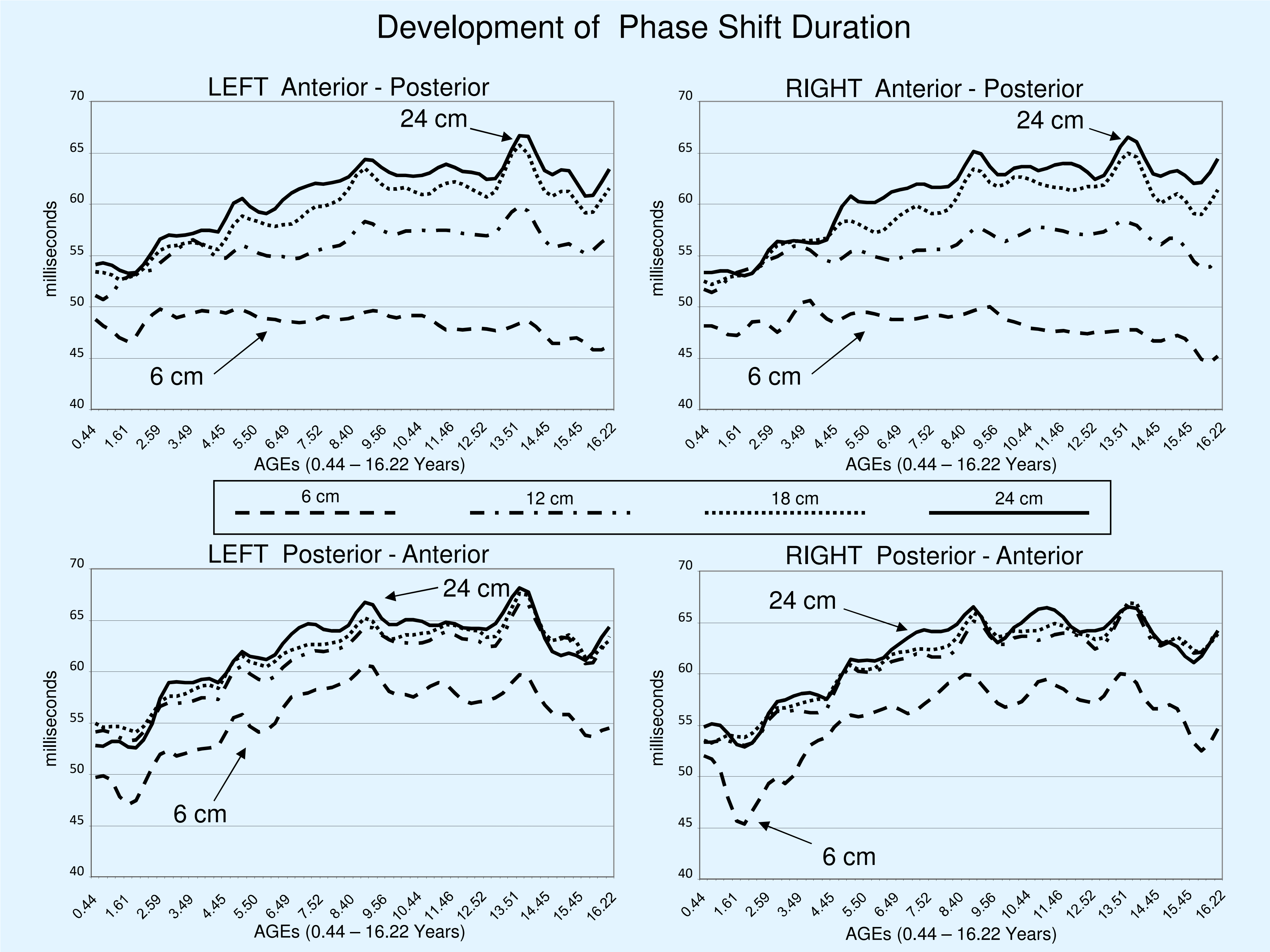
Phase Reset and Neural Resource Selection and Allocation


EEG Phase Reset as a Phase Transition in the Time Domain
90⁰
Phase difference at
t1, t2, t3, t4 = 45⁰
r1
r2
φ
Phase difference at
t5, t6, t7, t8 = 10⁰
0⁰
1st Derivative of Phase-Difference
Negative 1st Derivative
+
0
-
1 2 3 4 5 6 7 8
Time
Phase difference at
t5, t6, t7, t8 = 135⁰
Phase difference at
t1, t2, t3, t4 = 45⁰
r1
r2
φ
1st Derivative of Phase-Difference
Positive 1st Derivative
+
0
-
1 2 3 4 5 6 7 8
Time

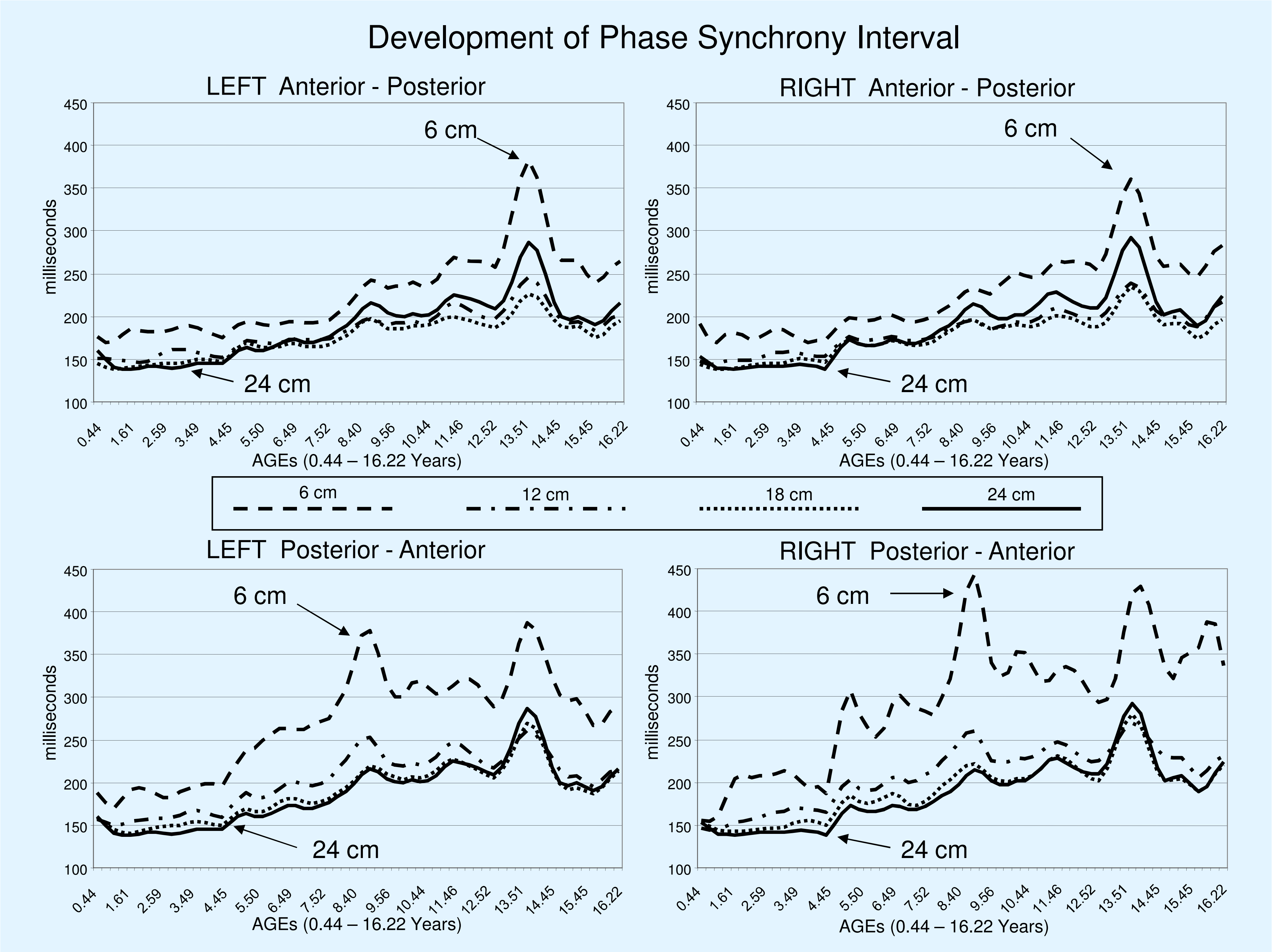
Phase Reset Metrics




Phase Shift
Phase Difference in Degrees
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23
1st Derivative deg/100 msec
Phase Shift Duration
Phase Lock Duration
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23



Development of Phase Shift Duration
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
24 cm
6 cm
milliseconds
70
65
60
55
50
45
40
0.44 1.61 2.59 3.49 4.45 5.50 6.49 7.52 8.40 9.56 10.44 11.46 12.52 13.51 14.45 15.45 16.22
AGEs (0.44 – 16.22 Years)
6 cm
12 cm
18 cm
24 cm


Development of Phase Synchrony Interval
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
milliseconds
AGEs (0.44 – 16.22 Years)
6 cm
24 cm
12 cm
18 cm
450
400
350
300
250
200
150
100
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22

Published in NeuroImage – NeuroImage, 42(4): 1639-1653, 2008.

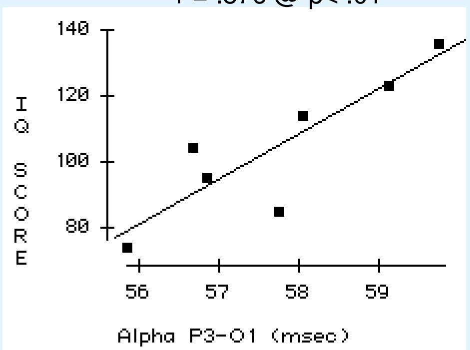
INTELLIGENCE AND EEG PHASE RESET: A TWO COMPARTMENTAL MODEL OF PHASE SHIFT AND LOCK

Thatcher, R. W. [1,2], North, D. M.[1], and Biver, C. J.[1]

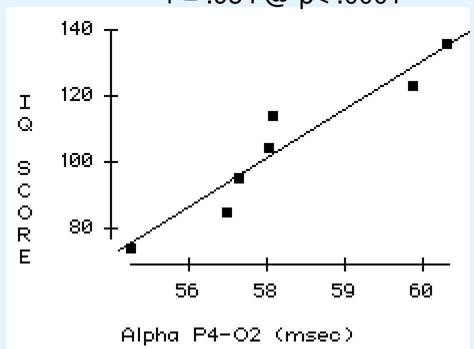
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute.
St. Petersburg, Fl[1] and Department of Neurology, University of South Florida
College of Medicine, Tampa, Fl.[2]

Regressions & Correlations of Phase Shift Duration Short Distances (6 cm)

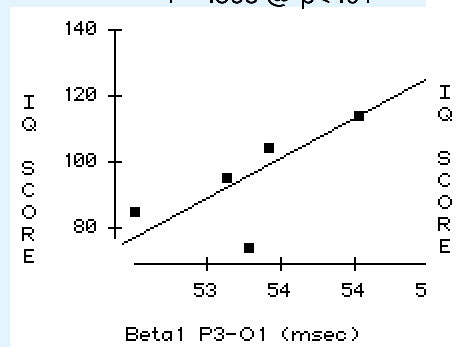
IQ = 78 + 13.78 x (msec)
r = .876 @ p< .01



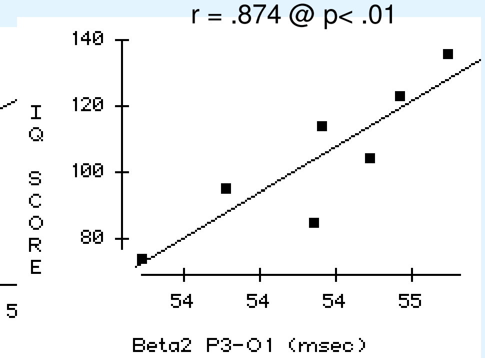
IQ = 70 +11.85 x (msec)
r = .954 @ p< .0001



IQ = 75 + 24.45 x (msec)
r = .868 @ p< .01

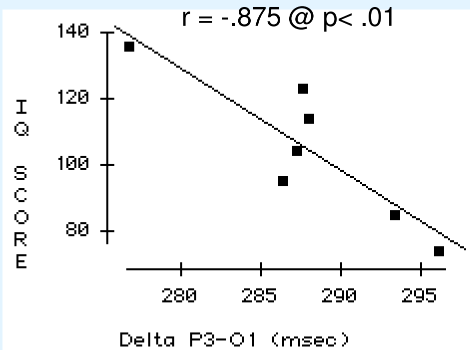


IQ = 68 + 34.40 x (msec)
r = .874 @ p< .01

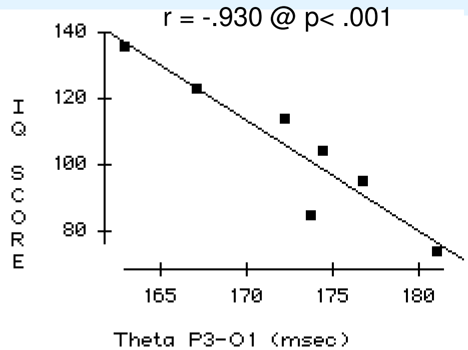


Regressions & Correlations of Phase Locking Interval Short Distances (6 cm)

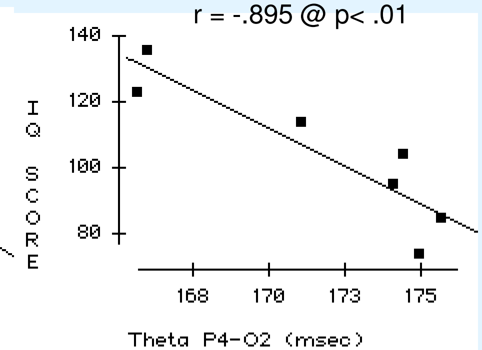
IQ = 143 - 3.11 x (msec)
r = -.875 @ p< .01



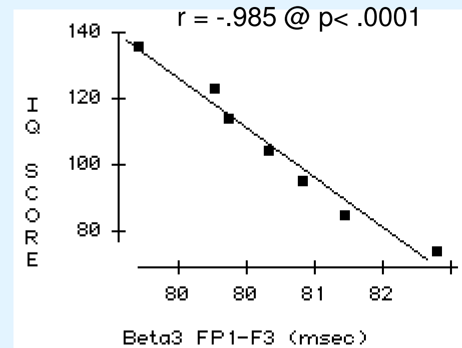
IQ = 142 - 3.36 x (msec)
r = -.930 @ p< .001



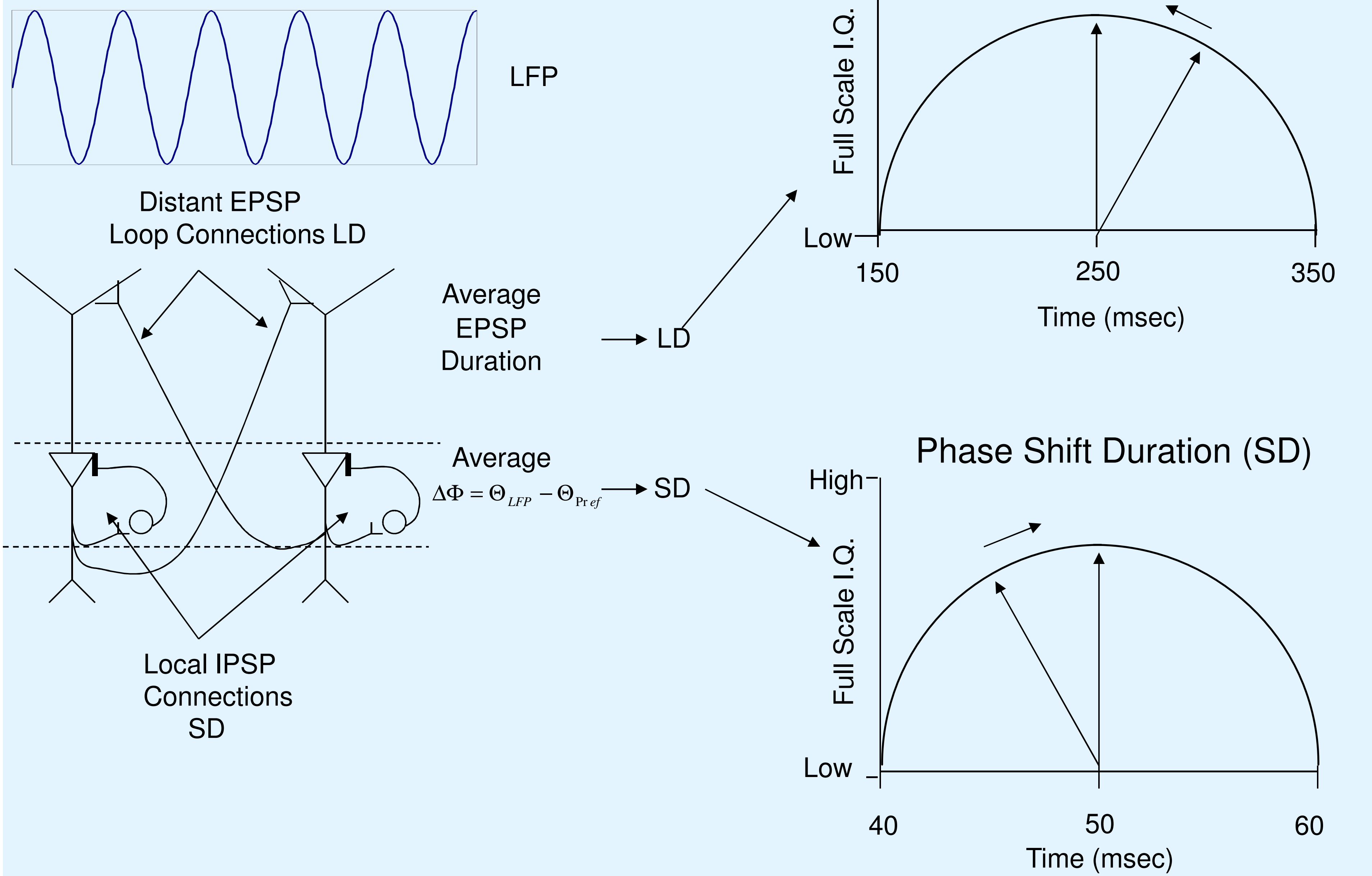
IQ = 132 - 4.57 x (msec)
r = -.895 @ p< .01



IQ = 140 - 20.08 x (msec)
r = -.985 @ p< .0001



Pyramidal Cell Model of EEG Phase Reset and Full Scale I.Q.



SCIENTIFIC REPORTS

OPEN

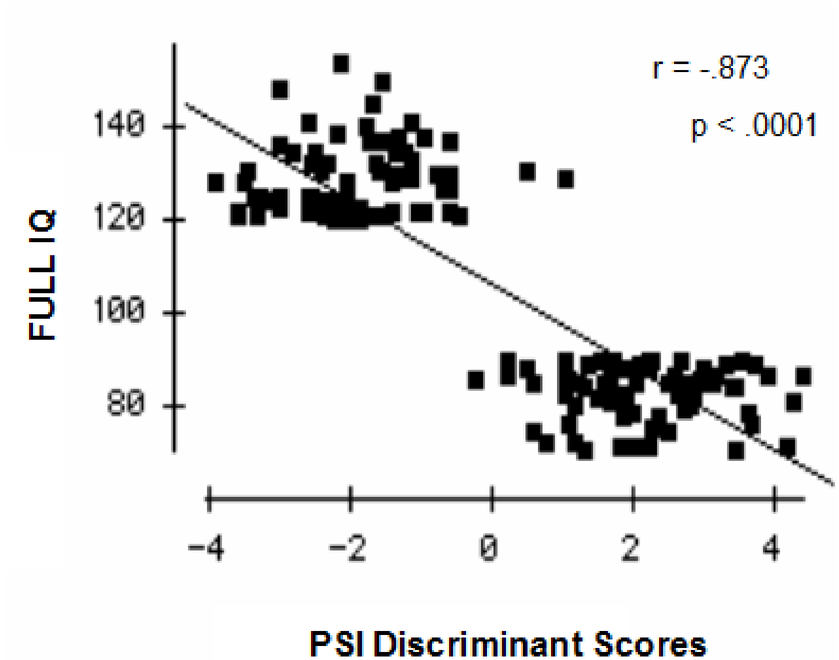
Intelligence and eeg measures of information flow: efficiency and homeostatic neuroplasticity

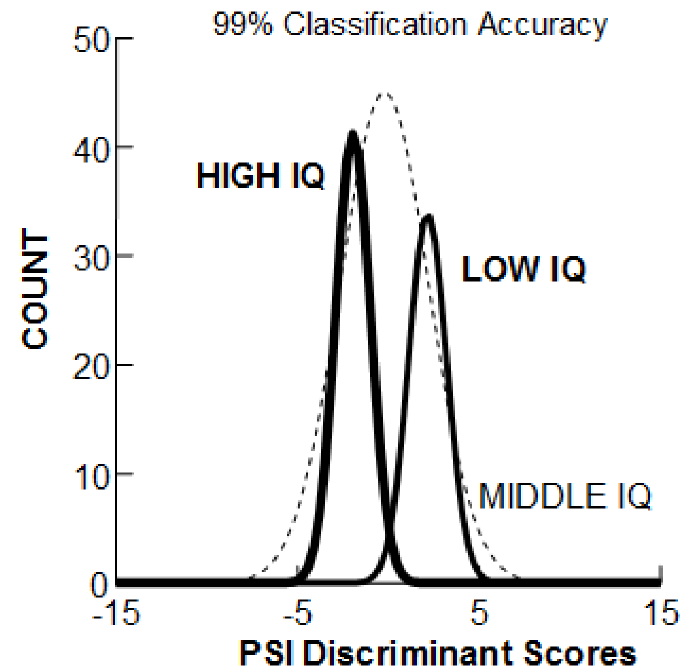
Received: 25 July 2016
Accepted: 14 November 2016
Published: 20 December 2016

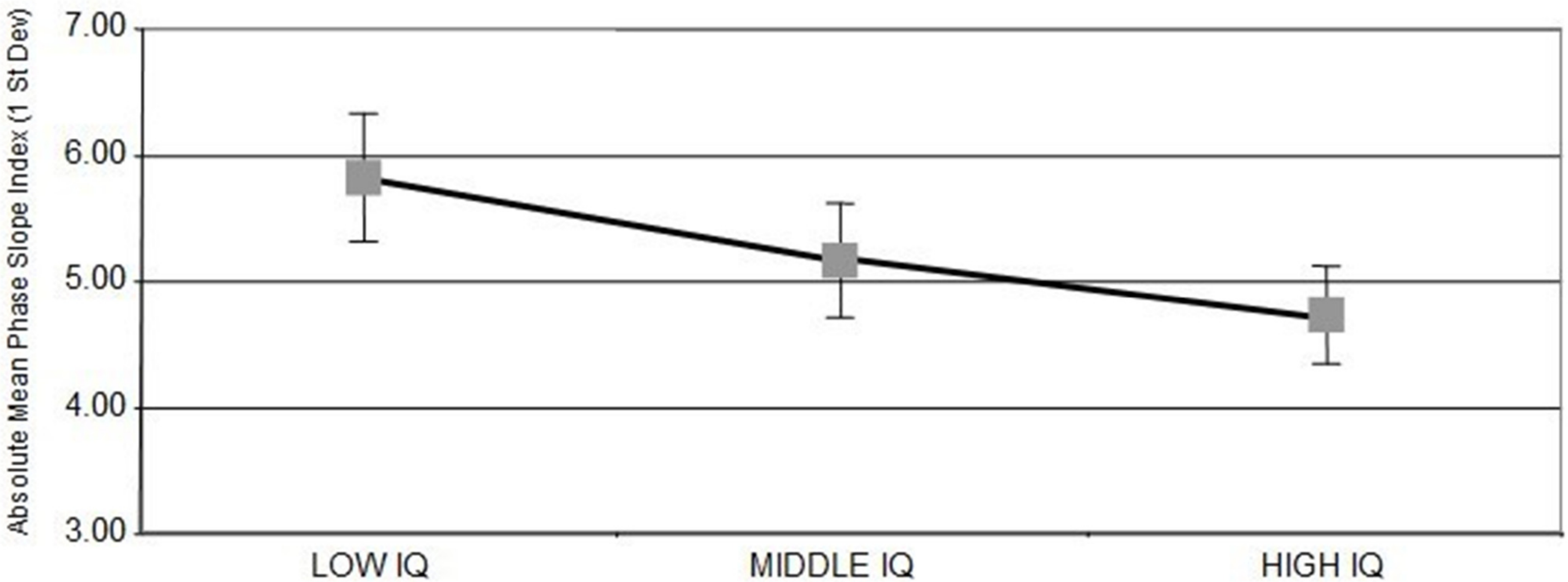
R. W. Thatcher, E. Palmero-Soler, D. M. North & C. J. Biver

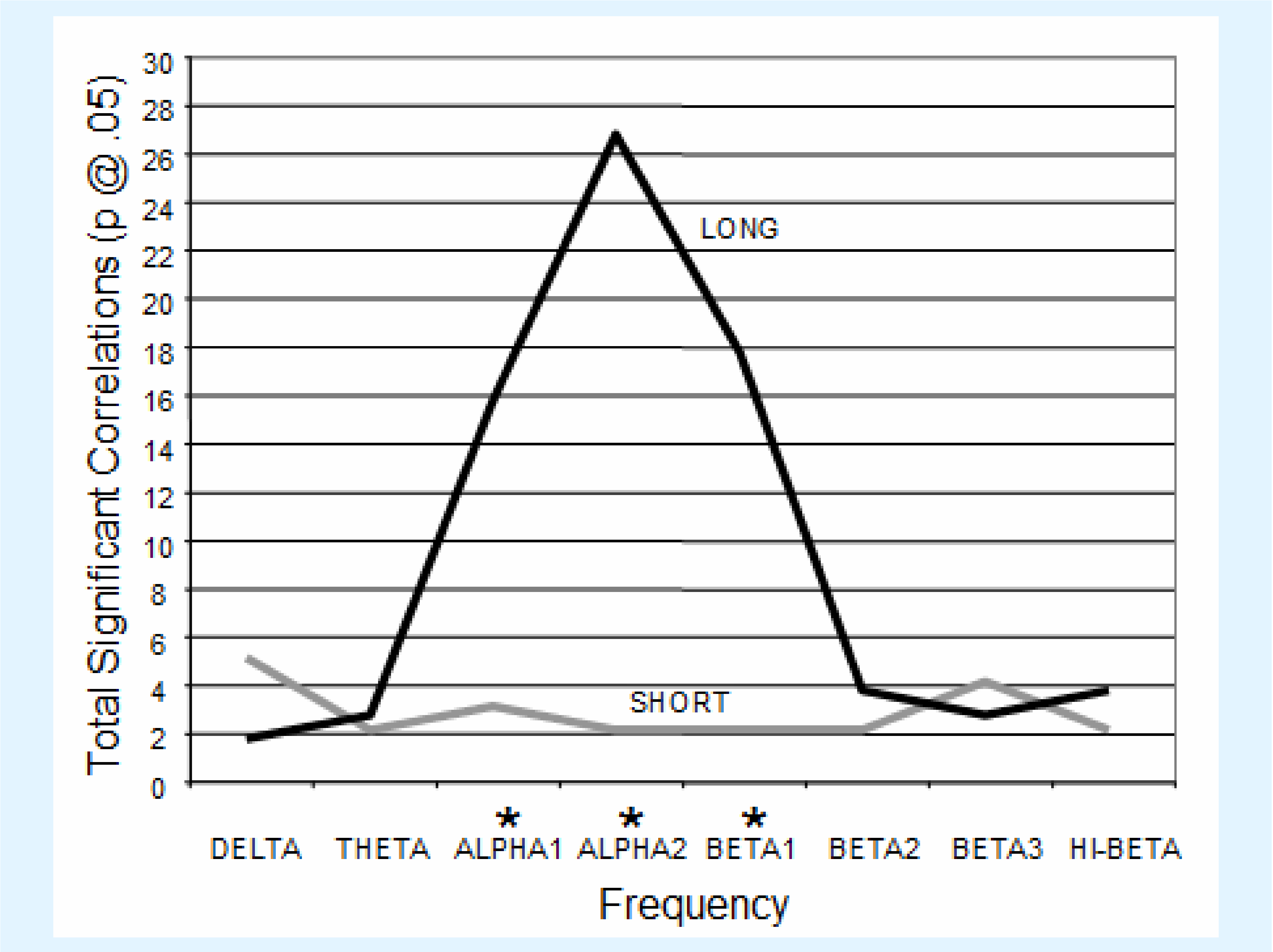
The purpose of this study was to explore the relationship between the magnitude of EEG information flow and intelligence. The electroencephalogram (EEG) was recorded from 19 scalp locations from 371 subjects ranging in age from 5 years to 17.6 years. The Wechler Intelligence Scale for Children (WISC-R) was administered for individuals between 5 years of age and 16 years and the Weschler Adult Intelligence Scale revised (WAIS-R) was administered to subjects older than 16 years to estimate I.Q. The phase slope index estimated the magnitude of information flow between all electrode combinations for difference frequency bands. Discriminant analyses were performed between high I.Q. (>120) and low I.Q. groups (<90). The magnitude of information flow was inversely related to I.Q. especially in the alpha and beta frequency bands. Long distance inter-electrode distances exhibited greater information flow than short inter-electrode distances. Frontal-parietal correlations were the most significant. It is concluded that higher I.Q. is related to increased efficiency of local information processing and reduced long distance compensatory dynamics that supports a small-world model of intelligence.

Discriminant Scores of the Magnitude of Phase Slope Index (PSI) with Full Scale IQ

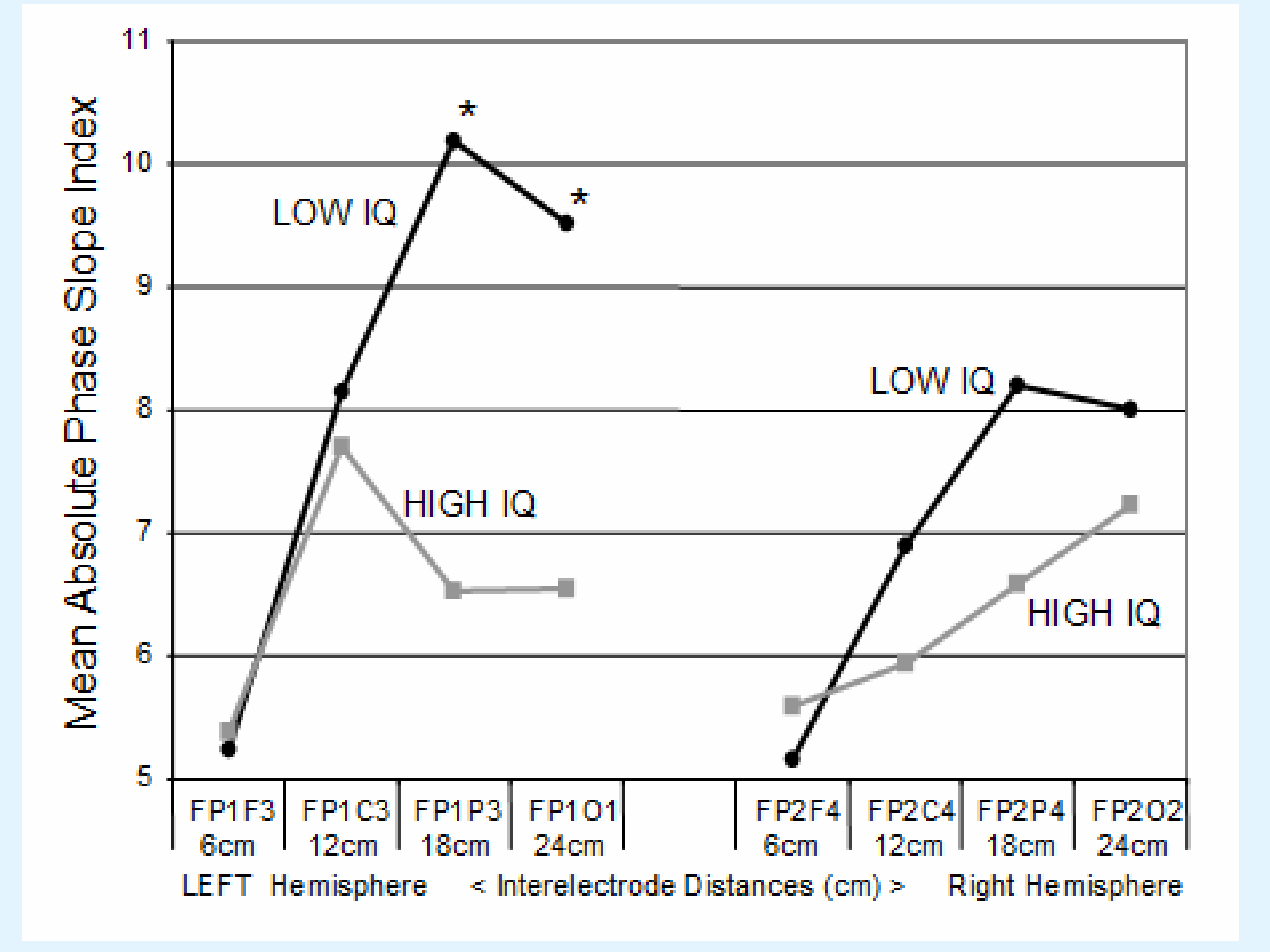


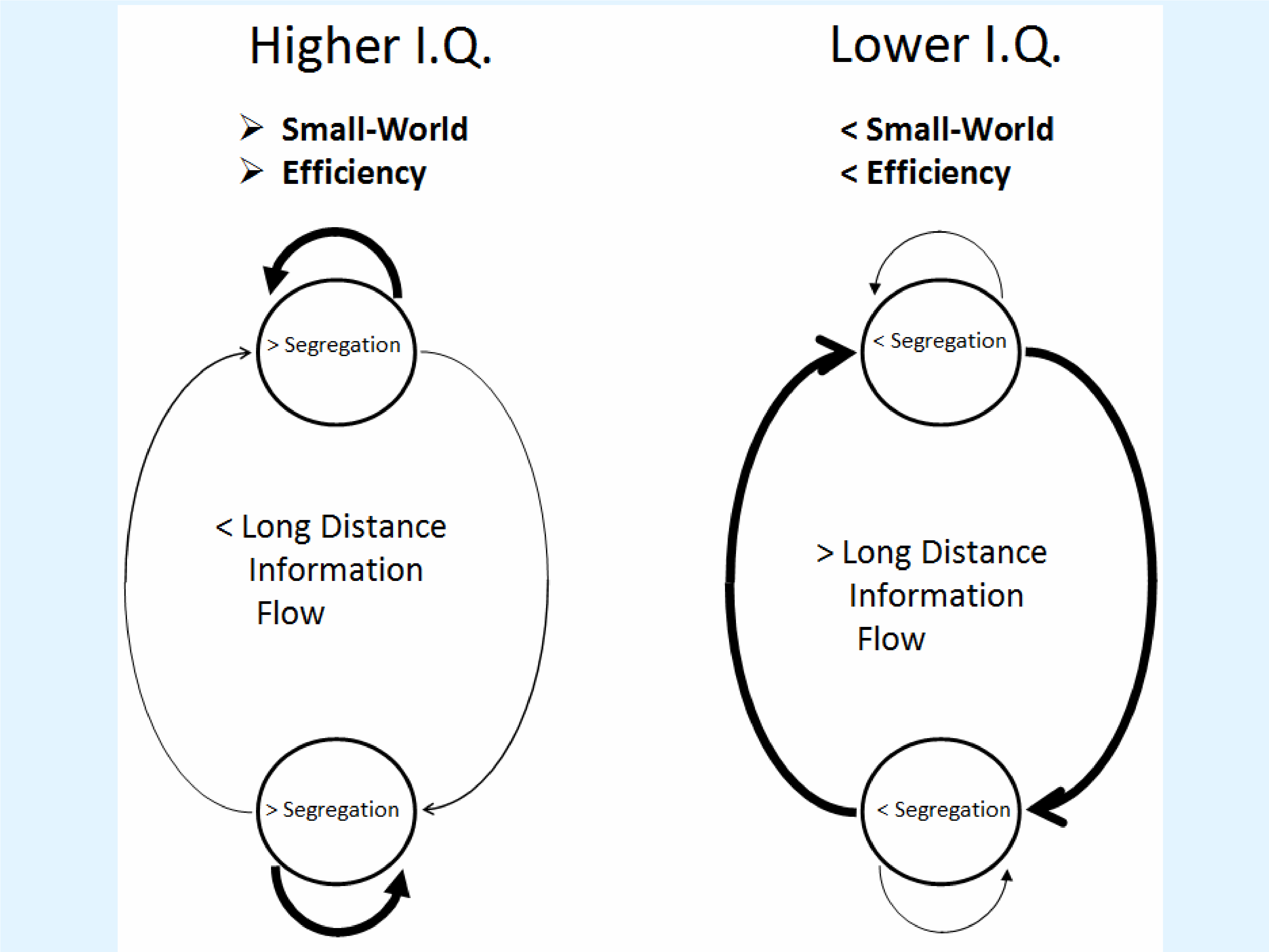



Absolute Mean Phase Slope Index (1 St Dev)
7.00
6.00
5.00
4.00
3.00
LOW IQ
MIDDLE IQ
HIGH IQ



Total Significant Correlations (p @ .05)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
LONG
SHORT
DELTA
THETA
* ALPHA1
* ALPHA2
* BETA1
BETA2
BETA3
HI-BETA
Frequency


Mean Absolute Phase Slope Index
11
10
9
8
7
6
5
LOW IQ
HIGH IQ
LOW IQ
HIGH IQ
*
*
FP1F3 6cm
FP1C3 12cm
FP1P3 18cm
FP1O1 24cm
FP2F4 6cm
FP2C4 12cm
FP2P4 18cm
FP2O2 24cm
LEFT Hemisphere
< Interelectrode Distances (cm) >
Right Hemisphere

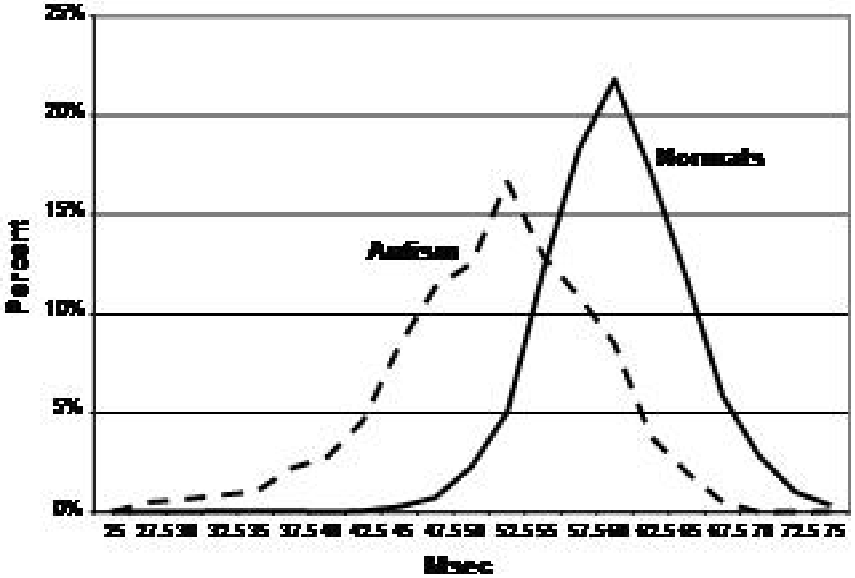

Higher I.Q.
➢ Small-World
➢ Efficiency
> Segregation
< Long Distance Information Flow
> Segregation
Lower I.Q.
< Small-World
< Efficiency
< Segregation
> Long Distance Information Flow
< Segregation

AUTISM AND EEG PHASE RESET:
A UNIFIED THEORY OF DEFICIENT GABA MEDIATED INHIBITION IN THALAMO-CORTICAL CONNECTIONS

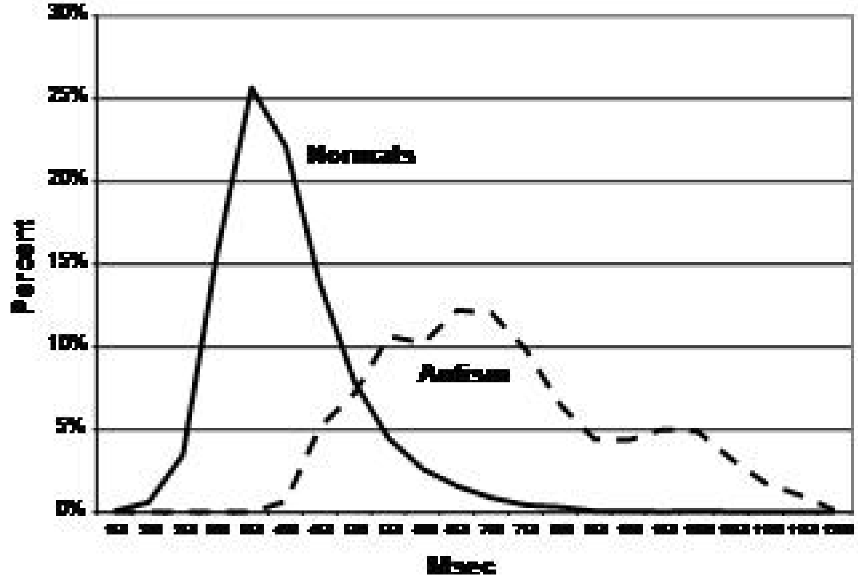
Thatcher, R. W. 1,2, Phillip DeFina2, James Neurbrander2, North, D. M.1, and Biver, C. J.1

EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute., St. Petersburg, Fl1 and the International Brain Research Foundation, Menlo Park, NJ2

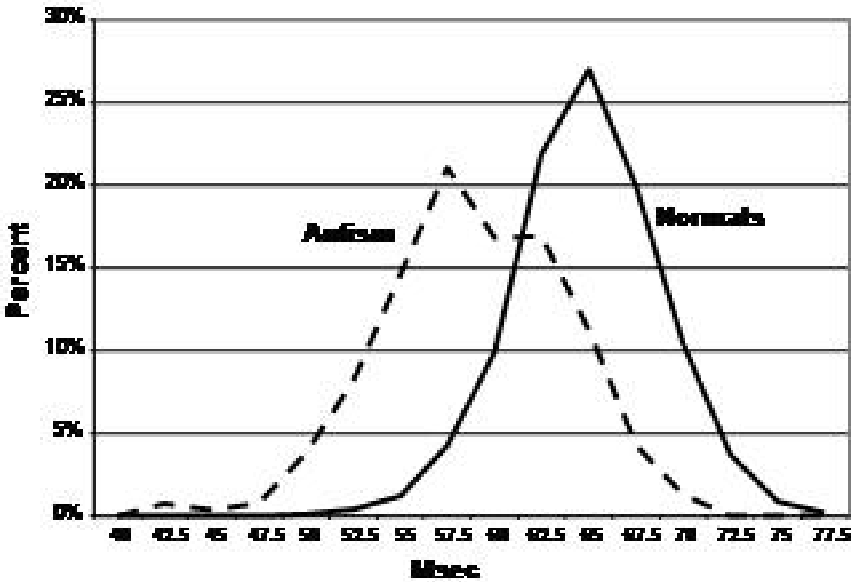
Alpha1 Shift Duration Short Distances



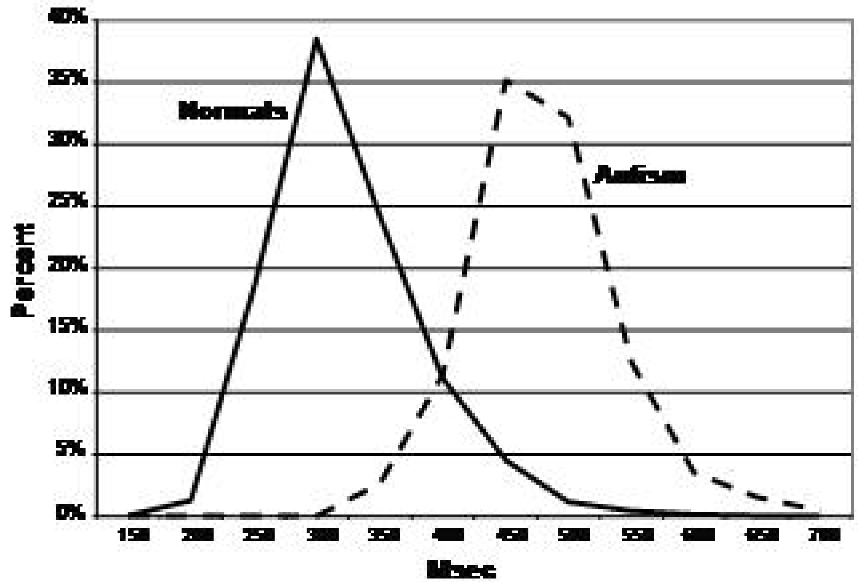
Alpha2 Lock Duration Short Distances



Alpha1 Shift Duration Long Distances



Alpha2 Lock Duration Long Distances



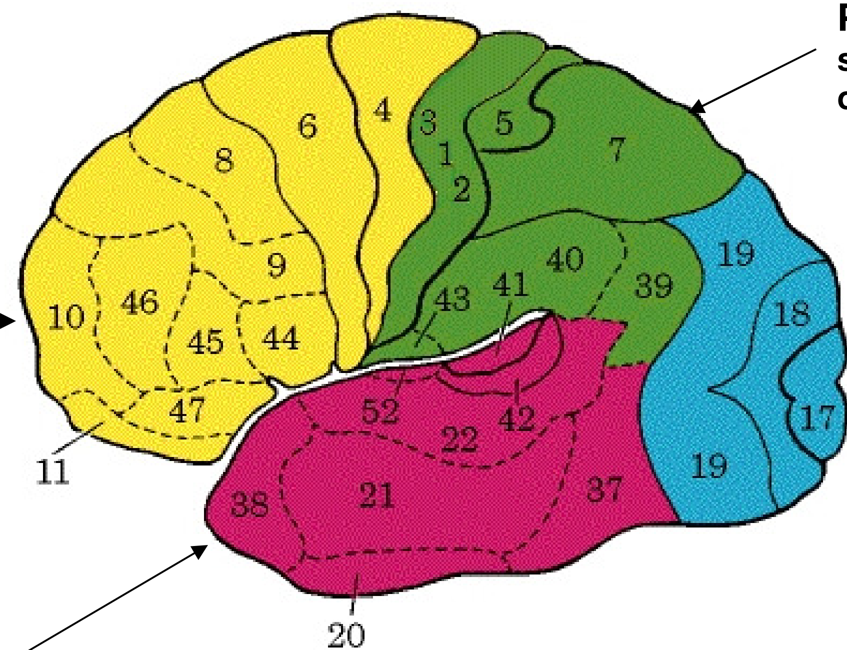
Electrical NeuroImaging of Functional Modules and Hubs as Measured by fMRI and PET

Phase Shift and Phase Lock Switch Dynamics that “Animate” Information Flow Within and Between Modules and Hubs

Brodmann Areas

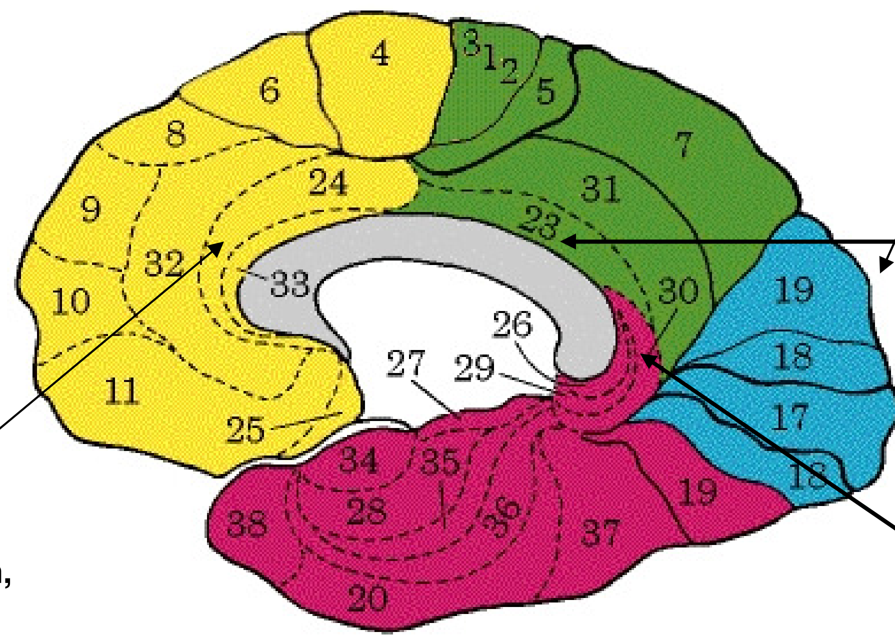
Parietal Lobe
somatosensory perception integration of visual & somatospatial information

Frontal Lobe
Thinking, Planning, Motor execution, Executive Functions, Mood Control



Temporal Lobe
language function and auditory perception involved in long term memory and emotion

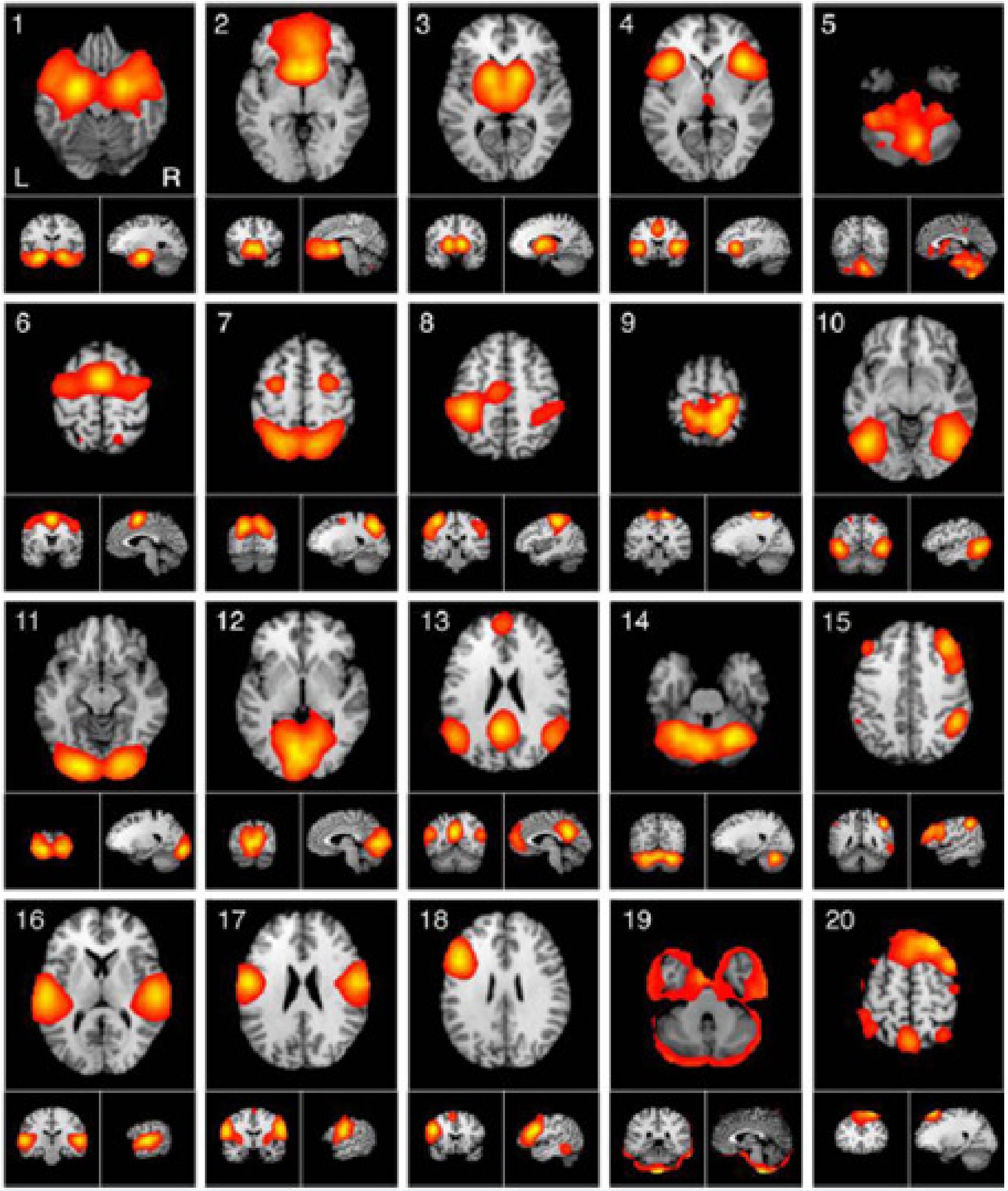
Occipital Lobe
Visual perception & Spatial processing



Posterior Cingulate
attention, long-term memory

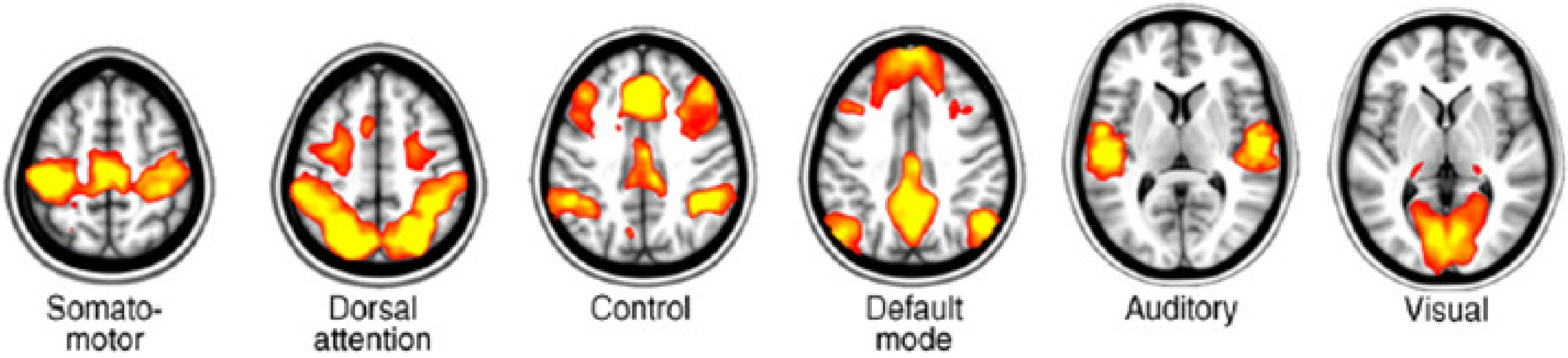
Anterior Cingulate Gyrus
Volitional movement, attention, long term memory

Parahippocampal Gyrus
Short-term memory, attention



Laird et al (2011) summarized the various "intrinsic connectivity networks" or ICNs into eighteen specific groupings based upon 30,000 fMRI and PET studies

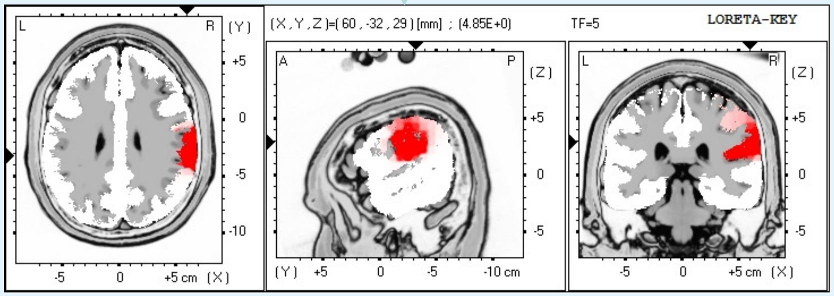
Six Functional Modules as Measured by fMRI



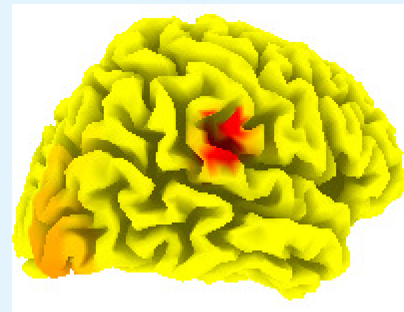
From Raichle, 2010

Electrical Neuroimaging and Cortical Source Localization

Horizontal, Sagital & Coronal Views of a Single Slice



Cortical Surface Projection



Tomographic Slice Display

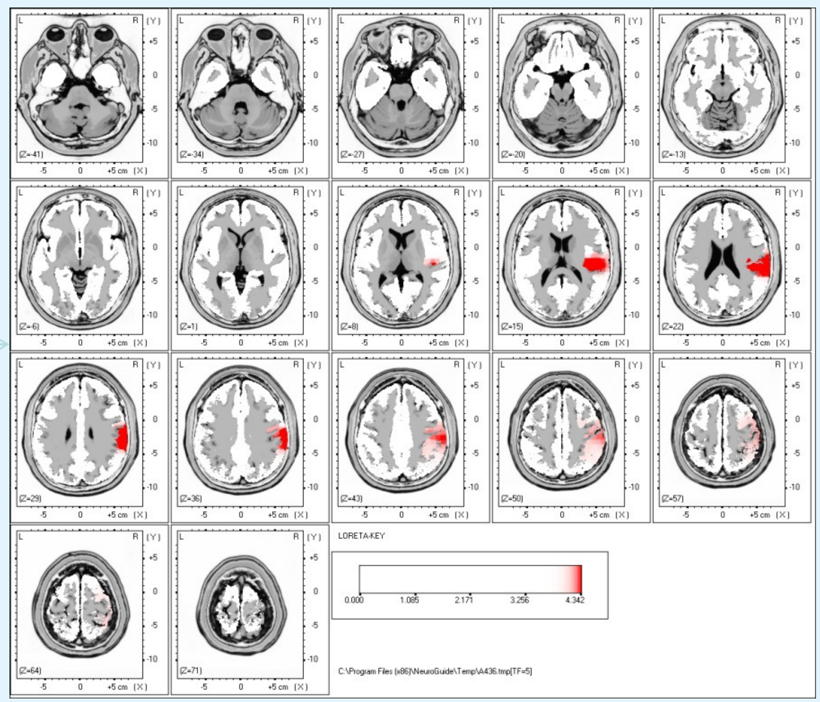


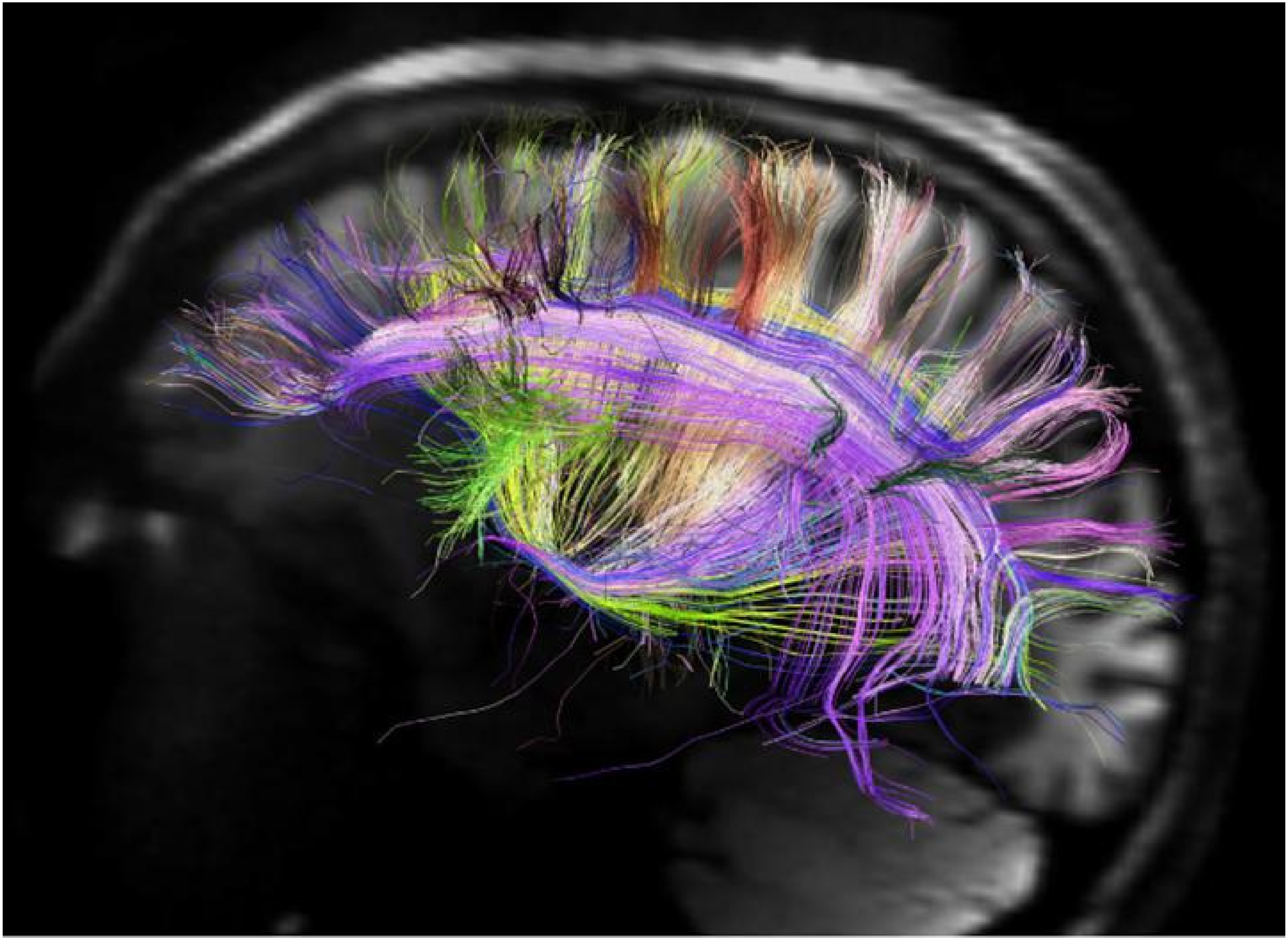
Table 5: Error measure ED1 for the four inverse algorithms, with regularization, under four different noise levels: 25 dB, 15 dB, 10 dB and 5 dB. Each cell value gives the mean and standard deviation.

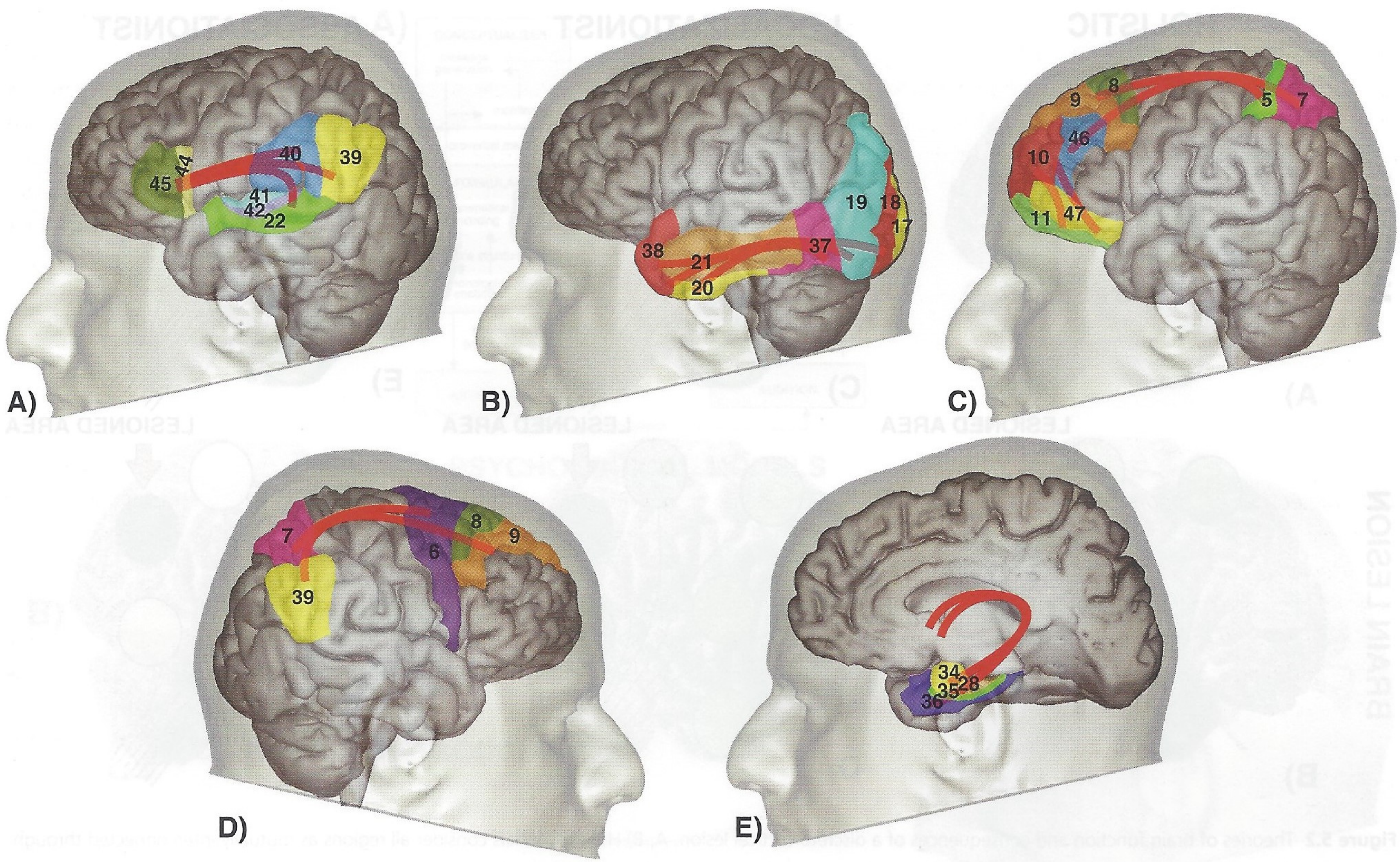
		ED1			
		Regularised			
	SNR/dB	5	10	15	25
	Layer				
WMN	Surface	3.46 ± 0.42	2.10 ± 0.28	1.34 ± 0.11	1.13 ± 0.03
	Middle	5.08 ± 0.50	3.94 ± 0.38	2.95 ± 0.21	2.40 ± 0.03
	Deep	5.91 ± 0.39	5.31 ± 0.36	4.61 ± 0.24	3.89 ± 0.15
sLORETA	Surface	0.99 ± 0.1	0.49 ± 0.08	0.11 ± 0.04	0.00 ± 0.00
	Middle	1.61 ± 0.13	0.84 ± 0.11	0.25 ± 0.07	0.00 ± 0.00
	Deep	1.79 ± 0.25	0.95 ± 0.16	0.39 ± 0.13	0.00 ± 0.00
LORETA	Surface	2.32 ± 0.08	2.18 ± 0.04	2.16 ± 0.03	2.21 ± 0.02
	Middle	1.51 ± 0.13	1.15 ± 0.08	0.95 ± 0.07	1.05 ± 0.06
	Deep	2.30 ± 0.21	1.81 ± 0.13	1.59 ± 0.11	1.53 ± 0.09
SLF	Surface	5.27 ± 0.30	4.50 ± 0.28	3.81 ± 0.20	2.98 ± 0.13
	Middle	4.53 ± 0.39	4.09 ± 0.35	3.50 ± 0.31	2.51 ± 0.15
	Deep	3.89 ± 0.55	3.70 ± 0.45	3.27 ± 0.48	1.73 ± 0.30

Electrical Neuroimaging – Assessment and Treatment

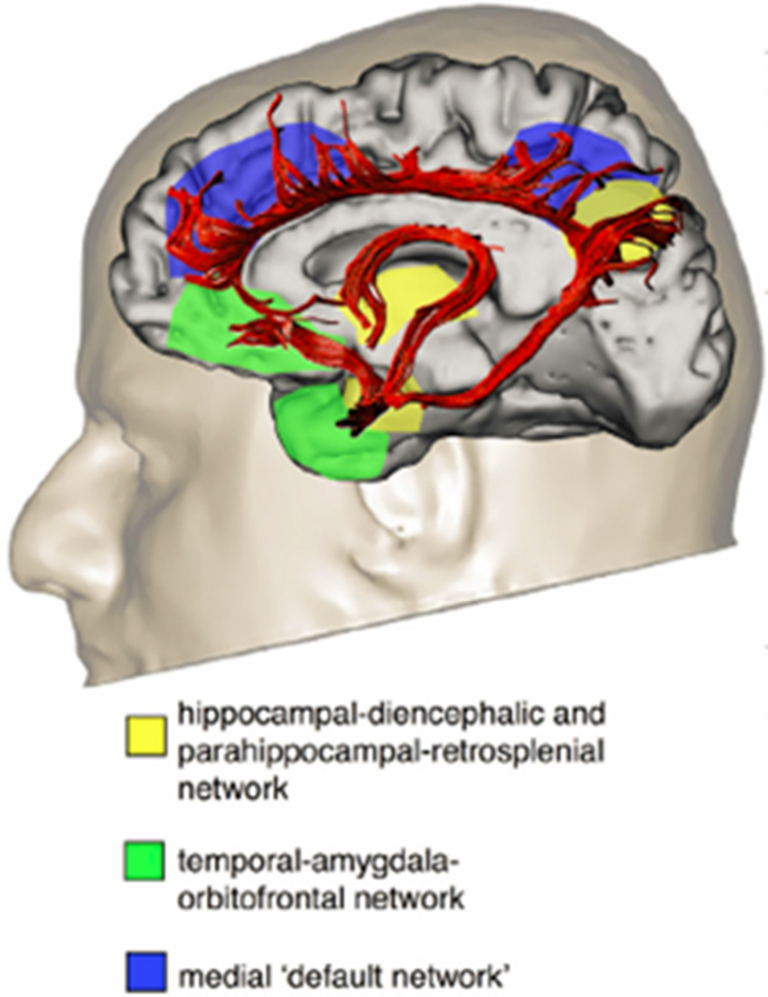
Advantages of Electrical Neuroimaging

1- Spatial Resolution – 1 cm to 3 cm
2- Temporal Resolution – 1 msec
3- Imaging of Current Sources
4- Imaging of Network Connections
5- Integration with DTI & fMRI (Brodmann Areas)
6- Inexpensive ($10,000 vs $3,000,000)
7- Dry Electrodes & Wireless Caps
8- Portable
9- Integration with Smart Phones & Tablets
10- Can Assess & Treat in Real-Time1



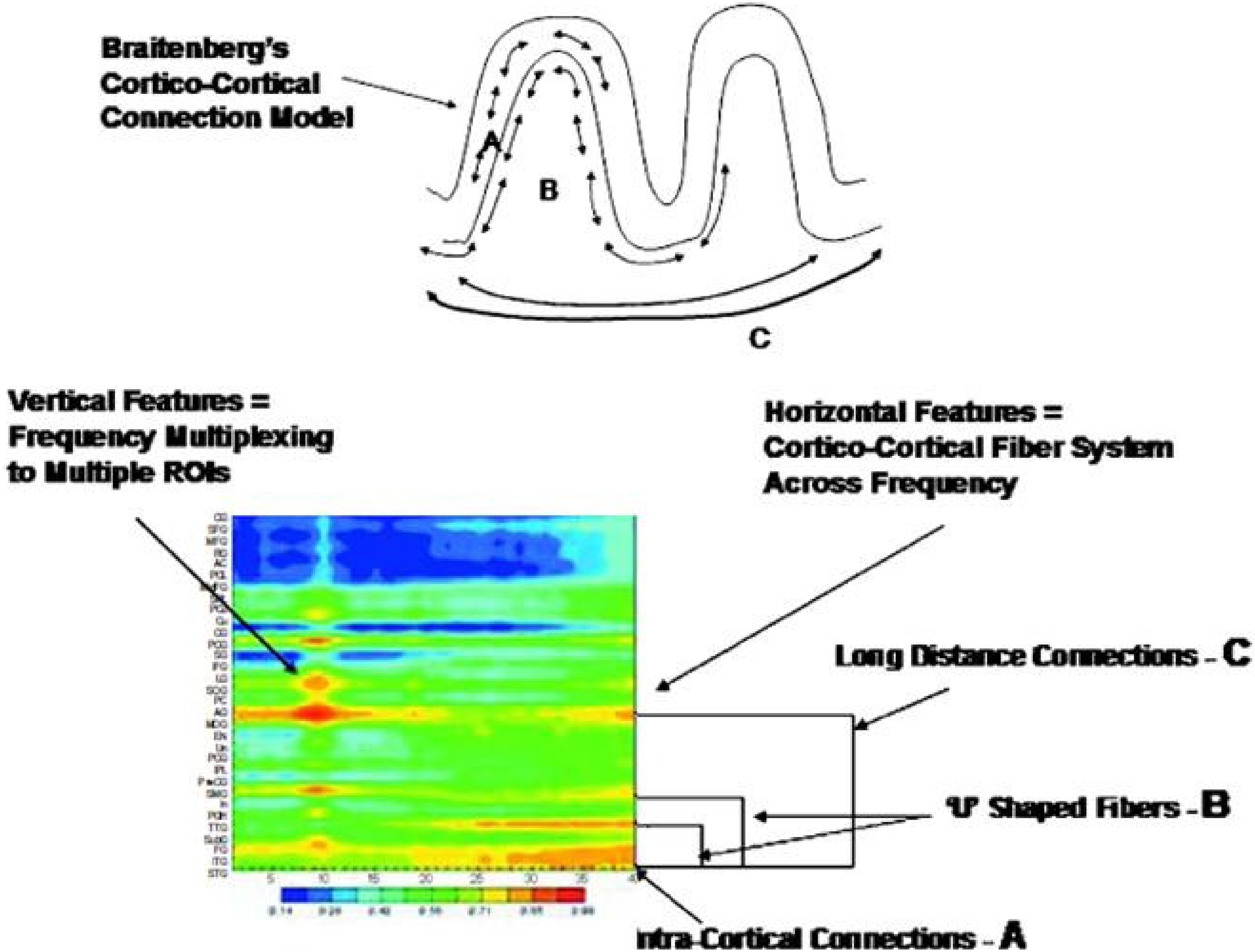


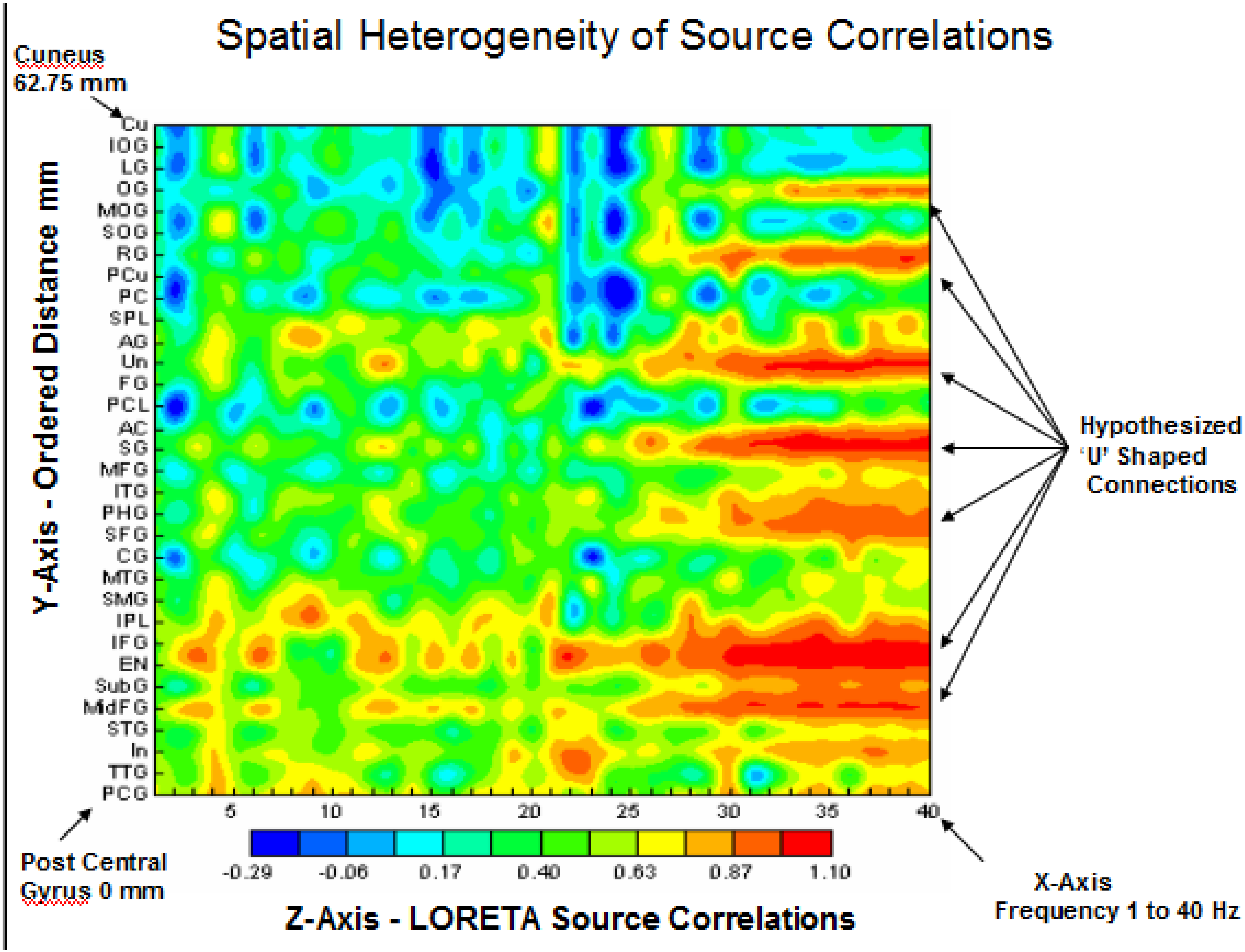
From Catani and deShotten, 2012



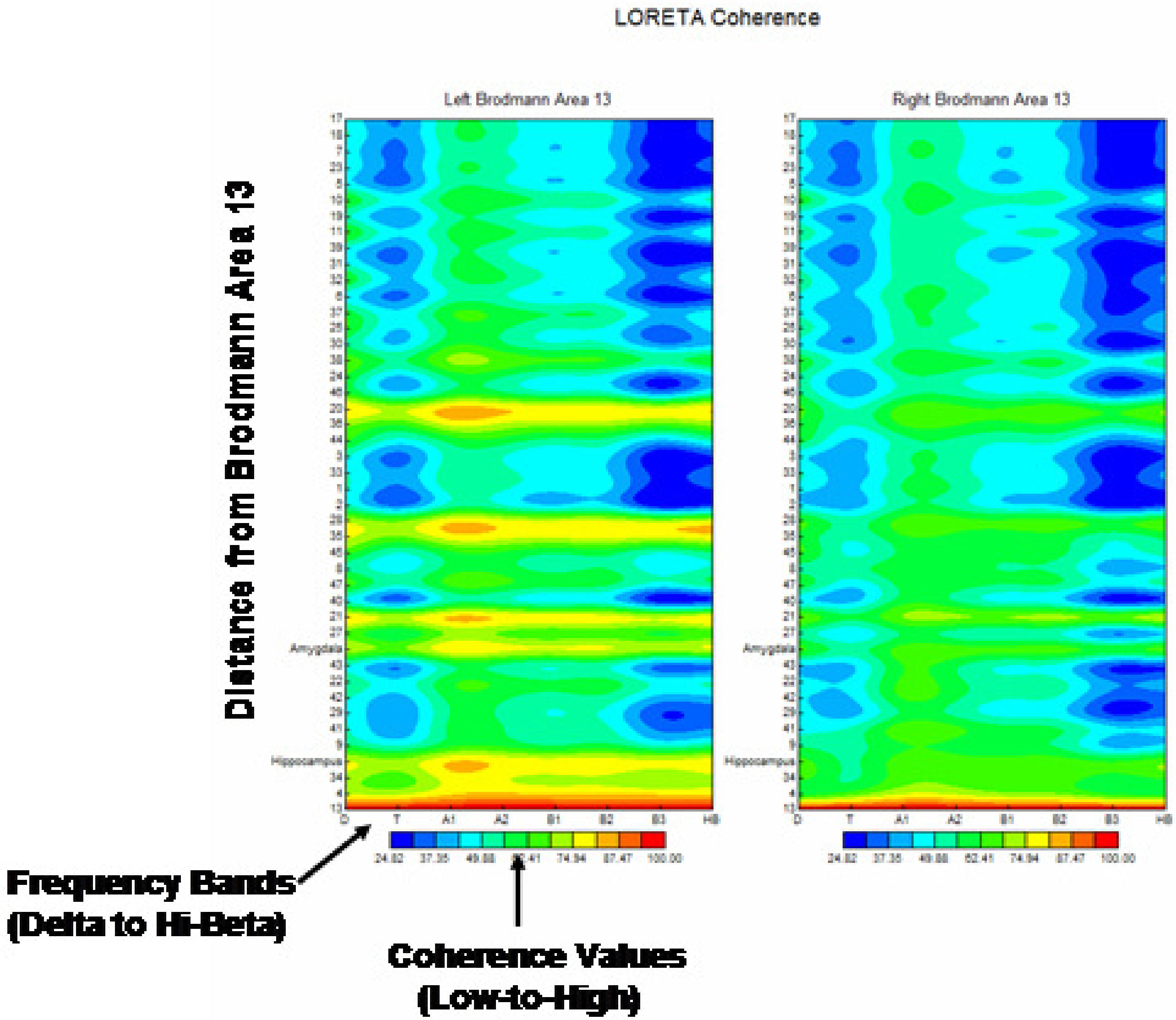
Network	Function	Disorder
Hippocampal-diencephalic and parahippocampal-retrosplenial	•memory •spatial orientation	•Amnesias •Korsakoff's syndrome •Mild Cognitive impairment •Alzheimer's disease (early) •Balint syndrome
Temporo-amydgala-orbitofrontal	•Behavioural inhibition •Memory for temporally complex visual information •Olfactory-gustatory-visceral functions •Multimodal sensory integration •Object-reward association learning •Outcome monitoring	•Alzheimer's Disease (advanced) •Semantic dementia •Klüver-Bucy syndrome •Temporal lobe epilepsy •Geschwind's syndromes •Psychopathy •Bipolar affective disorders
Dorsomedial default network	•Pain perception •Self-knowledge •Attention •Mentalizing •Empathy •Response selection and action monitoring •Autobiographical memory •Person perception	•Depression •Autism •Schizophrenia •Obsessive compulsive disorder •Mild Cognitive Impairmentt •Alzheimer's Disease (early) •Attention Deficit Hyperactivity Disorder •Anxiety

From Catani and deShotten, 2012

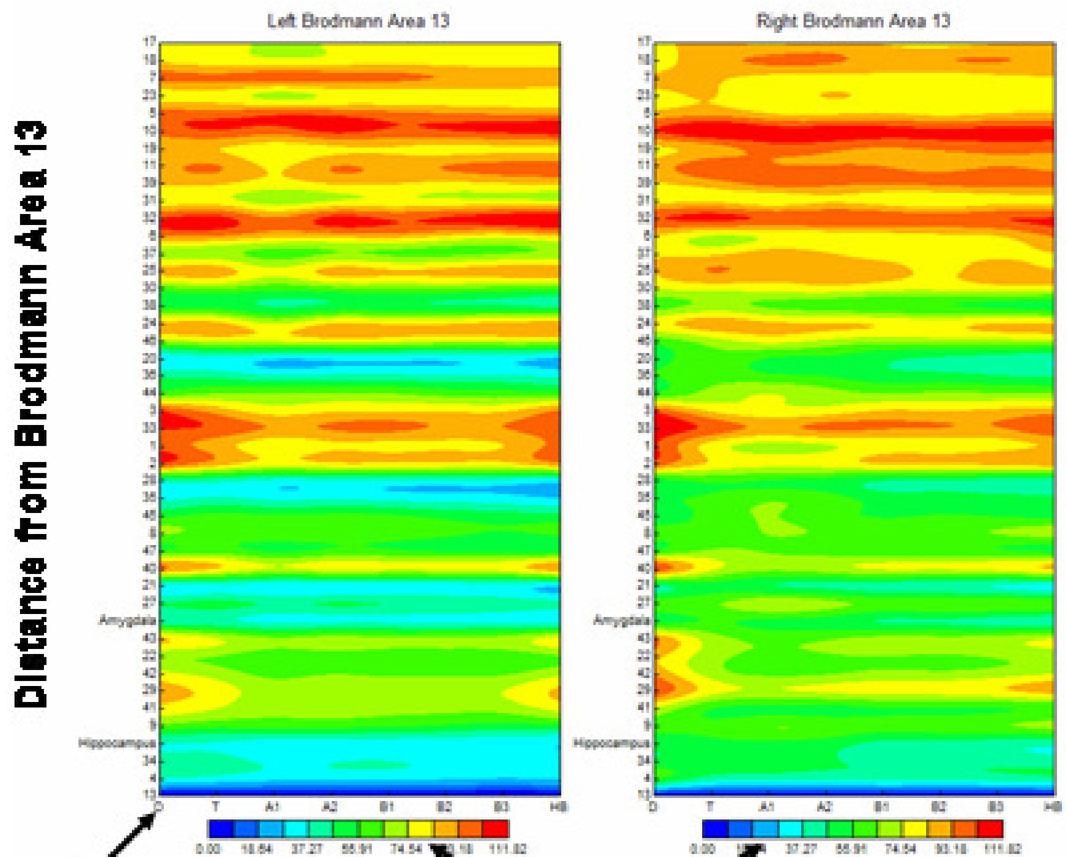

Braitenberg's
Cortico-Cortical
Connection Model
A
B
C
Vertical Features =
Frequency Multiplexing
to Multiple ROIs
Horizontal Features =
Cortico-Cortical Fiber System
Across Frequency
Long Distance Connections - C
'U' Shaped Fibers - B
ntra-Cortical Connections - A



Spatial Heterogeneity of Source Correlations
Cuneus 62.75 mm
Y-Axis - Ordered Distance mm
Cu
IOG
LG
OG
MOG
SOG
RG
PCu
PC
SPL
AG
Un
FG
PCL
AC
SG
MFG
ITG
PHG
SFG
CG
MTG
SMG
IPL
IFG
EN
SubG
MidFG
STG
In
TTG
PCG
5
10
15
20
25
30
35
40
-0.29
-0.06
0.17
0.40
0.63
0.87
1.10
Hypothesized 'U' Shaped Connections
Post Central Gyrus 0 mm
Z-Axis - LORETA Source Correlations
X-Axis Frequency 1 to 40 Hz


LORETA Coherence
Left Brodmann Area 13
Right Brodmann Area 13
Distance from Brodmann Area 13
Amygdala
Hippocampus
D T A1 A2 B1 B2 B3 HB
24.82 37.35 49.88 62.41 74.94 87.47 100.00
Frequency Bands
(Delta to Hi-Beta)
Coherence Values
(Low-to-High)

LORETA Absolute Phase



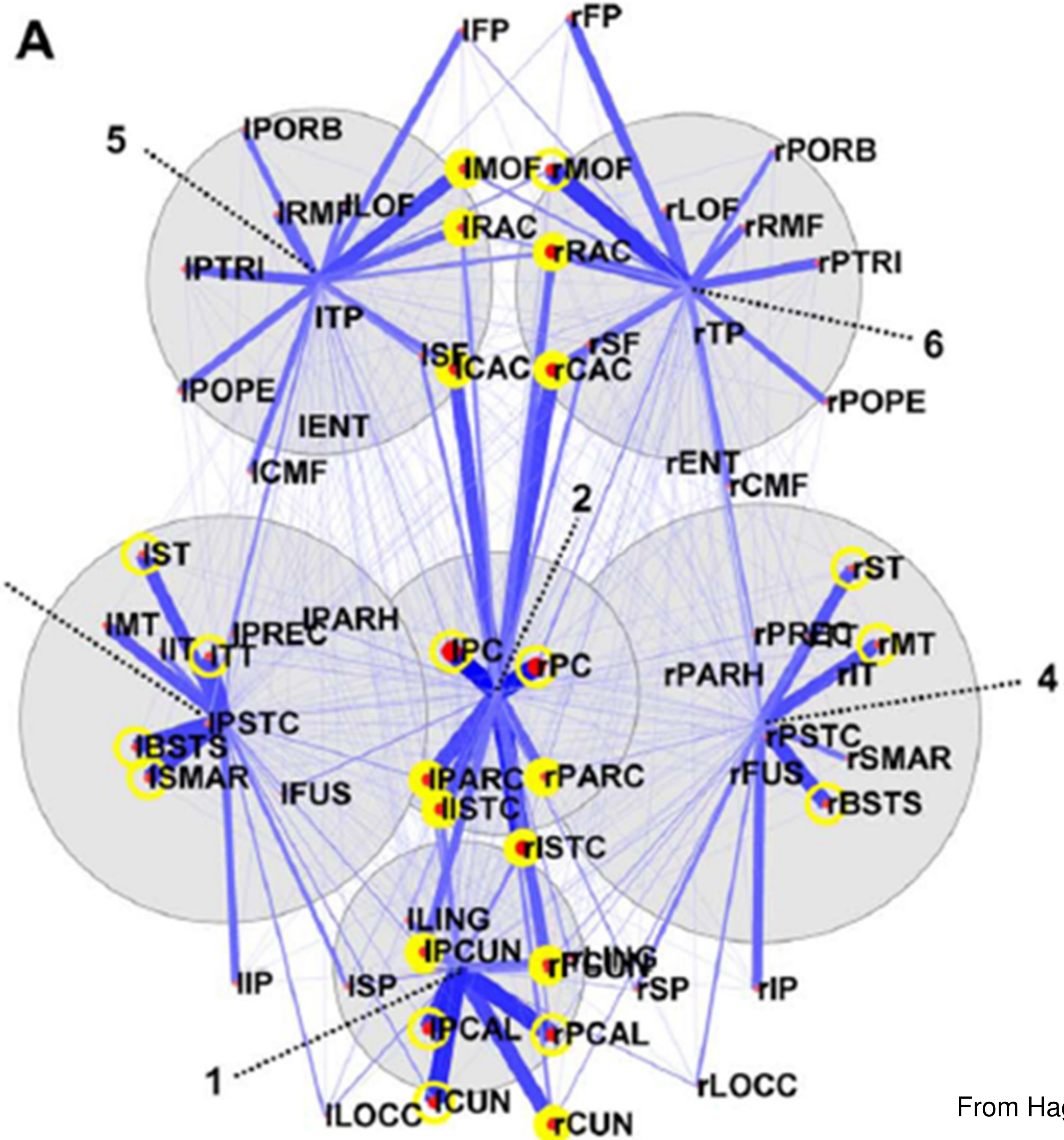
Frequency Bands (Delta to Hi-Beta)

Phase Difference (Deg) (short to long differences)

◆ Human Brain Mapping 33:1062–1075 (2012) ◆

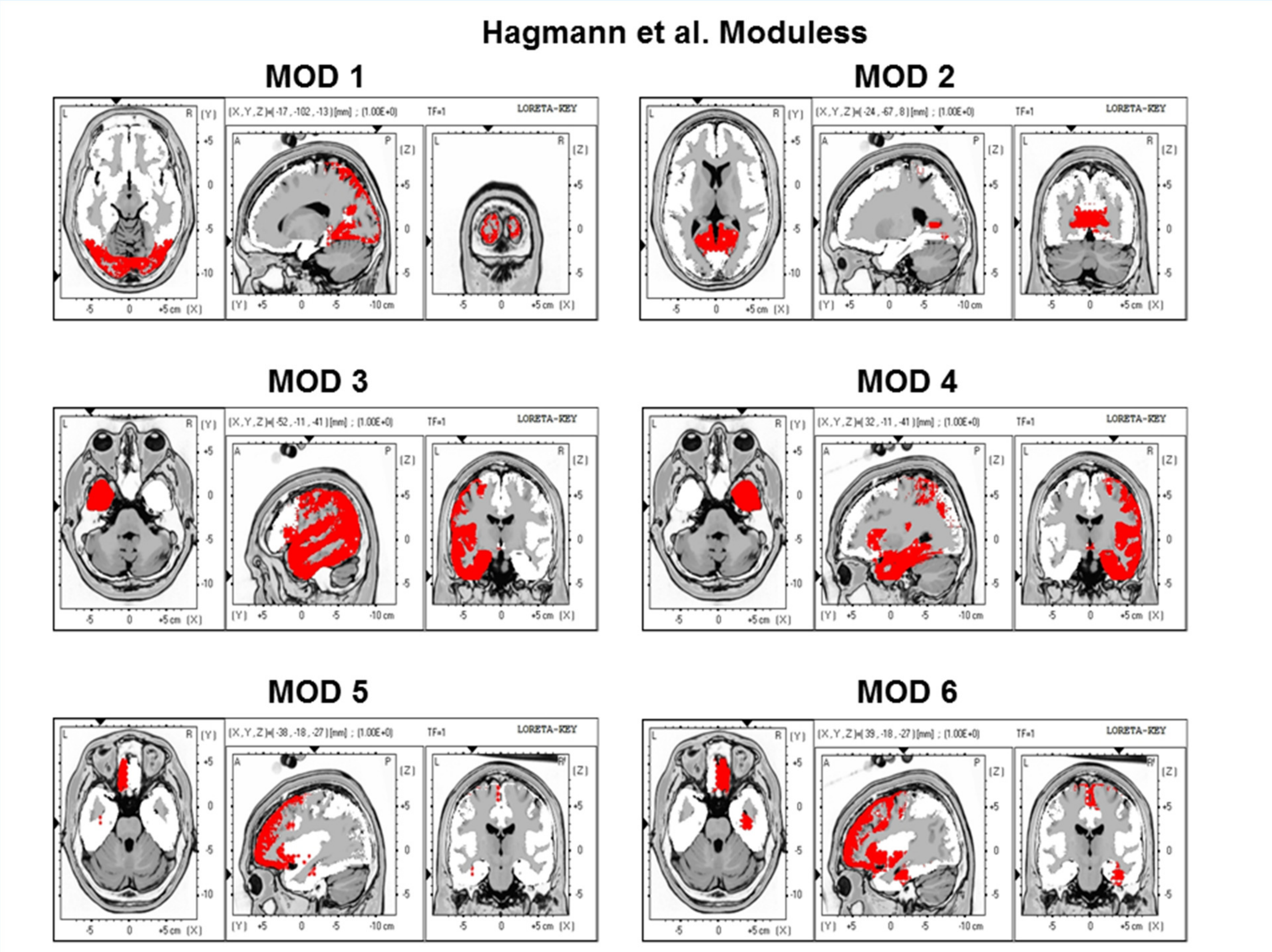
Diffusion Spectral Imaging Modules Correlate With EEG LORETA Neuroimaging Modules

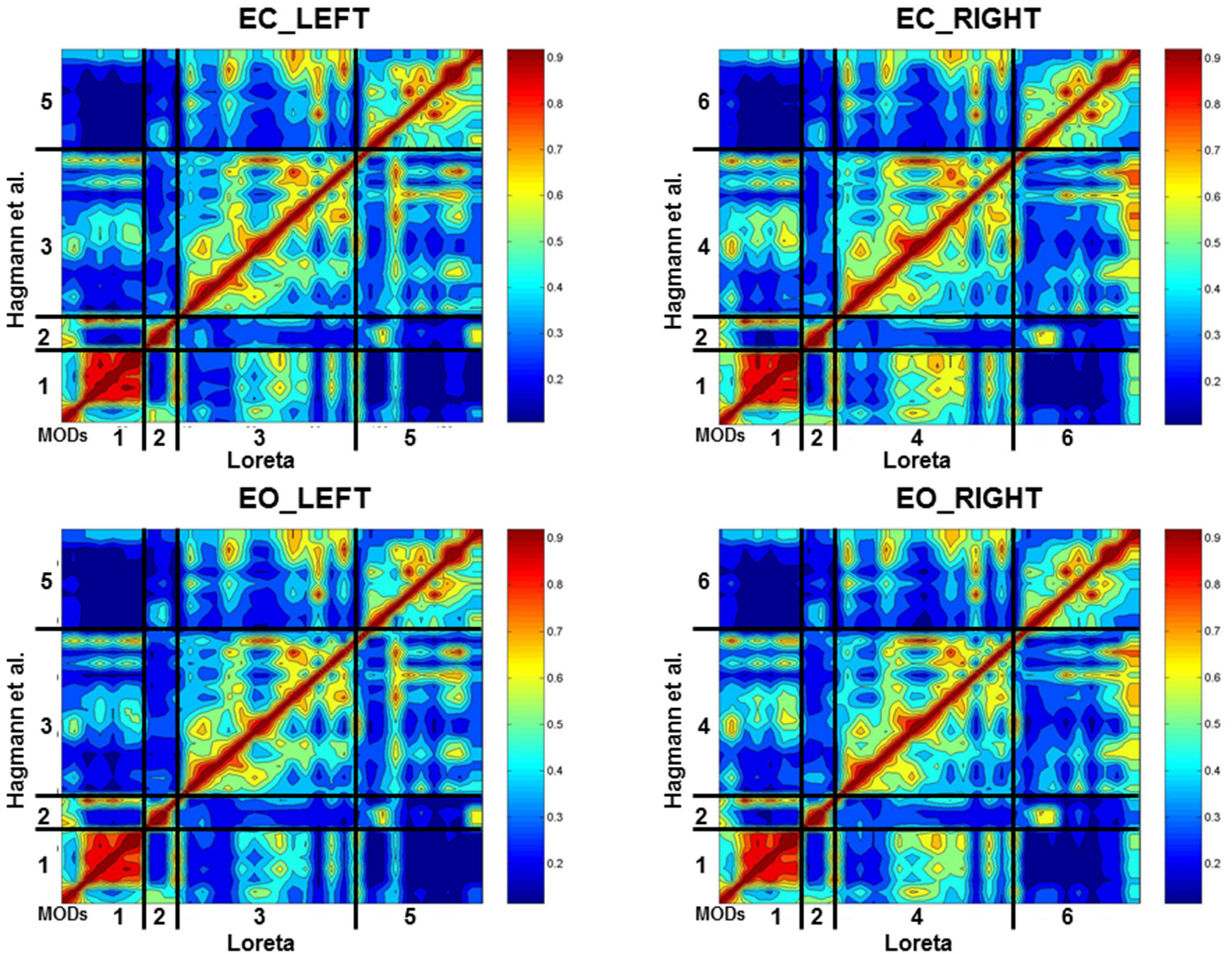
Robert W. Thatcher,* Duane M. North, and Carl J. Biver



From Hagmann et al, 2008

Correlations Between EEG Neuroimaging and Diffusion Spectral Imaging (DTI)




EC_LEFT
EC_RIGHT
EO_LEFT
EO_RIGHT
Hagmann et al.
Loreta
MODs
1
2
3
4
5
6
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2

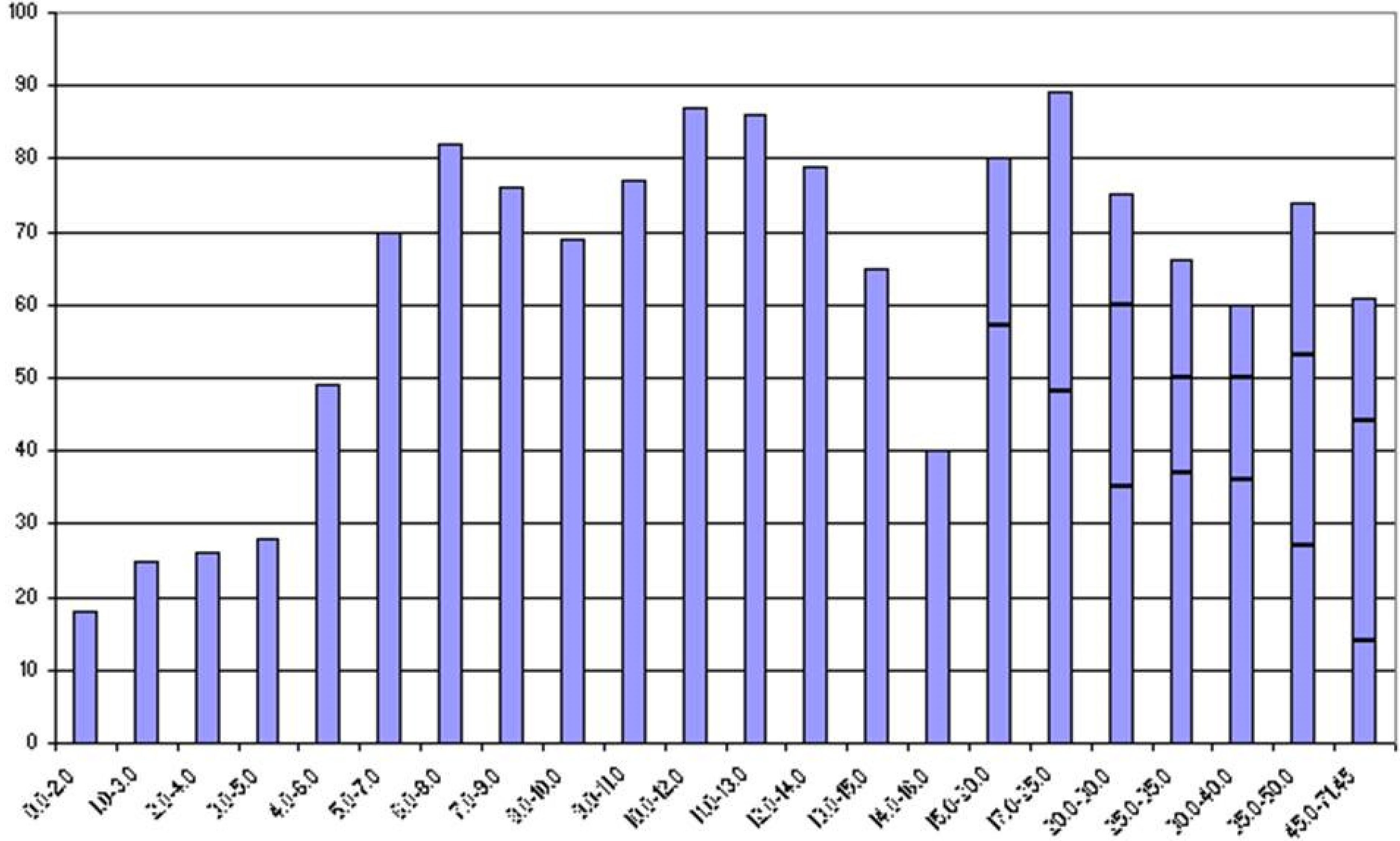
Published as a chapter in "Introduction to QEEG and Neurofeedback: Advanced Theory and Applications" Thomas Budzinsky, H. Budzinski, J. Evans and A. Abarbanel editors, Academic Press, San Diego, Calif, 2008.

HISTORY OF THE SCIENTIFIC STANDARDS OF QEEG NORMATIVE DATABASES

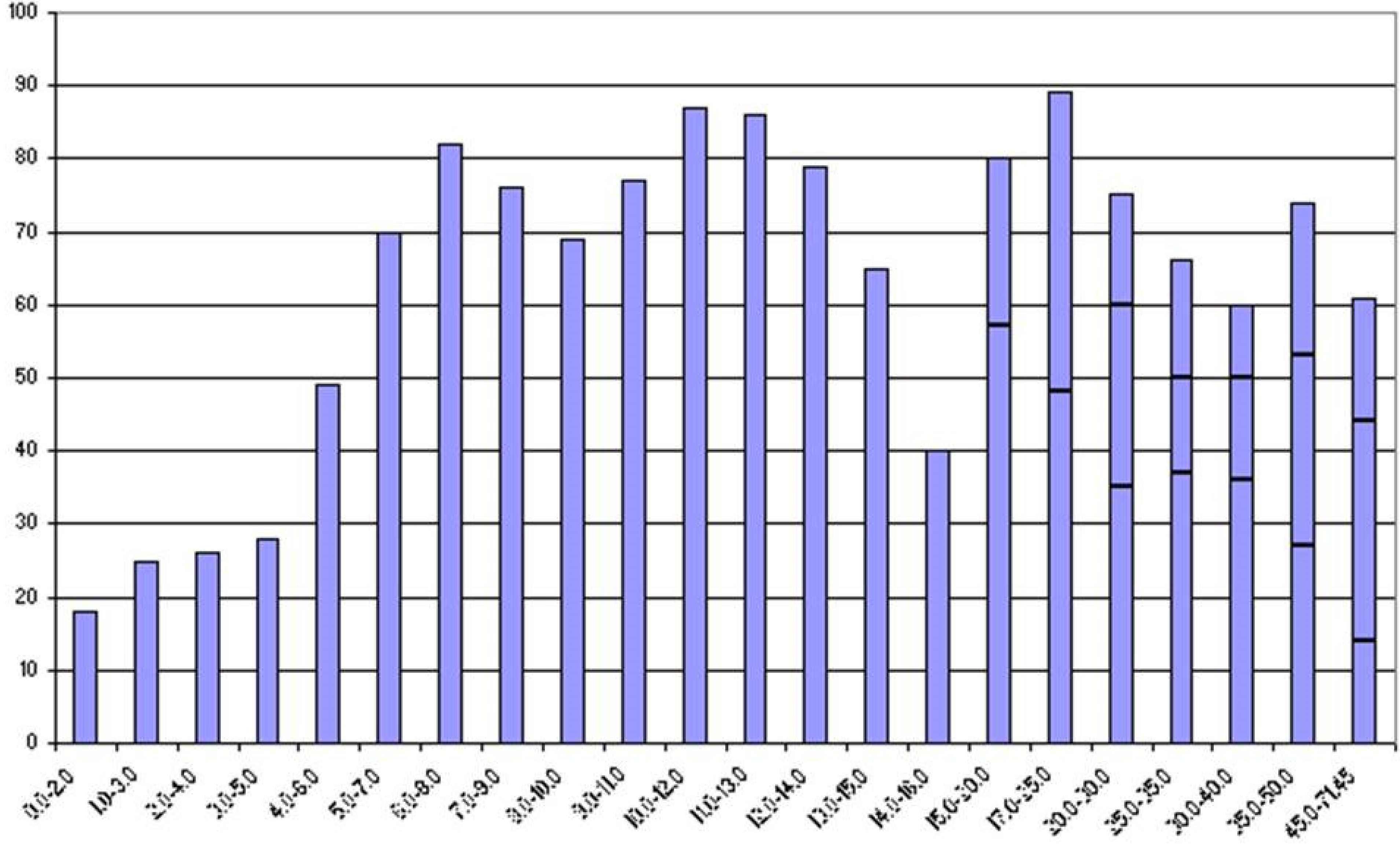
Thatcher, R.W. [1,2] and Lubar, J.F.[3]

Department of Neurology, University of South Florida College of Medicine, Tampa, Fl.[1] and EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, Fl[2] , Brain Research and Neuropsychology Lab, University of Tennessee, Knoxville, TN[3].

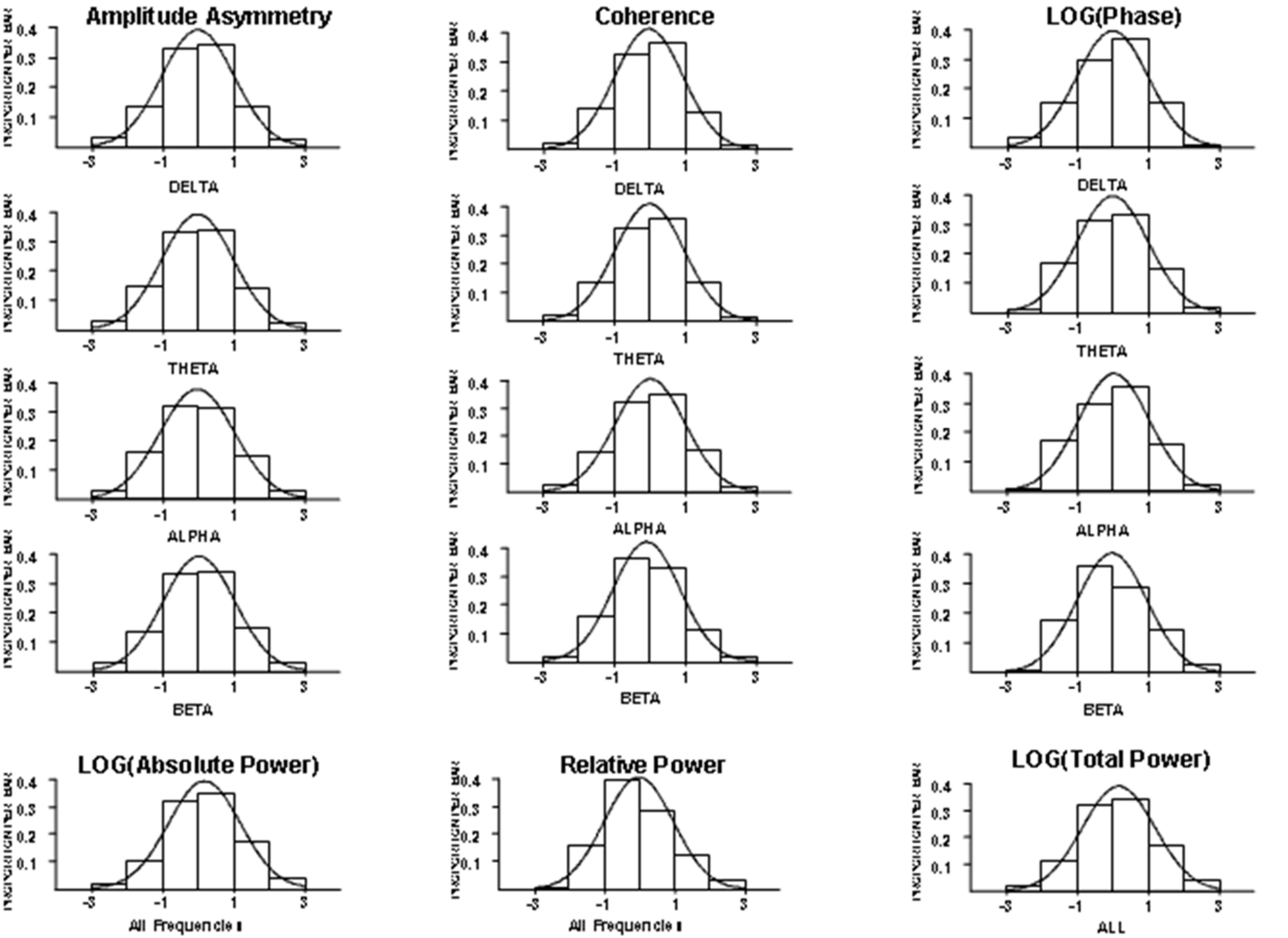
NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011



NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011

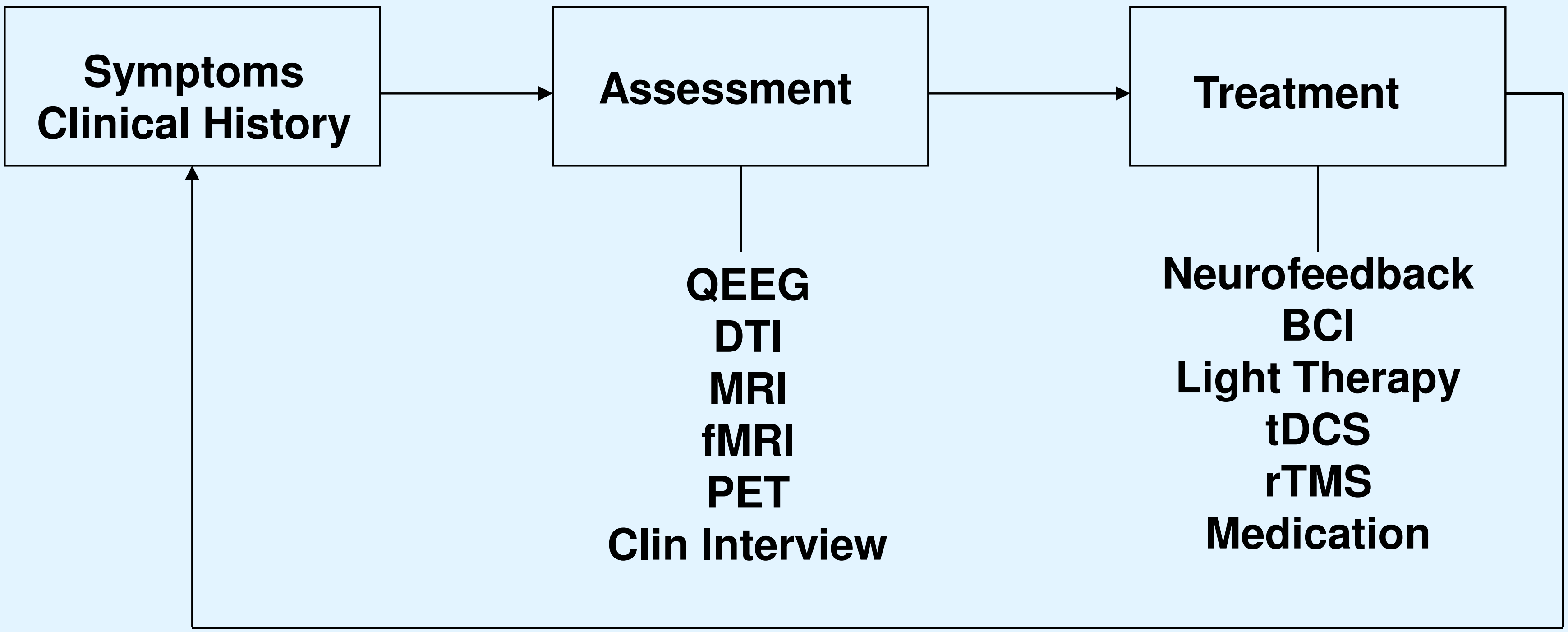


Cross-Validation Birth to 82 Year EEG Normative Database

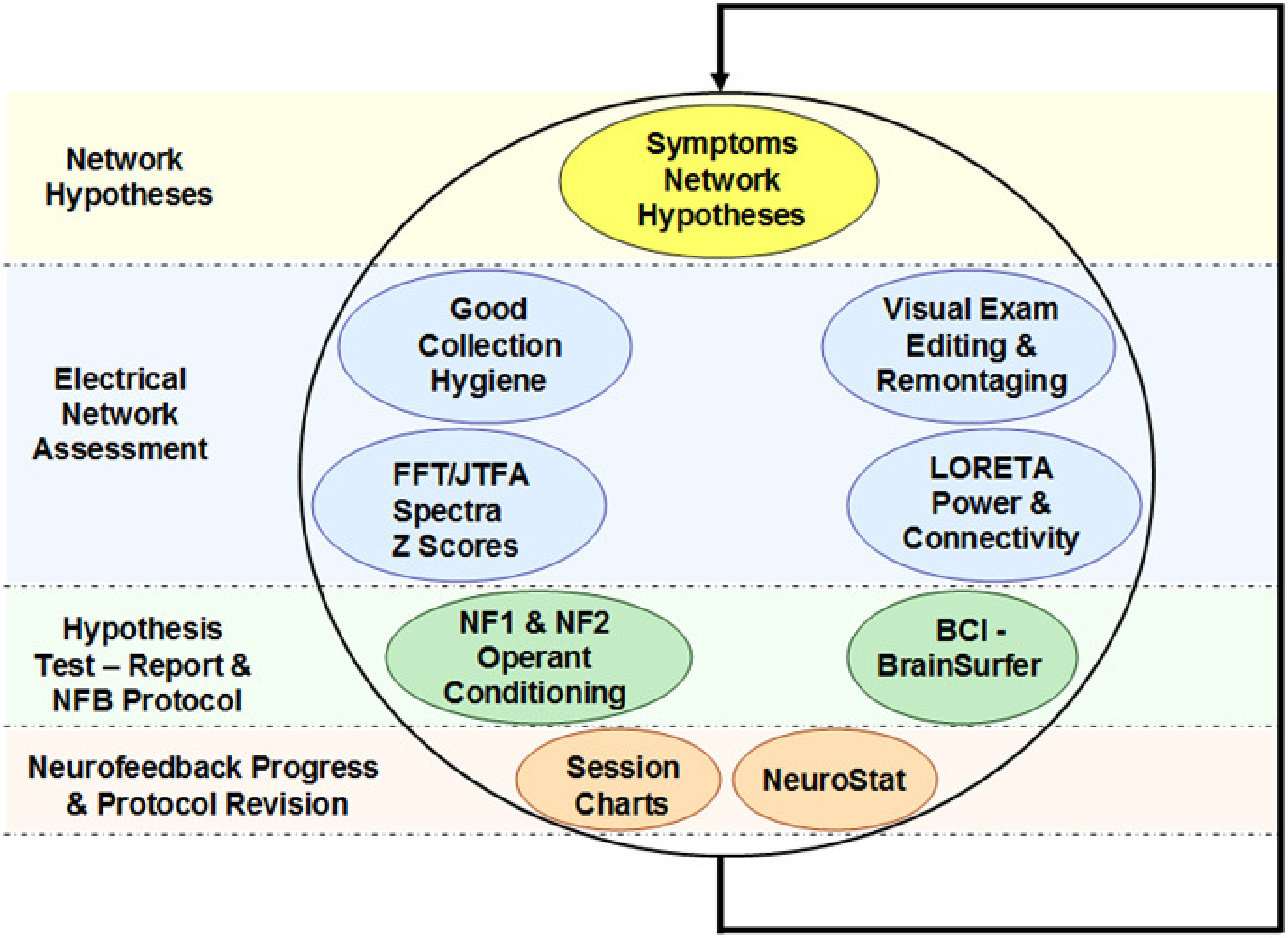


Essential Steps in Helping Patients with Neurological/Psychological Problems

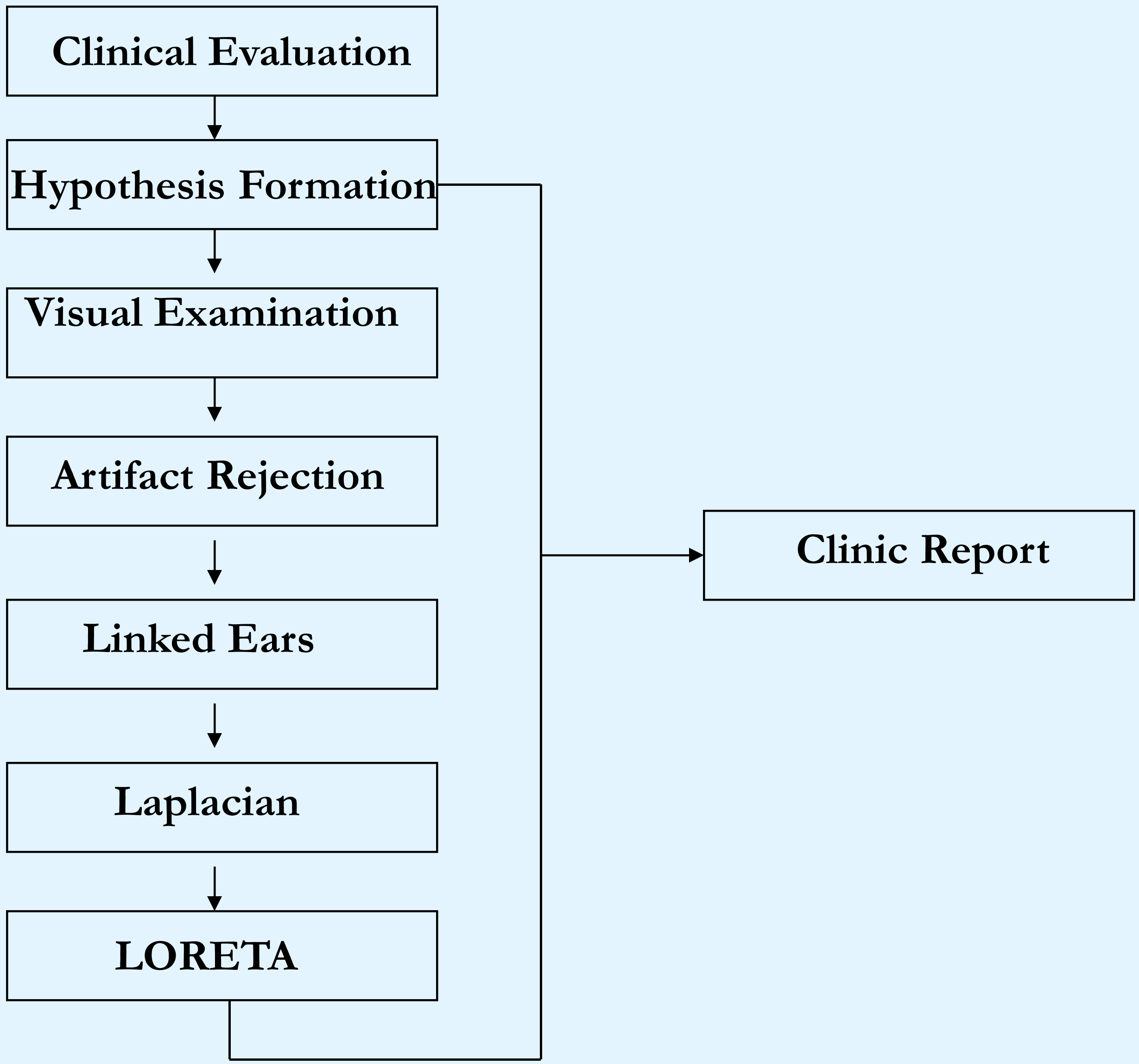
Assess, Address, Reassess …



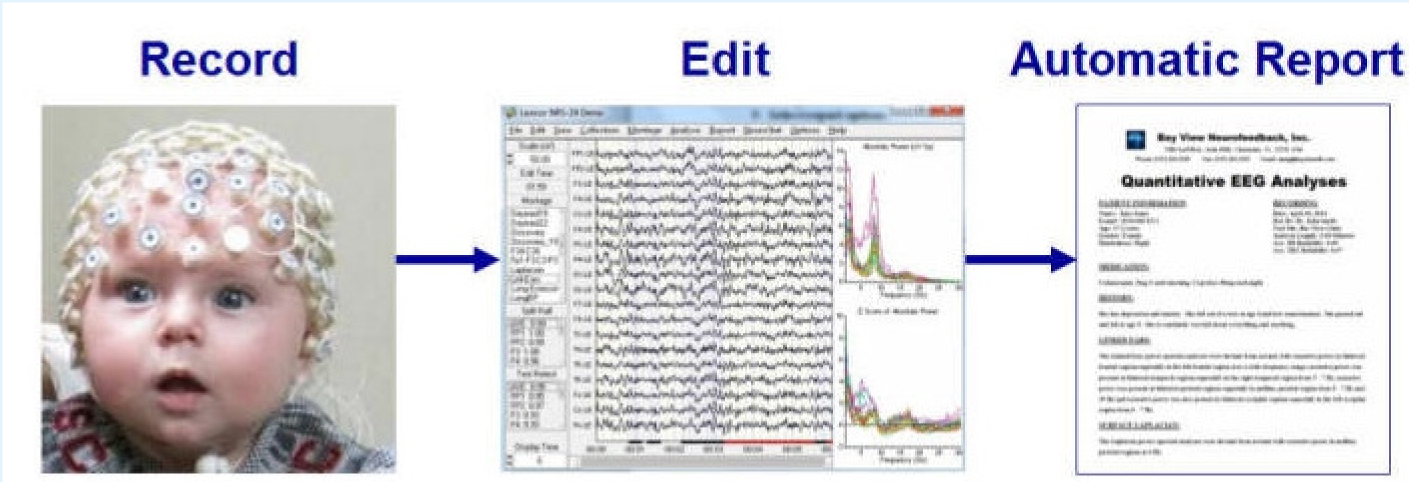
Linking Patient's Symptoms to Patient's Brain



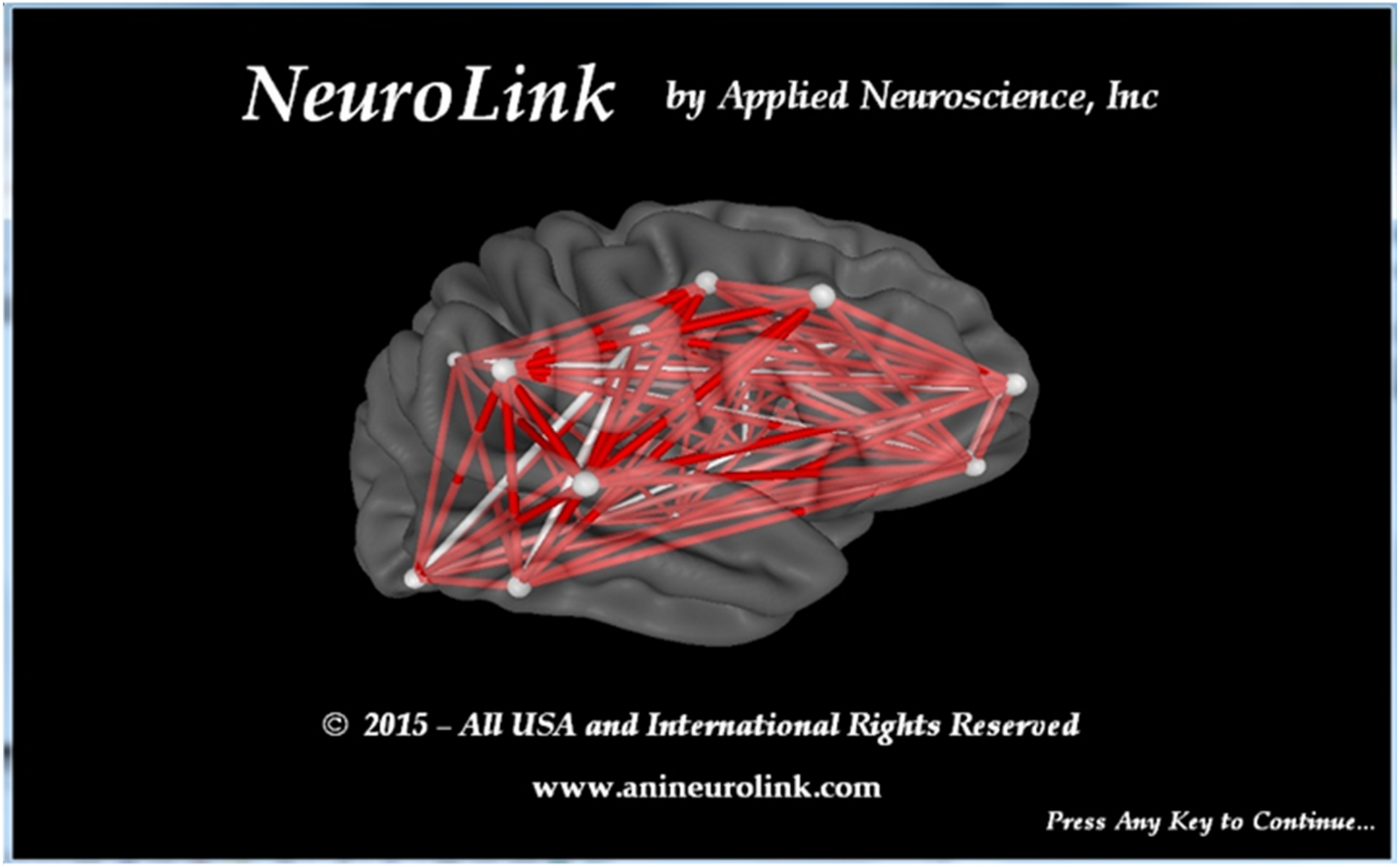
QEEG Report Generation Sequence



Automatic Clinical Report Writer (ACR)



- No Delays with Minimal Expense for a Professional Quality In-House QEEG Clinical Report
- Less than One Minute to Produce a Professional QEEG Clinical Report, in Microsoft Word format
- ACR Provides: Empowerment, Simplicity, Accuracy & Efficiency!
- Get Valid Normative Database Comparisons using without Depending on Internet Q-EEG Report Services!
- Get Relevant Content and Displays, plus Helpful NFB Recommendations in Less than a Minute.
- Increased Productivity by at Least 10 Fold, e.g. Ten Reports in an Hour!


NeuroLink by Applied Neuroscience, Inc
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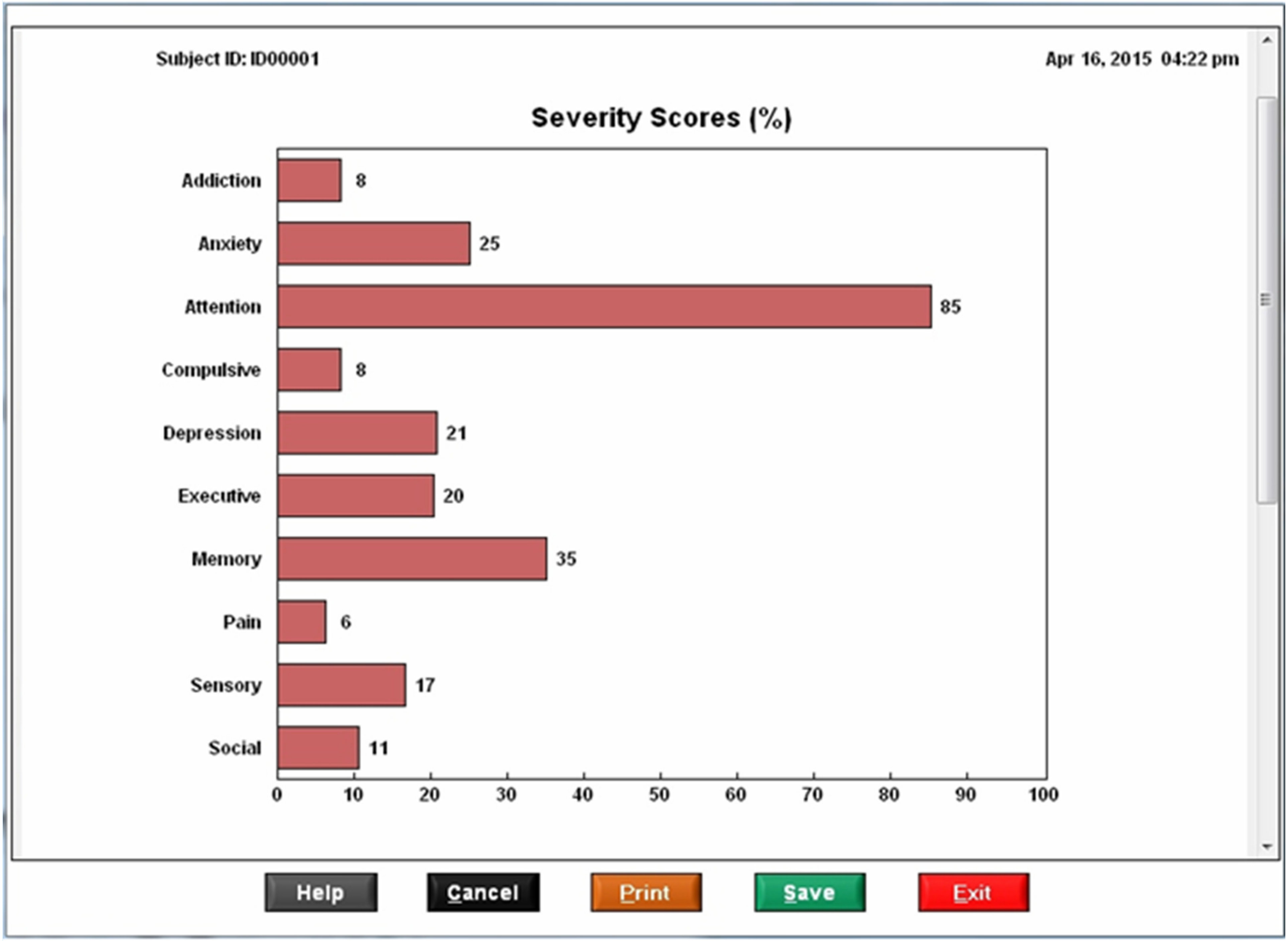
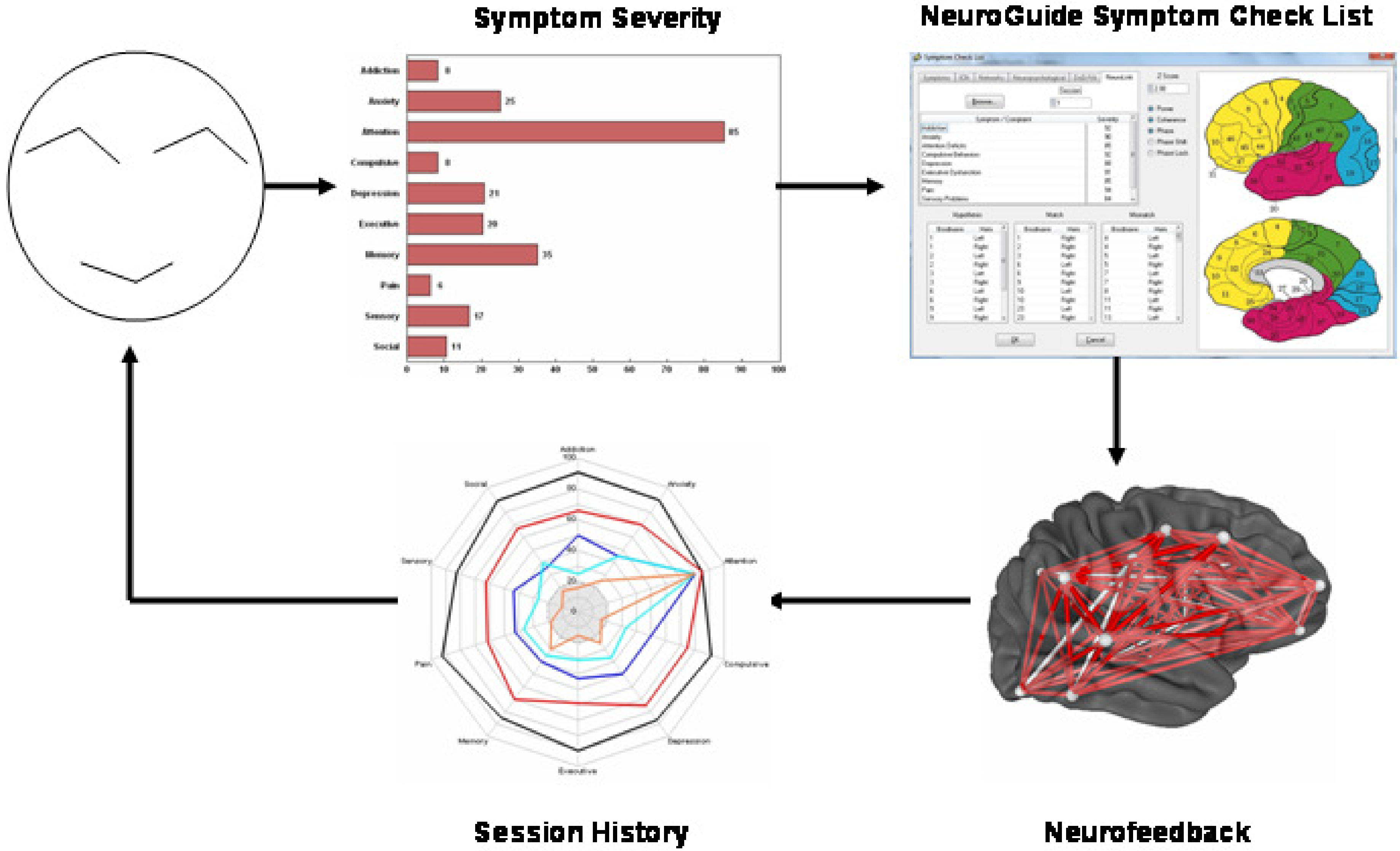
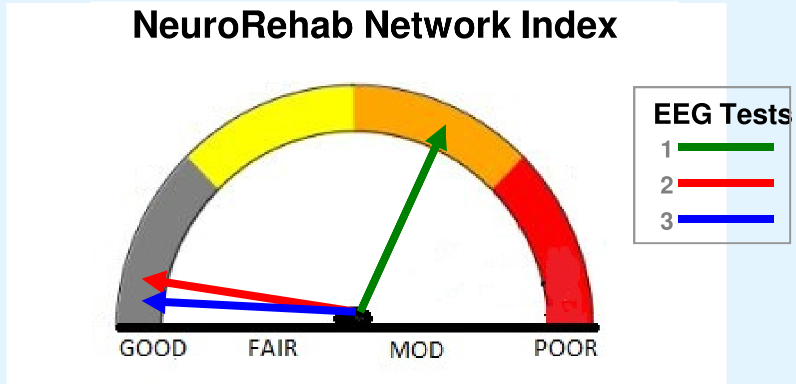
www.anineurolink.com
Press Any Key to Continue...

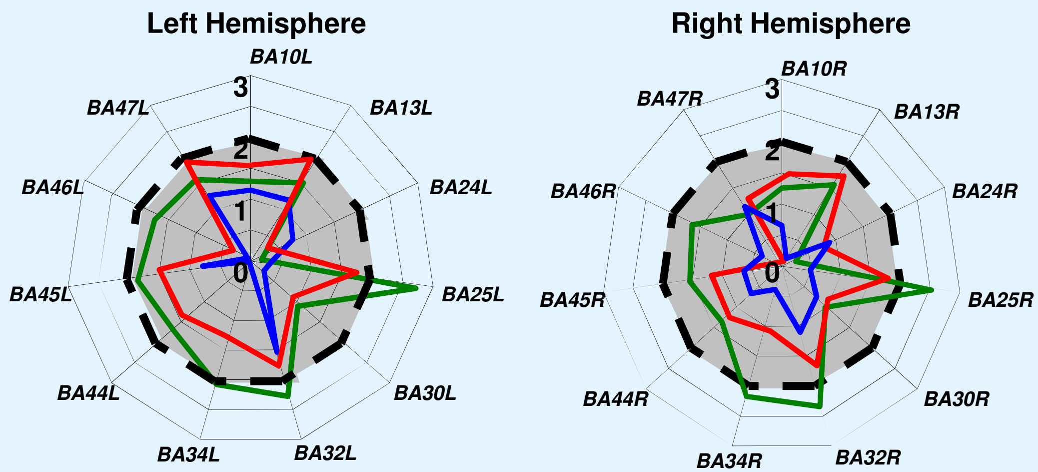

Subject ID: ID00001
Apr 16, 2015 04:22 pm
Severity Scores (%)
Addiction 8
Anxiety 25
Attention 85
Compulsive 8
Depression 21
Executive 20
Memory 35
Pain 6
Sensory 17
Social 11
0 10 20 30 40 50 60 70 80 90 100
Help
Cancel
Print
Save
Exit

NeuroLink and NeuroGuide Integration – Linking Symptoms to the Brain

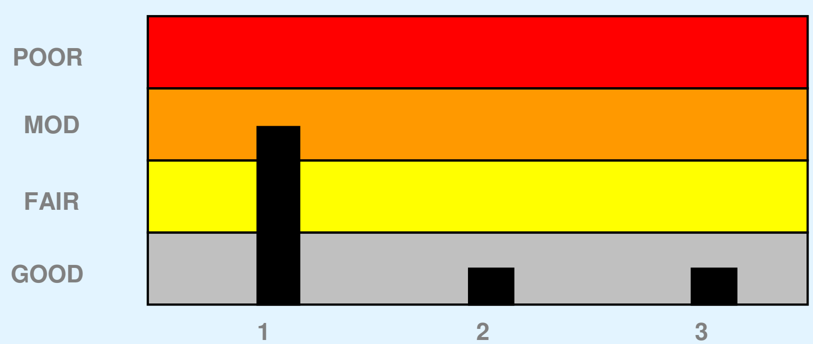


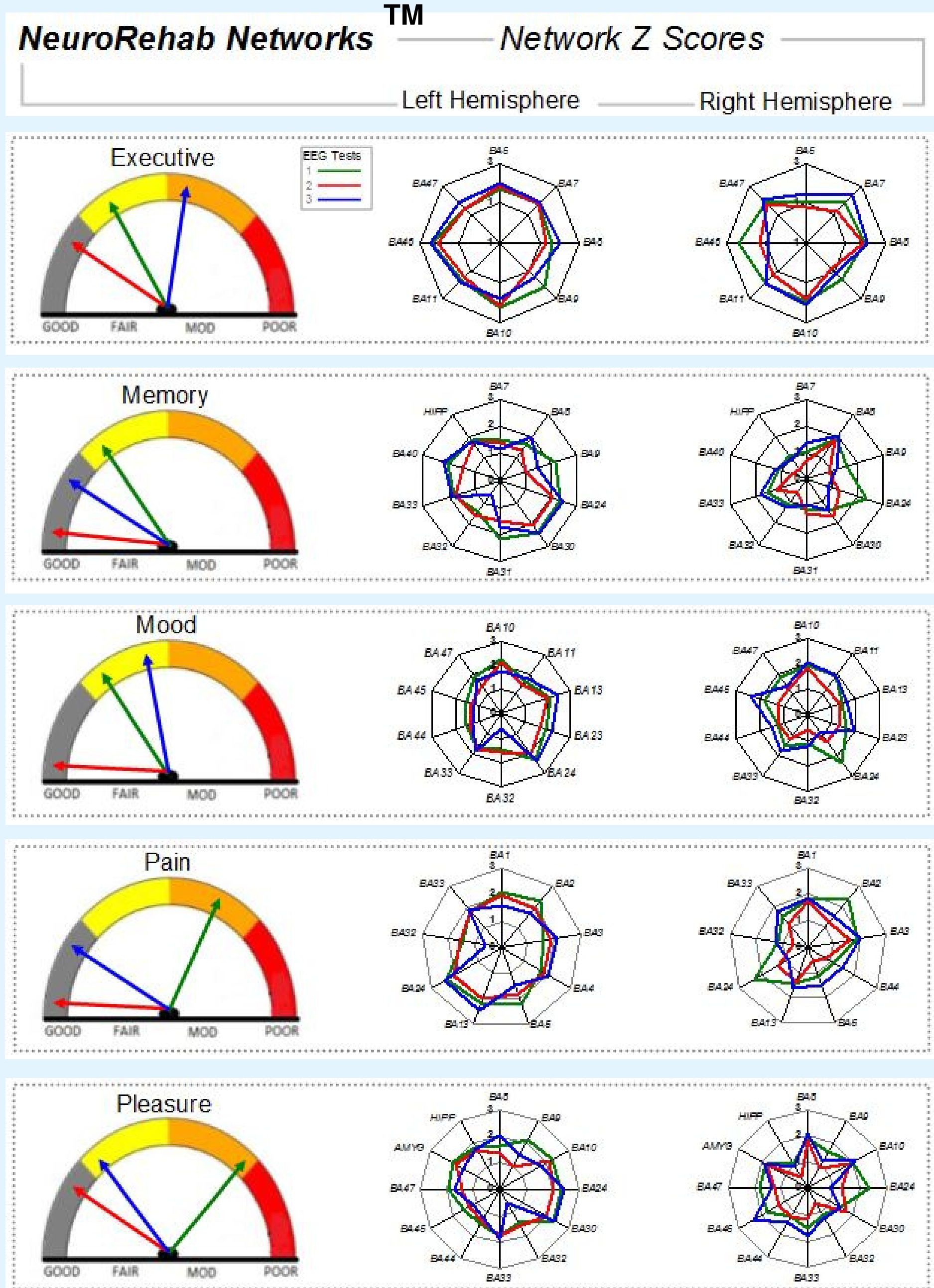


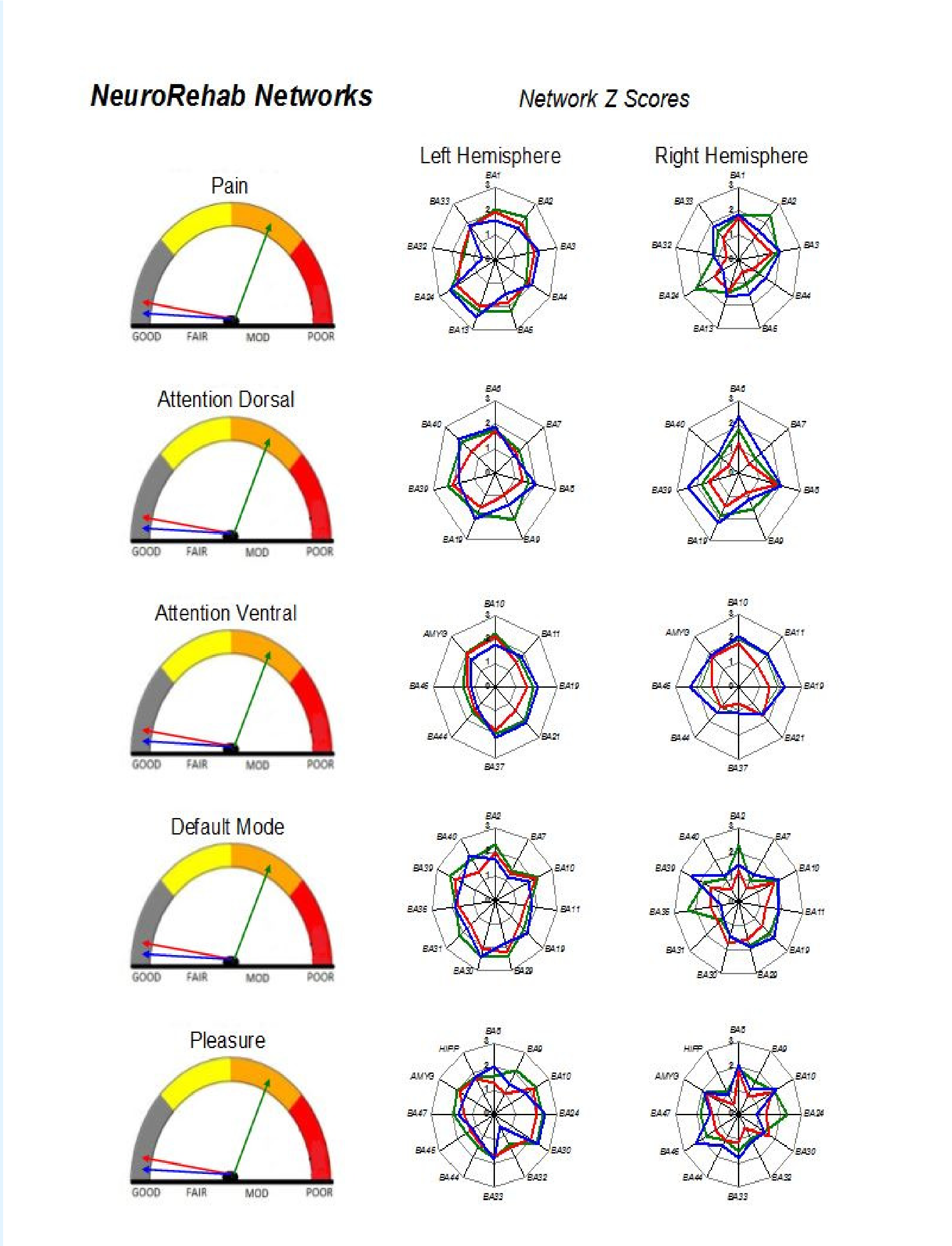
Addiction Network Z Scores



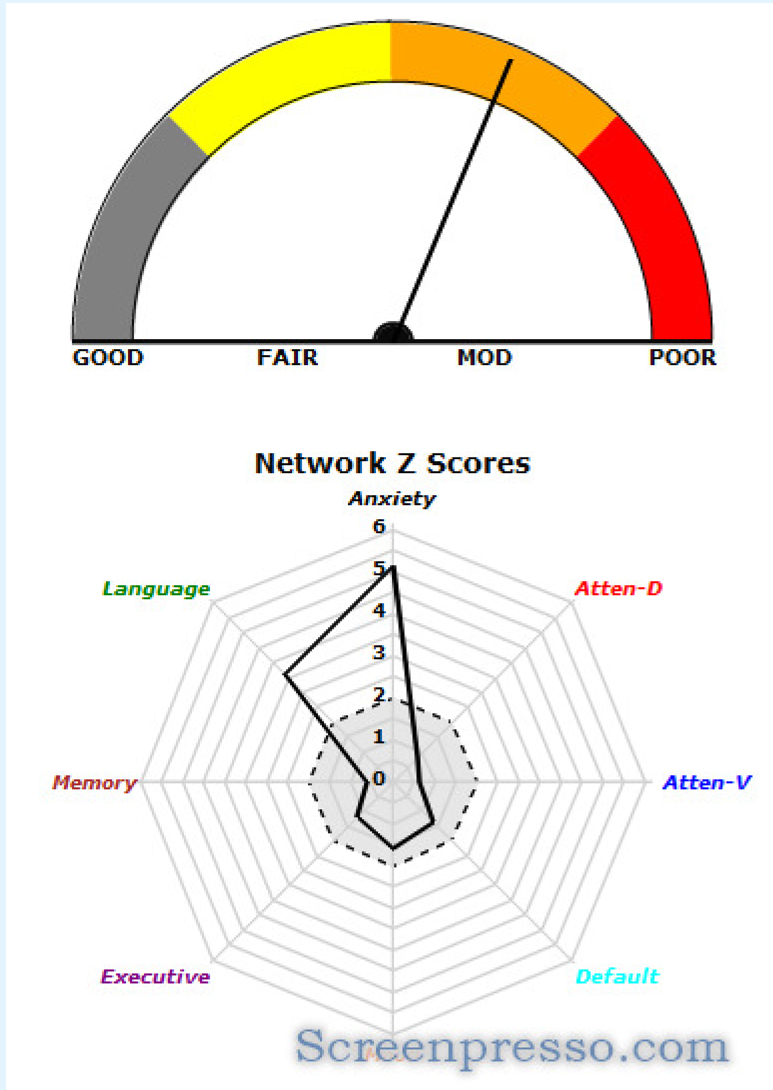
Rehabilitation History




NeuroRehab Networks TM
Network Z Scores
Left Hemisphere
Right Hemisphere
Executive
EEG Tests
1
2
3
BA6
BA7
BA8
BA9
BA10
BA11
BA46
BA47
GOOD
FAIR
MOD
POOR
Memory
BA7
BA8
BA9
BA24
BA30
BA31
BA32
BA33
BA40
HIPP
Mood
BA10
BA11
BA13
BA23
BA24
BA32
BA33
BA44
BA45
BA47
Pain
BA1
BA2
BA3
BA4
BA6
BA13
BA24
BA32
BA33
Pleasure
BA8
BA9
BA10
BA24
BA30
BA32
BA33
BA44
BA45
BA47
AMYG
HIPP

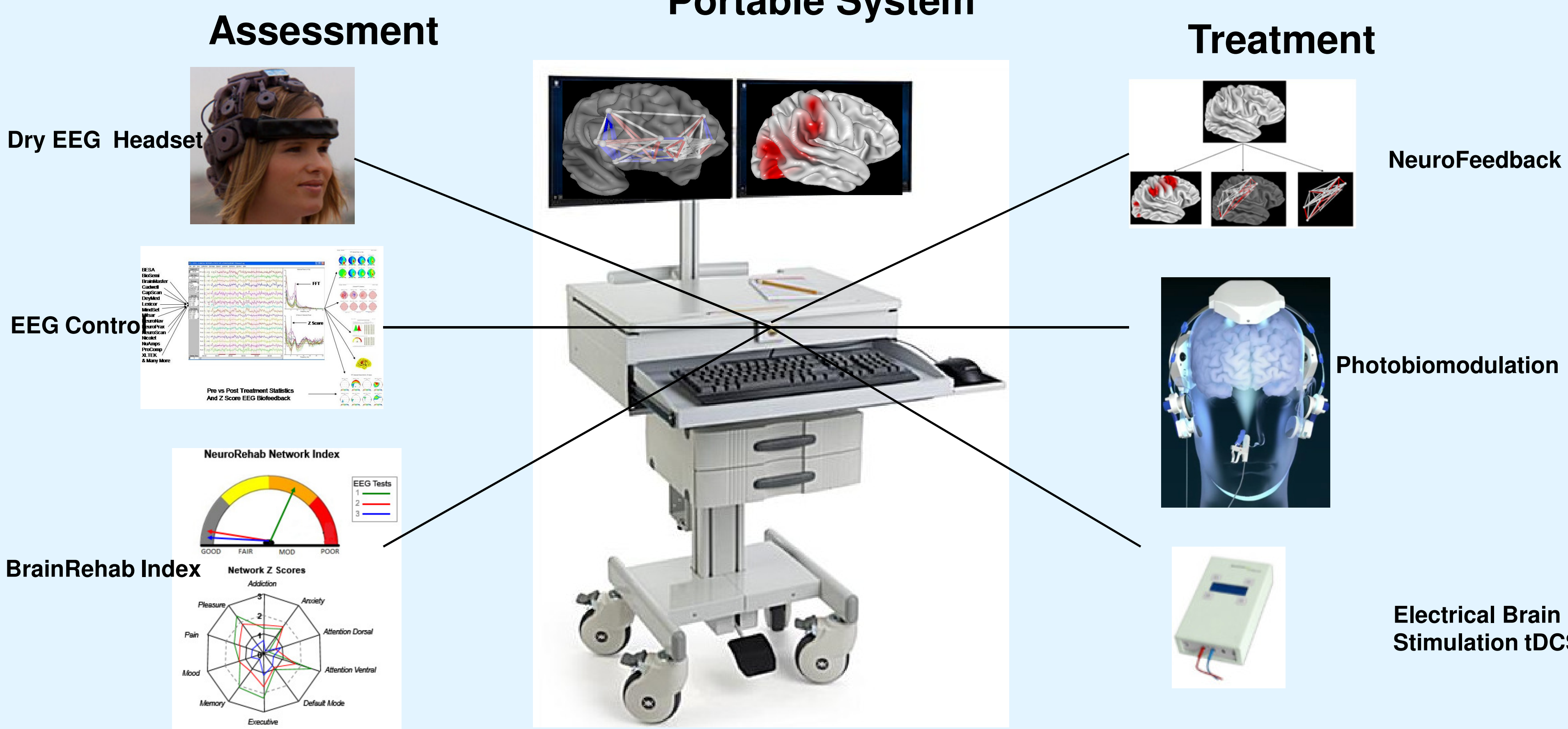

NeuroRehab Networks
Network Z Scores
Left Hemisphere
Right Hemisphere
Pain
Attention Dorsal
Attention Ventral
Default Mode
Pleasure
GOOD
FAIR
MOD
POOR

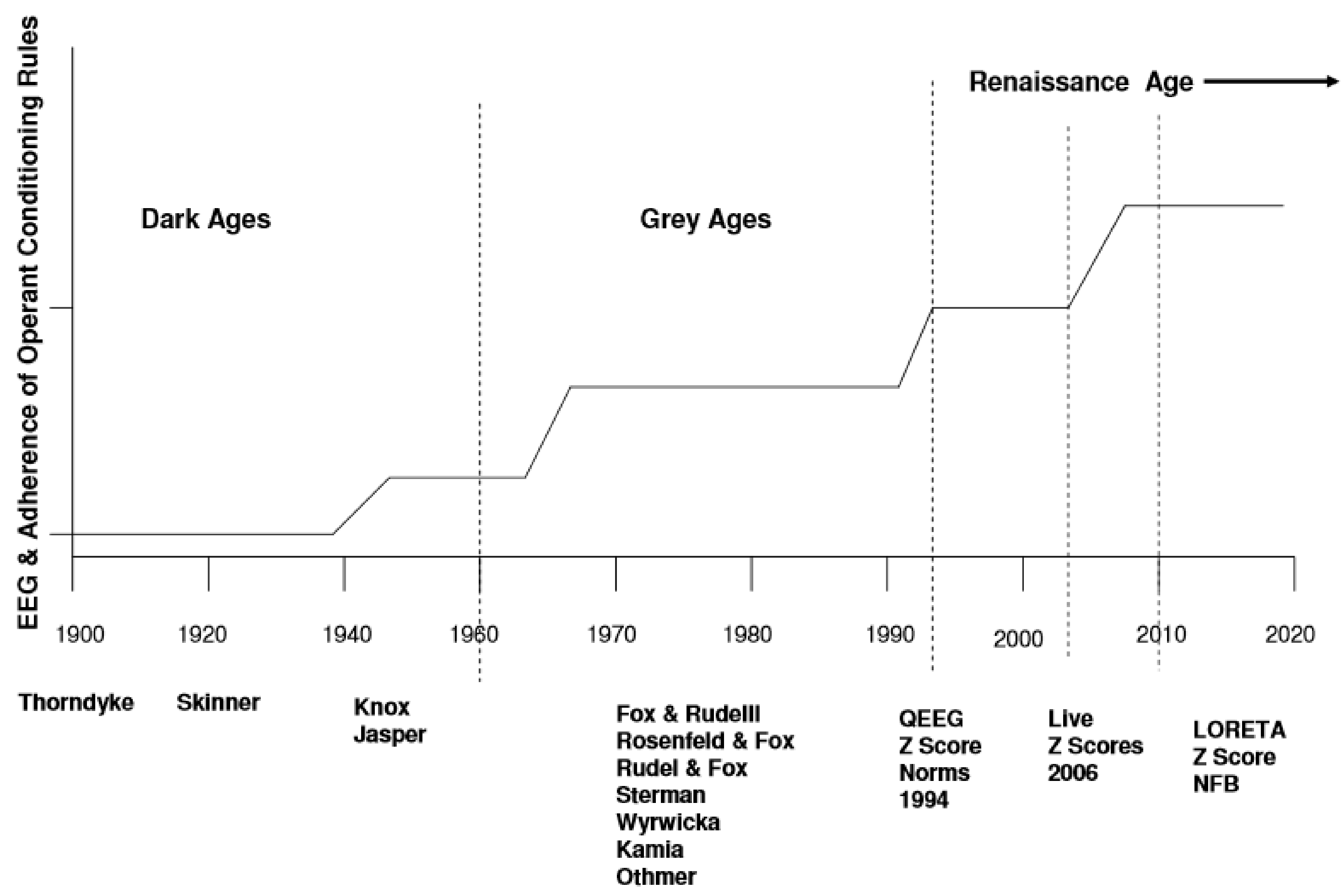
The BrainRehab Index



The BrainRehabilitator ™

Portable System





EEG & Adherence of Operant Conditioning Rules
Renaissance Age
Dark Ages
Grey Ages
1900
1920
1940
1960
1970
1980
1990
2000
2010
2020
Thorndyke
Skinner
Knox
Jasper
Fox & Rudelll
Rosenfeld & Fox
Rudel & Fox
Sterman
Wyrwicka
Kamia
Othmer
QEEG
Z Score
Norms
1994
Live
Z Scores
2006
LORETA
Z Score
NFB

What is the Future for Z Score Neurofeedback?

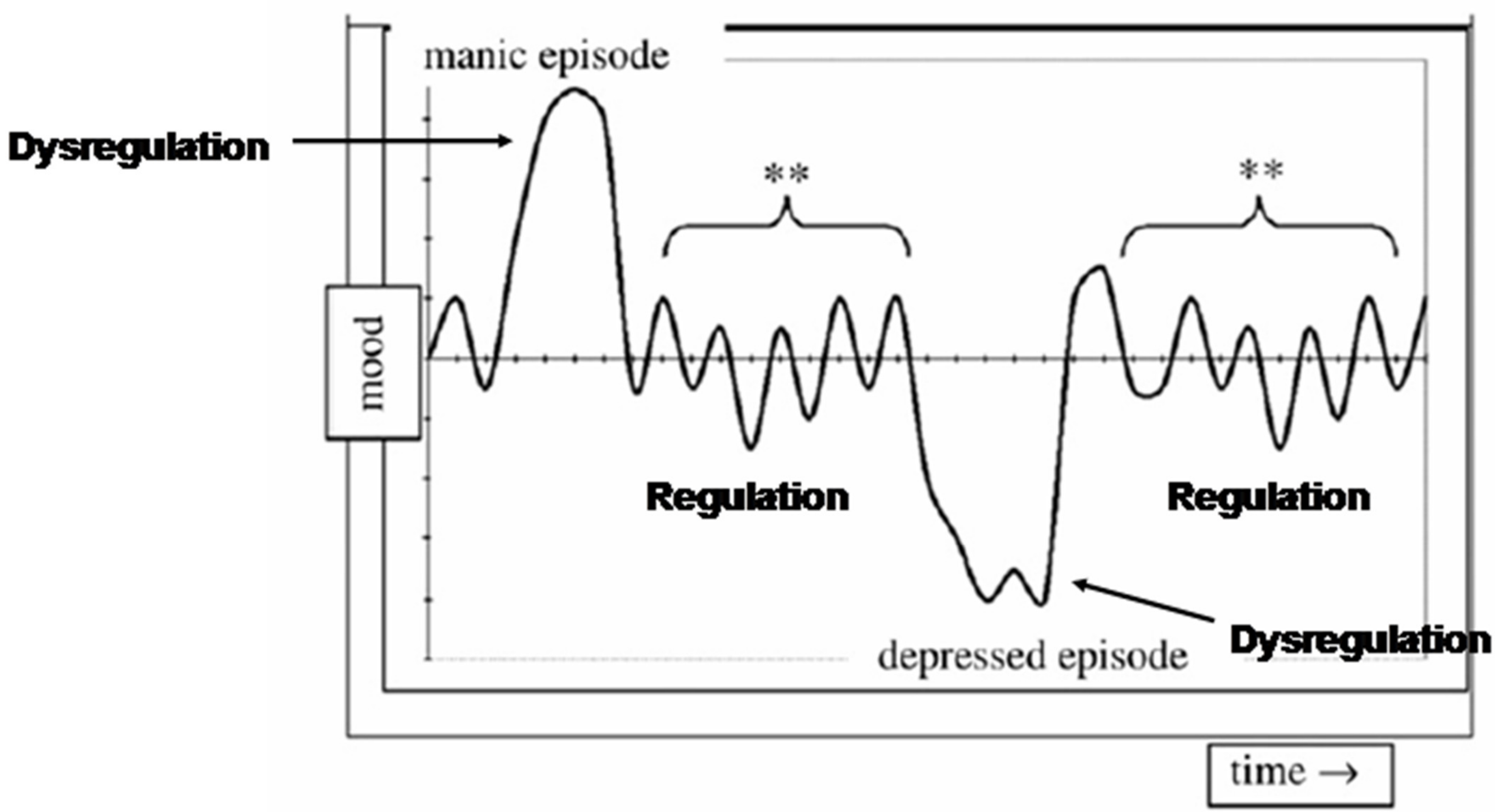
1- Expanding Number or Clinicians Using Z Score NFB

2- Expanding Number of Metrics:
- a- Effective Connectivity
- b- Cross-Frequency Coherence
- c- Cross-Frequency Effective Connectivity
- d- Phase Amplitude Cross-Frequency Coupling
- e- swLORETA – Individualized MRI & NFB

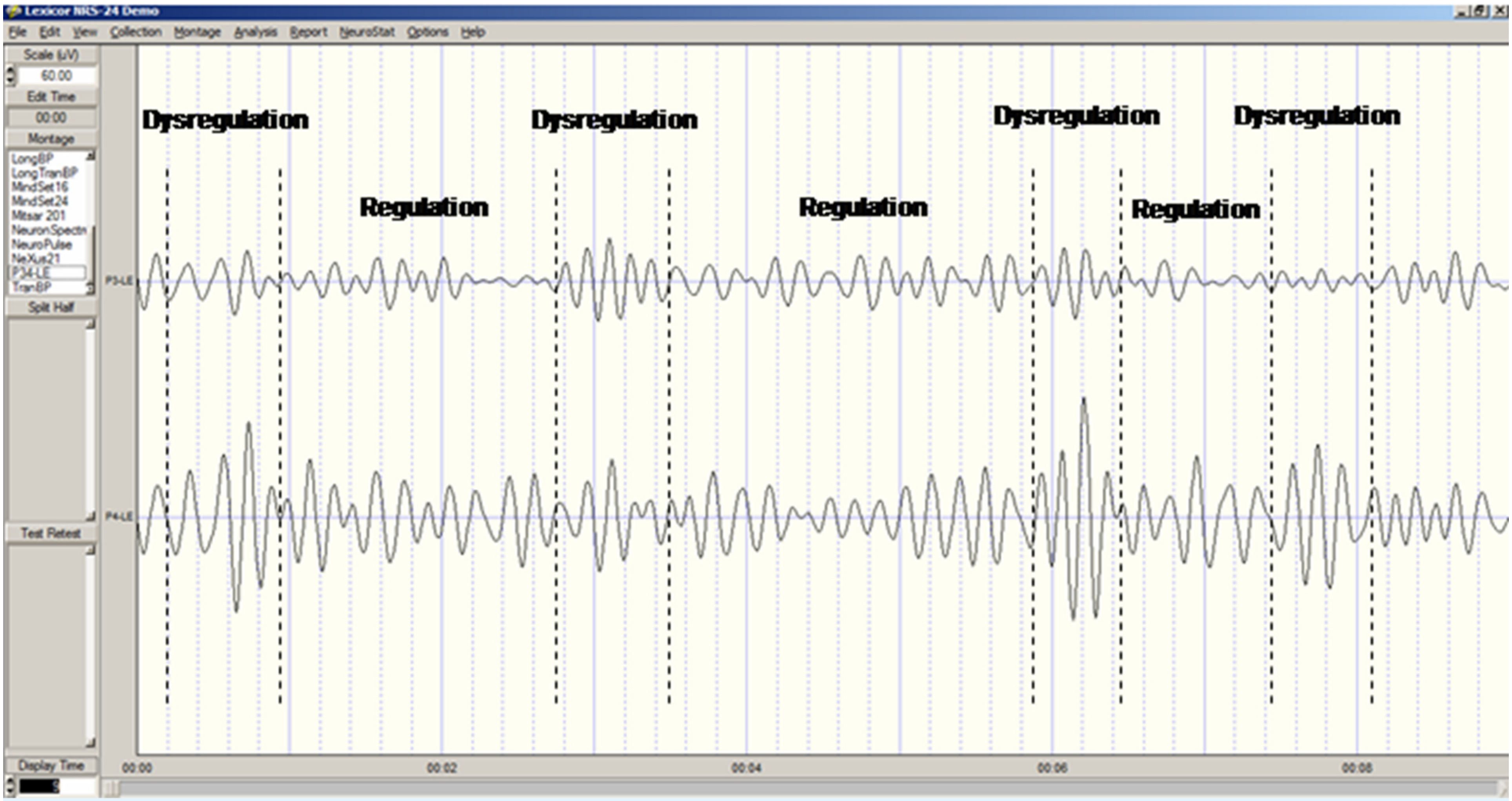
3- New Brain Imaging Technology

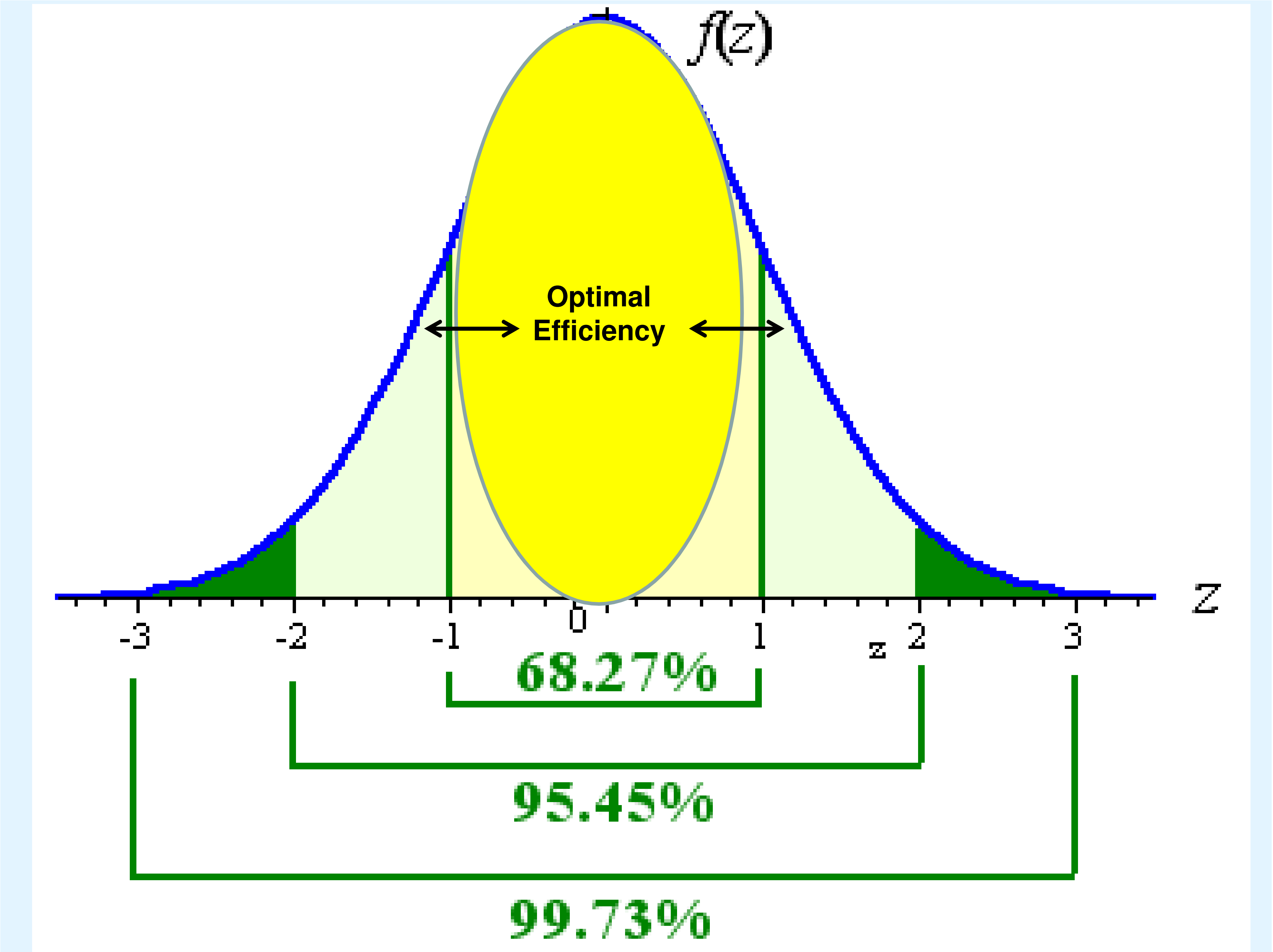
4- Smart Phone and Tablet Techology

Moment-to-Moment "Regulation" and "Dysregulation"



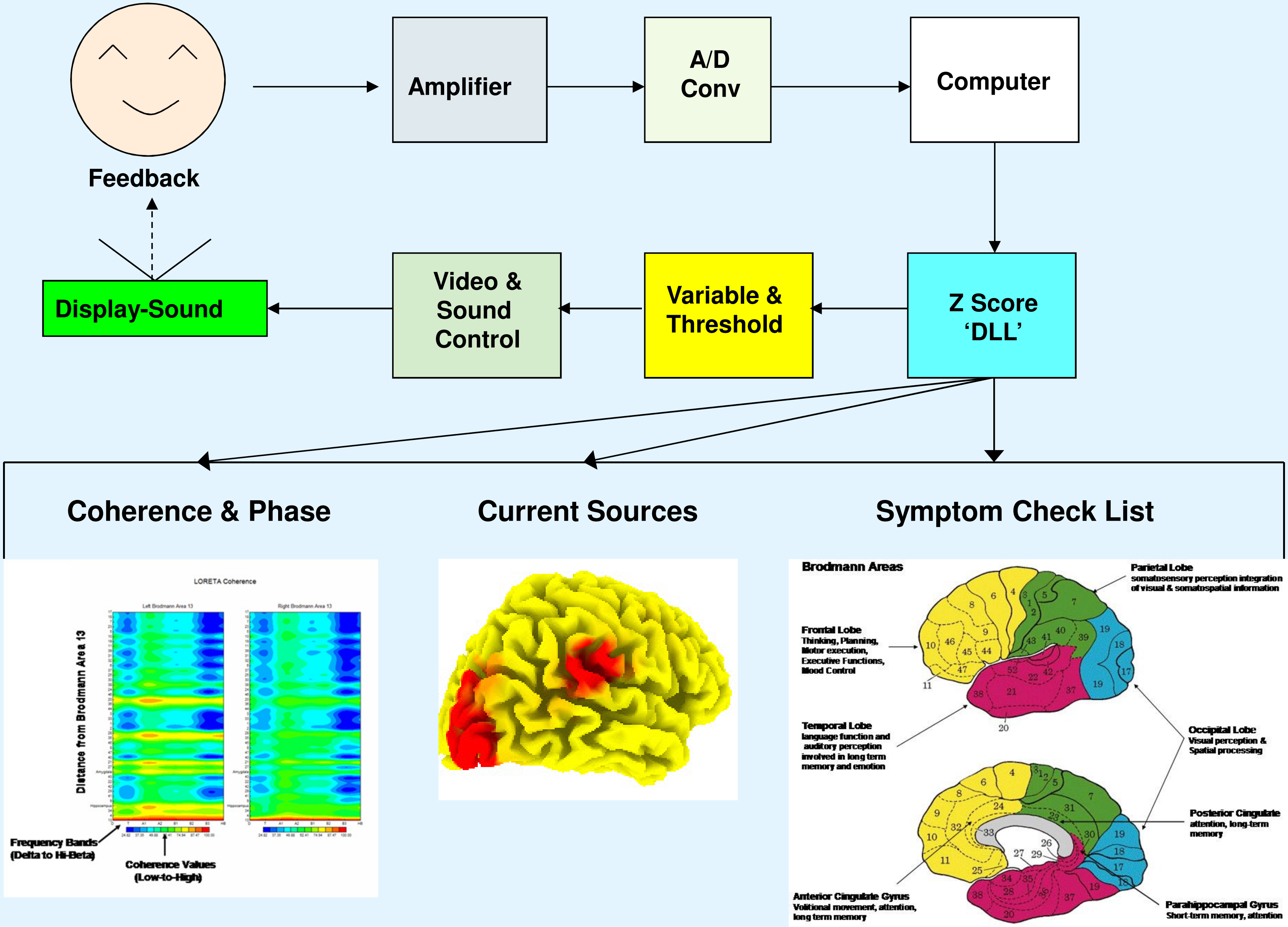
TBI Demo Right Parietal Lobe Alternating Degrees of Regulation Biofeedback's Goal is to Reduce the Frequency, Duration and Intensity of Dysregulation





f(z)
Optimal
Efficiency
Z
-3
-2
-1
0
1
z
2
3
68.27%
95.45%
99.73%

Neuroimaging Neurofeedback - Fort Campbell



LMU
KLINIKUM
DER UNIVERSITÄT MÜNCHEN
DEPARTMENT OF PSYCHIATRY
INSTITUTE OF CLINICAL RADIOLOGY

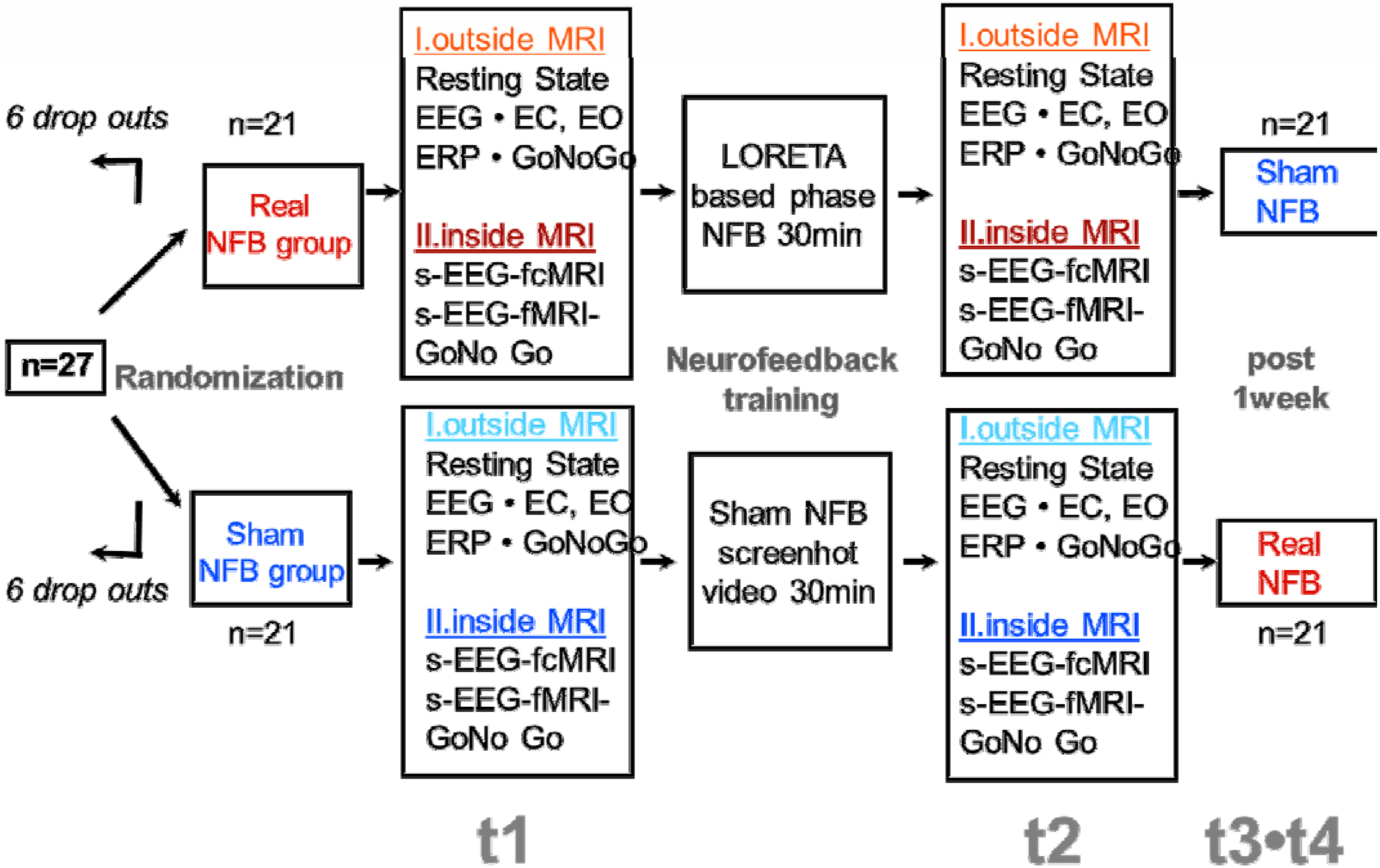
The impact of source-localized EEG phase neurofeedback on brain activity

A double-blinded placebo-controlled study using simultaneously EEG-fMRI – preliminary results

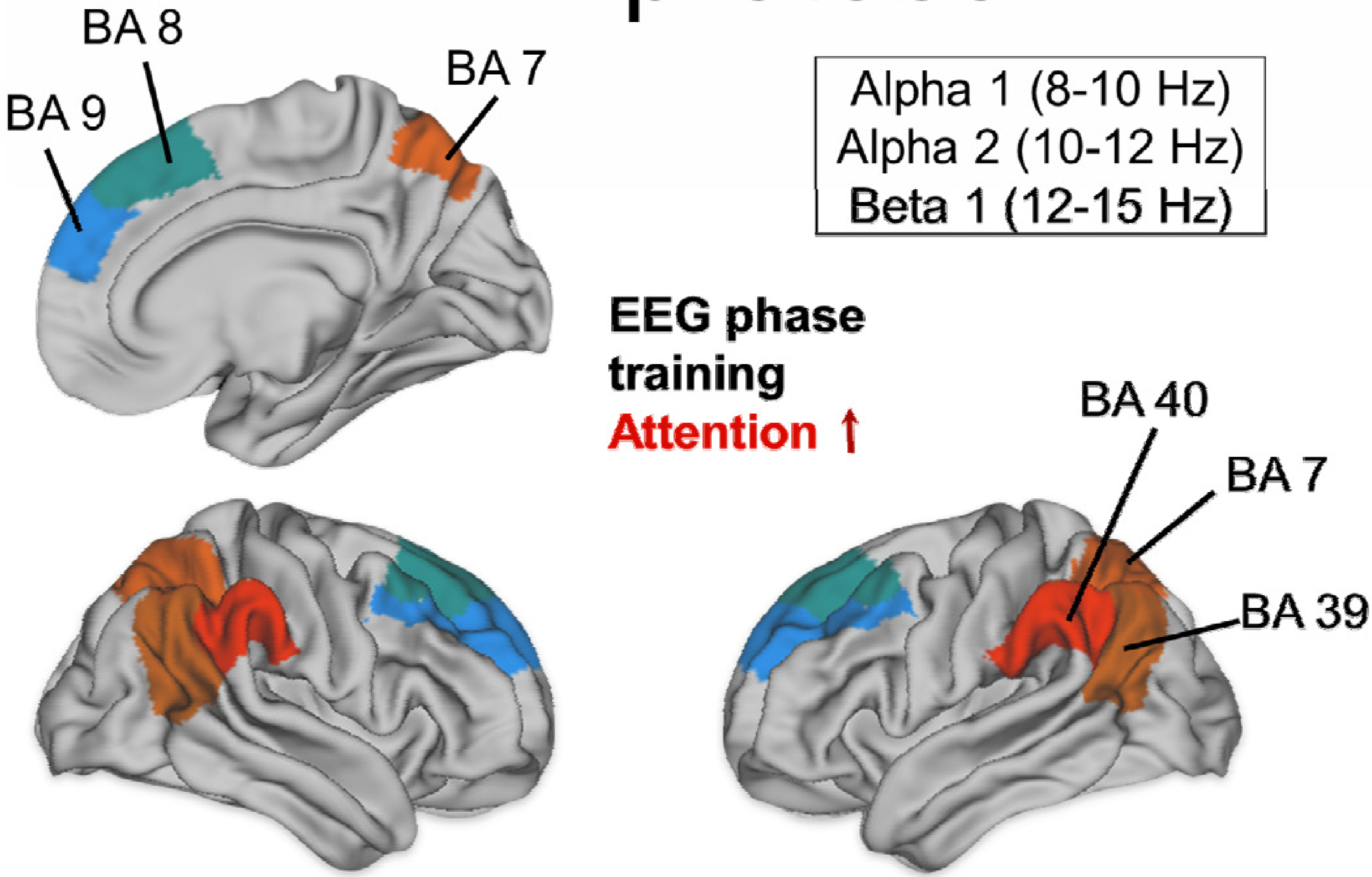
Daniel Keeser

Valerie Kirsch, Boris Rauchmann, Brian Stamm, Paul Reidler, Robert Thatcher, Susanne Karch, Oliver Pogarell, Birgit Ertl-Wagner

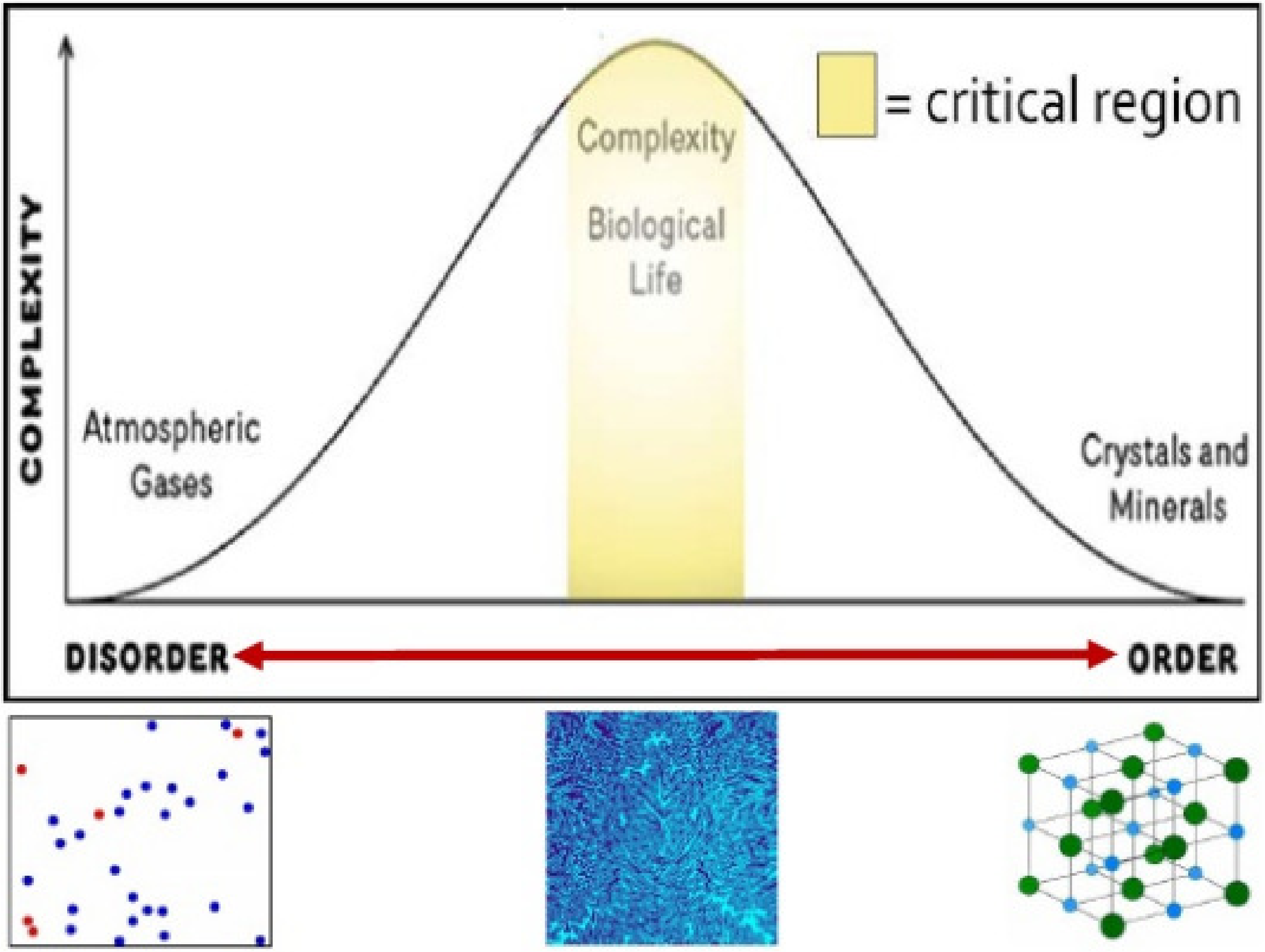
s-EEG-fcMRI neurofeedback study design



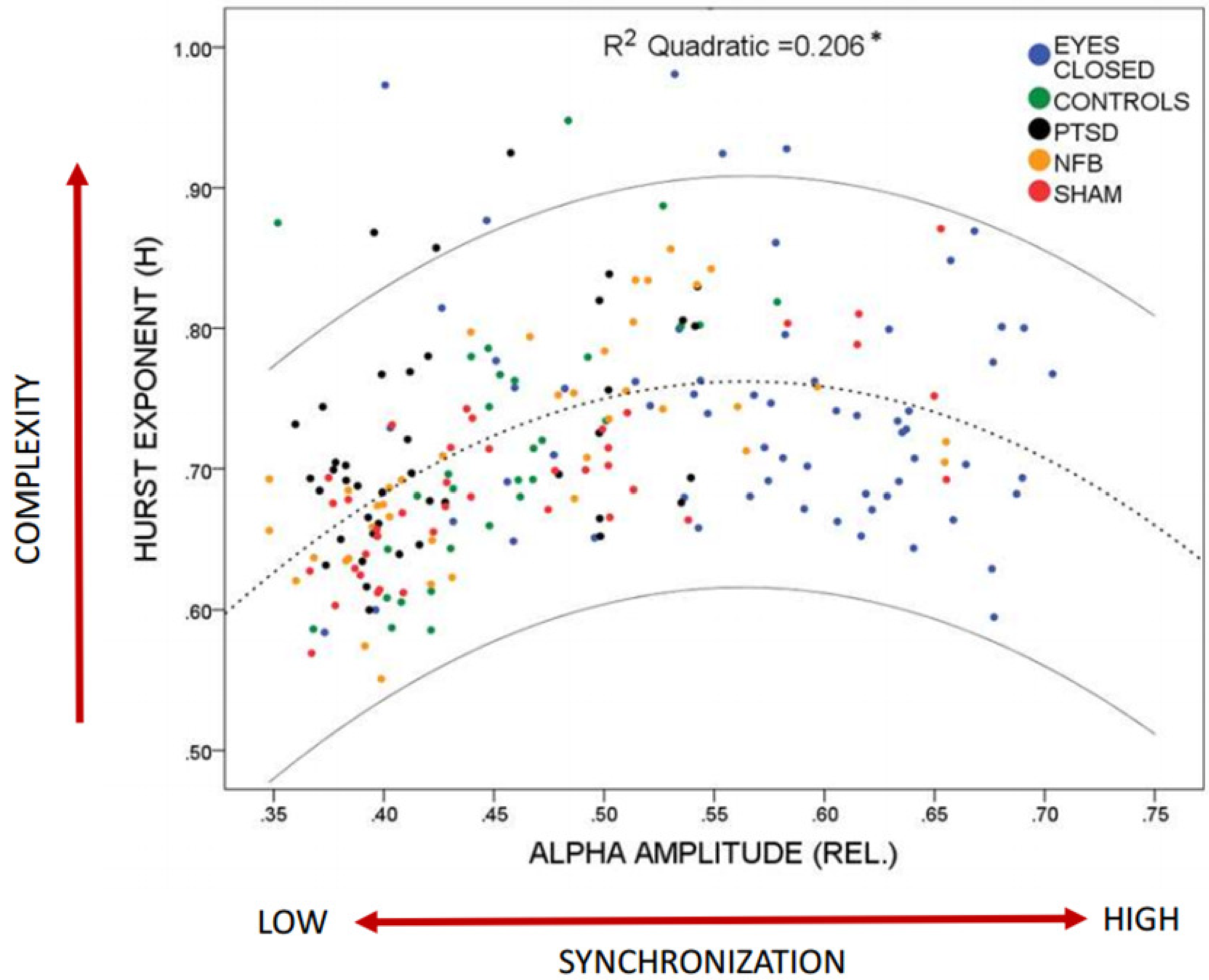
NFB protocol



The Theory of Self-Organised Criticality

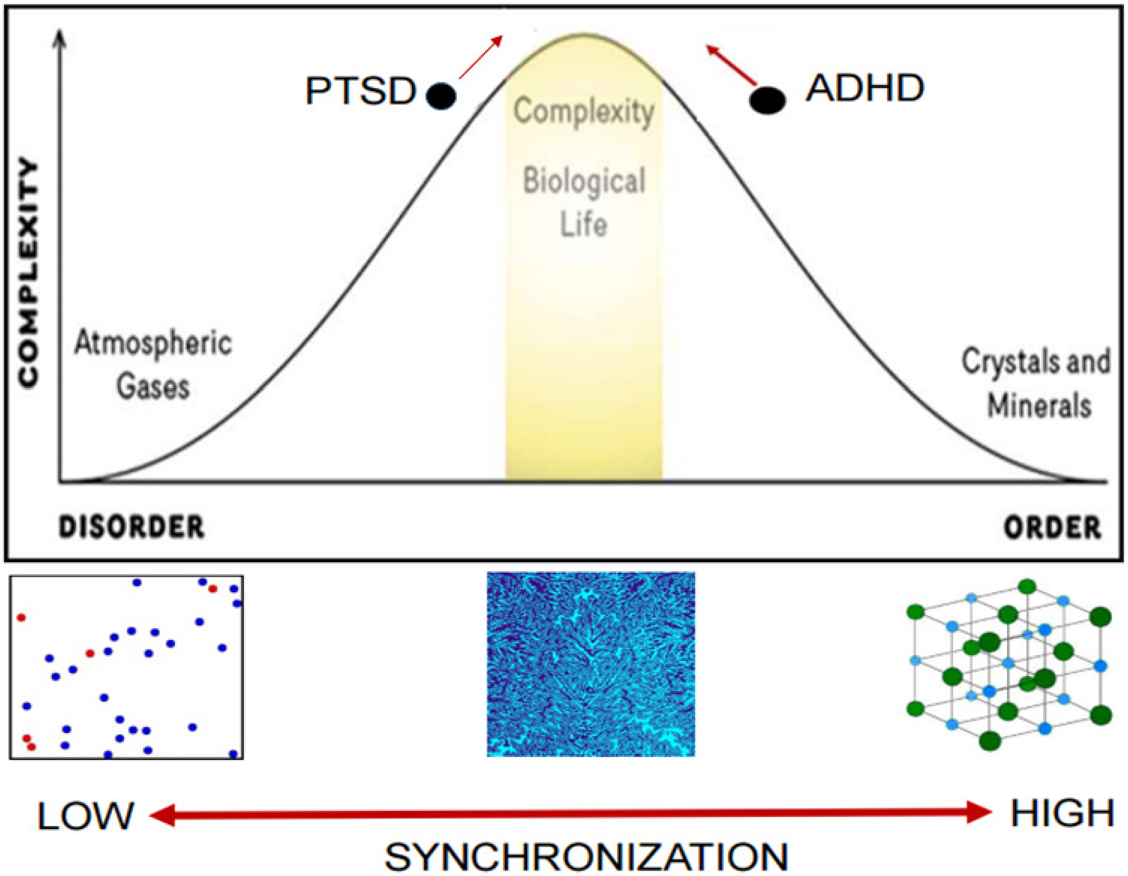


Tuning-pathological-brain-oscillations-Thomas Ros- 2016



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

Self-Organised Criticality: a potential mechanism?



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

frontiers in
HUMAN NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE
published: 18 December 2014
doi: 10.3389/fnhum.2014.01008

Tuning pathological brain oscillations with neurofeedback: a systems neuroscience framework

Tomas Ros[1]*, Bernard J. Baars[2], Ruth A. Lanius[3] and Patrik Vuilleumier[1]

[1] *Laboratory for Neurology and Imaging of Cognition, Department of Neurosciences, University of Geneva, Geneva, Switzerland*
[2] *Theoretical Neurobiology, The Neurosciences Institute, La Jolla, CA, USA*
[3] *Department of Psychiatry, University of Western Ontario, London, ON, Canada*

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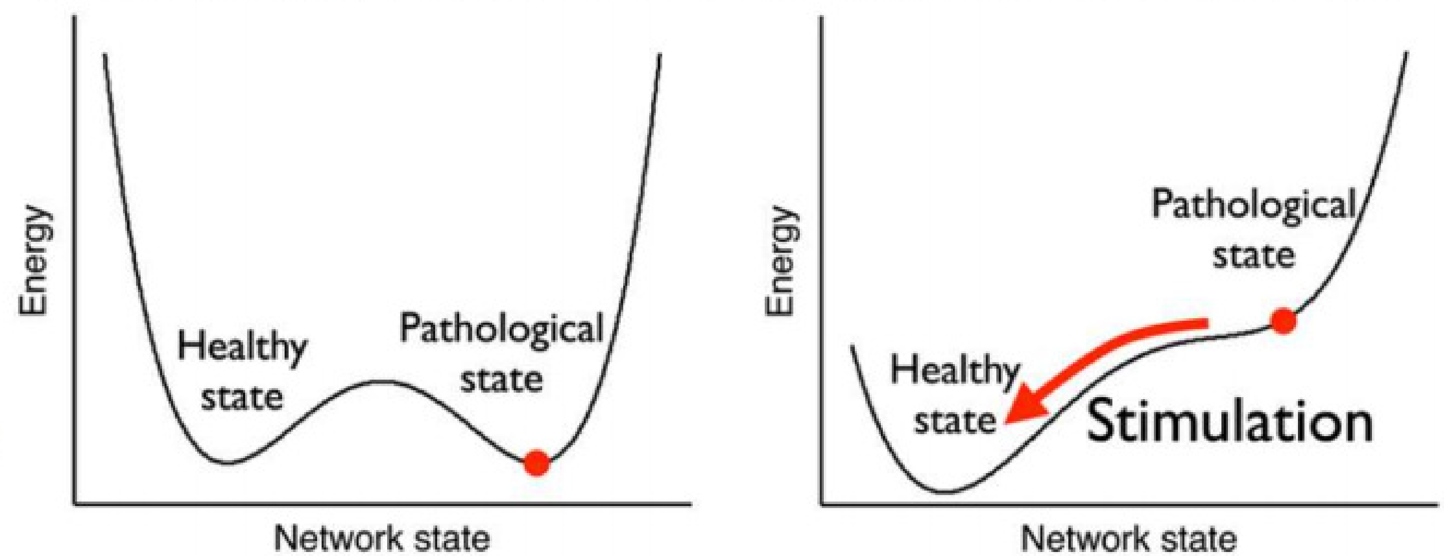
e-mail: dr.t.ros@gmail.com



Select a Network or Symptoms, Frequency and Metric

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Network	Severity
Addiction	0
Anxiety	0
Attention - Dorsal	0
Attention - Ventral	0
Attention - Emotional	0
Default Mode	0
Executive Function	0
Face, Object Recognition	0
Language	0
Memory - Emotion	0
Mirror Neuron	0
Mood	0
Pain	0
Pleasure	0
Salience	0
Schizophrenia	0
Working Memory	0
DTI - Frontal Limbic	0
DTI - Frontal Occipital	0
DTI - Frontal Parietal	0
DTI - Frontal Temporal	0
DTI - Local Frontal	0
DTI - Local Limbic	0
DTI - Local Occipital	0
DTI - Local Parietal	0
DTI - Local Temporal	0
Hagmann Module 1 (Vision)	0
Hagmann Module 2 (Attention, Working Memory)	0
Hagmann Module 3 (Auditory, Language, Memory)	0
Hagmann Module 4 (Auditory, Language, Memory)	0
Hagmann Module 5 (Executive, Sequential Planning)	0
Hagmann Module 6 (Executive, Social Skills)	0
Isocortex Hippocampocentric	0
Isocortex Olfactocentric	0
Mesocortex Hippocampocentric	0
Mesocortex Olfactocentric	0
Mesulam - Emotional Memory	0
Mesulam - Executive Function	0
Mesulam - Face/Object Indentification	0
Mesulam - Language	0
Mesulam - Spatial Attention	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Intrinsic Connectivity Network	Severity
ICN 1 (Limbic, Medial-Temporal, Emotion)	0
ICN 2 (Reward, Emotion)	0
ICN 4 (Language, Executive)	0
ICN 6 (Premotor, Supplemental Motor)	0
ICN 7 (Visual-Spatial Processing)	0
ICN 8, 17 (Primary Sensory Motor)	0
ICN 9 (Parietal)	0
ICN 10 (Picture Naming, Visual Tracking)	0
ICN 11, 12 (Visual System)	0
ICN 13 (Default Mode Network)	0
ICN 15 (Right Hemisphere, Attention, Reasoning, Memory)	0
ICN 16 (Auditory, Music)	0
ICN 18 (Left Hemisphere, Language)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Neuropsychological Diagnosis	Severity
Agnosia of Action Apperceptive	0
Agnosia of Action Associative	0
Agnosia Auditory Apperceptive	0
Agnosia Auditory Associative	0
Agnosia Auditory Space	0
Agnosia Prosopagnosia (Face)	0
Agnosia Social Emotional	0
Agnosia Social of Action - Theory of Mind	0
Agnosia Somatosensory Autotopagnosia	0
Agnosia Somatosensory Finger	0

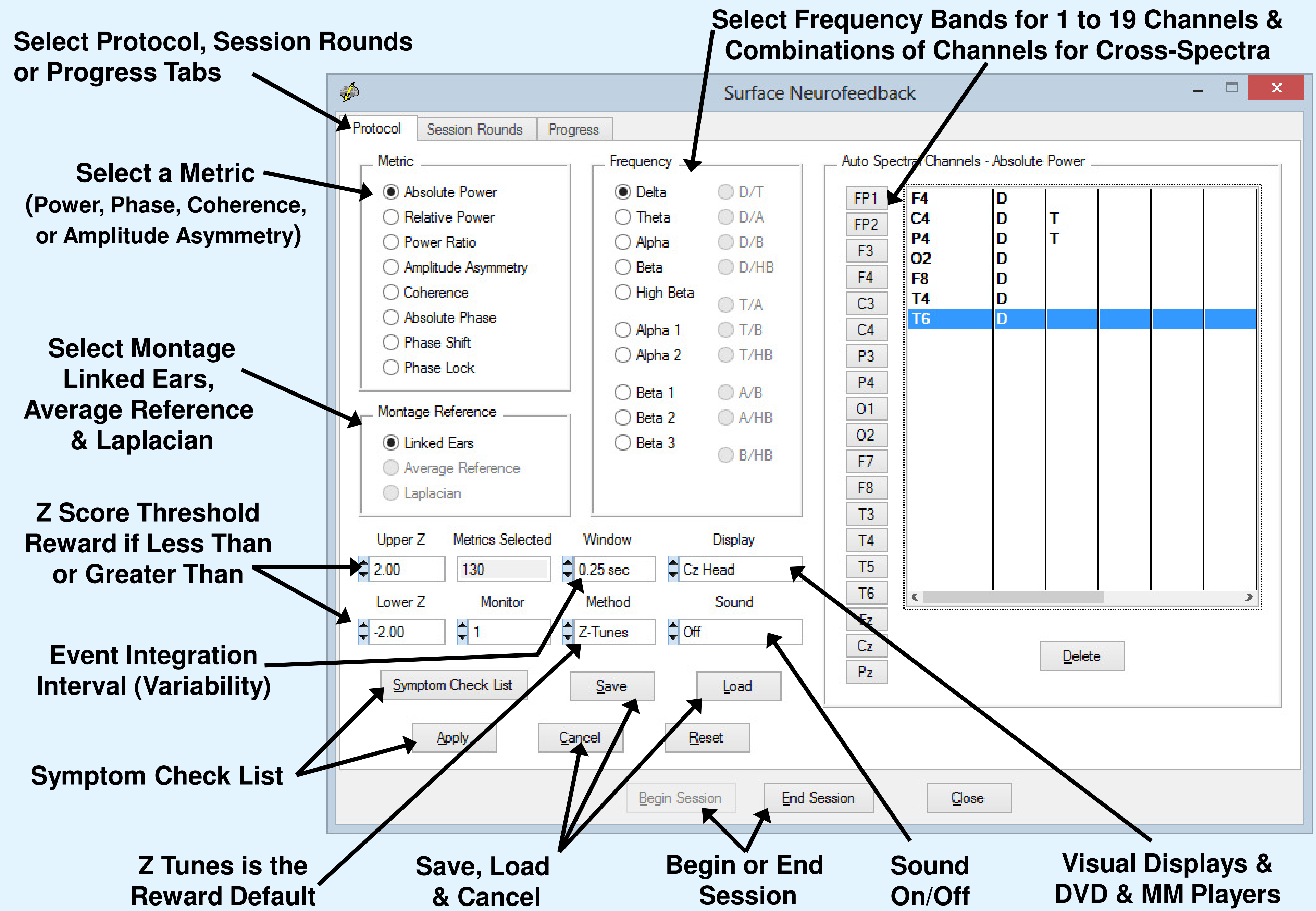
Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Attention - Re-Experiences Intrusive Memories	0
Attention - Emotional Numbing	0
Attention - Distracting Pain	0
Attention - Difficulty Multi-Tasking	0
Attention - Worsens with Emotional Stress	0
Attention - Dissociative Episodes	0
Attention - Worsens With Withdrawl Symptoms	0
Chronic Pain - Neuropathic	0
Chronic Pain - Musculoskeletal	0
Chronic Pain - Diffuse Pain (Entire Body)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Anosognosia - Denial of a Problem	0
Anxiety	0
Attention Deficits - Easily Distractible	0
Auditory Sequencing Problems	0
Balance Problems	0
Blurred Vision	0
Chronic Pain	0
Compulsive Behaviors and/or Thoughts	0
Concentration Problems	0
Decreased Tactile or Skin Sensitivity	0
Delusional	0
Depression (Sad & Blue)	0
Difficulty Comprehending Social Cues	0
Dyscalcula - Problems Calculating	0
Dyslexia - Letter Reversal	0
Executive Function Problems	0
Face Recognition Problems	0
Failure to Initiate Actions	0
Hyperactive and/or Agitation	0
Impulsive Behaviors	0
Insensitive to Others Emotional Expressions	0
Insensitive to Other's Feelings	0
Low Motivation	0
Low Threshold for Anger & Loss of Control	0
Migrane Headaches	0
Mood Swings	0
Multi-Tasking Problems	0
Obsessive Thoughts about Self	0
Obsessive Thoughts and/or Hyper Focused	0
Oppositional Defiant Conduct	0
Orientation in Space Problems	0
Perception of Letters Problems	0
Poor Judgement	0
Poor Skilled Motor Movements	0
Poor Social Skills	0
Receptive Language Problems	0
Recognizing Objects by Touch Problems	0
Self-Esteem Problems	0
Sequential Planning Problems	0
Short-Term Memory Problems	0
Slow Reader	0
Slowness of Thought - Easily Confused	0
Spatial Perception Problems	0
Speech Articulation Problems	0
Substance Abuse	0
Symptoms of Fibromyalgia	0
Word Finding Problems	0

Z Score Neurofeedback Panel



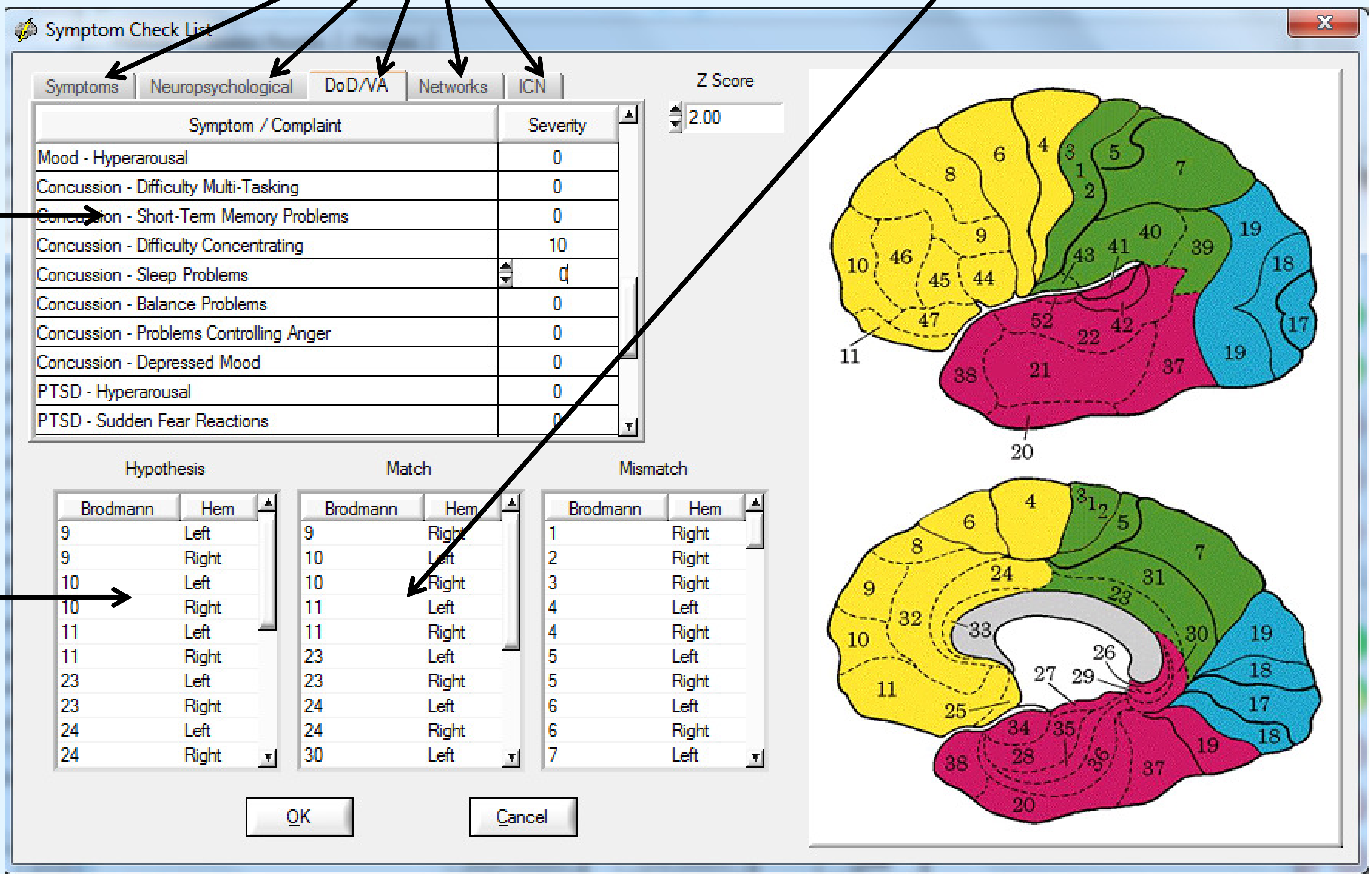
Neuroimaging Neurofeedback Symptom Check List

Click Symptoms or Neuropsychological Diagnoses or DoD/VA List or Networks & Severity

List of Matching Brodmann Areas

List of Symptoms

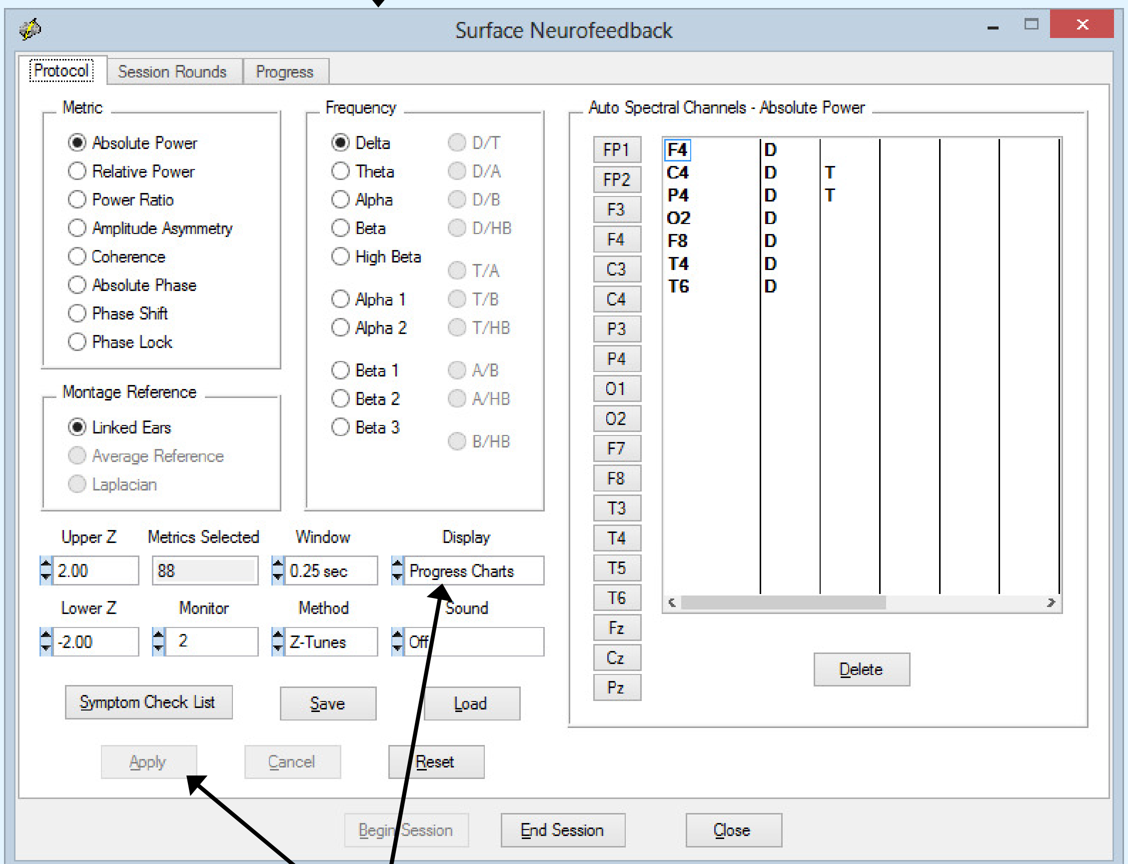
Anatomical Hypotheses

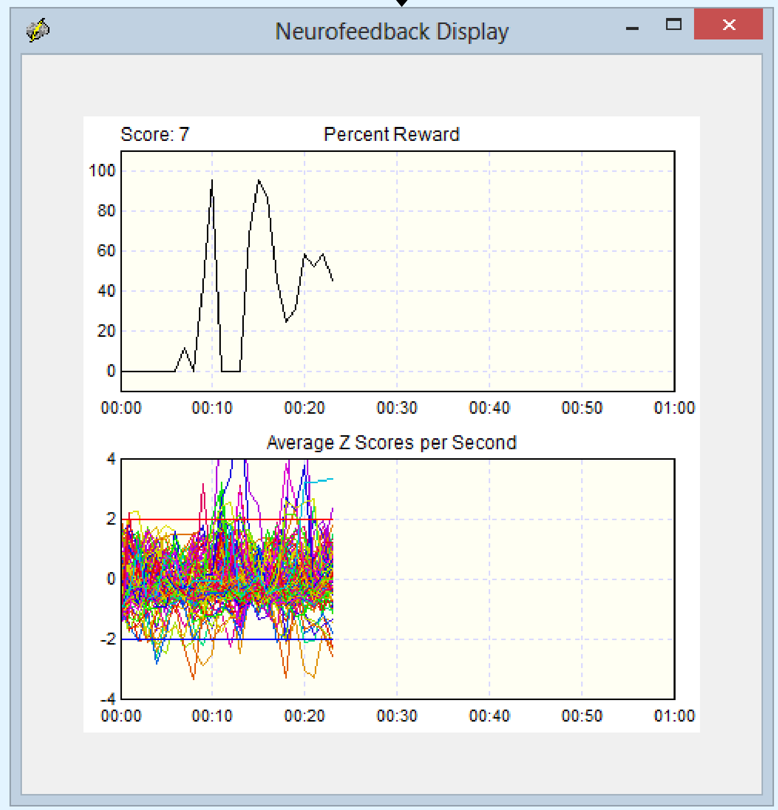


Use the Progress Chart as a Feedback Display

Neurofeedback Setup Panel

Move the Display to the Client's Monitor





Select Progress Charts as Feedback to a Client and then Click Apply

Move to the Client's Monitor

Progress Charts to be Monitored by the Clinician During Neurofeedback

Toggle Back & Forth between Protocol Window & Progress Charts

Red Mark Designates Settings Change

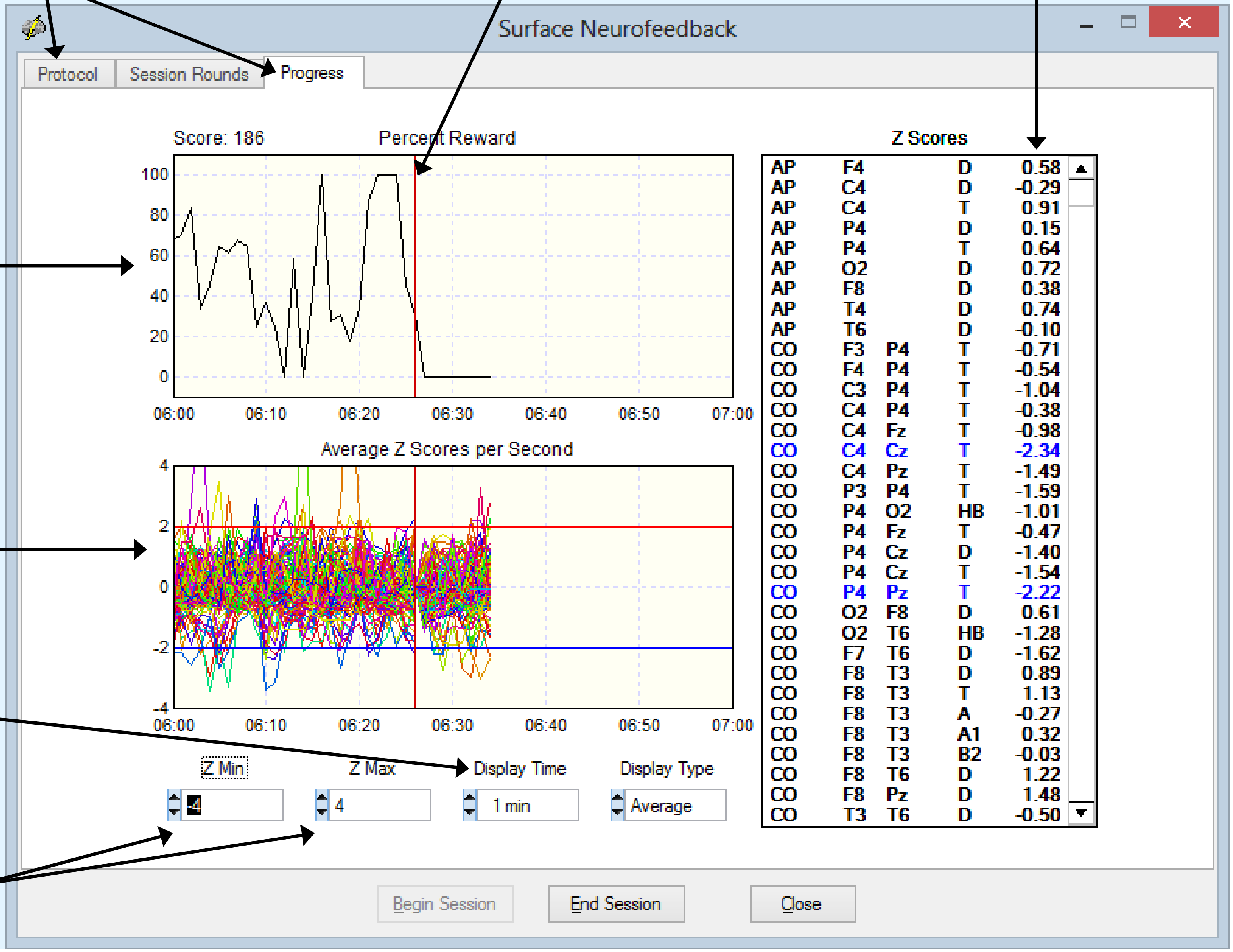
View Instantaneous Z Scores

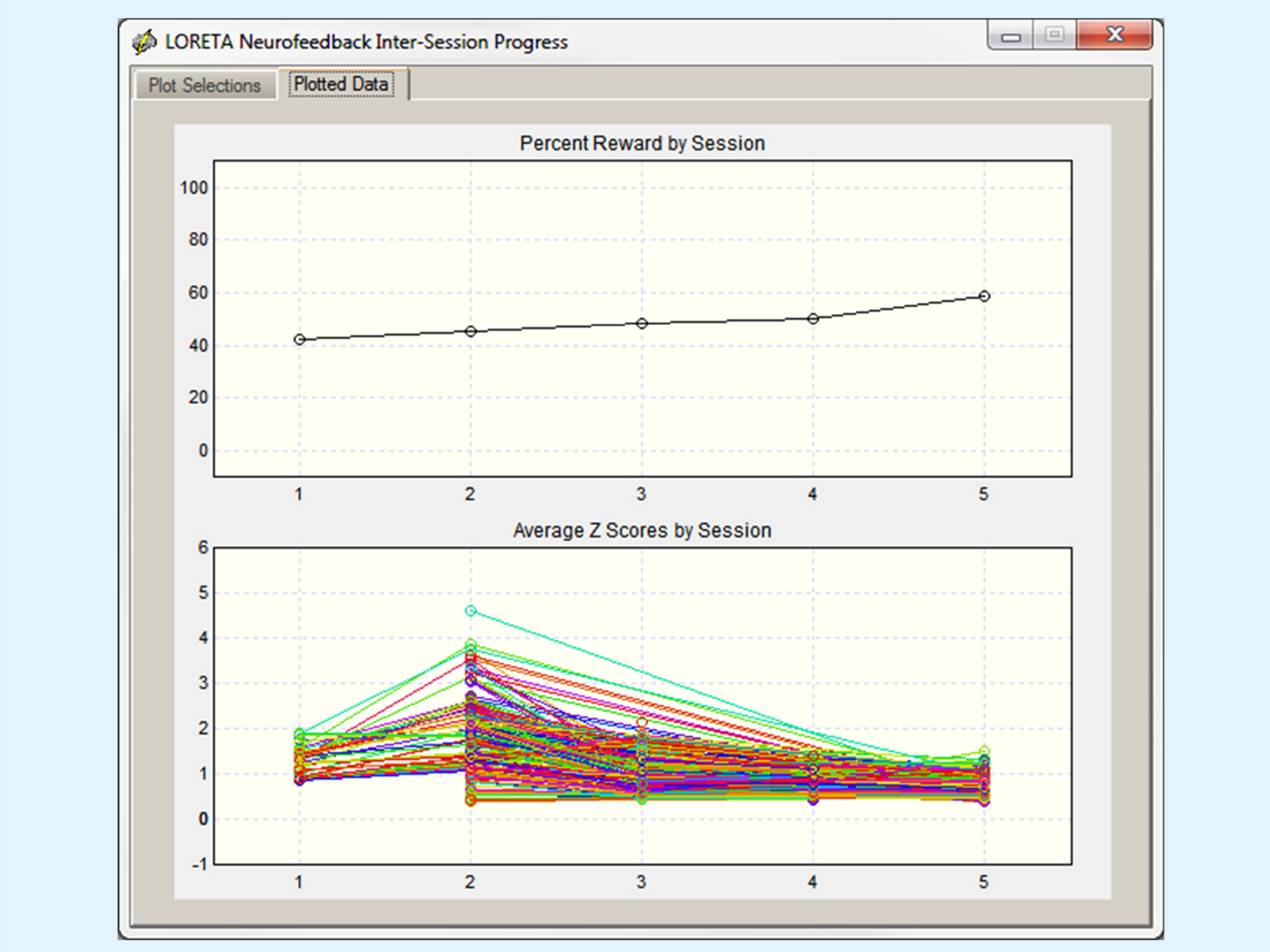
Percentage of Time that a Reward was Delivered (per sec)

Average Z Scores Updated Each Second

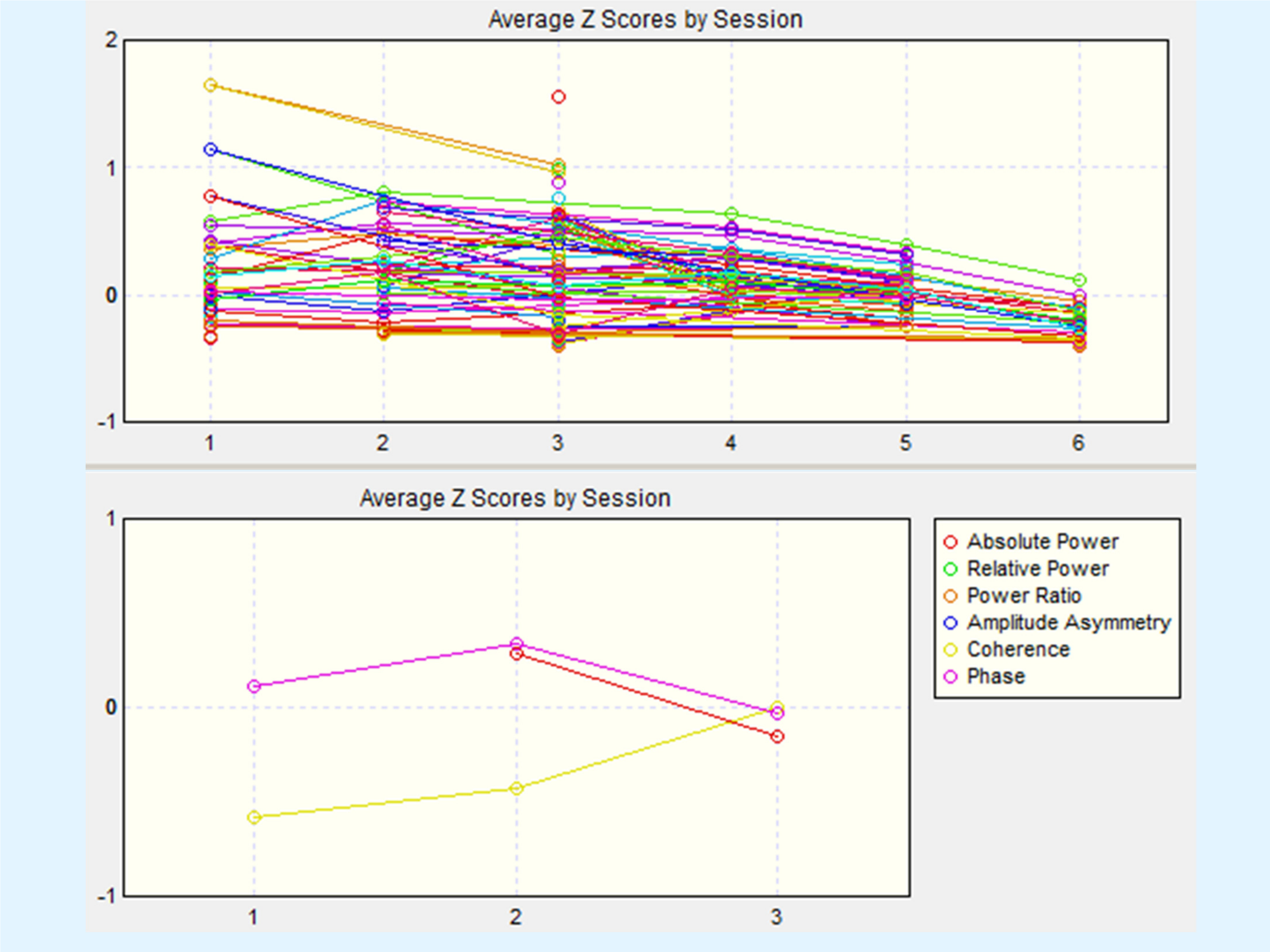
Display Time Base 1 min to 30 min

Z Score Range





LORETA Neurofeedback Inter-Session Progress
Plot Selections
Plotted Data
Percent Reward by Session
100
80
60
40
20
0
1
2
3
4
5
Average Z Scores by Session
6
5
4
3
2
1
0
-1
1
2
3
4
5

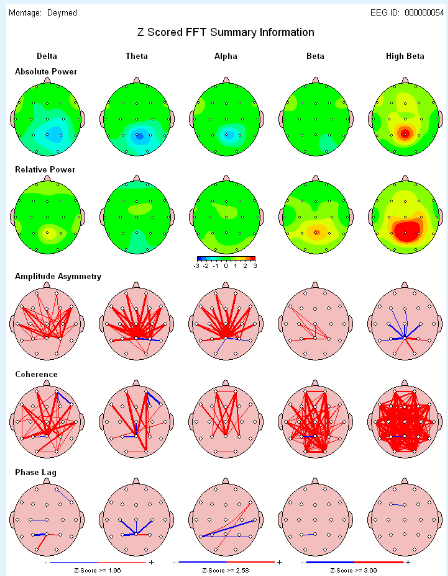

Average Z Scores by Session
2
1
0
-1
1
2
3
4
5
6
Average Z Scores by Session
1
0
-1
1
2
3
Absolute Power
Relative Power
Power Ratio
Amplitude Asymmetry
Coherence
Phase

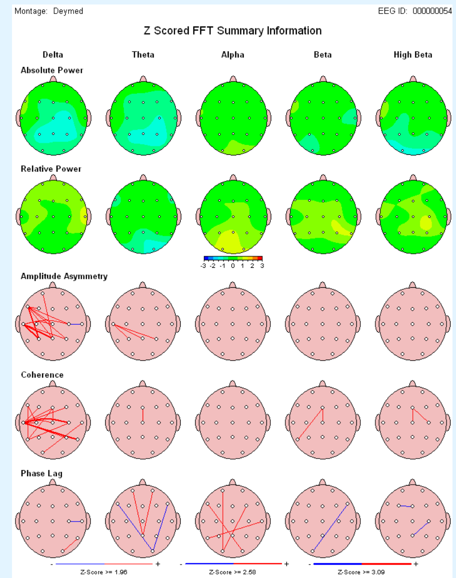
Examples of Surface EEG Changes After EEG Neurofeedback

Pre-Treatment

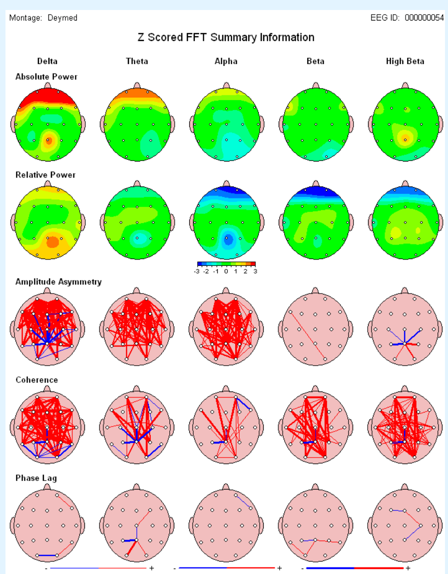
Post – 10 Treatments

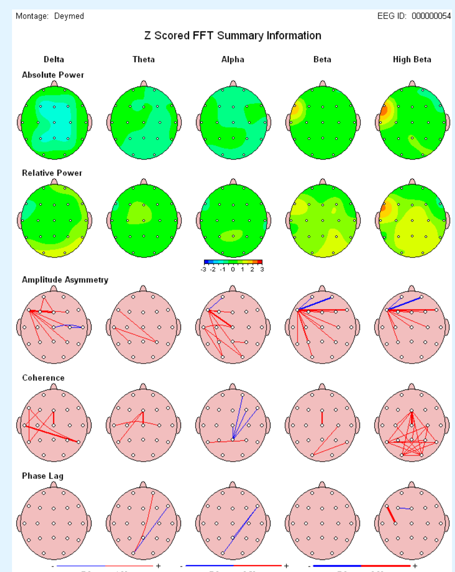
TBI Subject #1



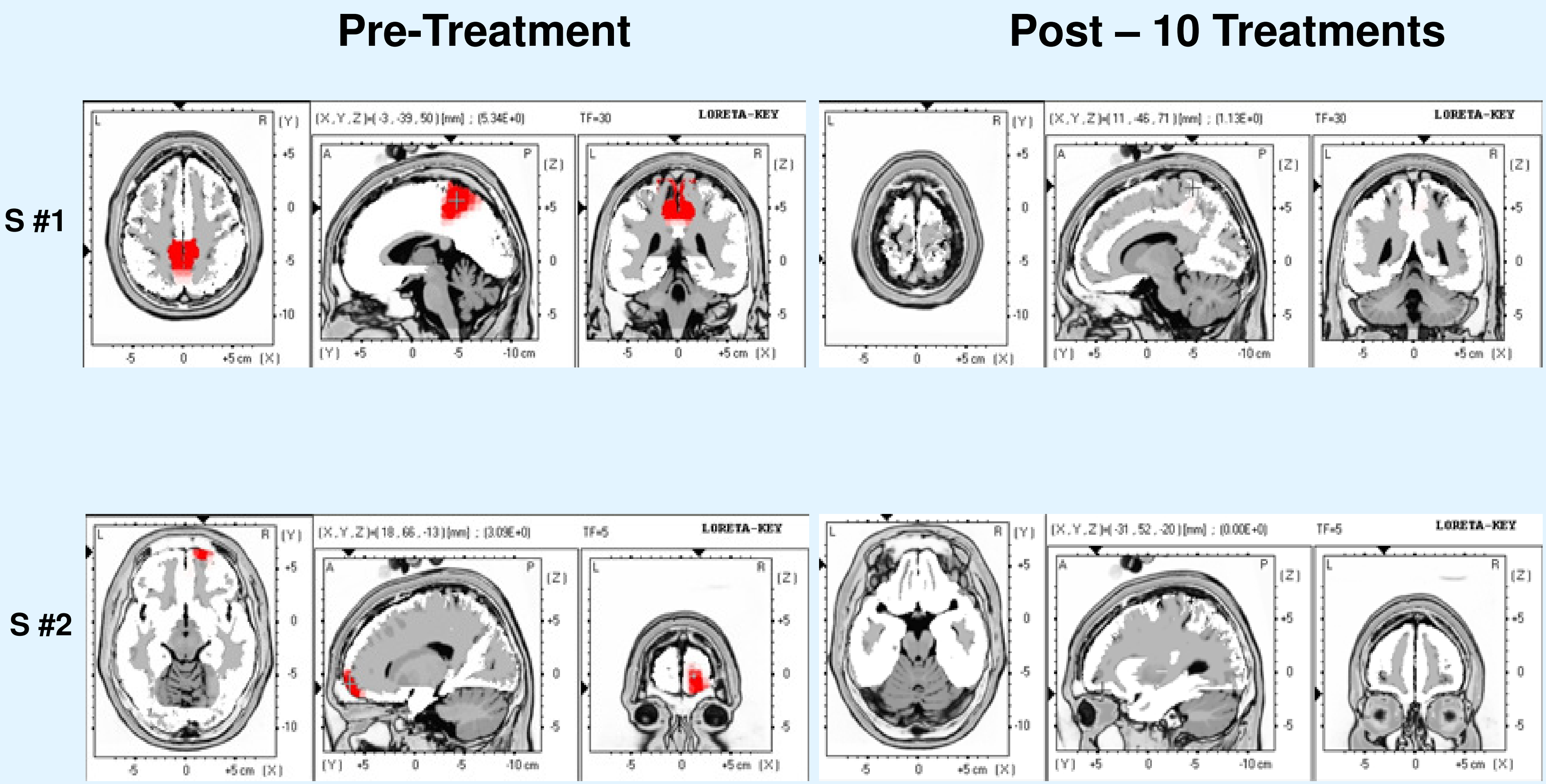


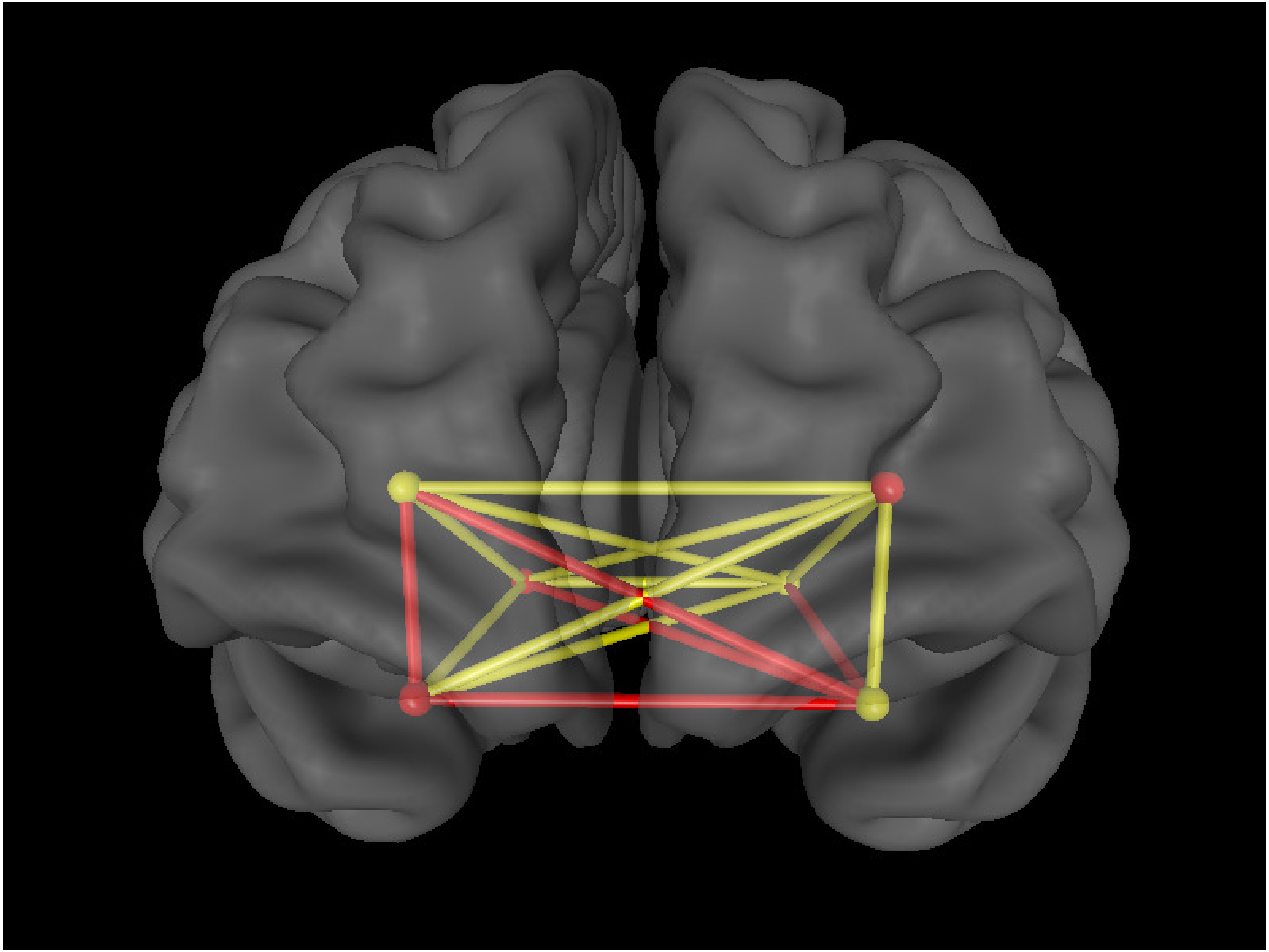
TBI Subject #2

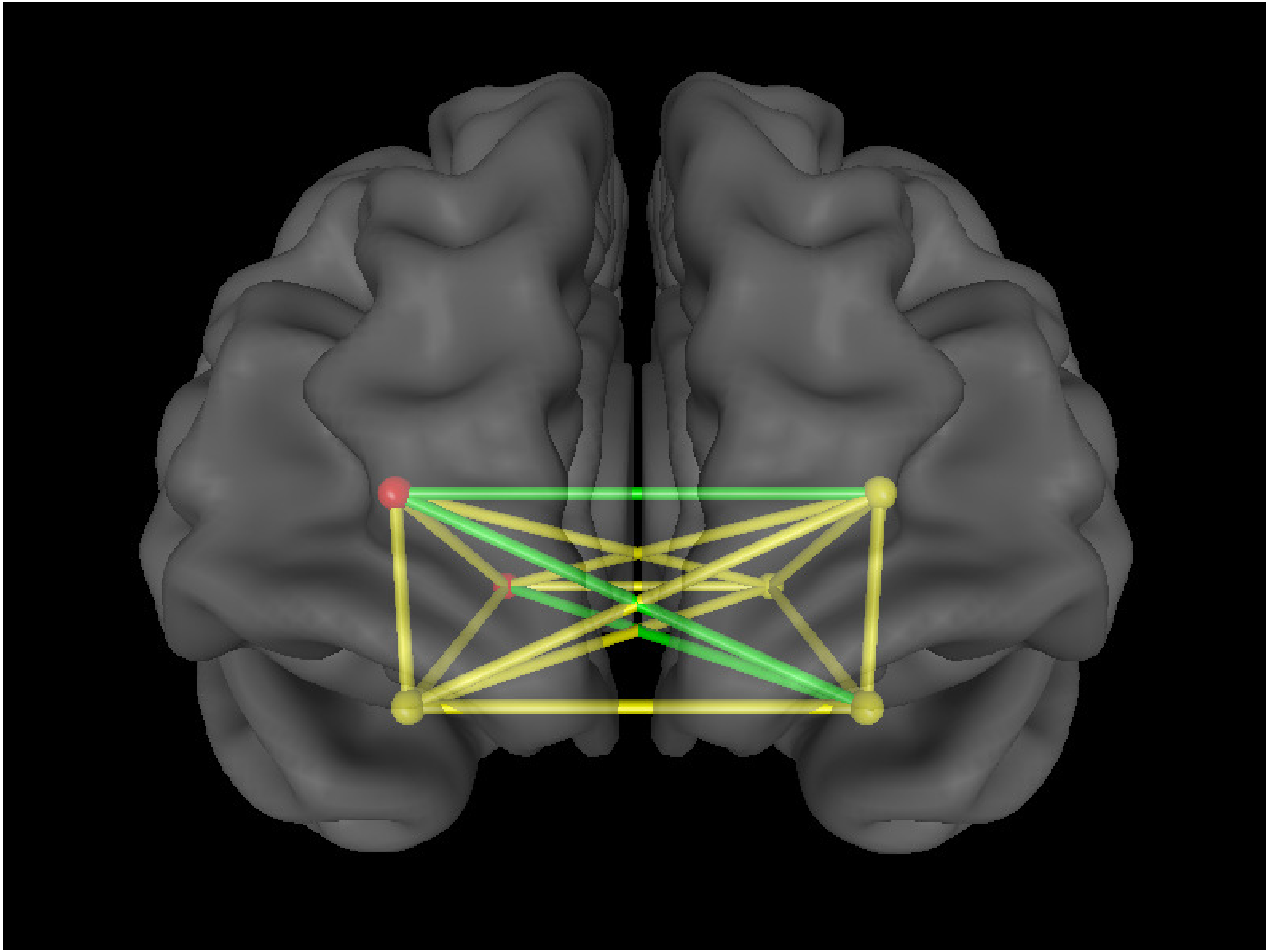


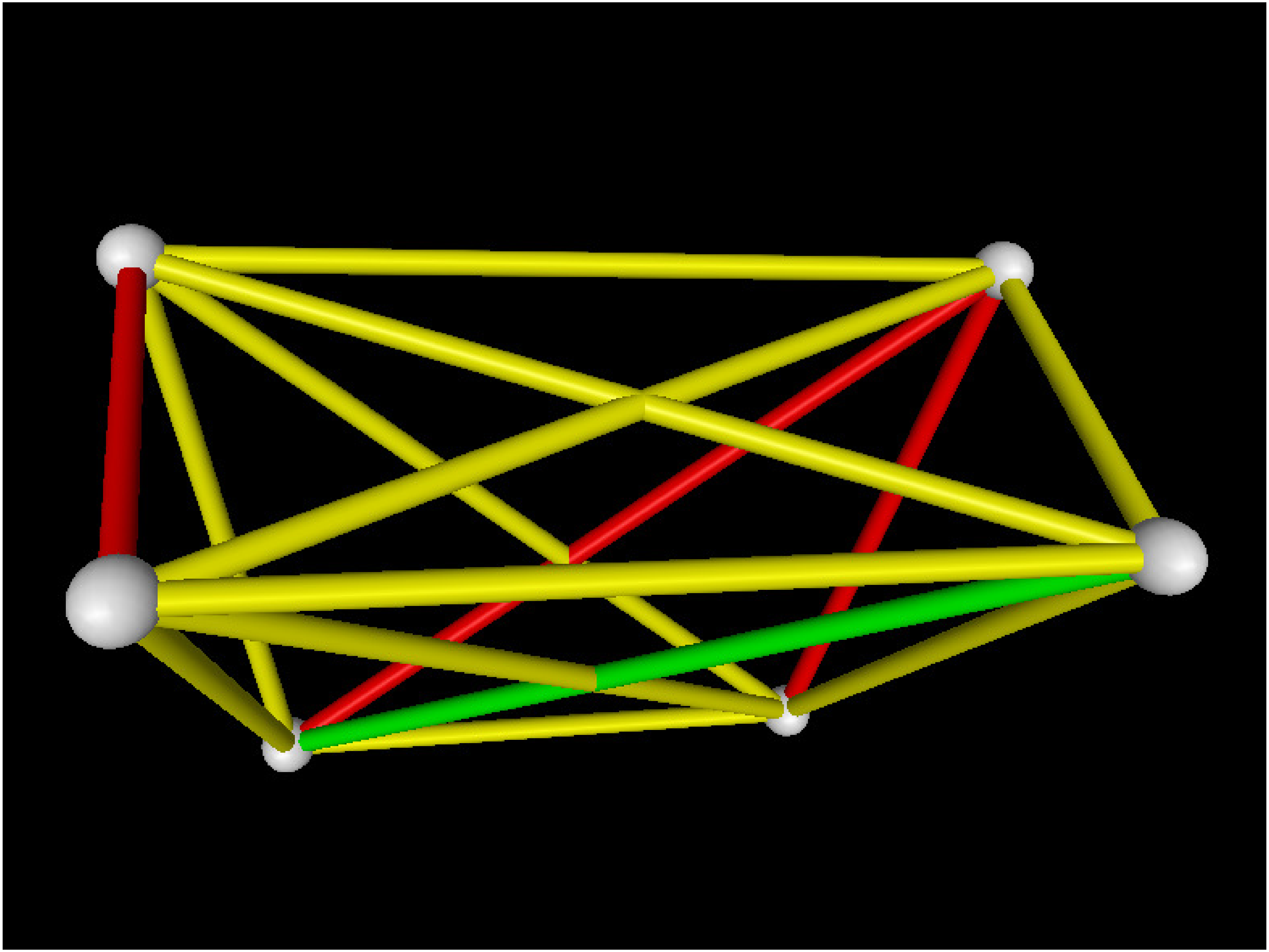


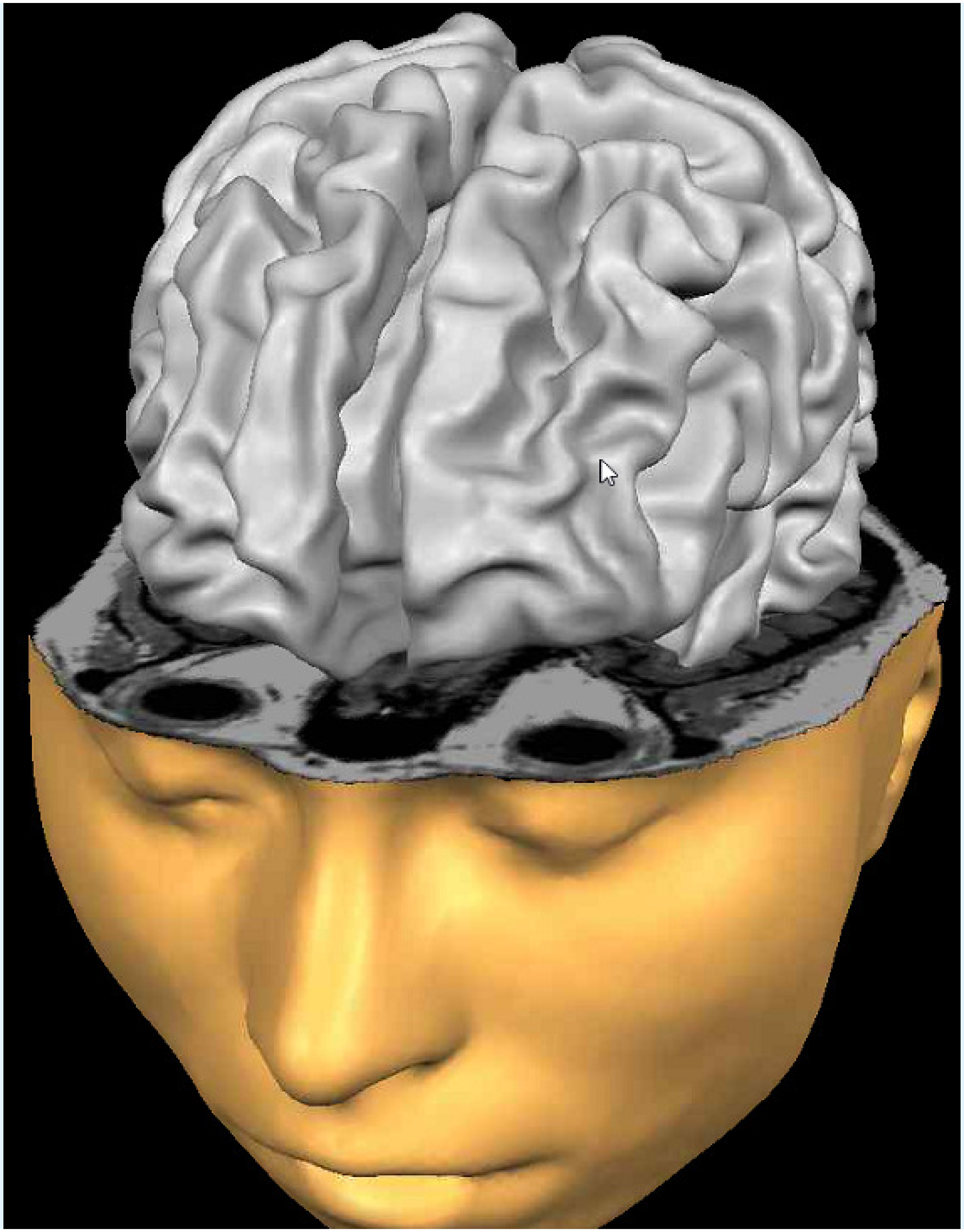
Examples of Electrical Neuroimaging After Neurofeedback

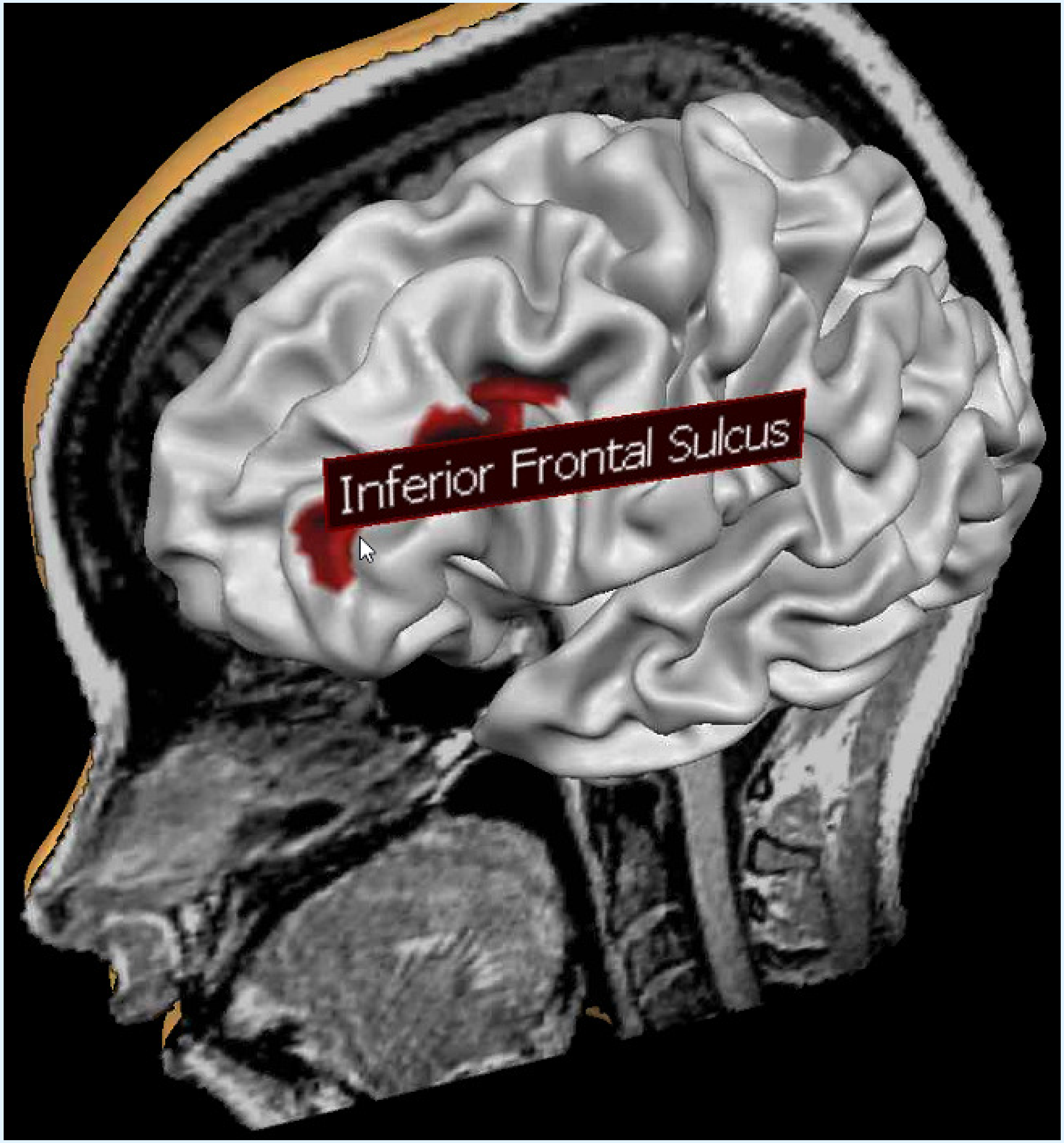











Inferior Frontal Sulcus

Advanced Concepts on EEG and QEEG Assessment and Human Performance

International Symposium on Clinical Neuroscience – Feb 3-5, 2017

Linking Symptoms to qEEG Biomarkers and Neurofeedback

Robert W. Thatcher, Ph.D.

Applied Neuroscience, Inc.
8200 Bryan Diary Rd., Suite 300
Largo, FL

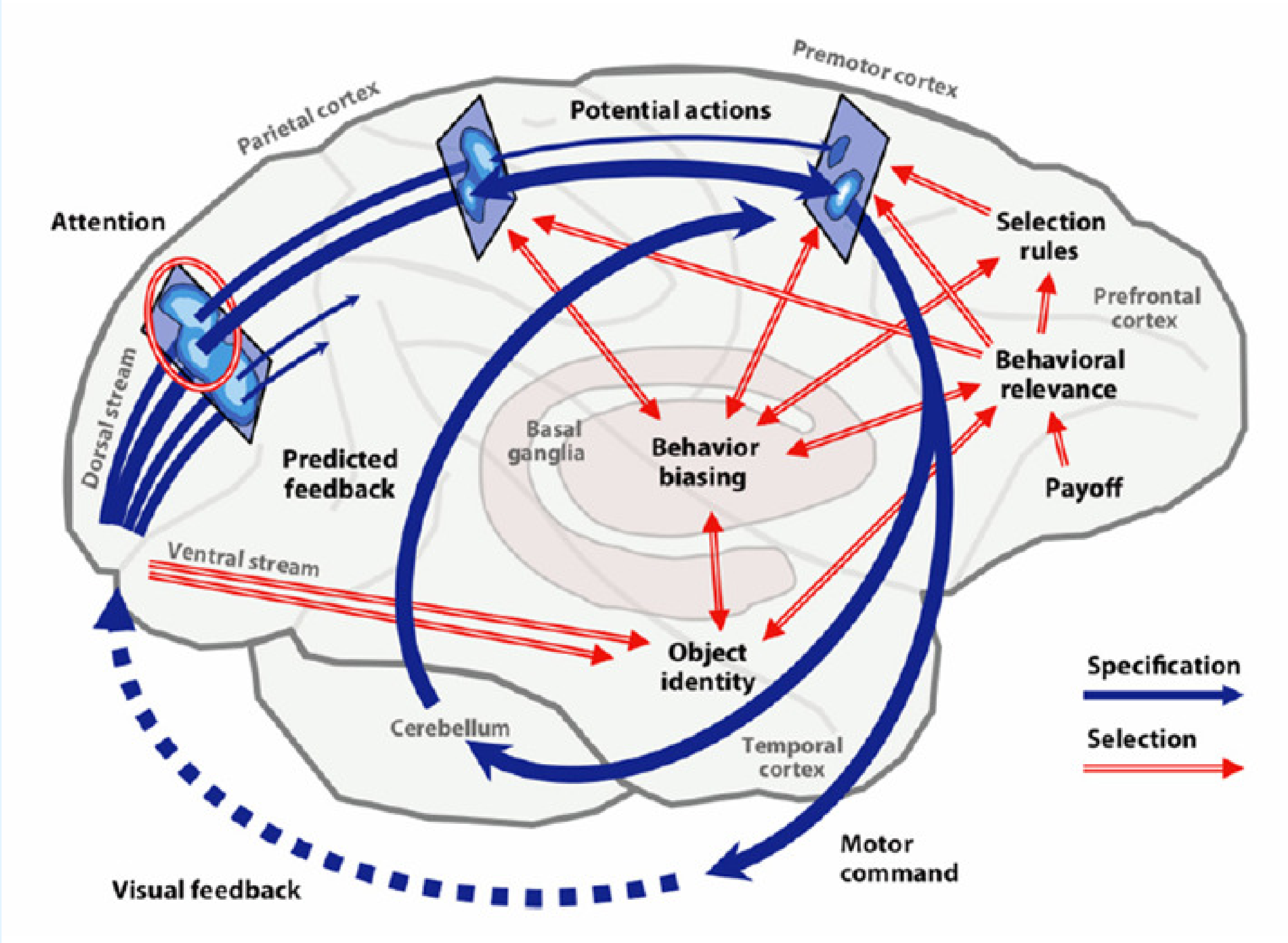
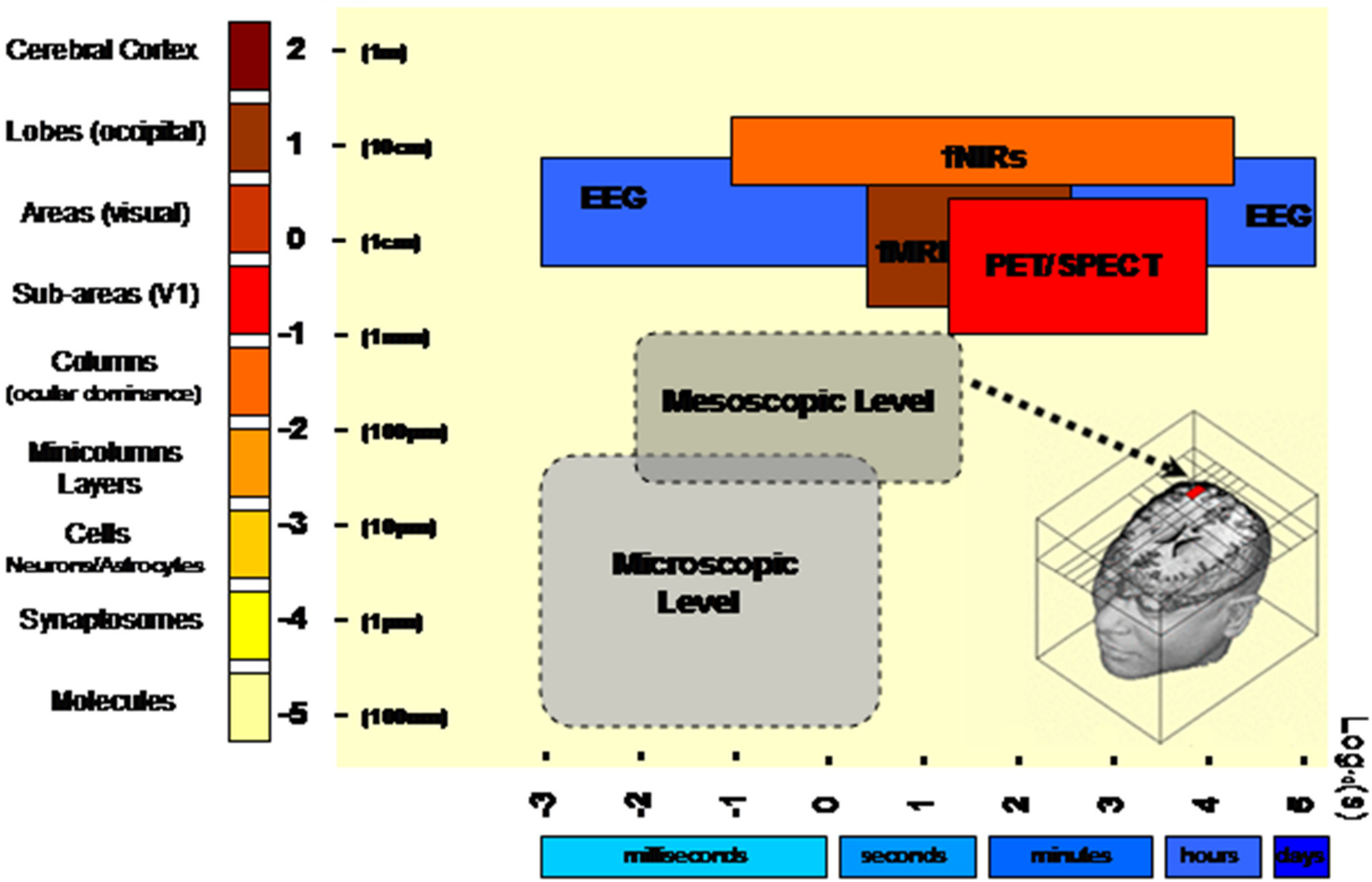
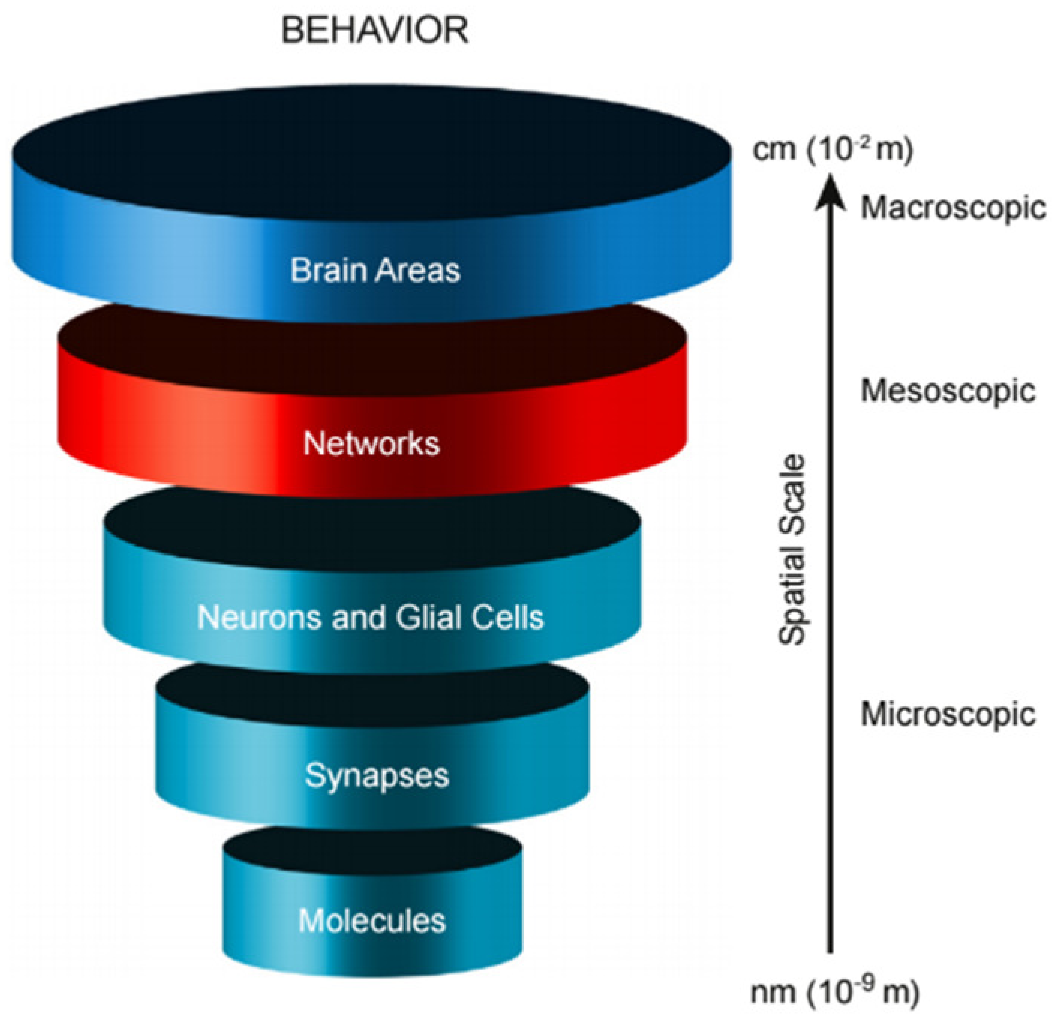


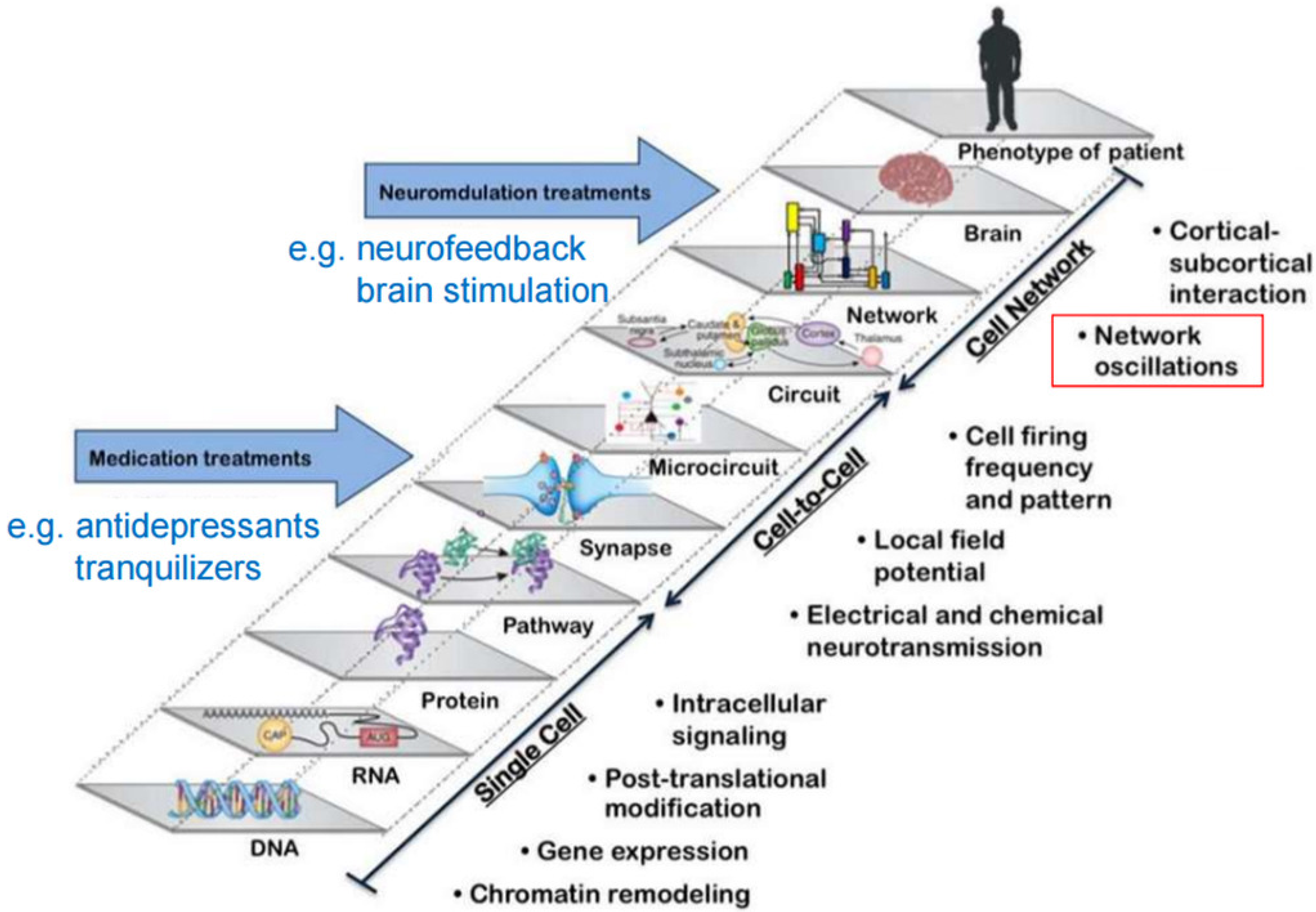
Illustration of brain information flow that can only be measured by the electroencephalogram using computers.
Information flow – Millisecond Match-Mismatch From Rabinovich et al, 2012

Functional Neuroimaging Modalities

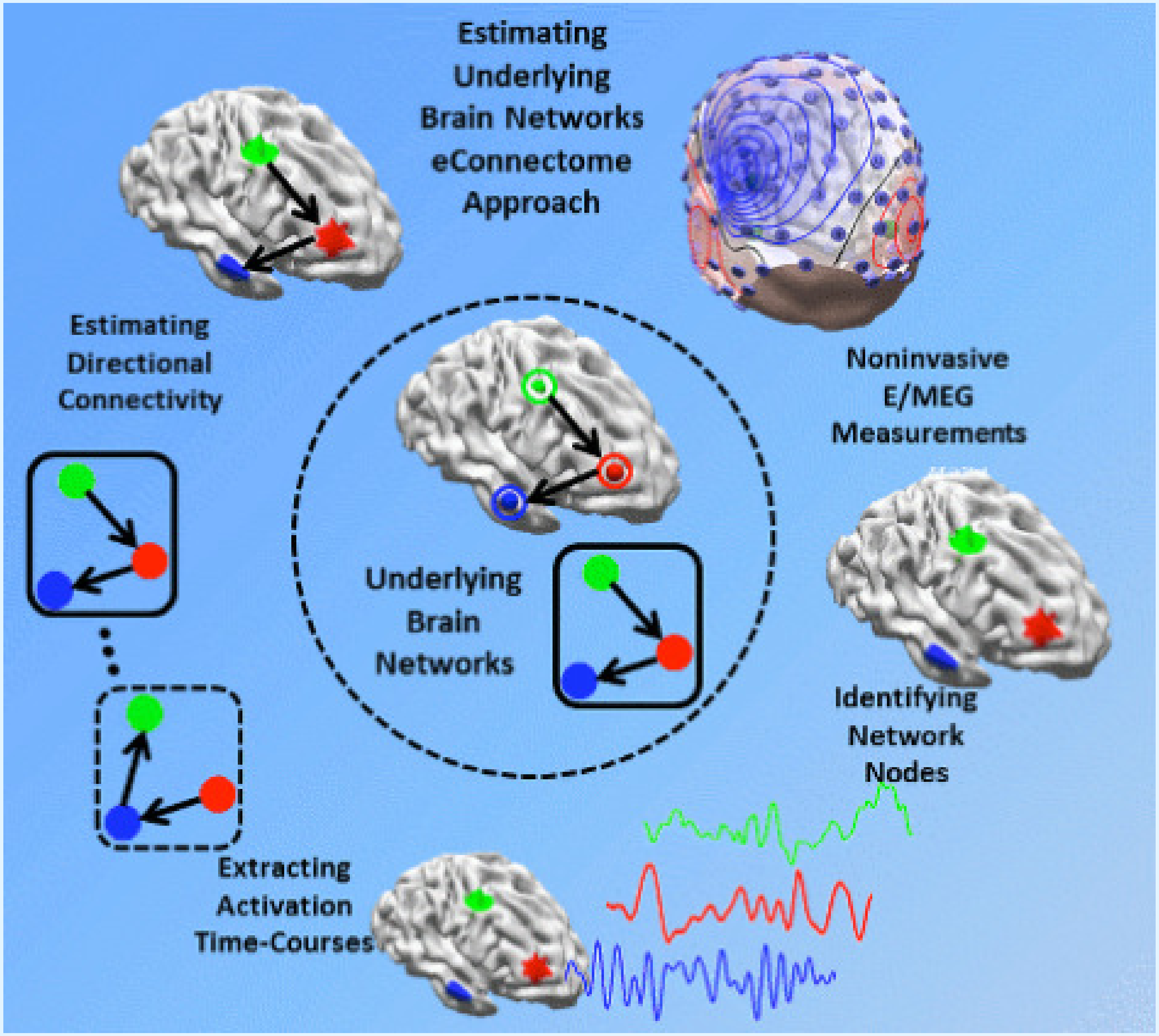




Frohlich, F., 2016. Network Neuroscience. Academic Press, NY



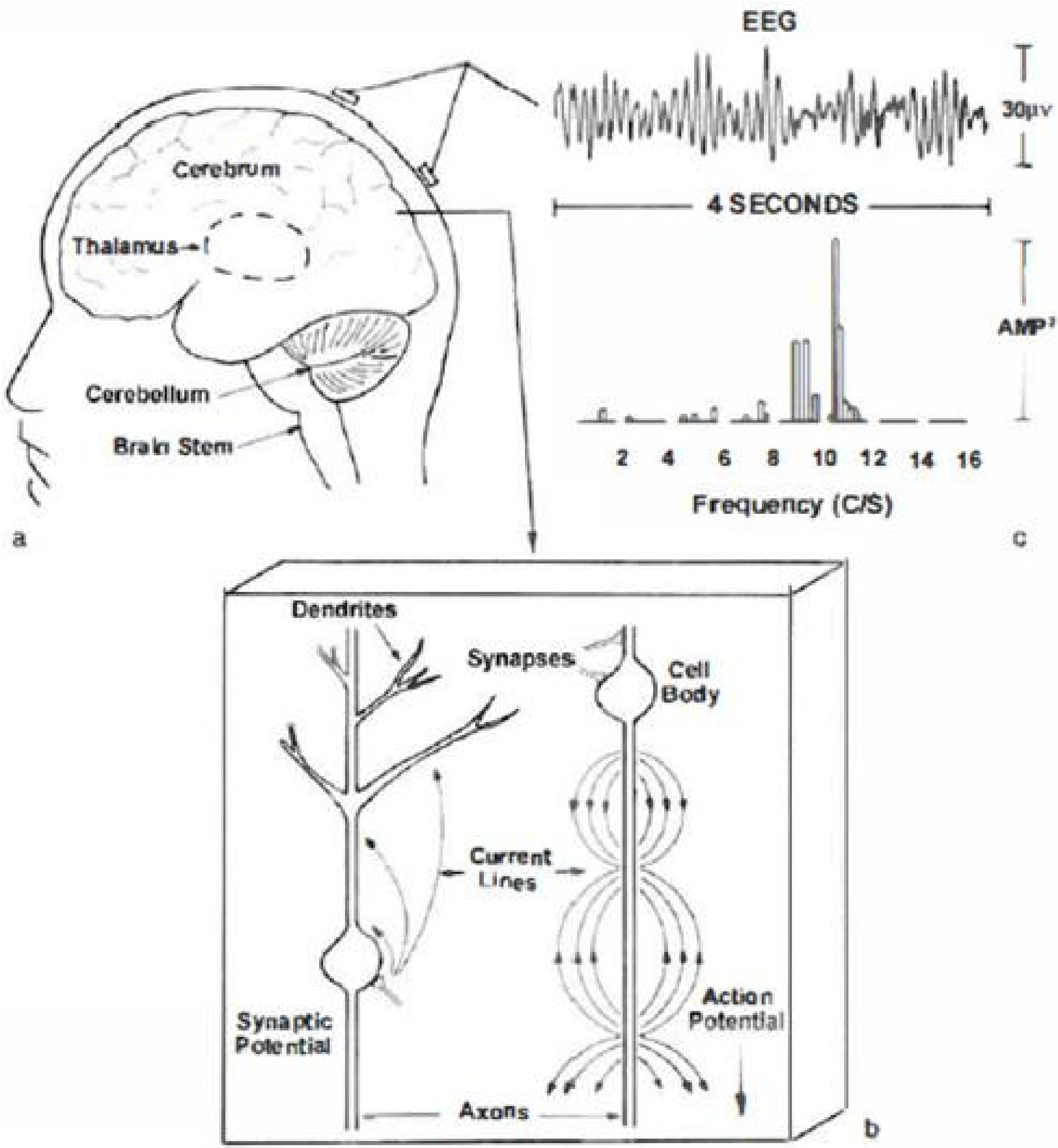
tuning-pathological-brain-oscillations-Thomas Ros-video -From Leuchter, 2015



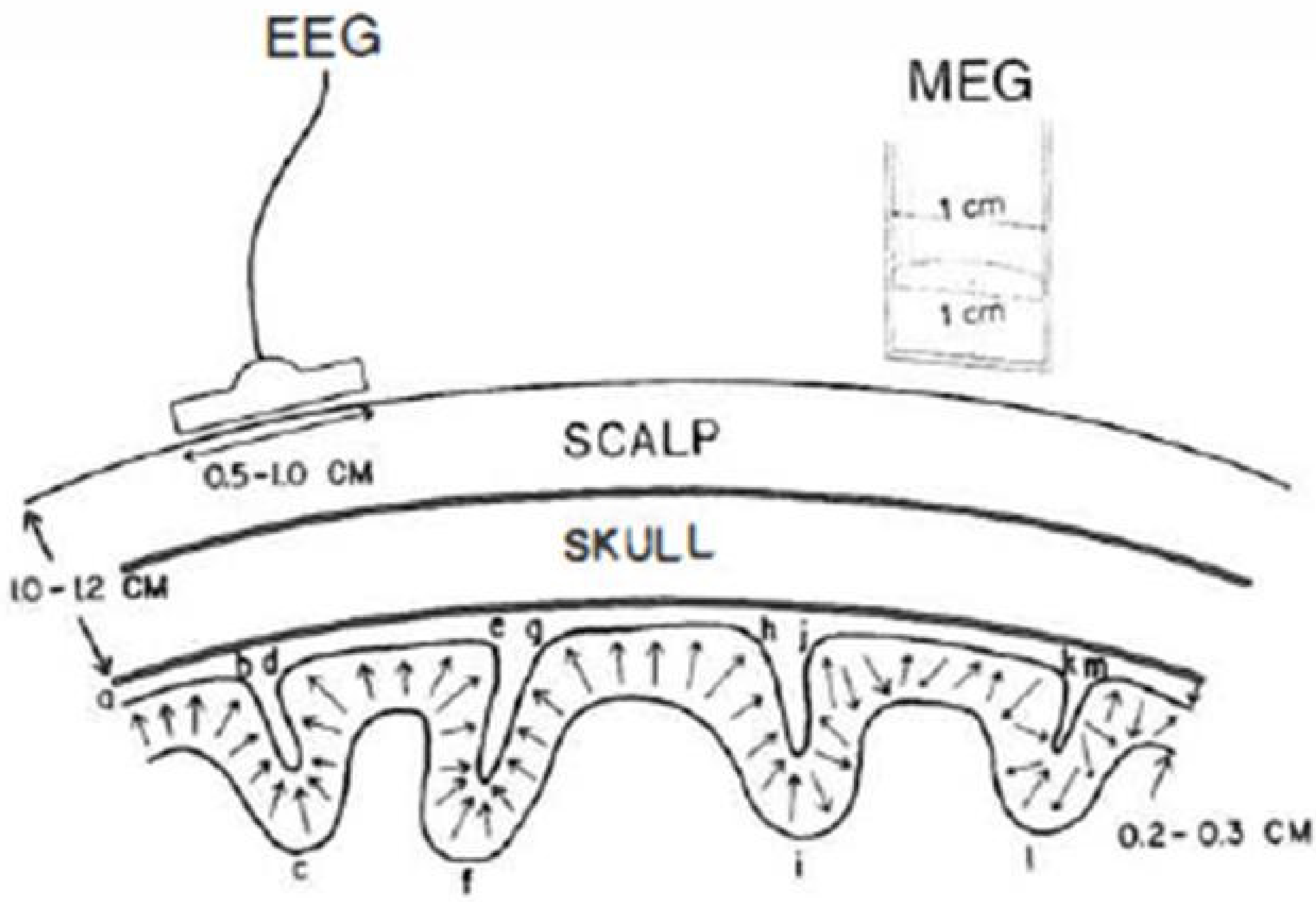
Noninvasive Electromagnetic Source Imaging and Granger Causality Analysis: An Electrophysiological Connectome (eConnectome) Approach ***Abbas Sohrabpour, Shuai Ye, Gregory Worrell, Wenbo Zhang, Bin He , University of Minnesota, USA,*** [*Volume: 63, Issue:12, Pages:2474-2487, 2016*]

Genesis of the Human Electroencephalogram - EEG

1- Pyramidal Neuron Dipoles
2- Oscillations In an Approx. 2mm thick sheet
3- Summated Local Field Potentials (LFP)
4- Amplitude = Proportion of Synchronous/Square Root of Proportion of Asynchronous Generators
5- Pacemakers and Resonance

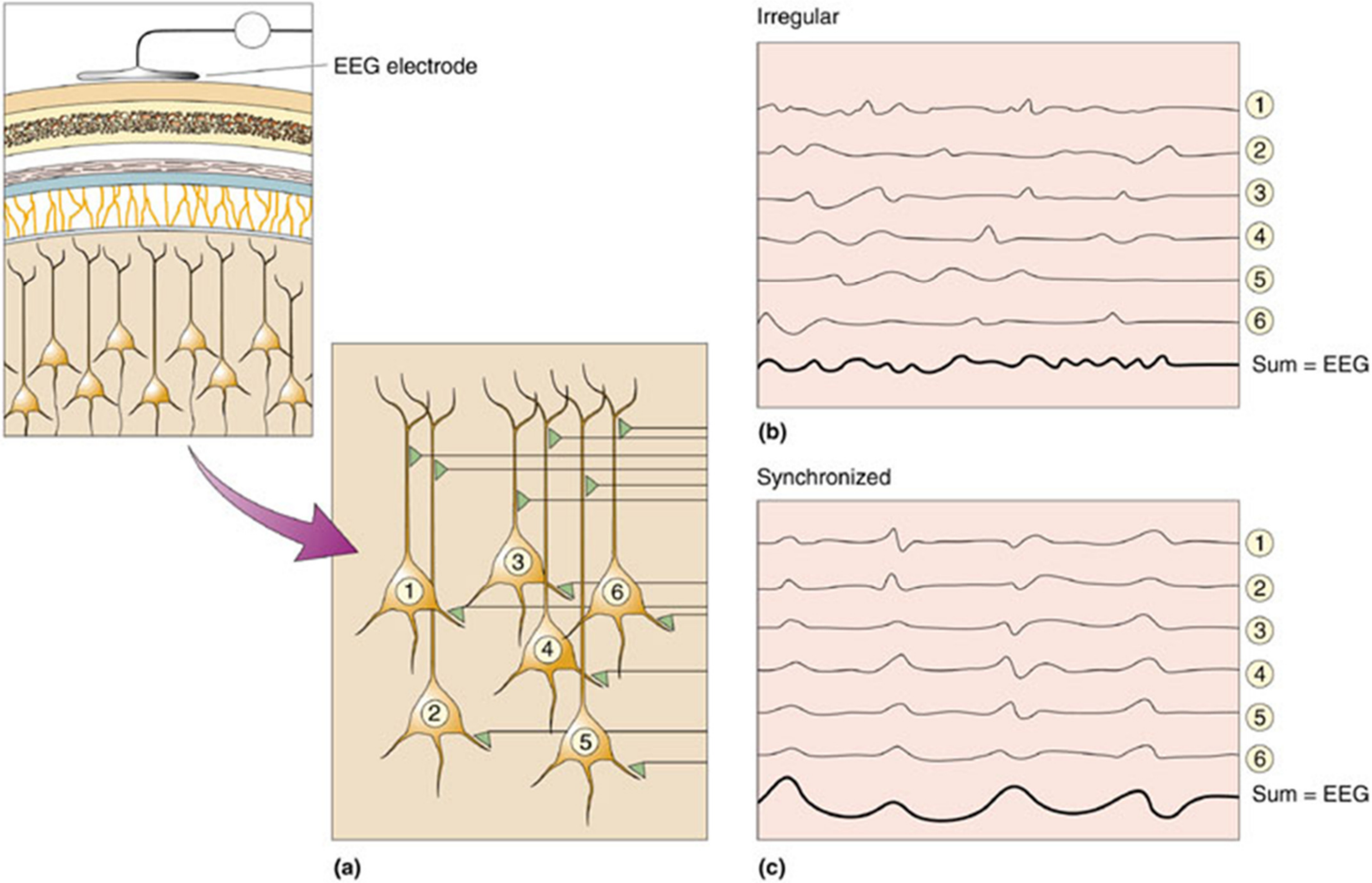


EEG
30µv
4 SECONDS
AMP²
2 4 6 8 10 12 14 16
Frequency (C/S)
Cerebrum
Thalamus
Cerebellum
Brain Stem
a
c
Dendrites
Synapses
Cell Body
Current Lines
Synaptic Potential
Action Potential
Axons
b

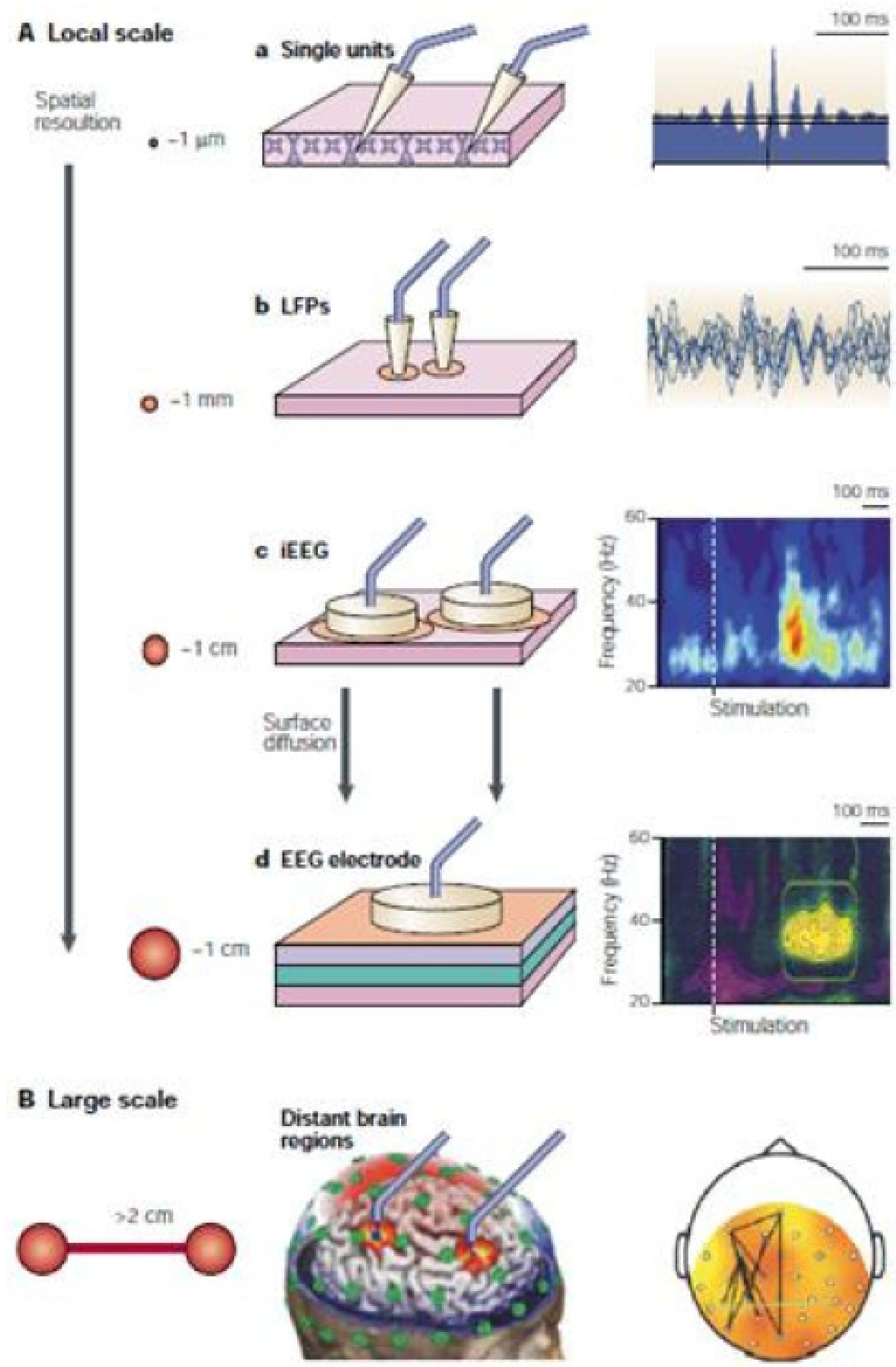


From Nunez, Electrical Fields of the Brain, Oxford Univ. Press, 1981

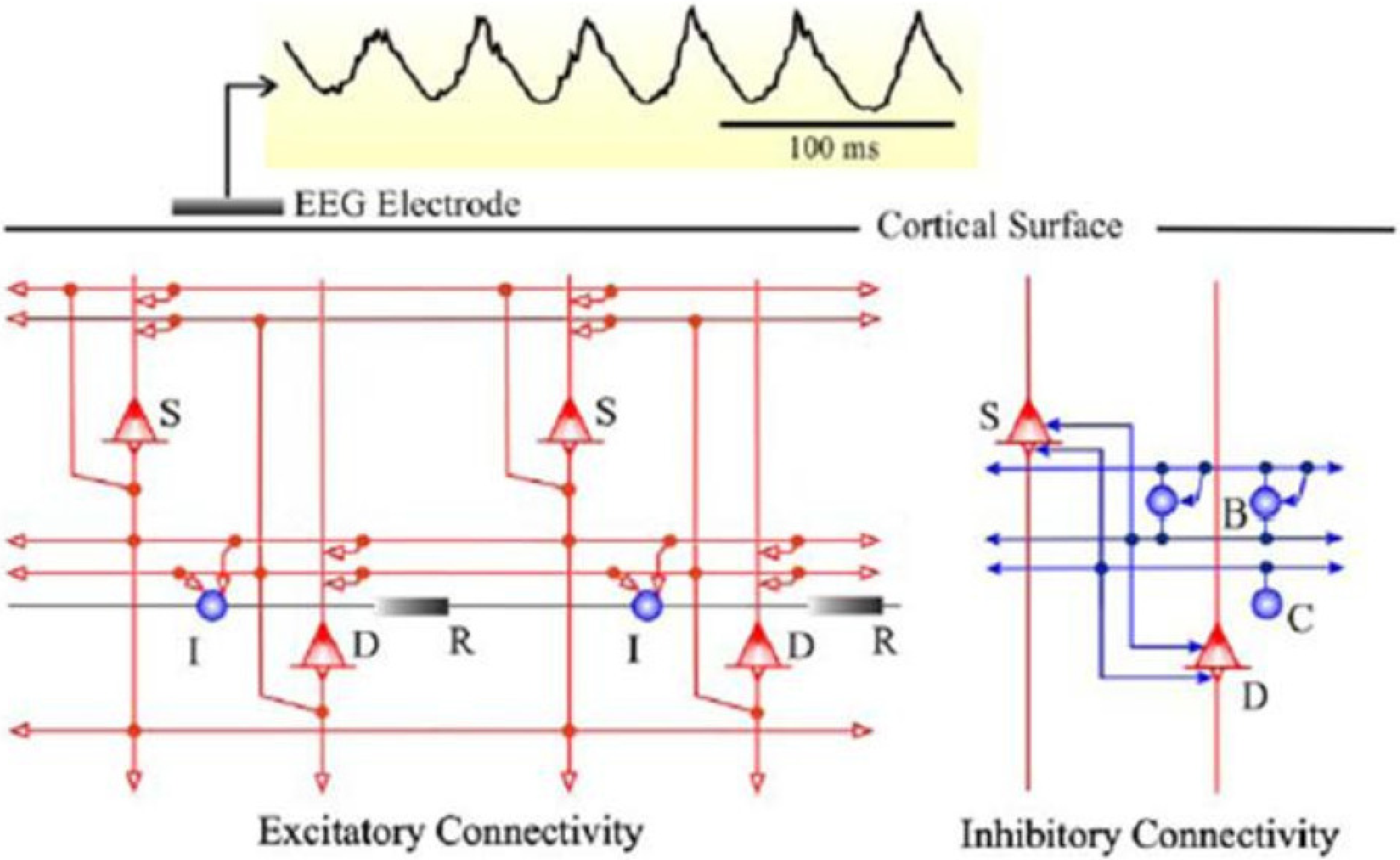
EEG = Summated Potentials at the Scalp



(a) (b) (c)

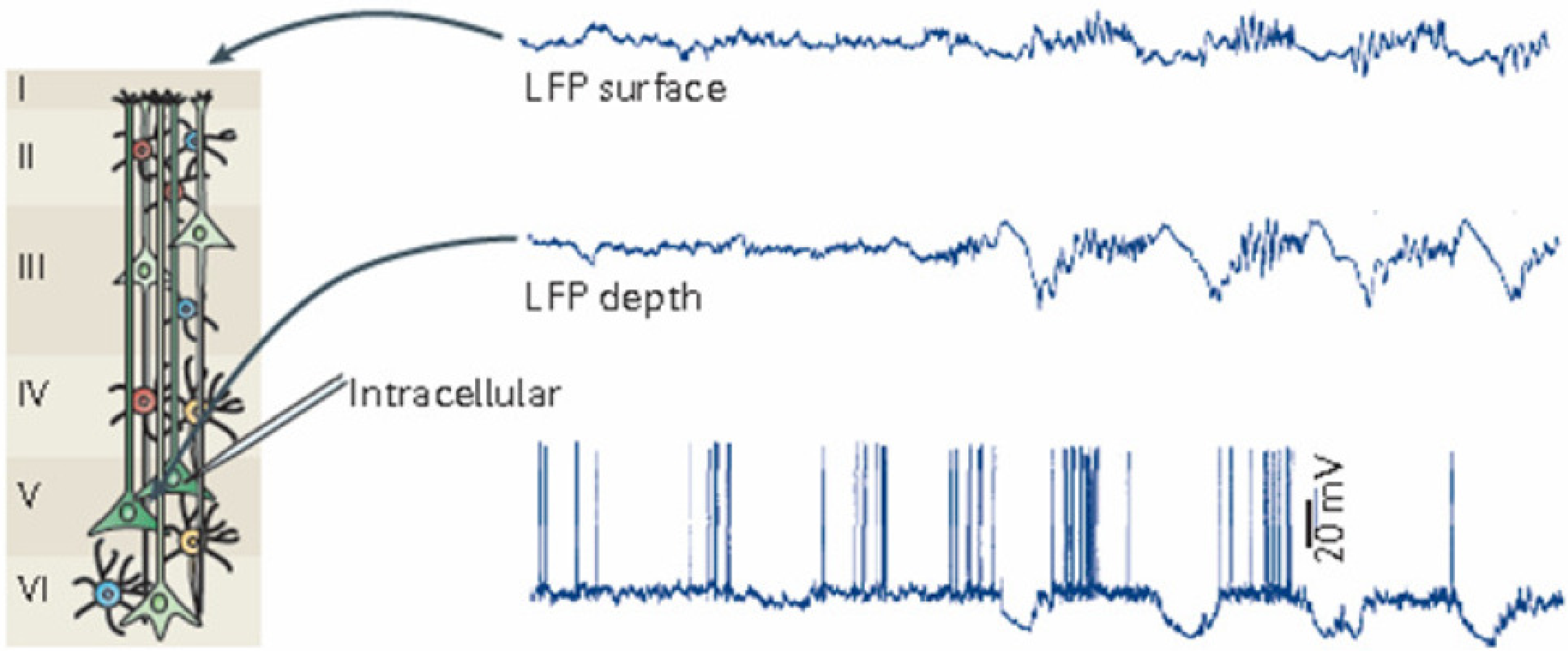


From Varela et al, 2001

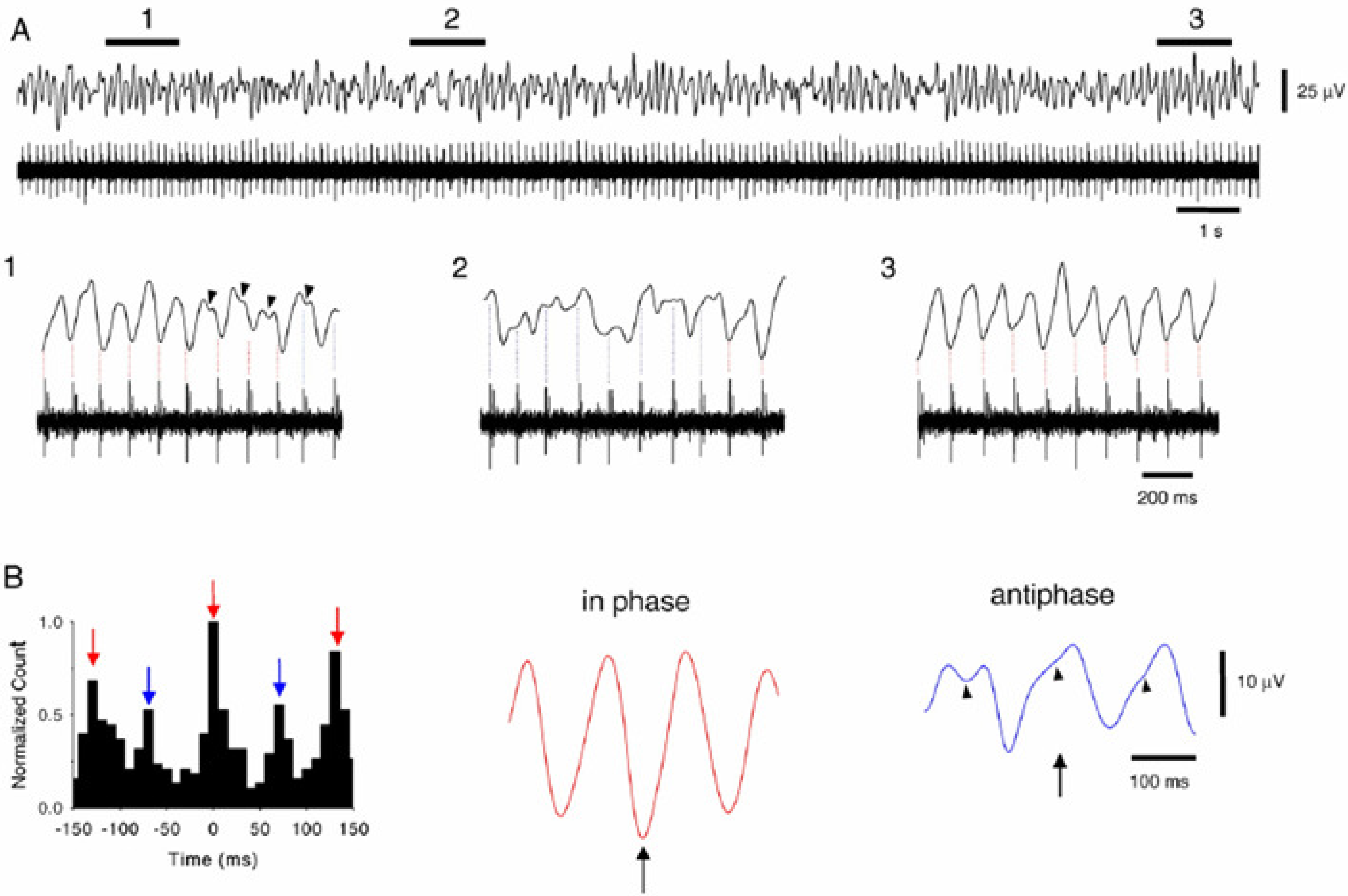

100 ms
EEG Electrode
Cortical Surface
S
S
S
I
D
R
I
D
R
B
C
D
Excitatory Connectivity
Inhibitory Connectivity

How Neurons are Selected For Brief Periods of Time

Shifting In-Phase vs Anti-Phase

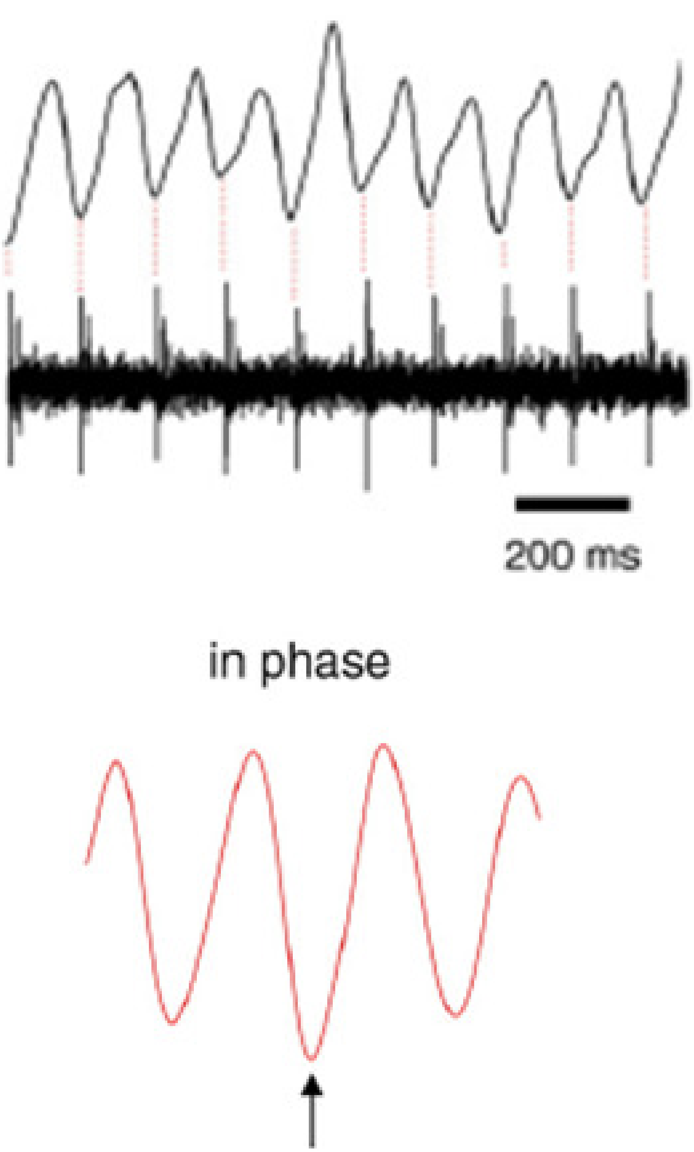


I
II
III
IV
V
VI
LFP surface
LFP depth
Intracellular
20 mV

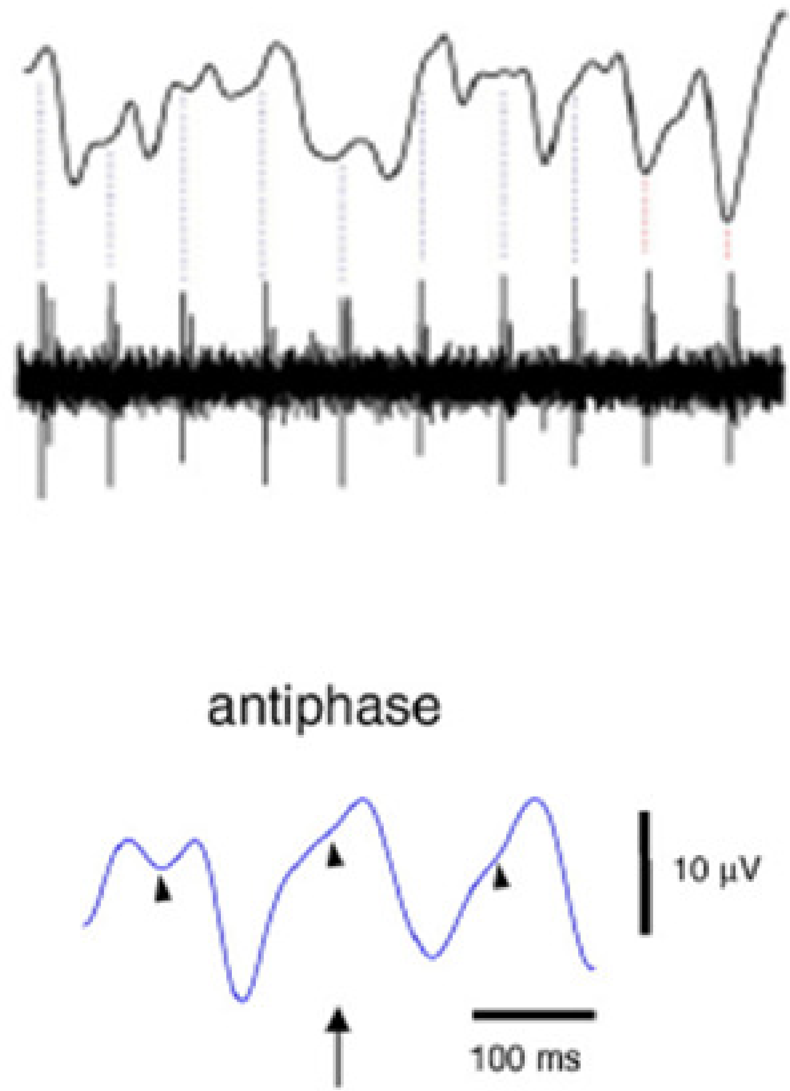


From Hughes et al, 2004

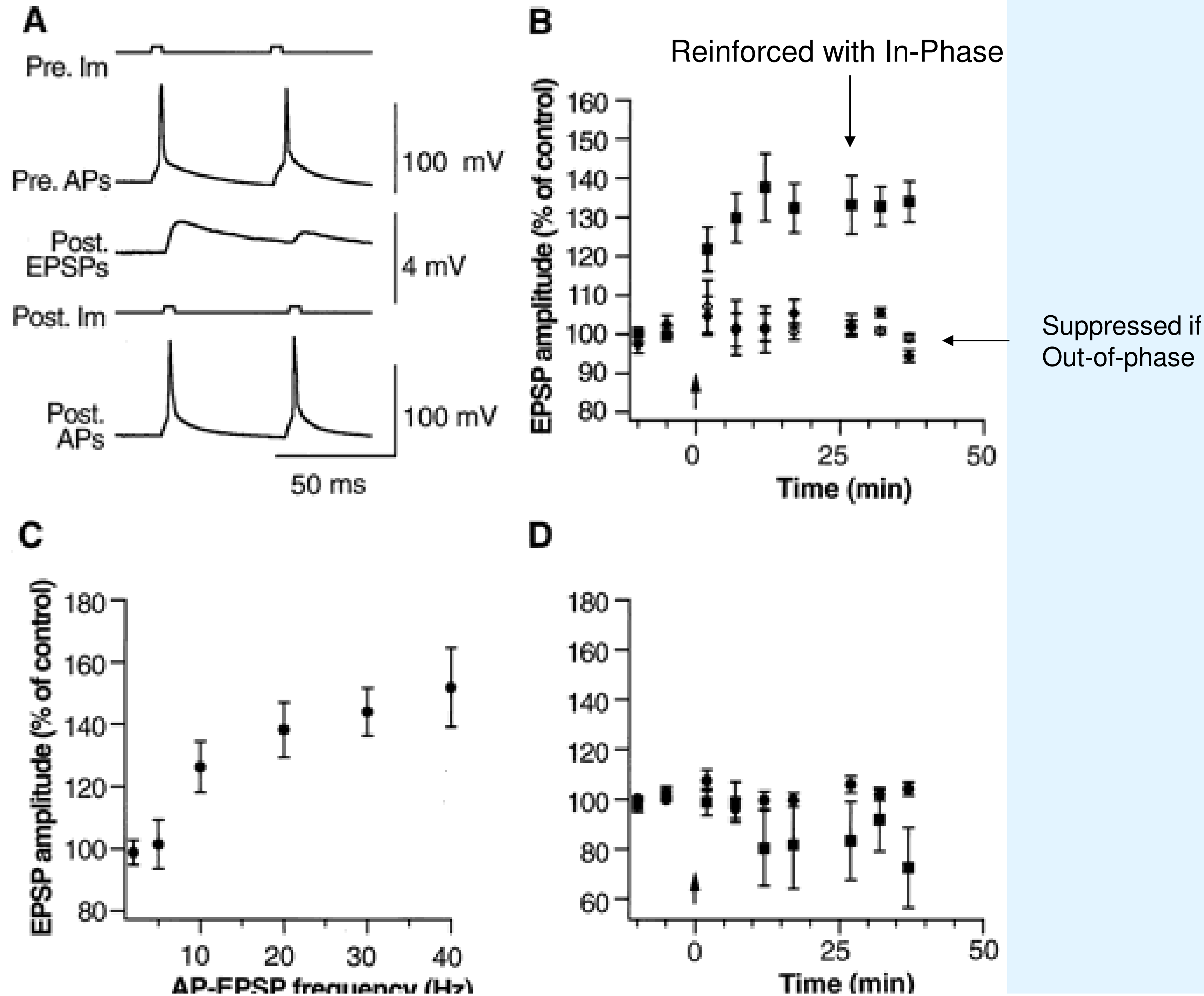
LFPs & In-Phase Action Potentials



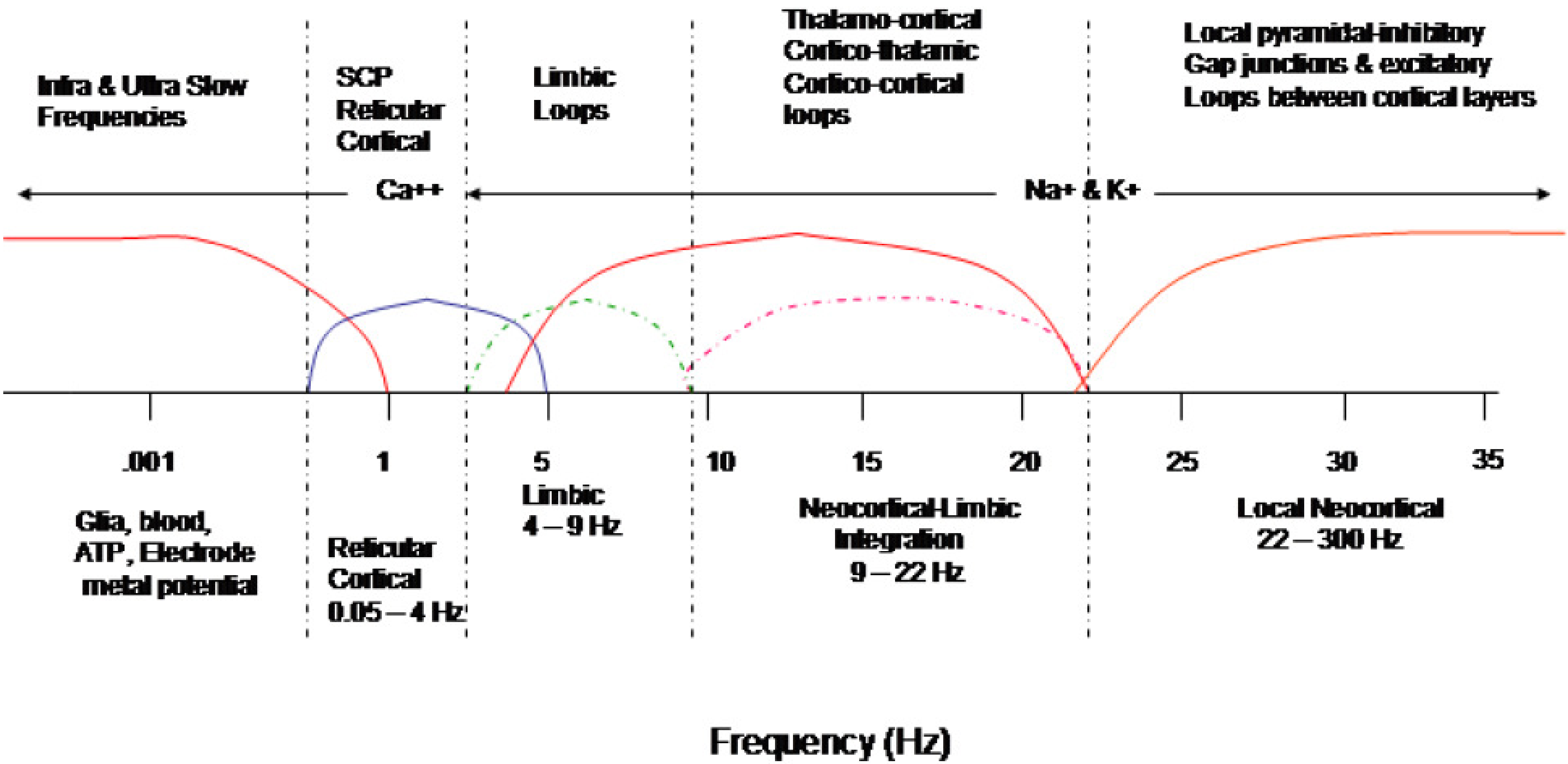
LFPs & Anti-Phase Action Potentials

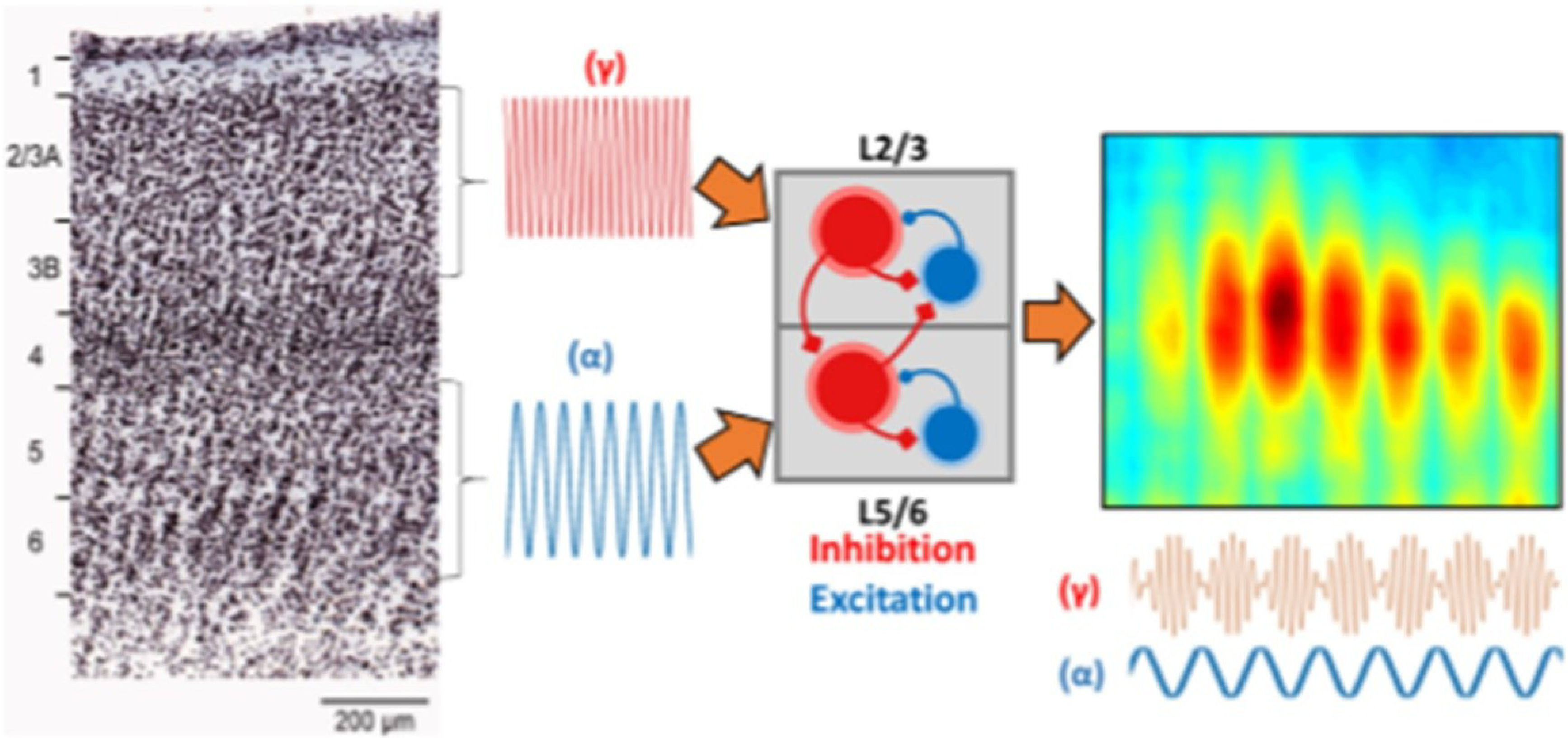


From Hughes et al, 2004

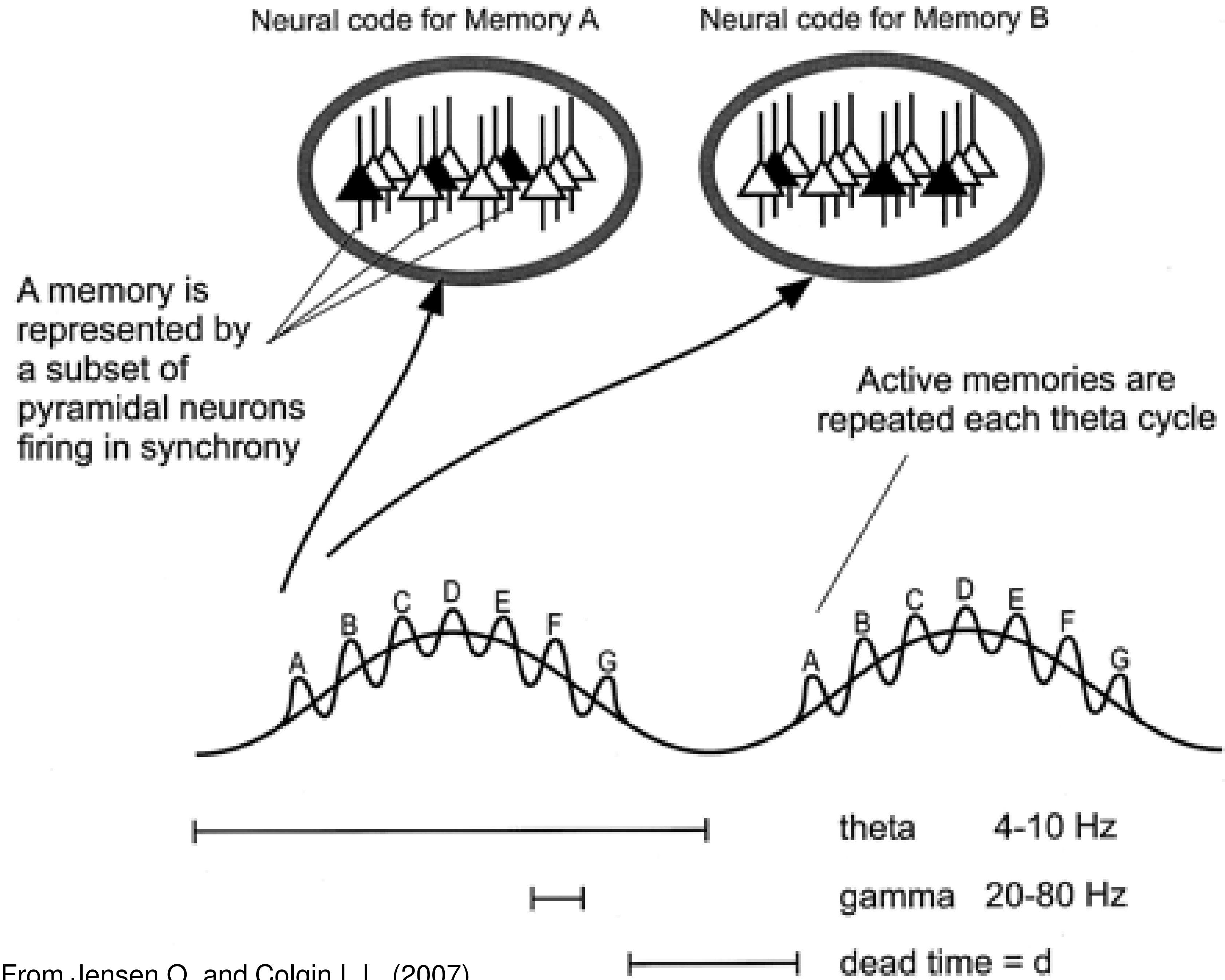

A
Pre. Im
Pre. APs
100 mV
Post. EPSPs
4 mV
Post. Im
Post. APs
100 mV
50 ms
B
Reinforced with In-Phase
EPSP amplitude (% of control)
160
150
140
130
120
110
100
90
80
0
25
50
Time (min)
Suppressed if Out-of-phase
C
EPSP amplitude (% of control)
180
160
140
120
100
80
10
20
30
40
D
180
160
140
120
100
80
60
0
25
50

Cross-Frequency Phase Lock and Phase Shift Spectrum

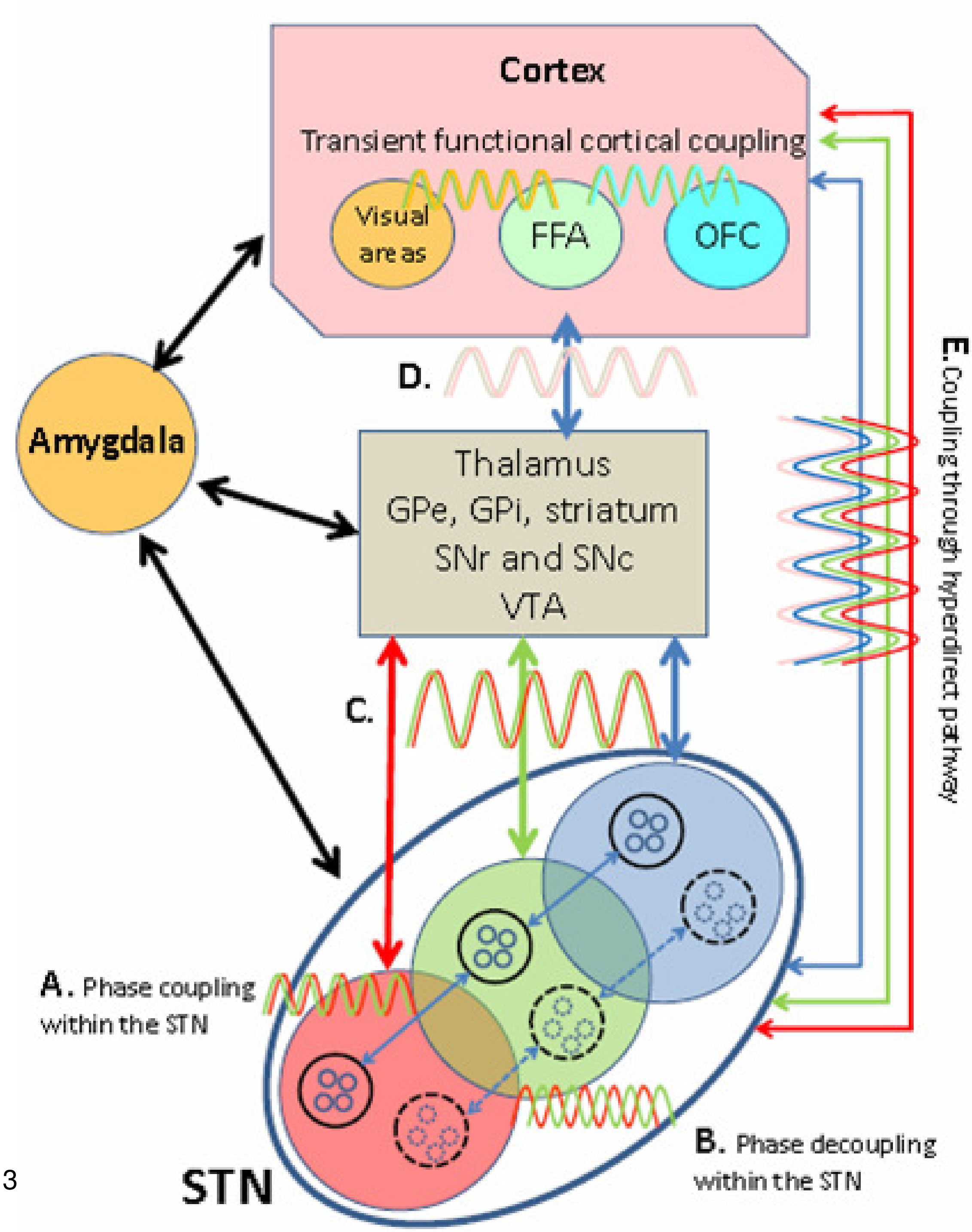




K. Kessler et al. J.; Neuroscience and Behavioral Reviews. 71(2016) 601-620



From Jensen,O.,and Colgin,L.L. (2007)

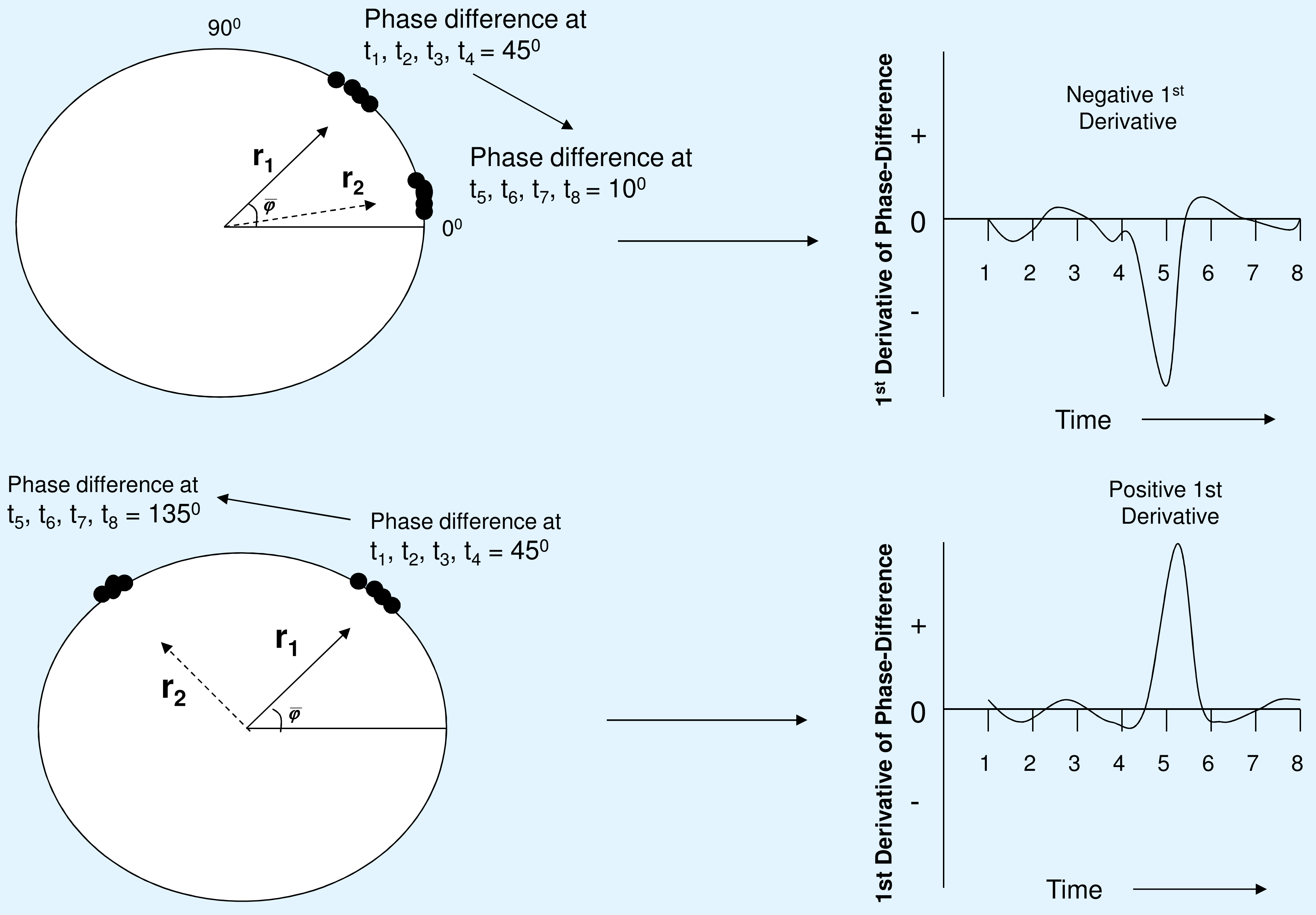


From Peron et al, 2013

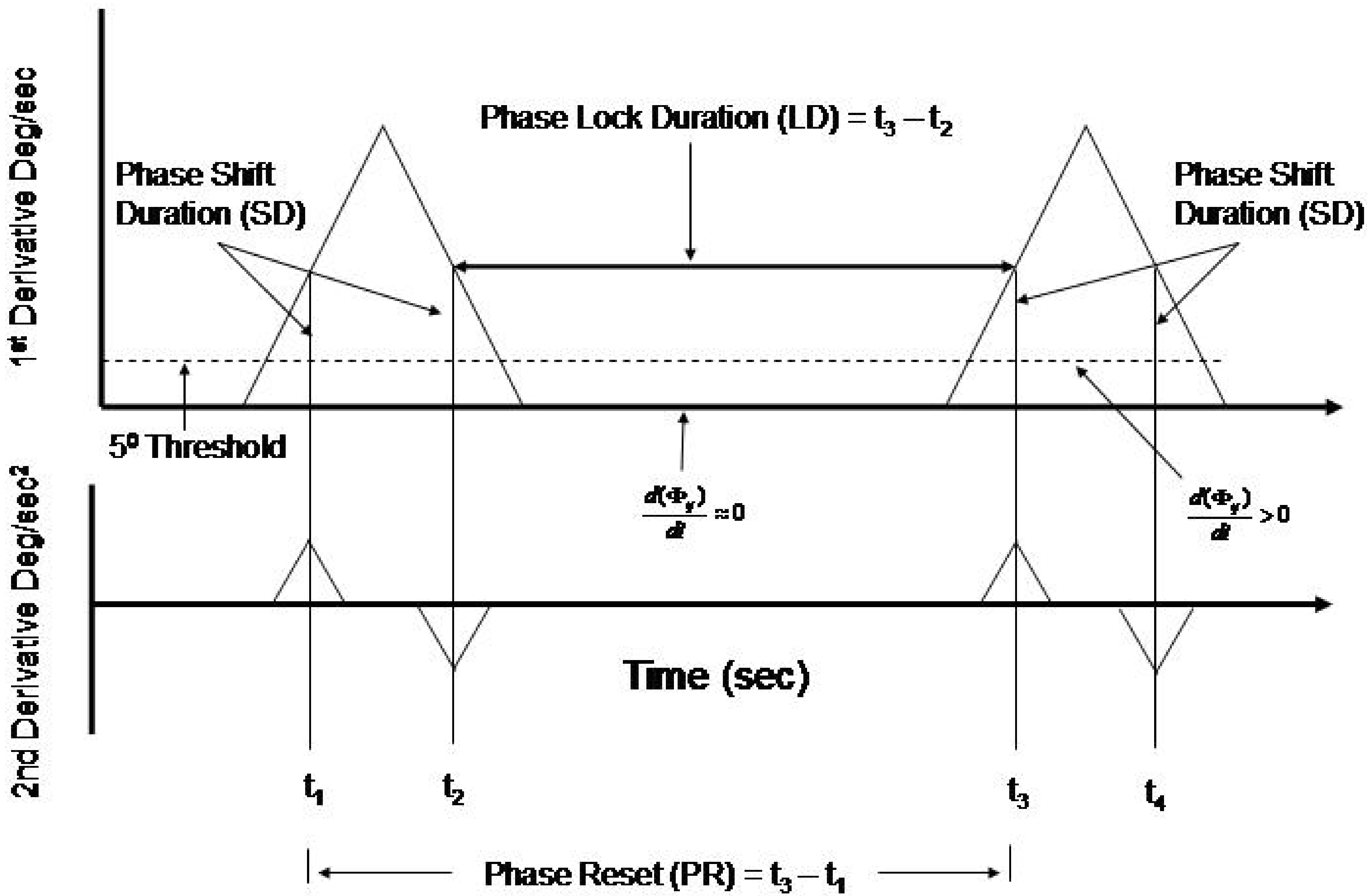
How to Measure Phase Shift and Phase Lock

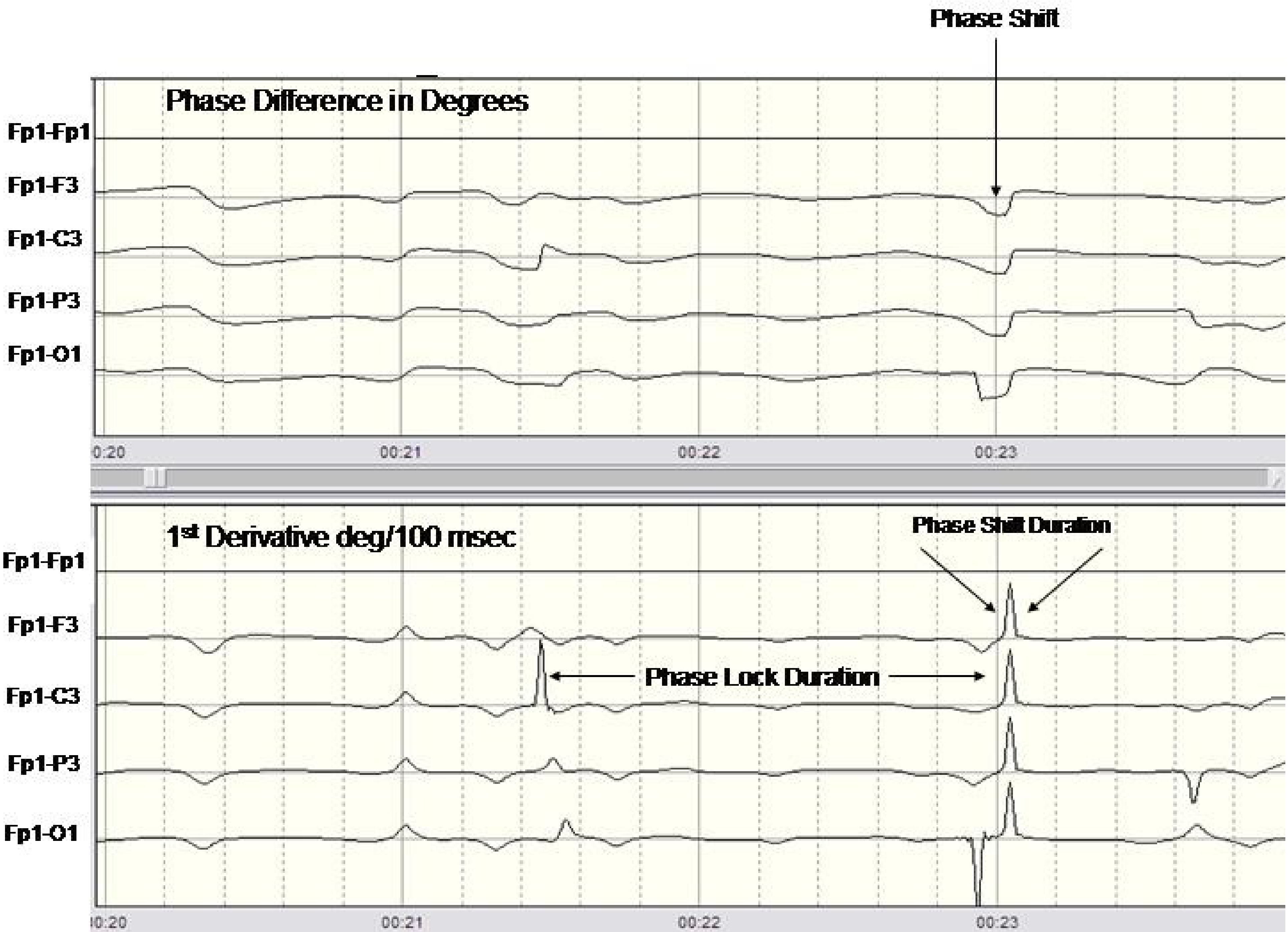
Phase Reset and Neural Resource Selection and Allocation

EEG Phase Reset as a Phase Transition in the Time Domain

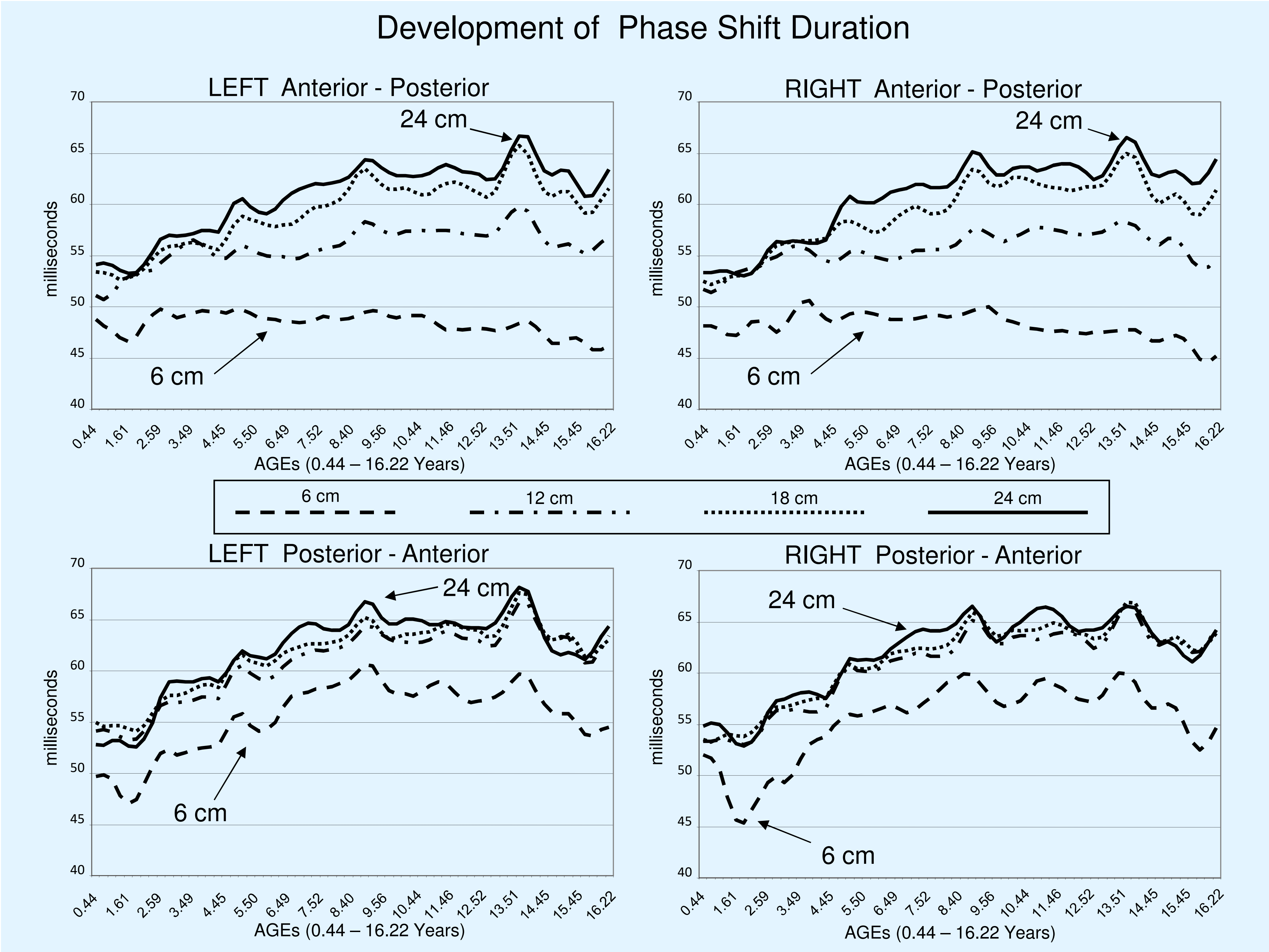


Phase Reset Metrics

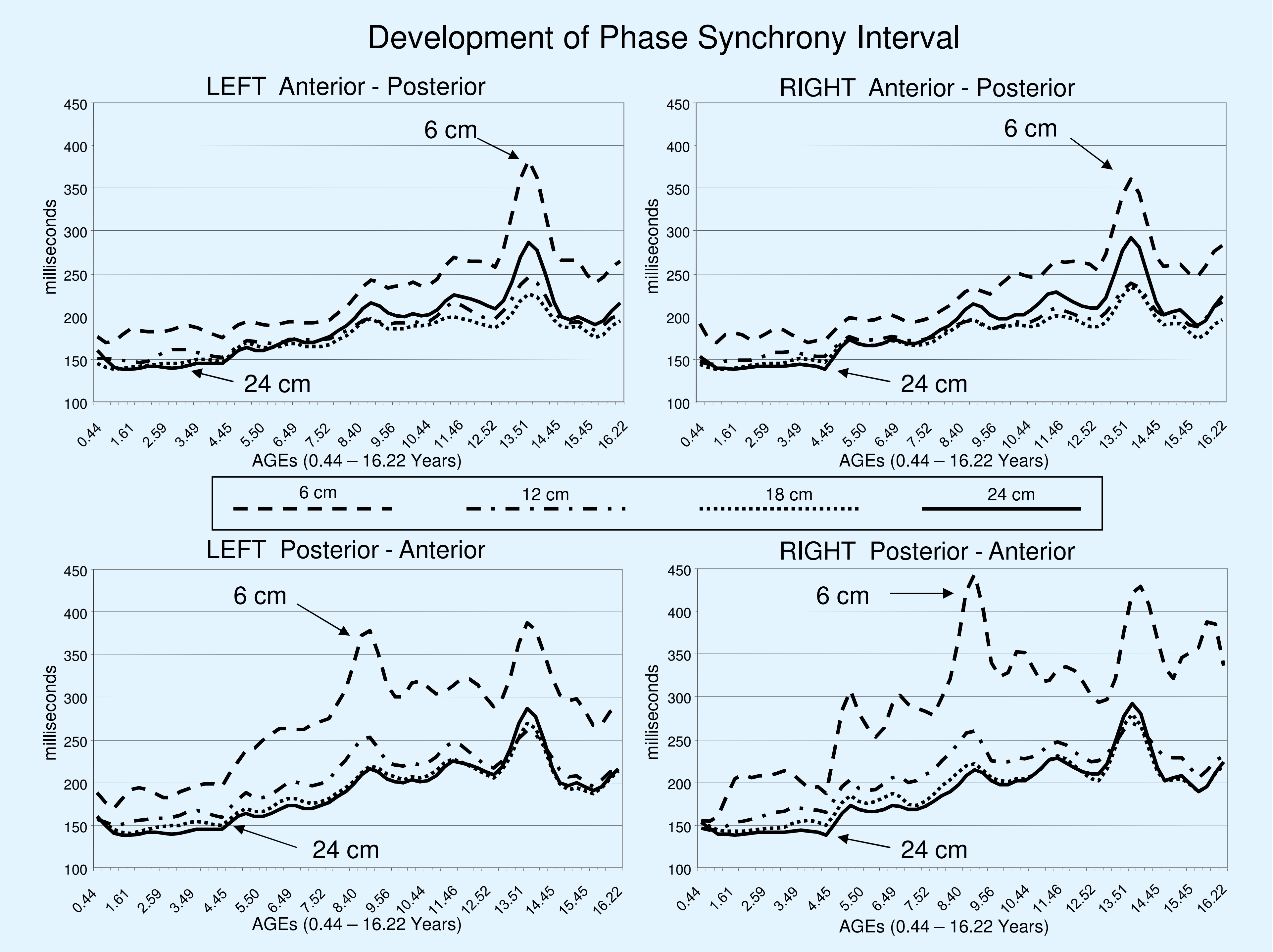




Phase Shift
Phase Difference in Degrees
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23
1st Derivative deg/100 msec
Phase Shift Duration
Phase Lock Duration
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
00:20
00:21
00:22
00:23



Development of Phase Shift Duration
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
milliseconds
AGEs (0.44 – 16.22 Years)
24 cm
6 cm
6 cm
12 cm
18 cm
24 cm
70
65
60
55
50
45
40
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22



Development of Phase Synchrony Interval
LEFT Anterior - Posterior
RIGHT Anterior - Posterior
LEFT Posterior - Anterior
RIGHT Posterior - Anterior
milliseconds
AGEs (0.44 – 16.22 Years)
0.44
1.61
2.59
3.49
4.45
5.50
6.49
7.52
8.40
9.56
10.44
11.46
12.52
13.51
14.45
15.45
16.22
100
150
200
250
300
350
400
450
6 cm
24 cm
6 cm
12 cm
18 cm
24 cm

Published in NeuroImage – NeuroImage, 42(4): 1639-1653, 2008.

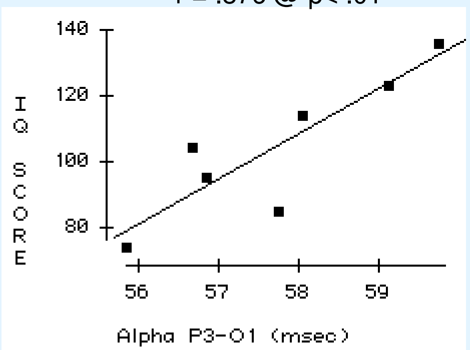
INTELLIGENCE AND EEG PHASE RESET: A TWO COMPARTMENTAL MODEL OF PHASE SHIFT AND LOCK

Thatcher, R. W. [1,2], North, D. M.[1], and Biver, C. J.[1]

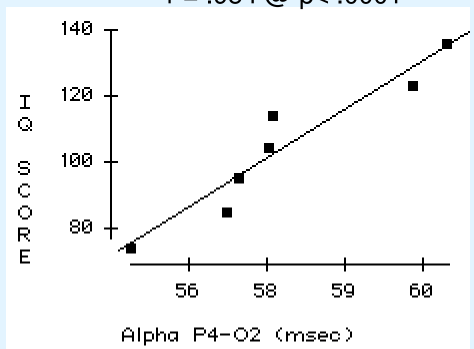
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute.
St. Petersburg, Fl[1] and Department of Neurology, University of South Florida
College of Medicine, Tampa, Fl.[2]

Regressions & Correlations of Phase Shift Duration Short Distances (6 cm)

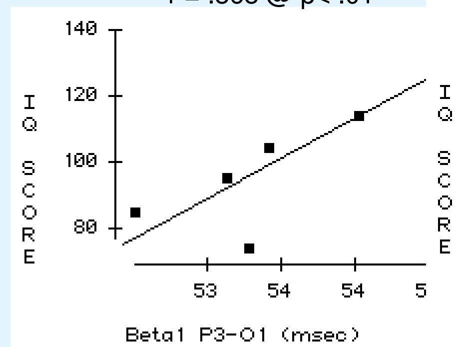
IQ = 78 + 13.78 x (msec)
r = .876 @ p< .01



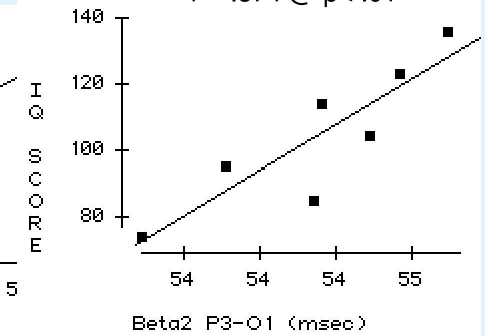
IQ = 70 +11.85 x (msec)
r = .954 @ p< .0001



IQ = 75 + 24.45 x (msec)
r = .868 @ p< .01

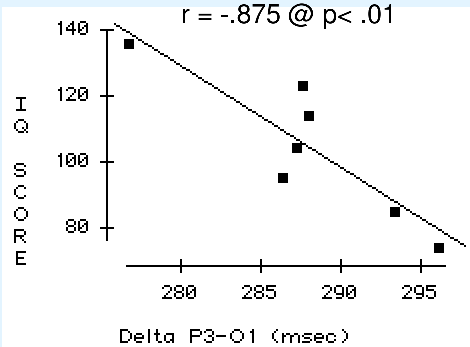


IQ = 68 + 34.40 x (msec)
r = .874 @ p< .01

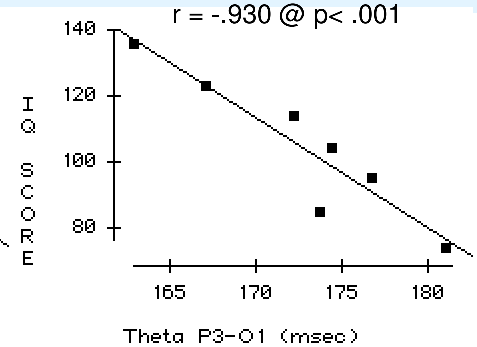


Regressions & Correlations of Phase Locking Interval Short Distances (6 cm)

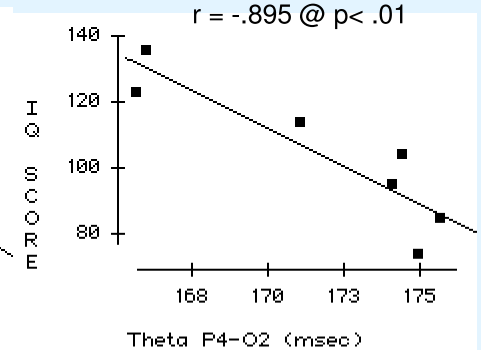
IQ = 143 - 3.11 x (msec)
r = -.875 @ p< .01



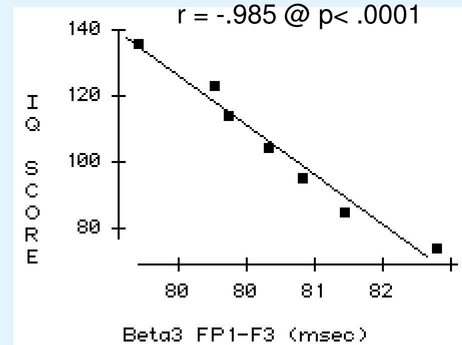
IQ = 142 - 3.36 x (msec)
r = -.930 @ p< .001



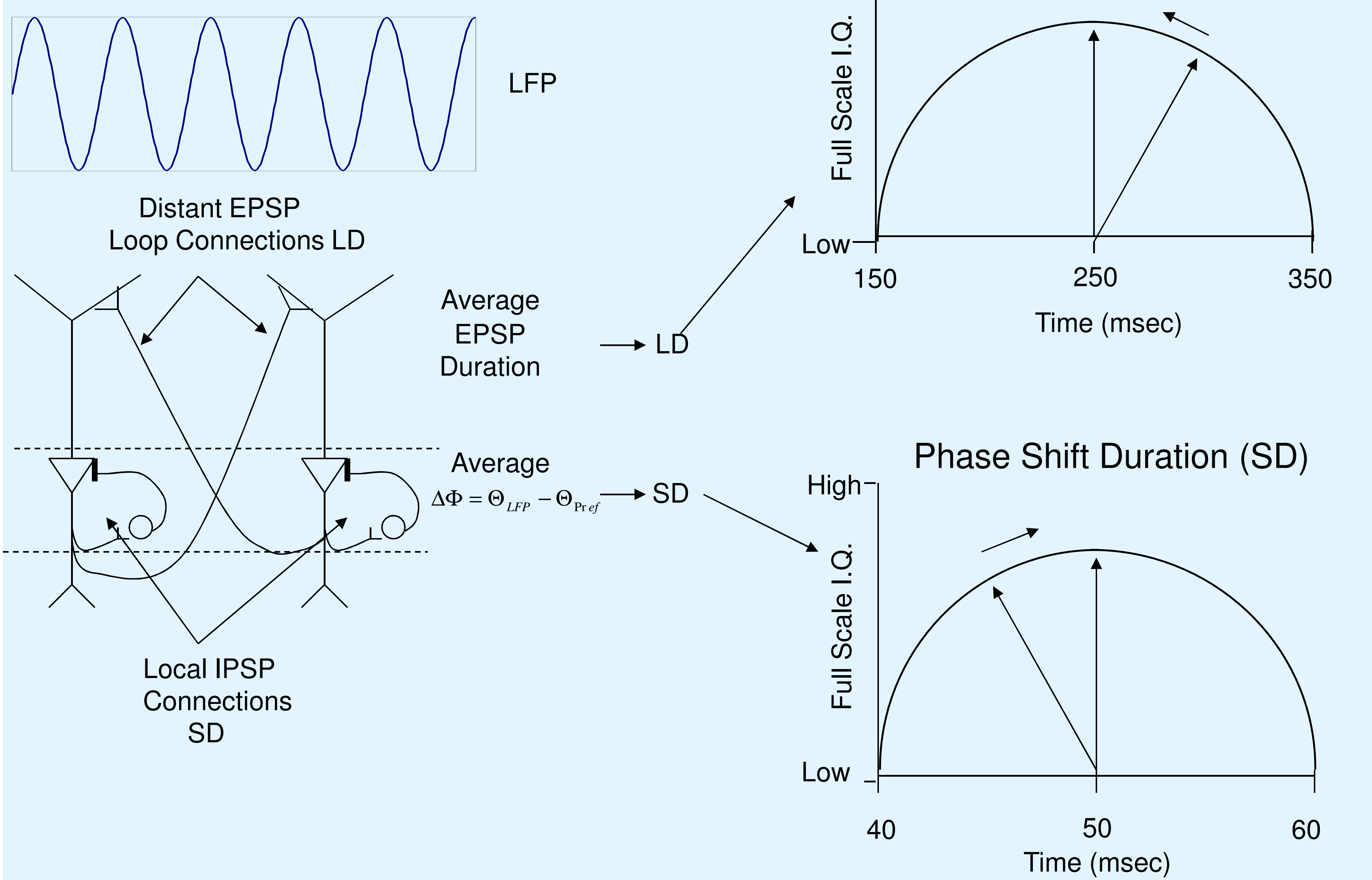
IQ = 132 - 4.57 x (msec)
r = -.895 @ p< .01



IQ = 140 - 20.08 x (msec)
r = -.985 @ p< .0001



Pyramidal Cell Model of EEG Phase Reset and Full Scale I.Q.



SCIENTIFIC REPORTS

OPEN

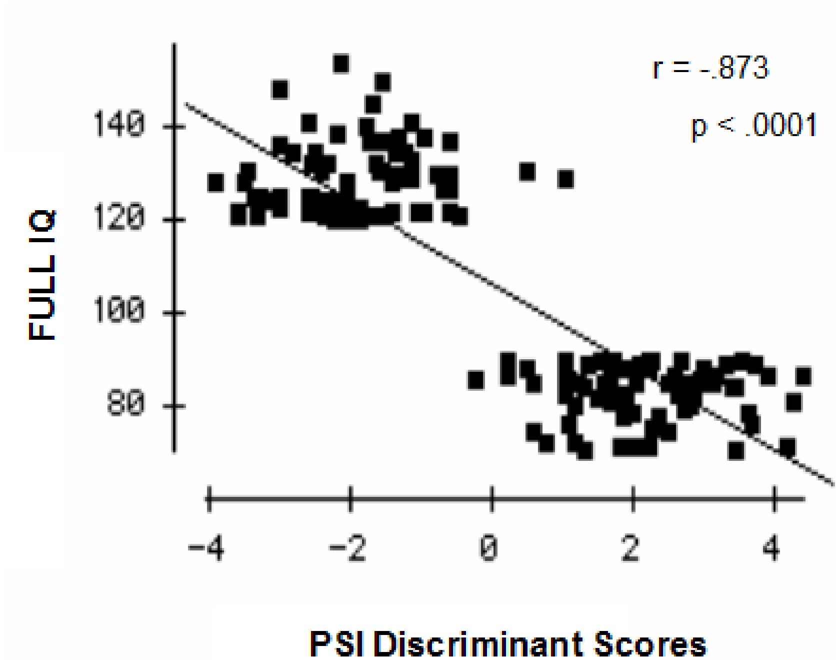
Intelligence and eeg measures of information flow: efficiency and homeostatic neuroplasticity

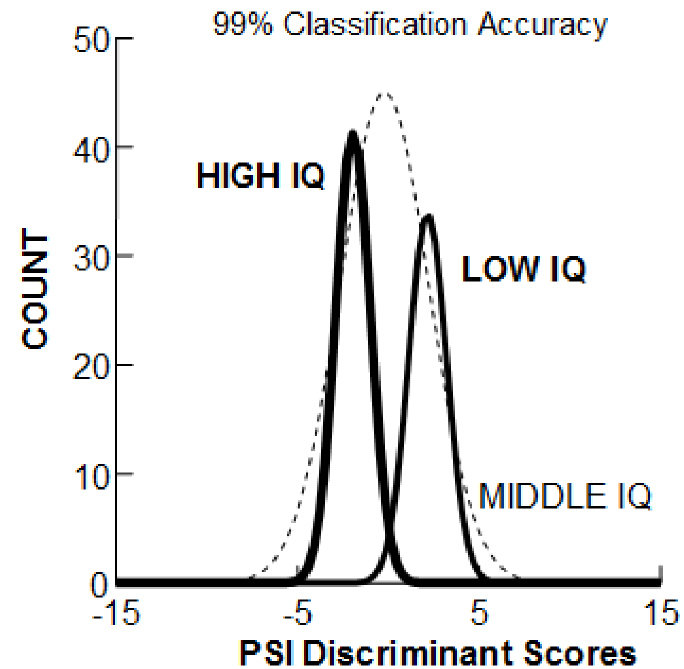
Received: 25 July 2016
Accepted: 14 November 2016
Published: 20 December 2016

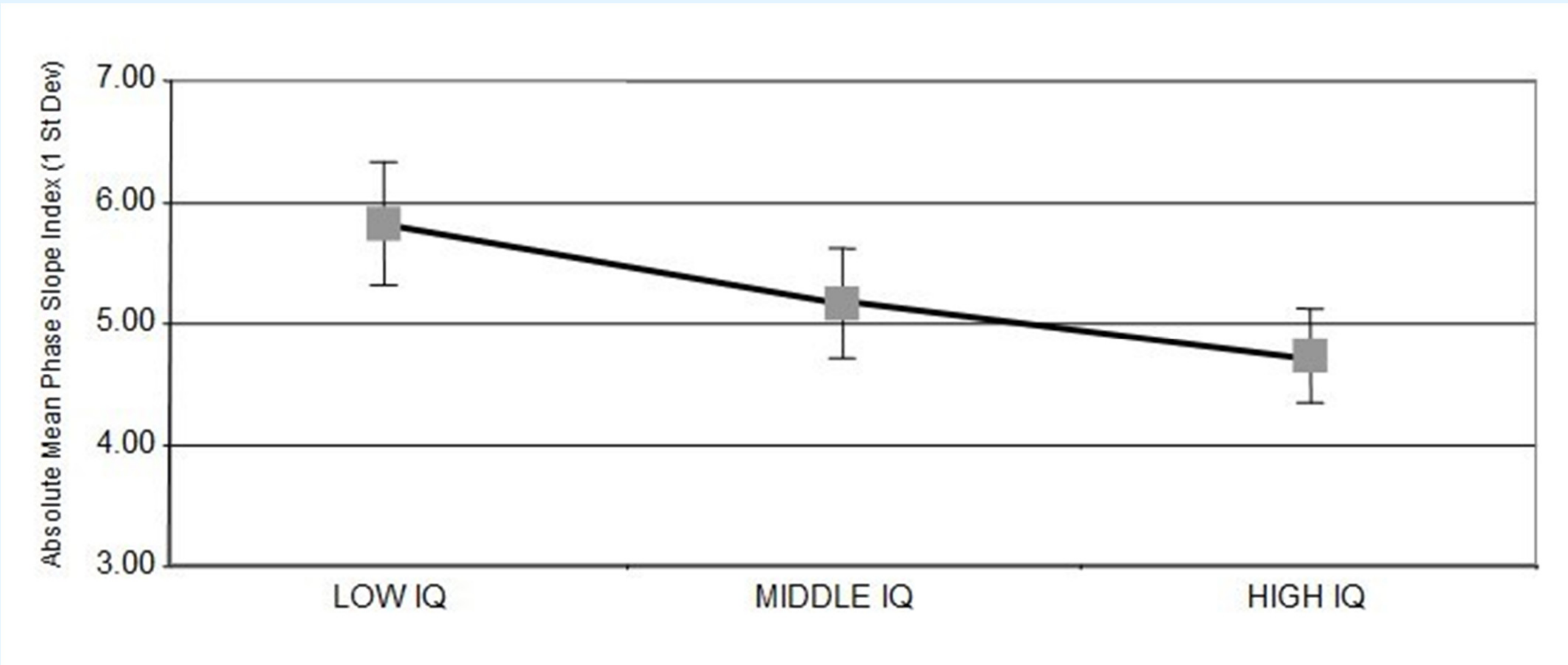
R. W. Thatcher, E. Palmero-Soler, D. M. North & C. J. Biver

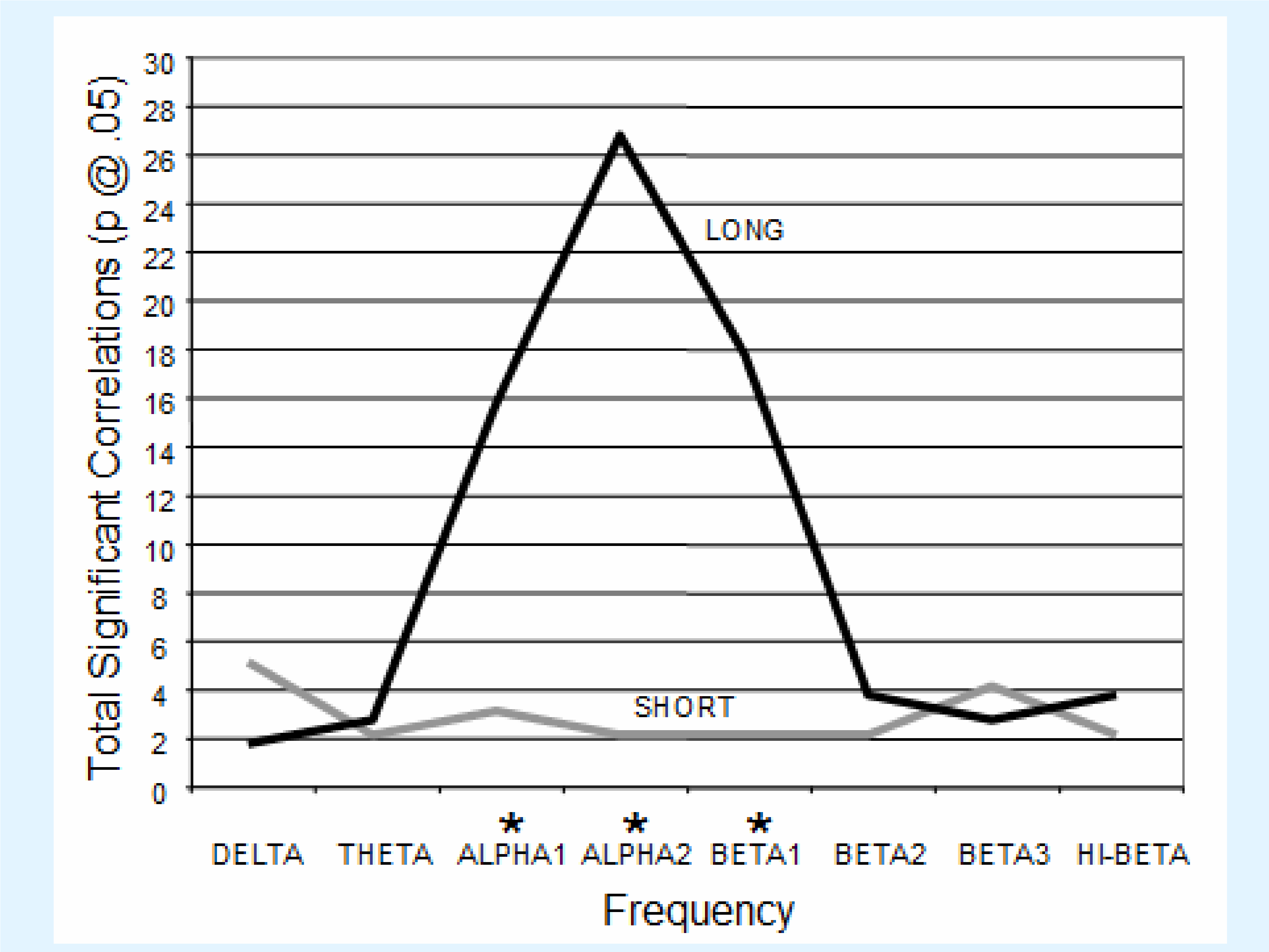
The purpose of this study was to explore the relationship between the magnitude of EEG information flow and intelligence. The electroencephalogram (EEG) was recorded from 19 scalp locations from 371 subjects ranging in age from 5 years to 17.6 years. The Wechler Intelligence Scale for Children (WISC-R) was administered for individuals between 5 years of age and 16 years and the Weschler Adult Intelligence Scale revised (WAIS-R) was administered to subjects older than 16 years to estimate I.Q. The phase slope index estimated the magnitude of information flow between all electrode combinations for difference frequency bands. Discriminant analyses were performed between high I.Q. (>120) and low I.Q. groups (<90). The magnitude of information flow was inversely related to I.Q. especially in the alpha and beta frequency bands. Long distance inter-electrode distances exhibited greater information flow than short inter-electrode distances. Frontal-parietal correlations were the most significant. It is concluded that higher I.Q. is related to increased efficiency of local information processing and reduced long distance compensatory dynamics that supports a small-world model of intelligence.

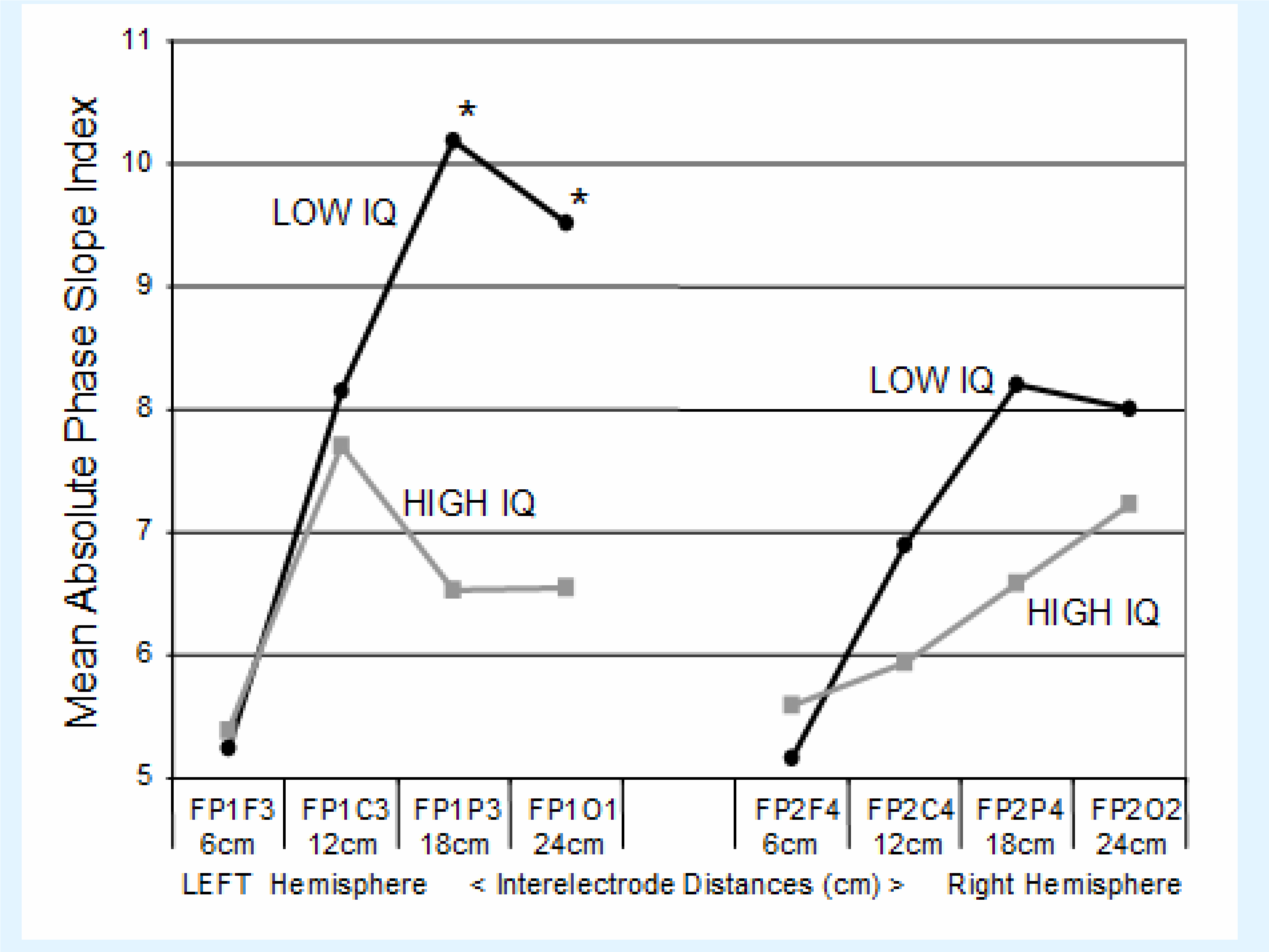
Discriminant Scores of the Magnitude of Phase Slope Index (PSI) with Full Scale IQ



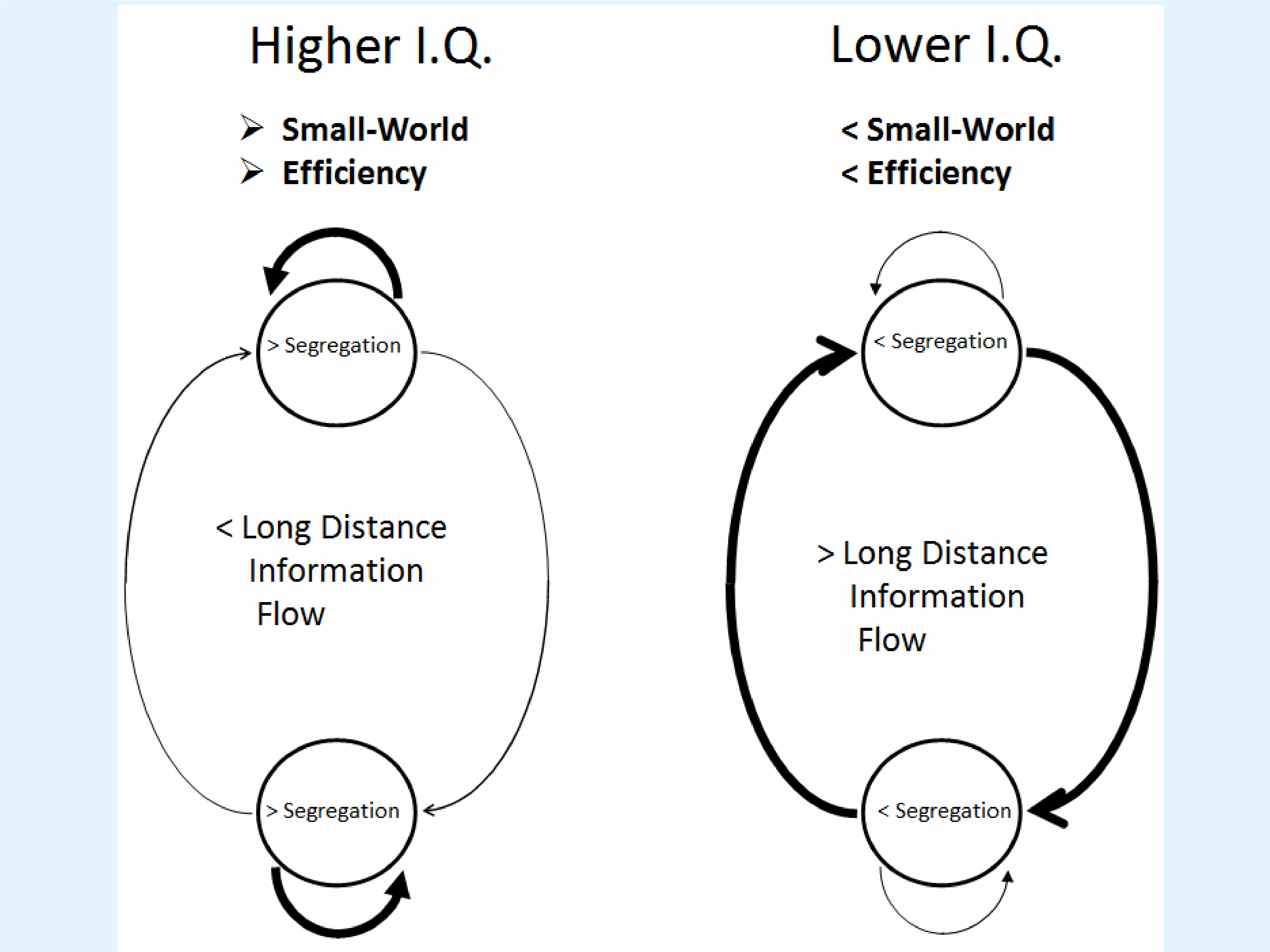



Absolute Mean Phase Slope Index (1 St Dev)
7.00
6.00
5.00
4.00
3.00
LOW IQ
MIDDLE IQ
HIGH IQ


Total Significant Correlations (p @ .05)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
LONG
SHORT
DELTA
THETA
* ALPHA1
* ALPHA2
* BETA1
BETA2
BETA3
HI-BETA
Frequency



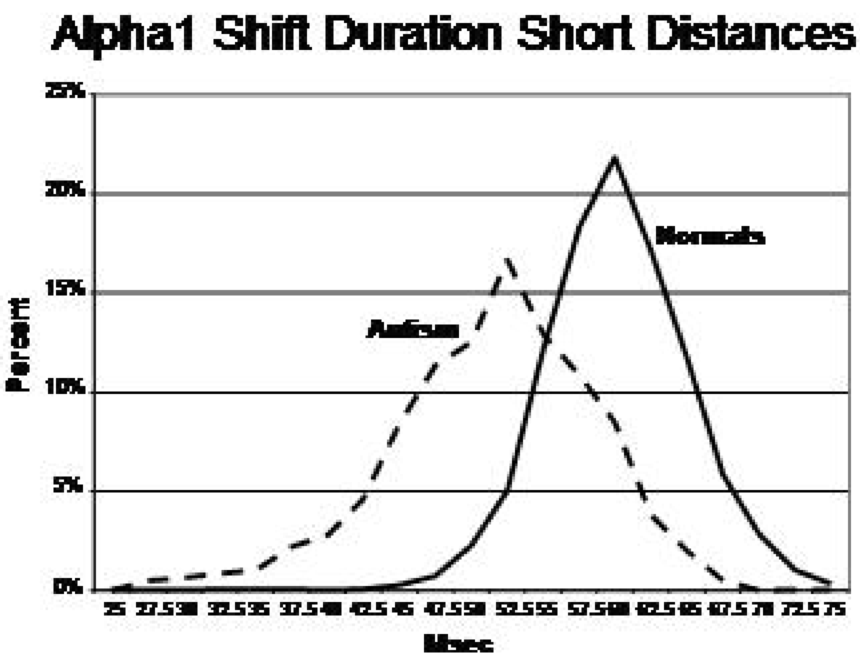
Mean Absolute Phase Slope Index
11
10
9
8
7
6
5
LOW IQ
HIGH IQ
LOW IQ
HIGH IQ
*
*
FP1F3 6cm
FP1C3 12cm
FP1P3 18cm
FP1O1 24cm
FP2F4 6cm
FP2C4 12cm
FP2P4 18cm
FP2O2 24cm
LEFT Hemisphere < Interelectrode Distances (cm) > Right Hemisphere

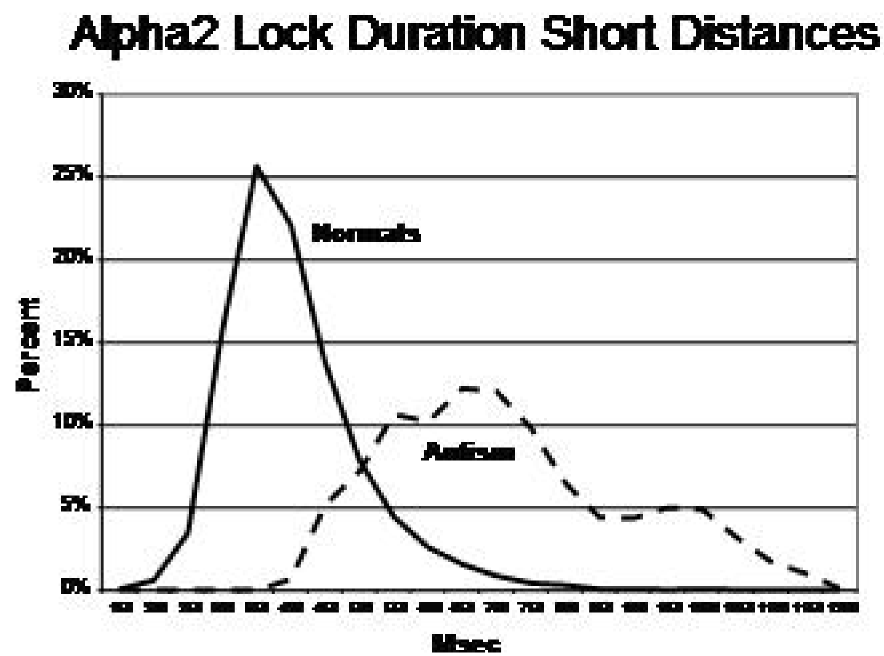

Higher I.Q.
Small-World
Efficiency
> Segregation
< Long Distance Information Flow
> Segregation
Lower I.Q.
< Small-World
< Efficiency
< Segregation
> Long Distance Information Flow
< Segregation

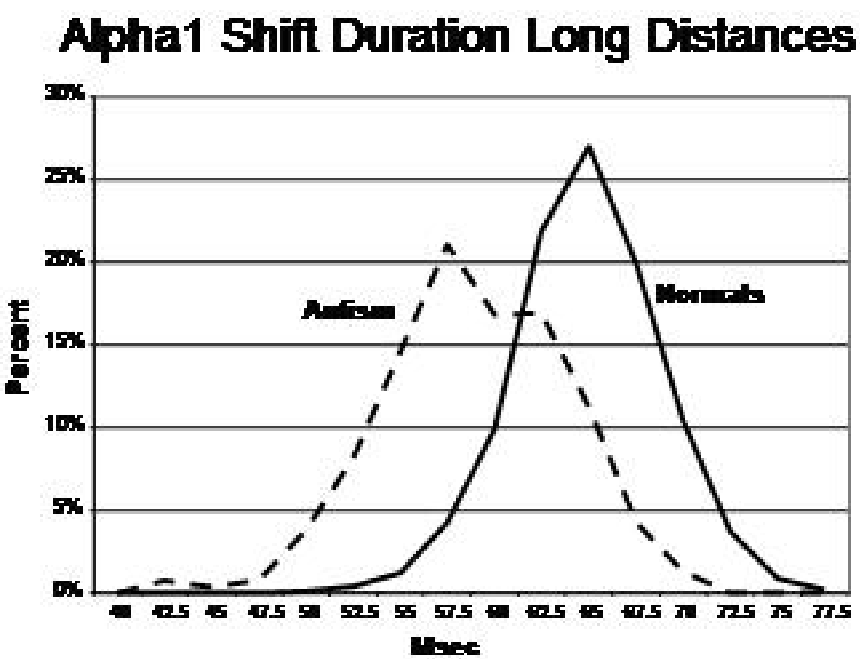
AUTISM AND EEG PHASE RESET:
A UNIFIED THEORY OF DEFICIENT GABA MEDIATED INHIBITION IN THALAMO-CORTICAL CONNECTIONS

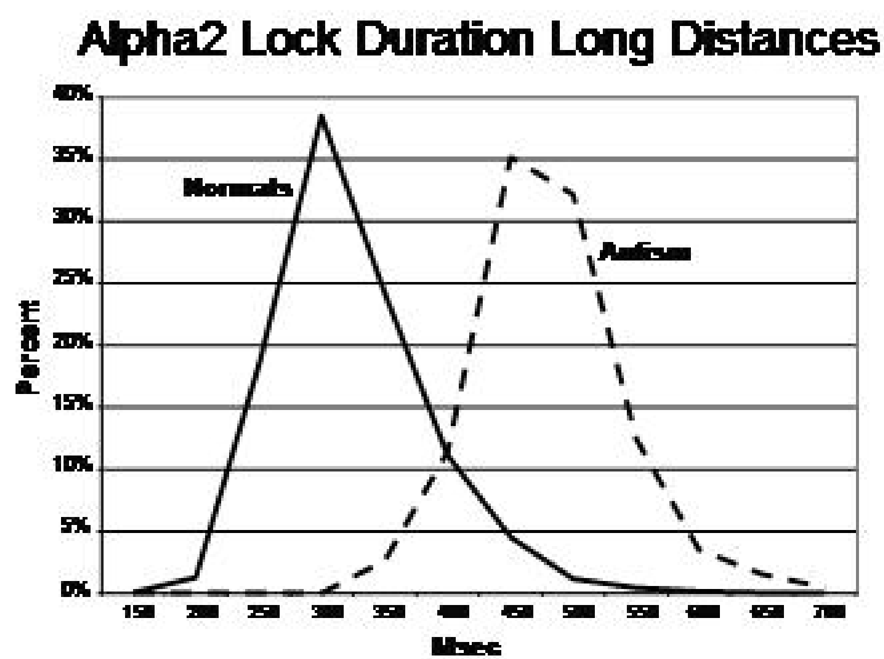
Thatcher, R. W. [1,2], Phillip DeFina[2], James Neurbrander[2], North, D. M.[1], and Biver, C. J.[1]

EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute., St. Petersburg, Fl[1] and the International Brain Research Foundation, Menlo Park, NJ[2]


Alpha1 Shift Duration Short Distances
Percent
Msec
Normals
Autism


Alpha2 Lock Duration Short Distances
Percent
Msec
Normals
Autism


Alpha1 Shift Duration Long Distances
Percent
Msec
Normals
Autism


Alpha2 Lock Duration Long Distances
Percent
Msec
Normals
Autism

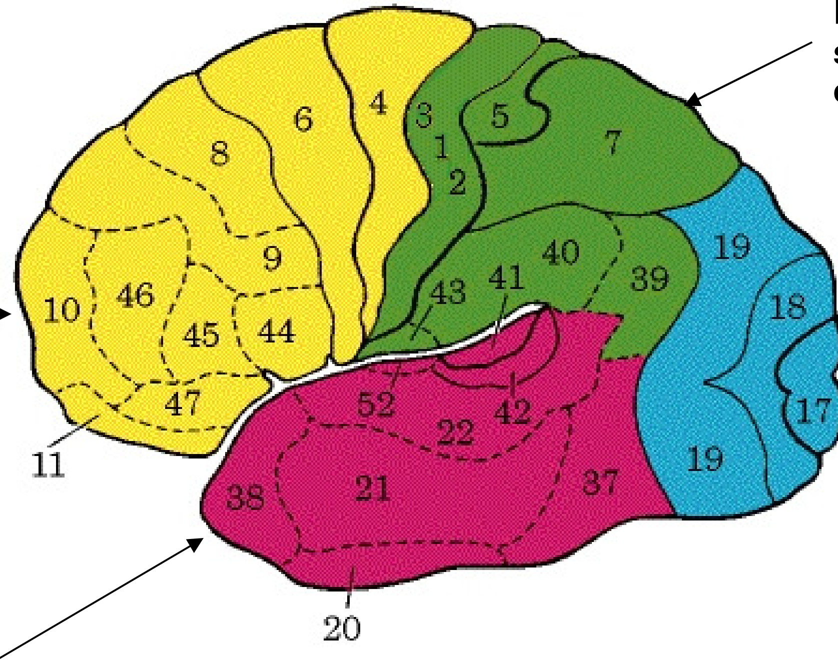
Electrical NeuroImaging of Functional Modules and Hubs as Measured by fMRI and PET

Phase Shift and Phase Lock Switch Dynamics that “Animate” Information Flow Within and Between Modules and Hubs

Brodmann Areas

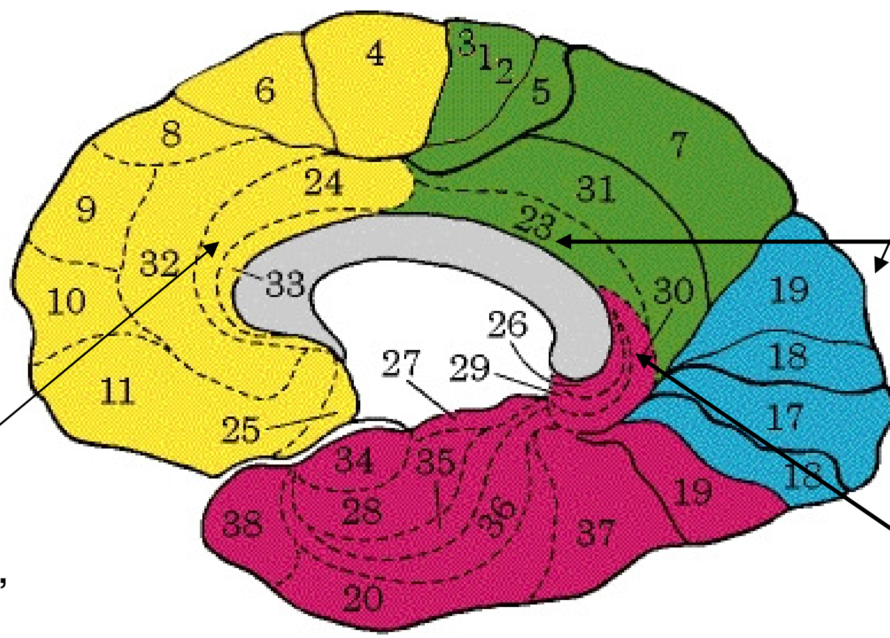
Frontal Lobe
Thinking, Planning, Motor execution, Executive Functions, Mood Control

Parietal Lobe
somatosensory perception integration of visual & somatospatial information



Temporal Lobe
language function and auditory perception involved in long term memory and emotion

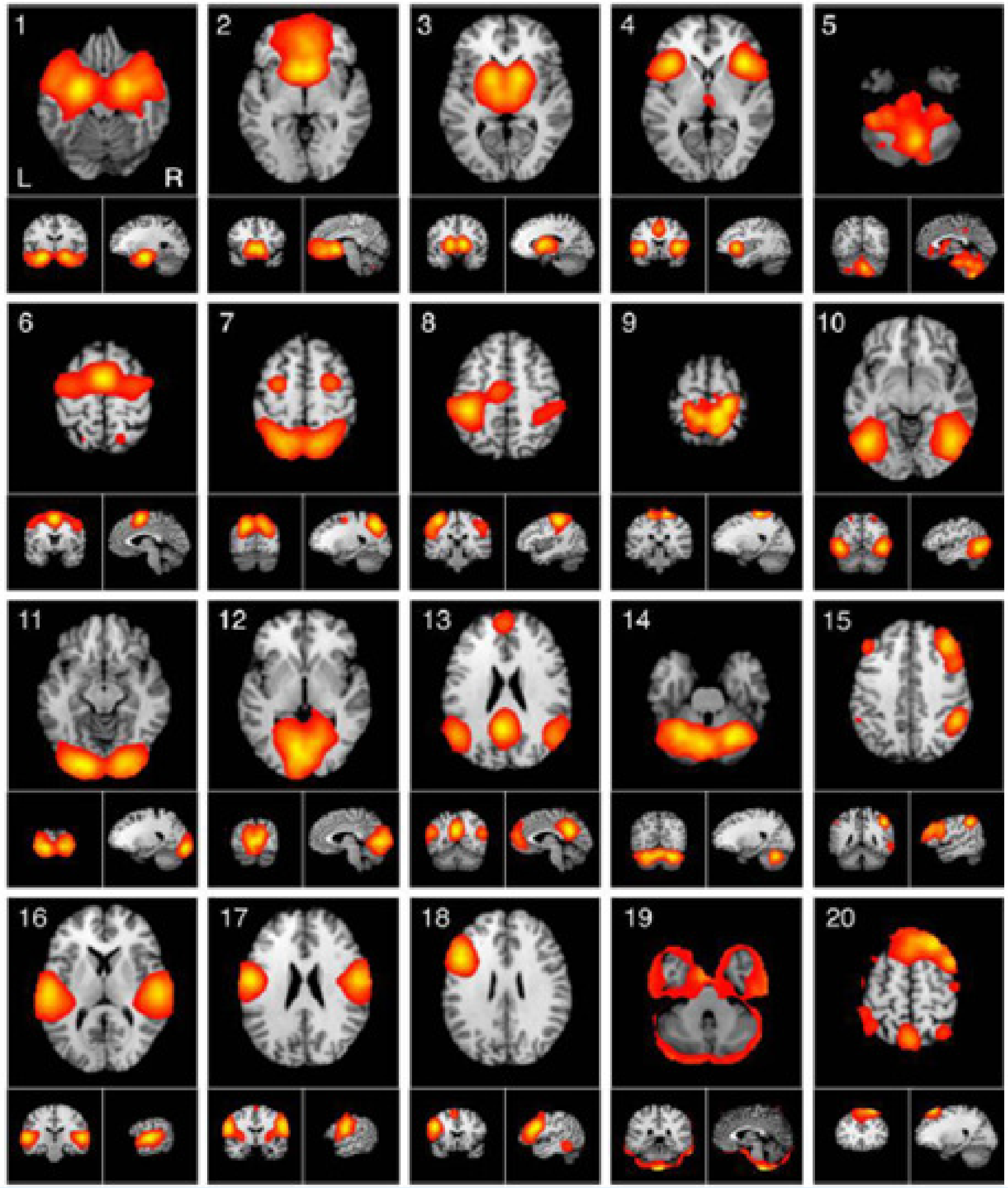
Occipital Lobe
Visual perception & Spatial processing



Posterior Cingulate
attention, long-term memory

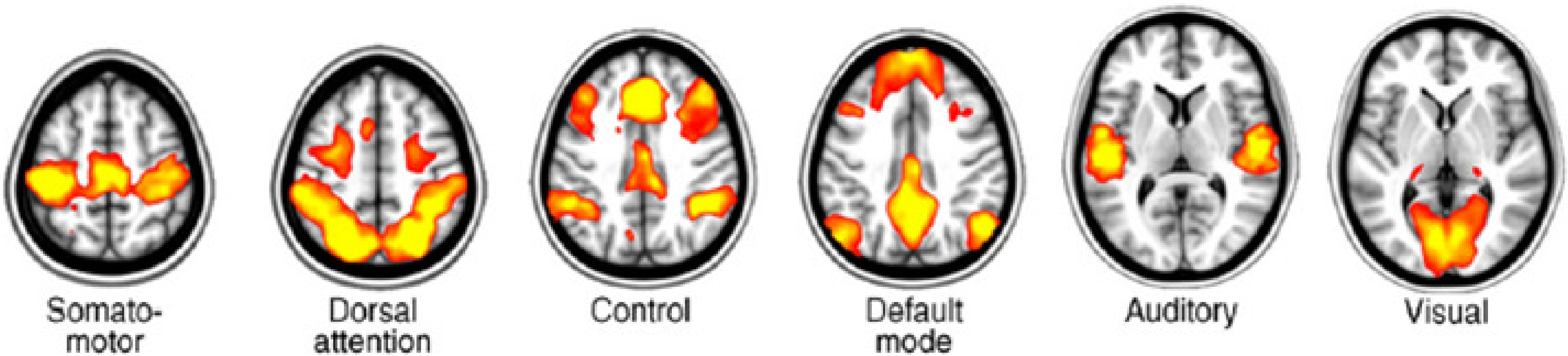
Anterior Cingulate Gyrus
Volitional movement, attention, long term memory

Parahippocampal Gyrus
Short-term memory, attention



Laird et al (2011) summarized the various "intrinsic connectivity networks" or ICNs into eighteen specific groupings based upon 30,000 fMRI and PET studies

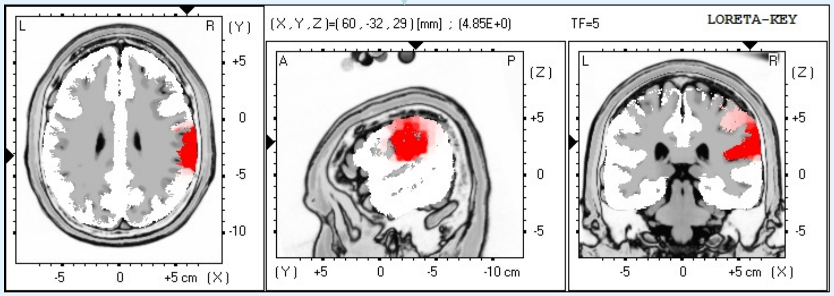
Six Functional Modules as Measured by fMRI



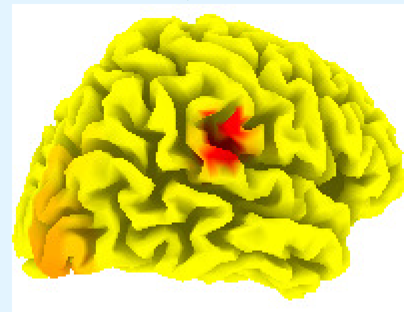
From Raichle, 2010

Electrical Neuroimaging and Cortical Source Localization

Horizontal, Sagital & Coronal Views of a Single Slice



Cortical Surface Projection



Tomographic Slice Display

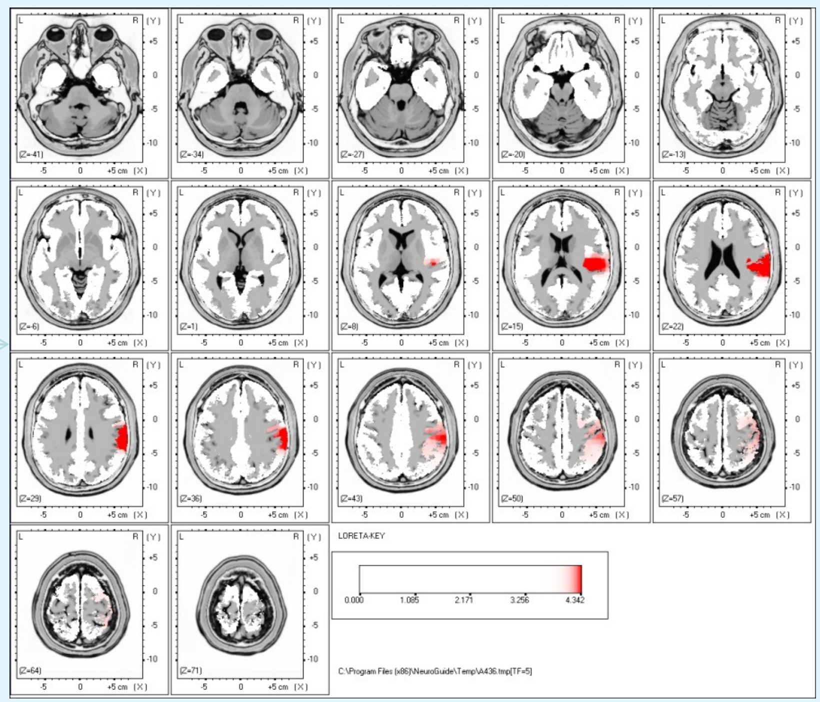


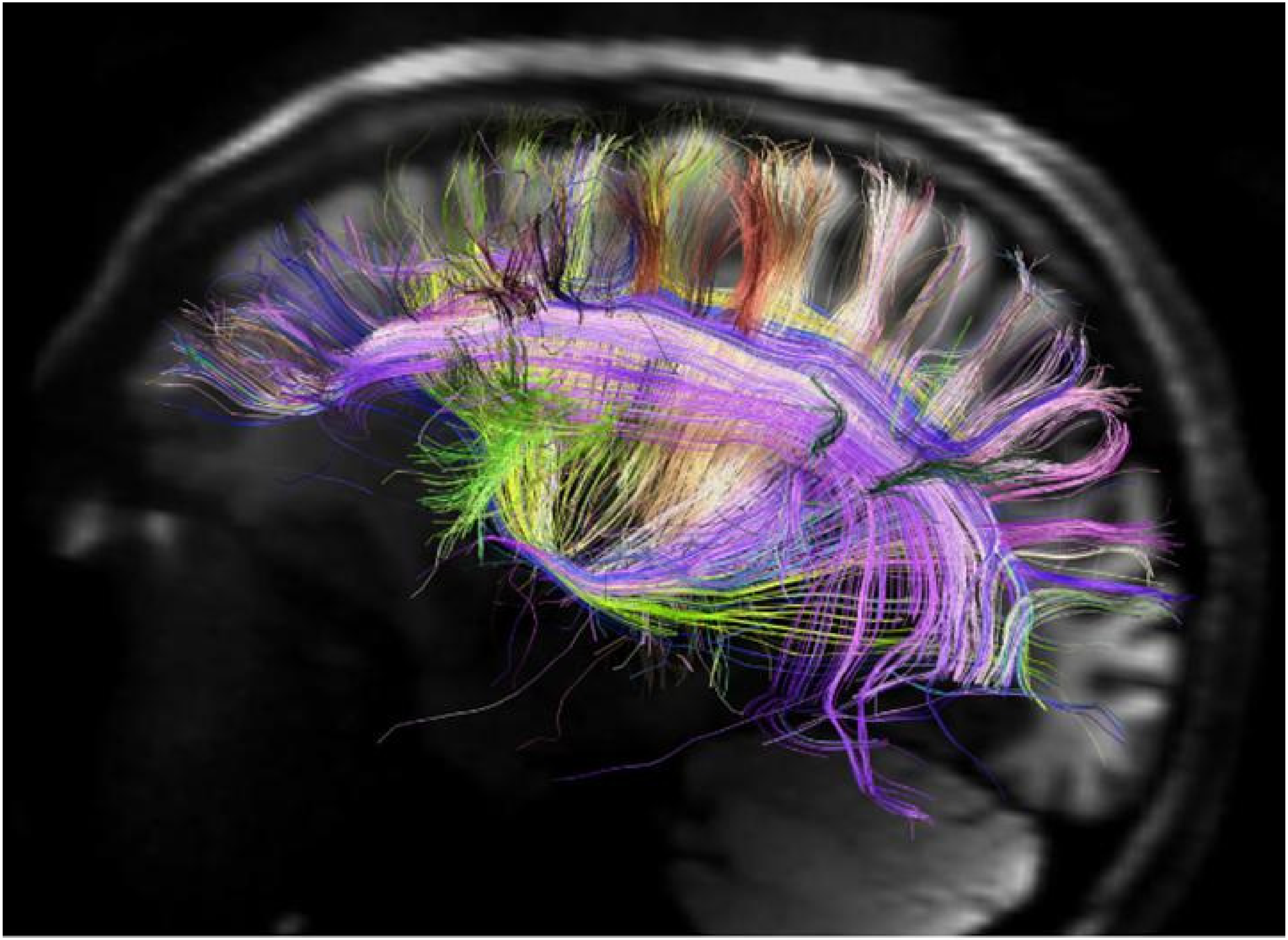
Table 5: Error measure ED1 for the four inverse algorithms, with regularization, under four different noise levels: 25 dB, 15 dB, 10 dB and 5 dB. Each cell value gives the mean and standard deviation.

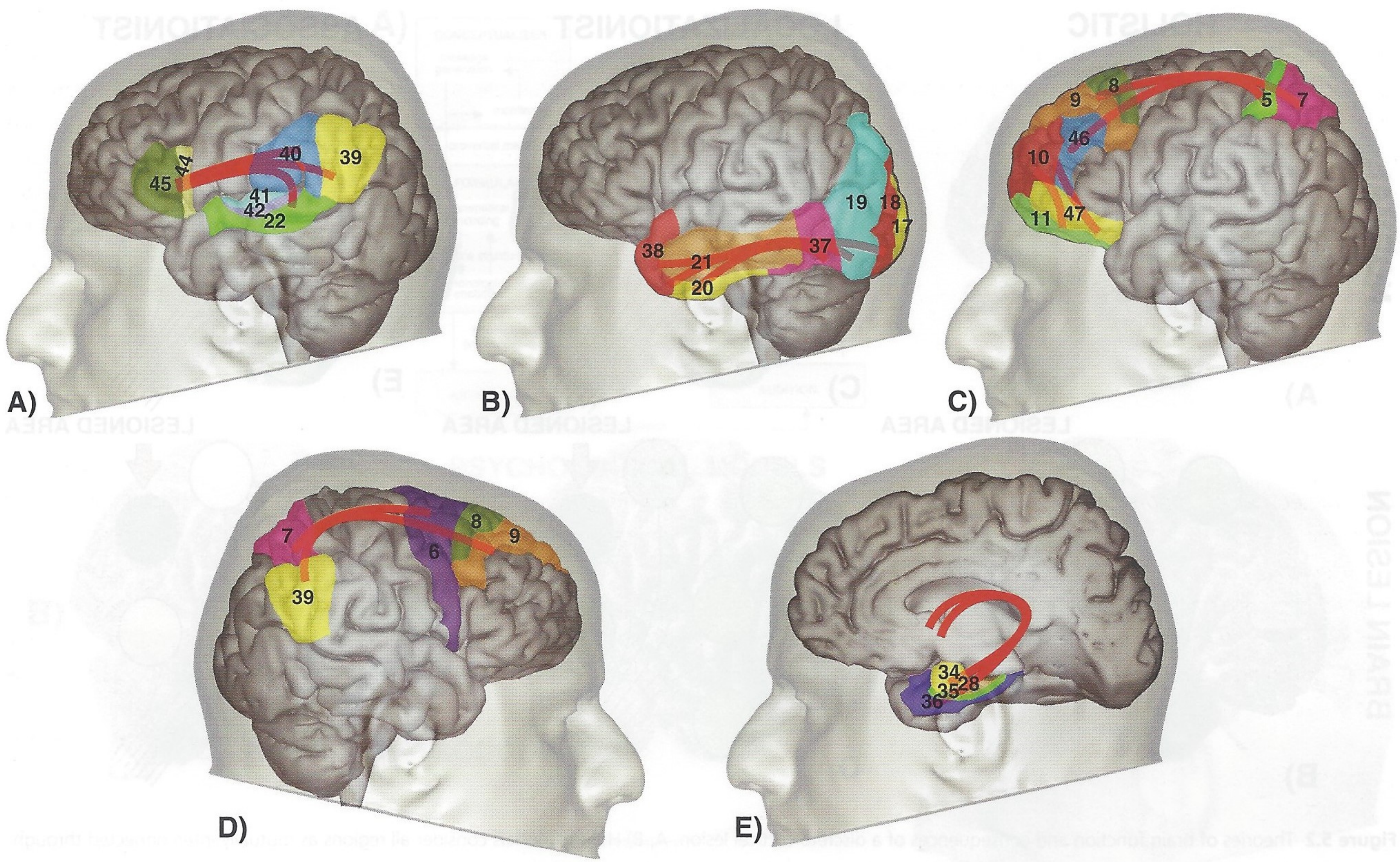
		ED1			
		Regularised			
	SNR/dB	5	10	15	25
	Layer				
WMN	Surface	3.46 ± 0.42	2.10 ± 0.28	1.34 ± 0.11	1.13 ± 0.03
	Middle	5.08 ± 0.50	3.94 ± 0.38	2.95 ± 0.21	2.40 ± 0.03
	Deep	5.91 ± 0.39	5.31 ± 0.36	4.61 ± 0.24	3.89 ± 0.15
sLORETA	Surface	0.99 ± 0.1	0.49 ± 0.08	0.11 ± 0.04	0.00 ± 0.00
	Middle	1.61 ± 0.13	0.84 ± 0.11	0.25 ± 0.07	0.00 ± 0.00
	Deep	1.79 ± 0.25	0.95 ± 0.16	0.39 ± 0.13	0.00 ± 0.00
LORETA	Surface	2.32 ± 0.08	2.18 ± 0.04	2.16 ± 0.03	2.21 ± 0.02
	Middle	1.51 ± 0.13	1.15 ± 0.08	0.95 ± 0.07	1.05 ± 0.06
	Deep	2.30 ± 0.21	1.81 ± 0.13	1.59 ± 0.11	1.53 ± 0.09
SLF	Surface	5.27 ± 0.30	4.50 ± 0.28	3.81 ± 0.20	2.98 ± 0.13
	Middle	4.53 ± 0.39	4.09 ± 0.35	3.50 ± 0.31	2.51 ± 0.15
	Deep	3.89 ± 0.55	3.70 ± 0.45	3.27 ± 0.48	1.73 ± 0.30

Electrical Neuroimaging – Assessment and Treatment

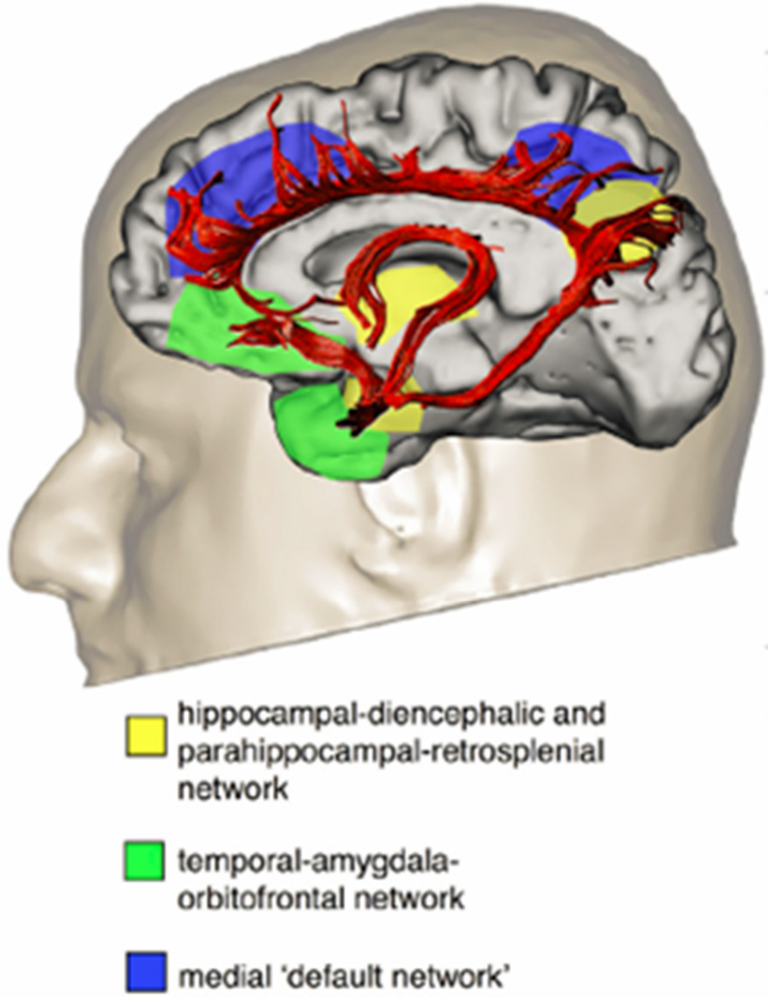
Advantages of Electrical Neuroimaging

1- Spatial Resolution – 1 cm to 3 cm
2- Temporal Resolution – 1 msec
3- Imaging of Current Sources
4- Imaging of Network Connections
5- Integration with DTI & fMRI (Brodmann Areas)
6- Inexpensive ($10,000 vs $3,000,000)
7- Dry Electrodes & Wireless Caps
8- Portable
9- Integration with Smart Phones & Tablets
10- Can Assess & Treat in Real-Time1



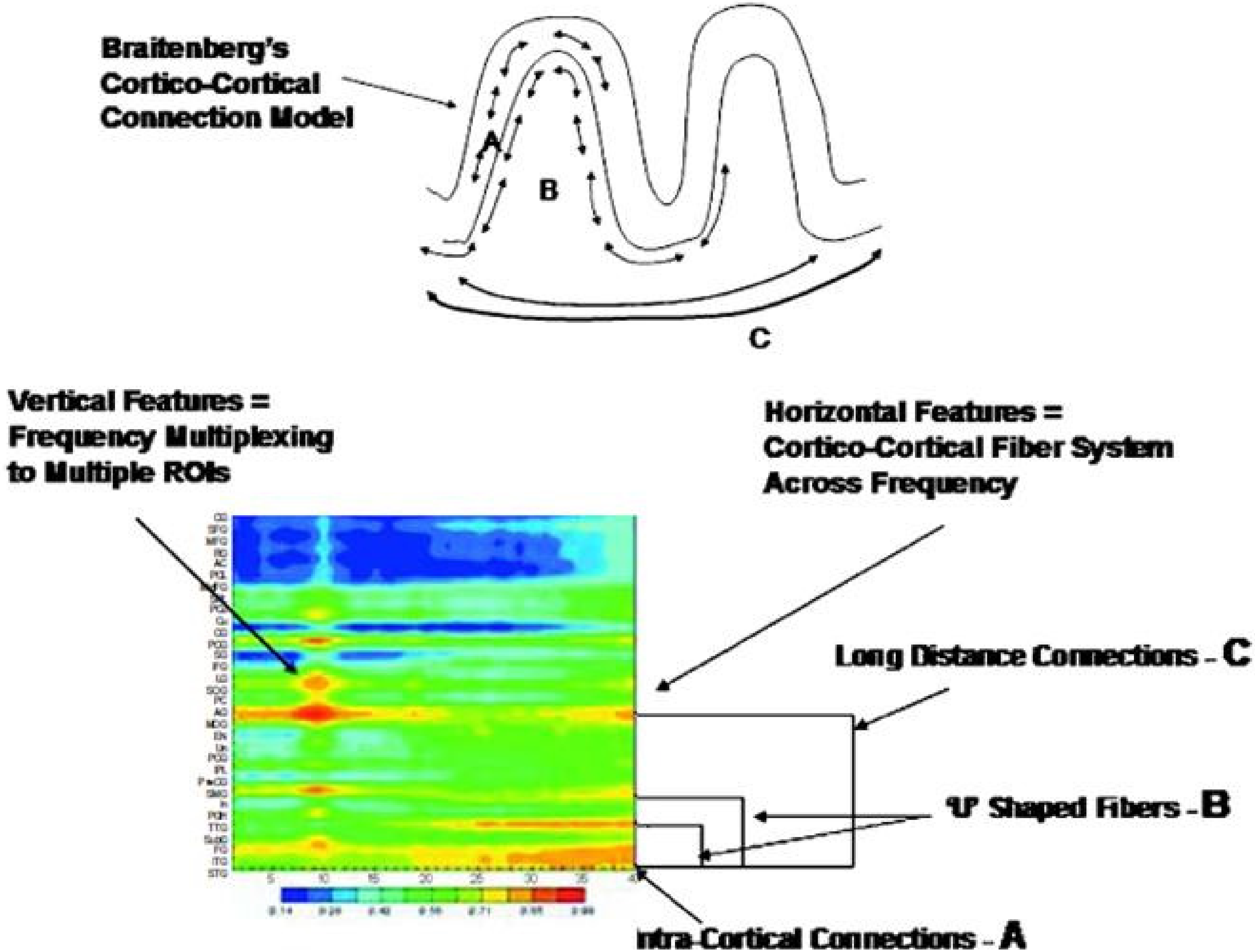


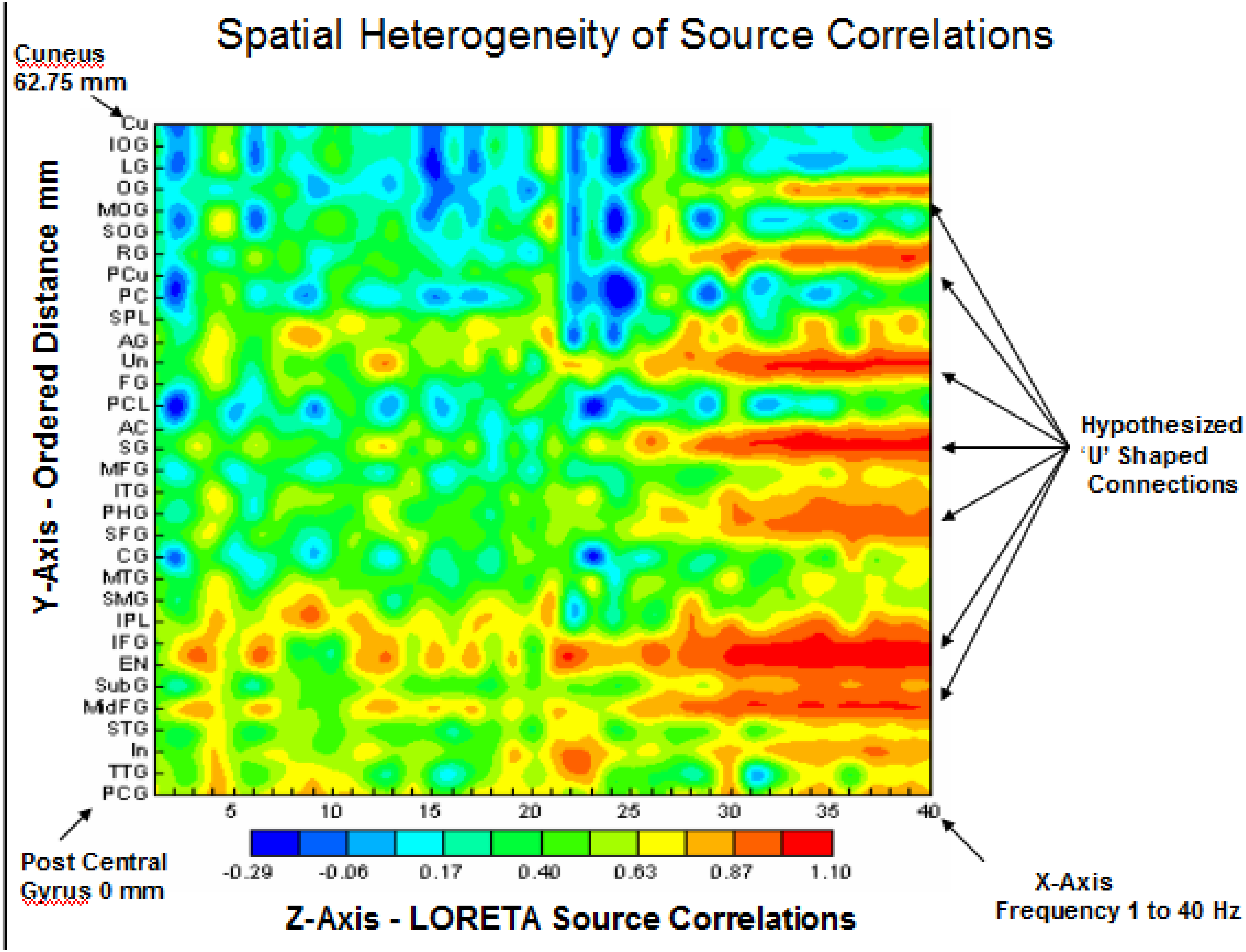
From Catani and deShotten, 2012



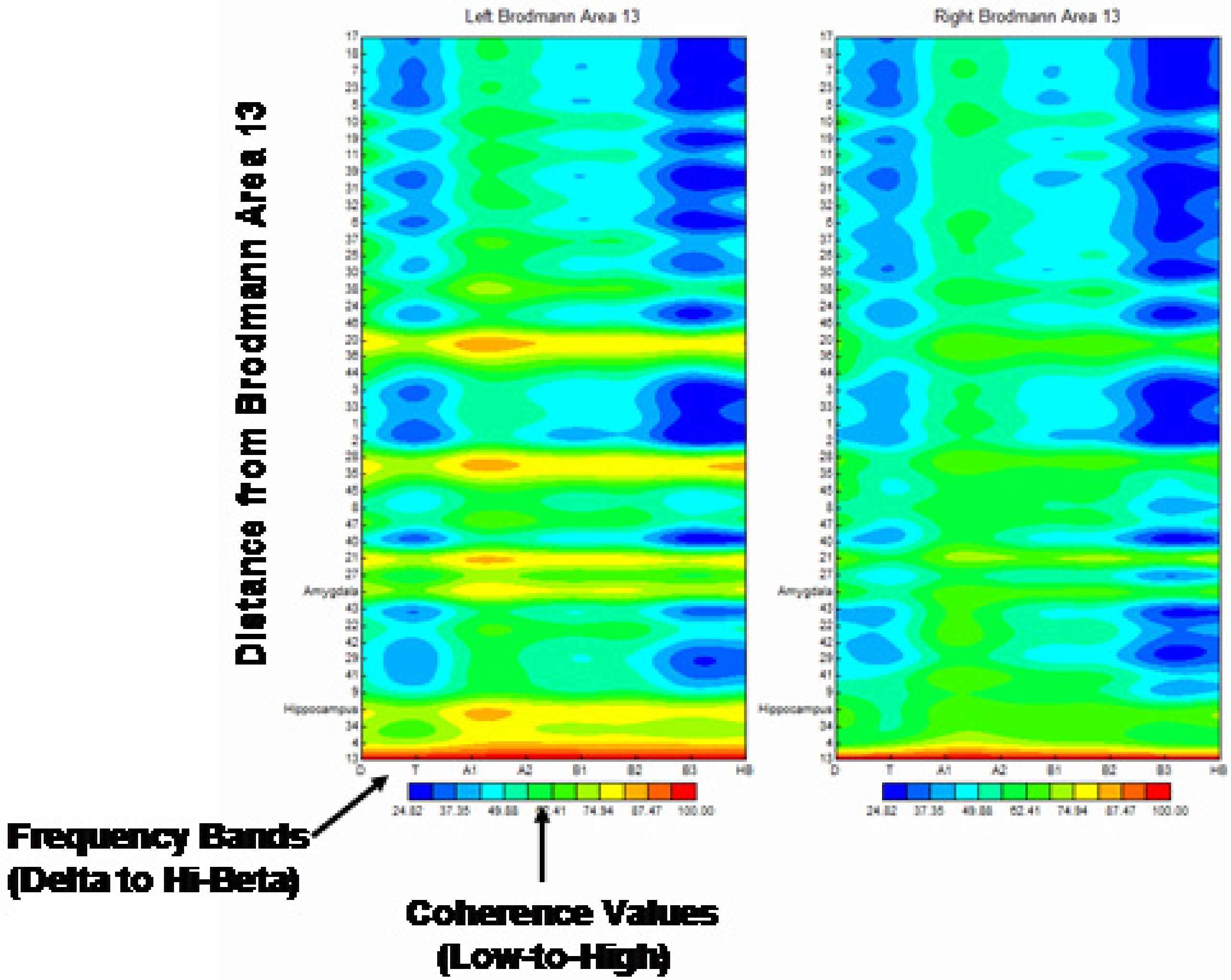
Network	Function	Disorder
Hippocampal-diencephalic and parahippocampal-retrosplenial	•memory •spatial orientation	•Amnesias •Korsakoff's syndrome •Mild Cognitive impairment •Alzheimer's disease (early) •Balint syndrome
Temporo-amygdala-orbitofrontal	•Behavioural inhibition •Memory for temporally complex visual information •Olfactory-gustatory-visceral functions •Multimodal sensory integration •Object-reward association learning •Outcome monitoring	•Alzheimer's Disease (advanced) •Semantic dementia •Klüver-Bucy syndrome •Temporal lobe epilepsy •Geschwind's syndromes •Psychopathy •Bipolar affective disorders
Dorsomedial default network	•Pain perception •Self-knowledge •Attention •Mentalizing •Empathy •Response selection and action monitoring •Autobiographical memory •Person perception	•Depression •Autism •Schizophrenia •Obsessive compulsive disorder •Mild Cognitive Impairmentt •Alzheimer's Disease (early) •Attention Deficit Hyperactivity Disorder •Anxiety

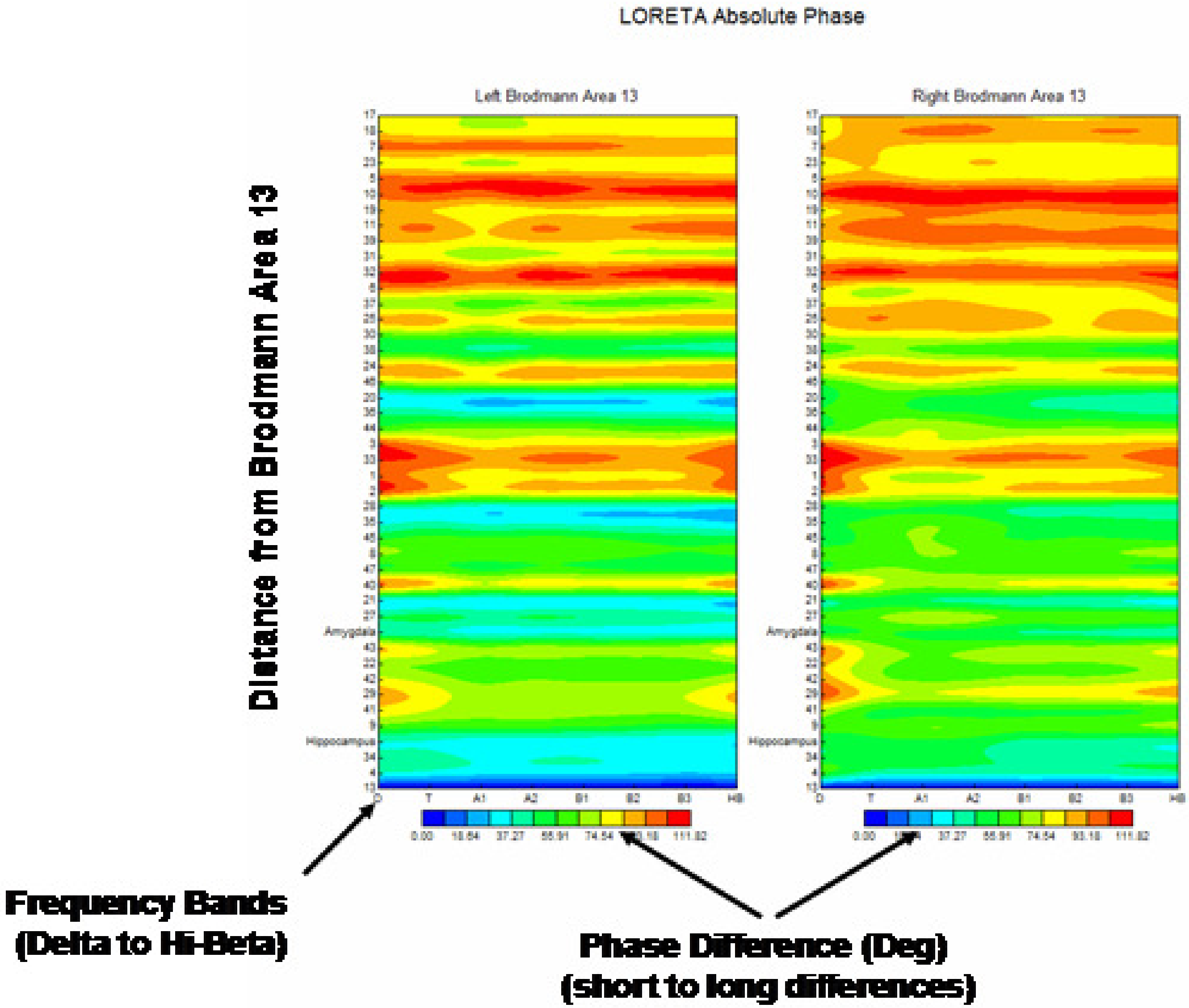
From Catani and deShotten, 2012


Braitenberg's
Cortico-Cortical
Connection Model
A
B
C
Vertical Features =
Frequency Multiplexing
to Multiple ROIs
Horizontal Features =
Cortico-Cortical Fiber System
Across Frequency
Long Distance Connections - C
'U' Shaped Fibers - B
ntra-Cortical Connections - A


Spatial Heterogeneity of Source Correlations
Cuneus
62.75 mm
Cu
IOG
LG
OG
MOG
SOG
RG
PCu
PC
SPL
AG
Un
FG
PCL
AC
SG
MFG
ITG
PHG
SFG
CG
MTG
SMG
IPL
IFG
EN
SubG
MidFG
STG
In
TTG
PCG
Y-Axis - Ordered Distance mm
5
10
15
20
25
30
35
40
-0.29
-0.06
0.17
0.40
0.63
0.87
1.10
Post Central
Gyrus 0 mm
Z-Axis - LORETA Source Correlations
Hypothesized
'U' Shaped
Connections
X-Axis
Frequency 1 to 40 Hz

LORETA Coherence

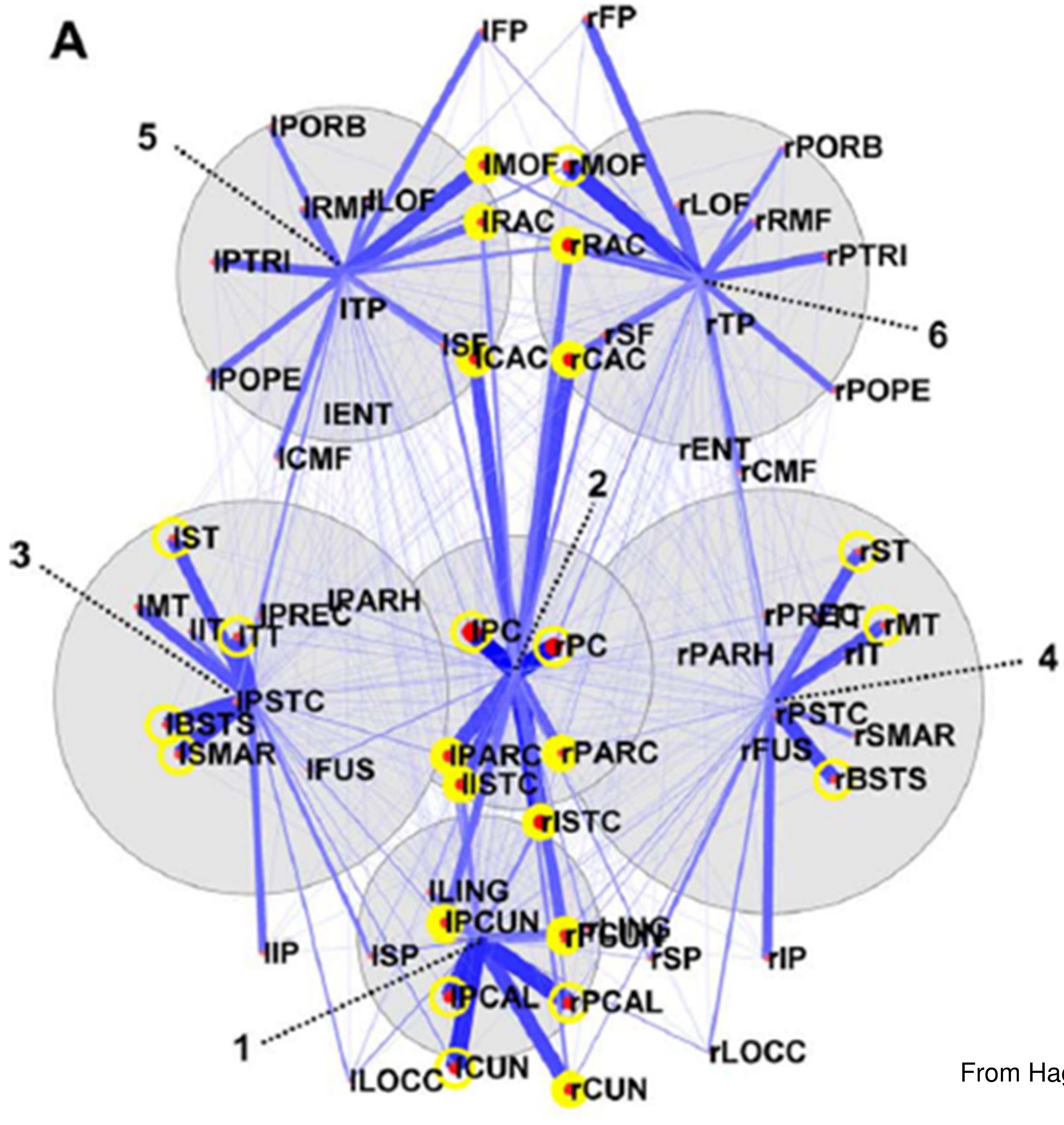



LORETA Absolute Phase
Left Brodmann Area 13
Right Brodmann Area 13
Distance from Brodmann Area 13
Amygdala
Hippocampus
D T A1 A2 B1 B2 B3 HB
0.00 18.64 37.27 55.91 74.54 93.18 111.82
Frequency Bands
(Delta to Hi-Beta)
Phase Difference (Deg)
(short to long differences)

• Human Brain Mapping 33:1062–1075 (2012) •

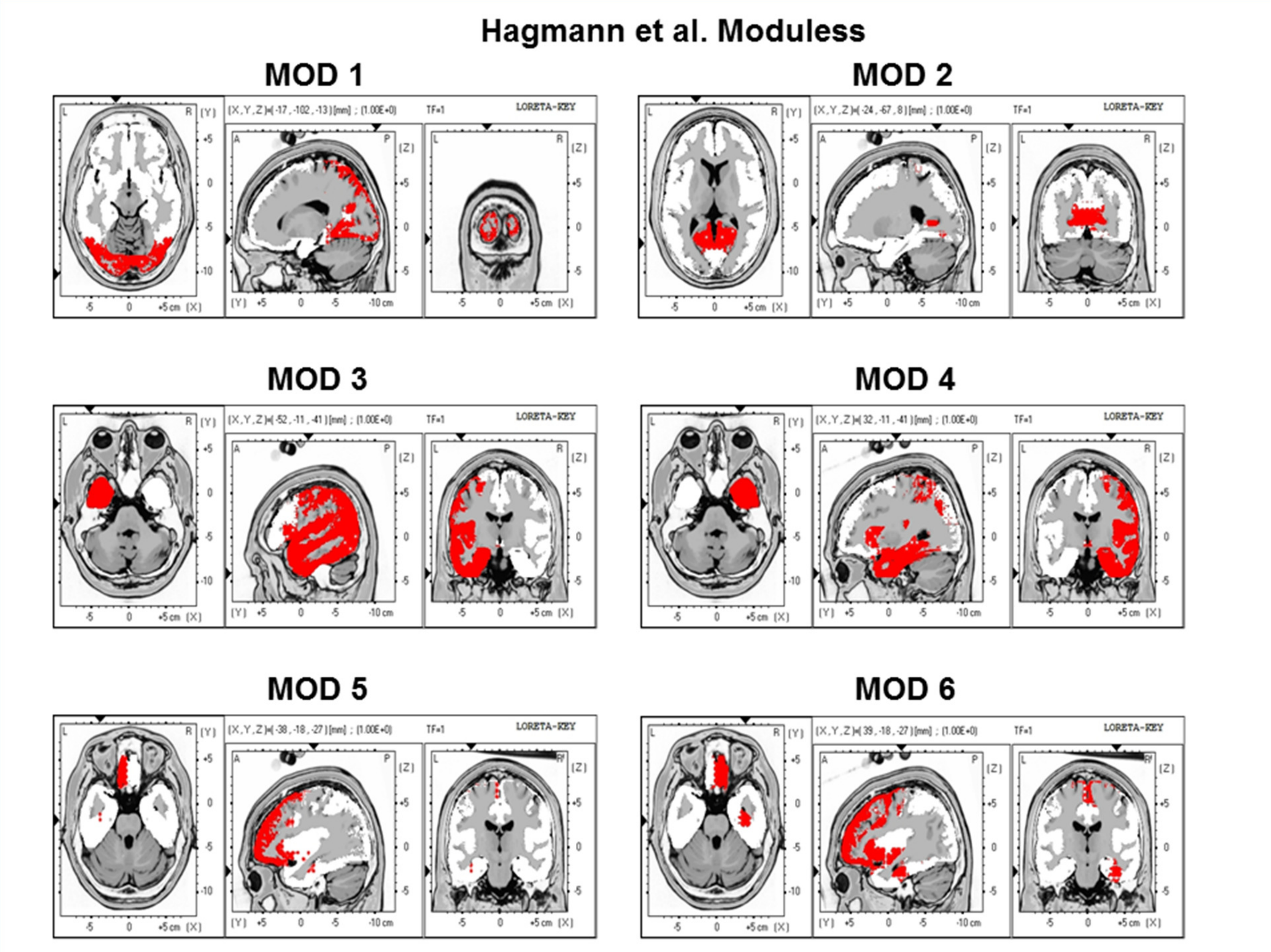
Diffusion Spectral Imaging Modules Correlate With EEG LORETA Neuroimaging Modules

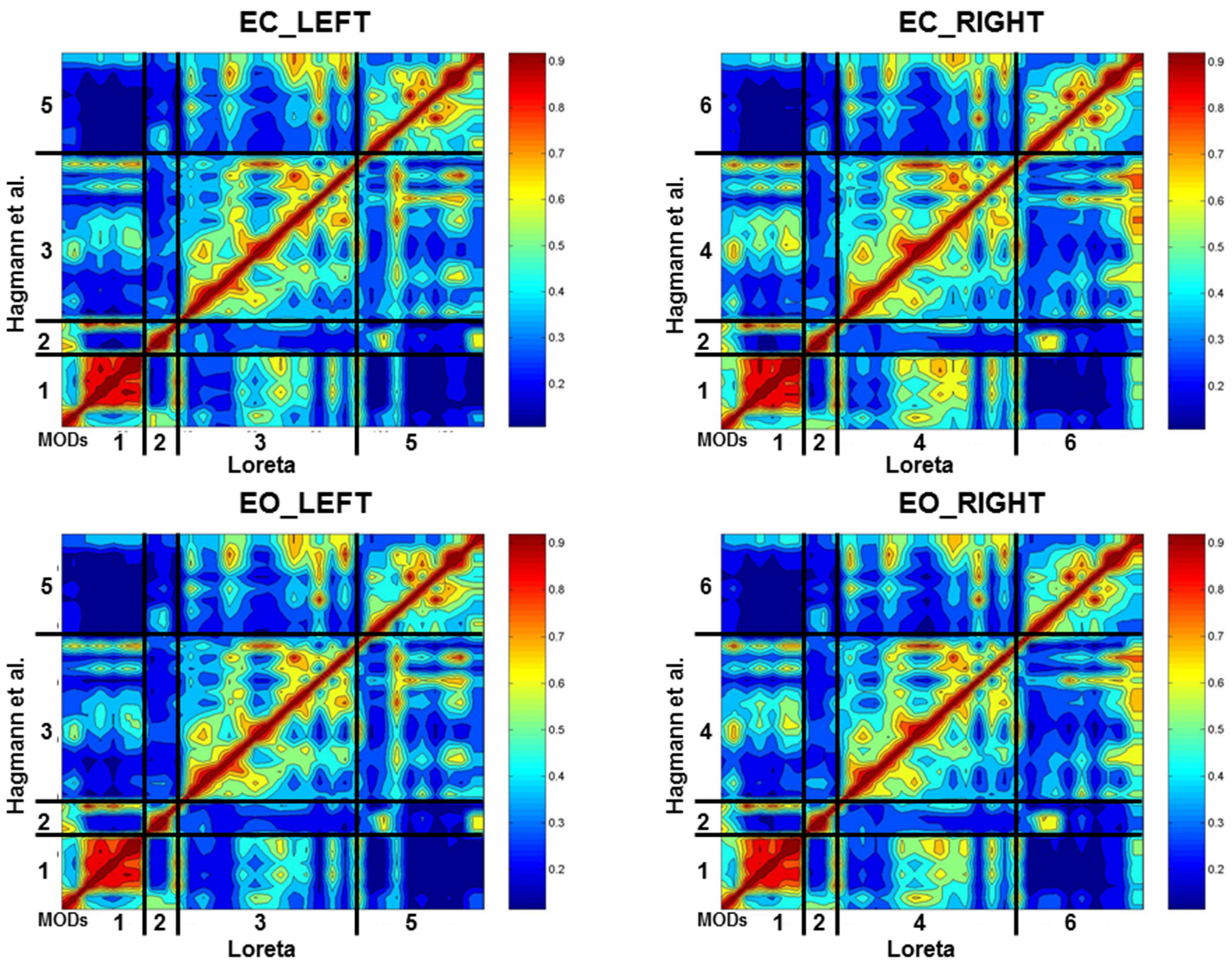
Robert W. Thatcher,* Duane M. North, and Carl J. Biver



From Hagmann et al, 2008

Correlations Between EEG Neuroimaging and Diffusion Spectral Imaging (DTI)




EC_LEFT
EC_RIGHT
EO_LEFT
EO_RIGHT
Hagmann et al.
Loreta
MODs
1
2
3
4
5
6
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2

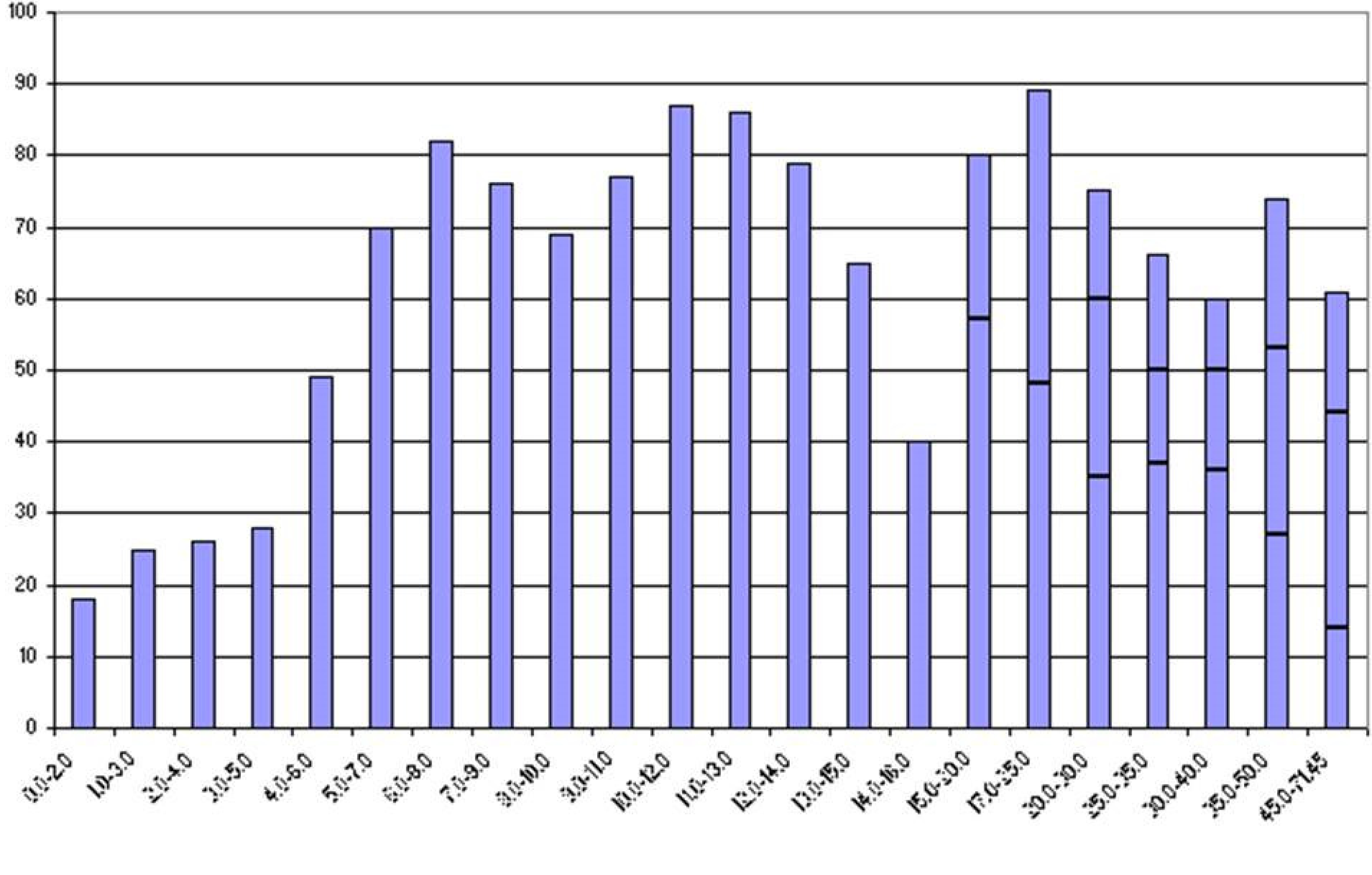
Published as a chapter in “Introduction to QEEG and Neurofeedback: Advanced Theory and Applications” Thomas Budzinsky, H. Budzinski, J. Evans and A. Abarbanel editors, Academic Press, San Diego, Calif, 2008.

HISTORY OF THE SCIENTIFIC STANDARDS OF QEEG NORMATIVE DATABASES

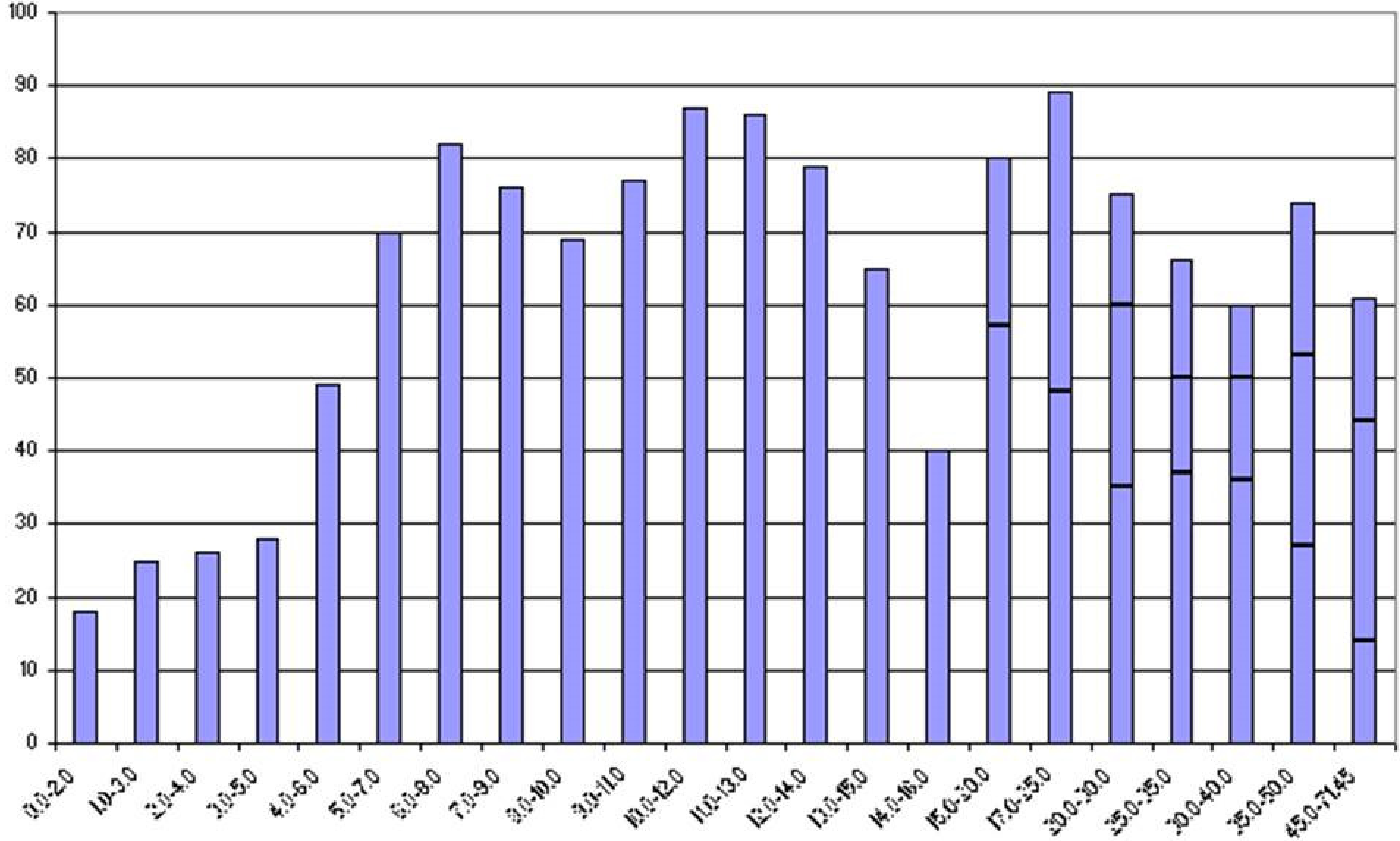
Thatcher, R.W. [1,2] and Lubar, J.F.[3]

Department of Neurology, University of South Florida College of Medicine, Tampa, Fl.[1] and EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, Fl[2] , Brain Research and Neuropsychology Lab, University of Tennessee, Knoxville, TN[3].

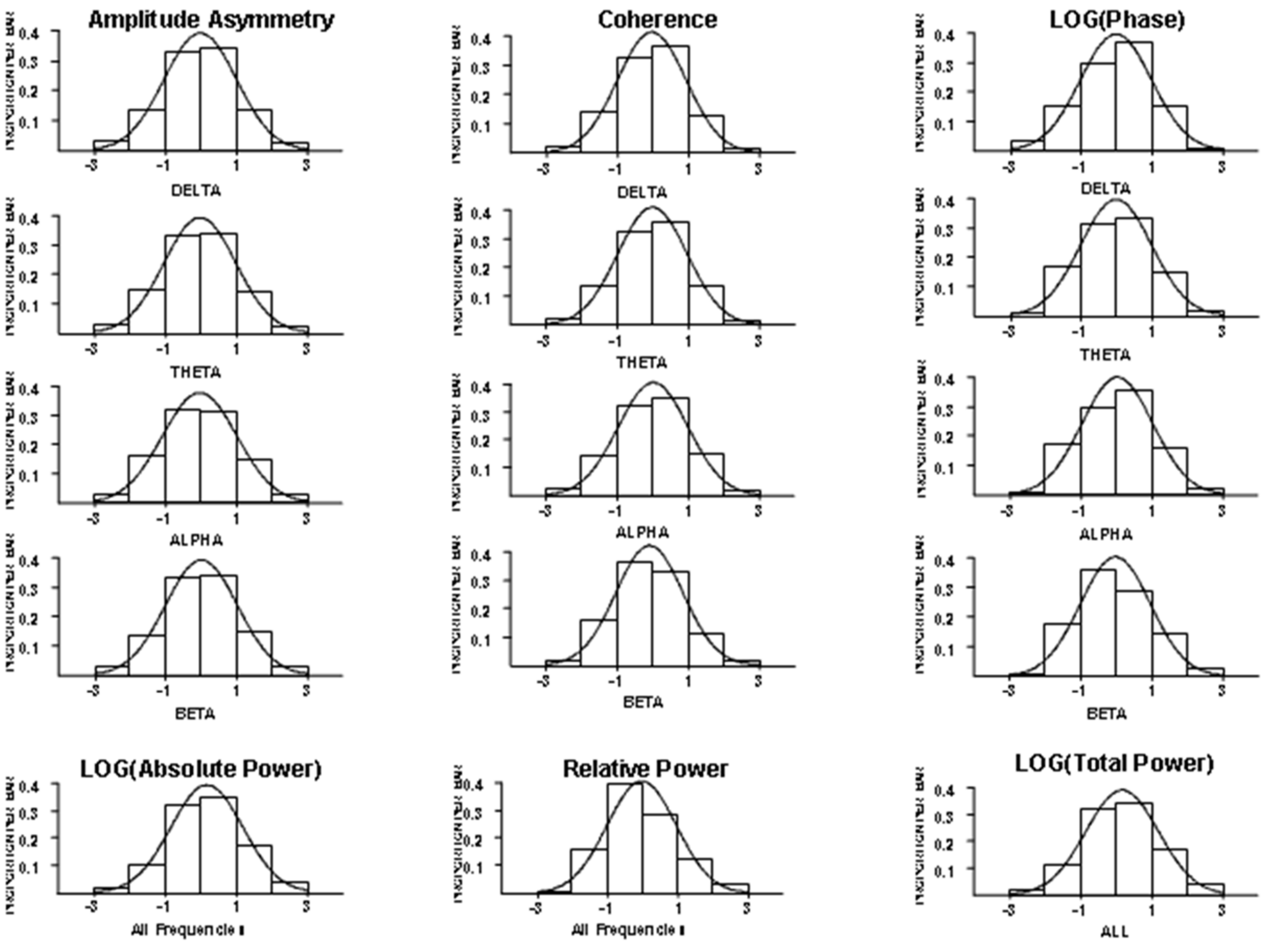
NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011



NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011

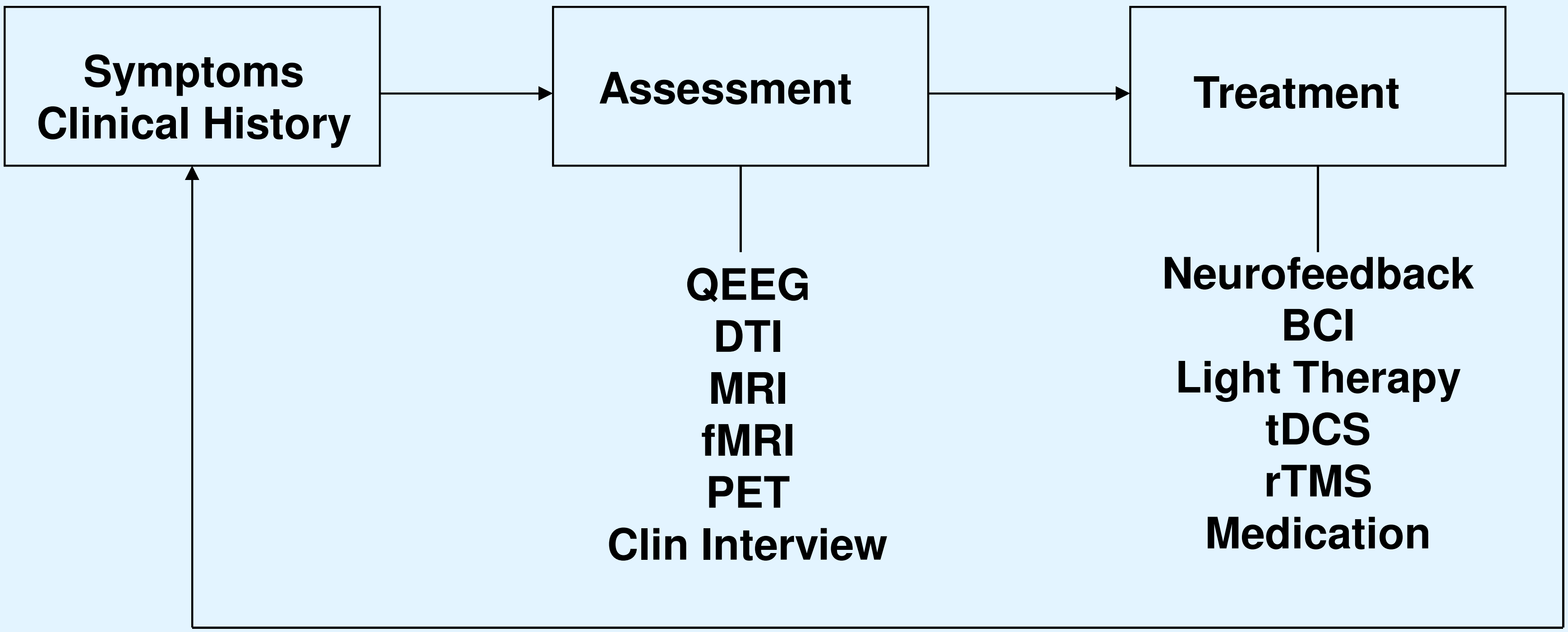


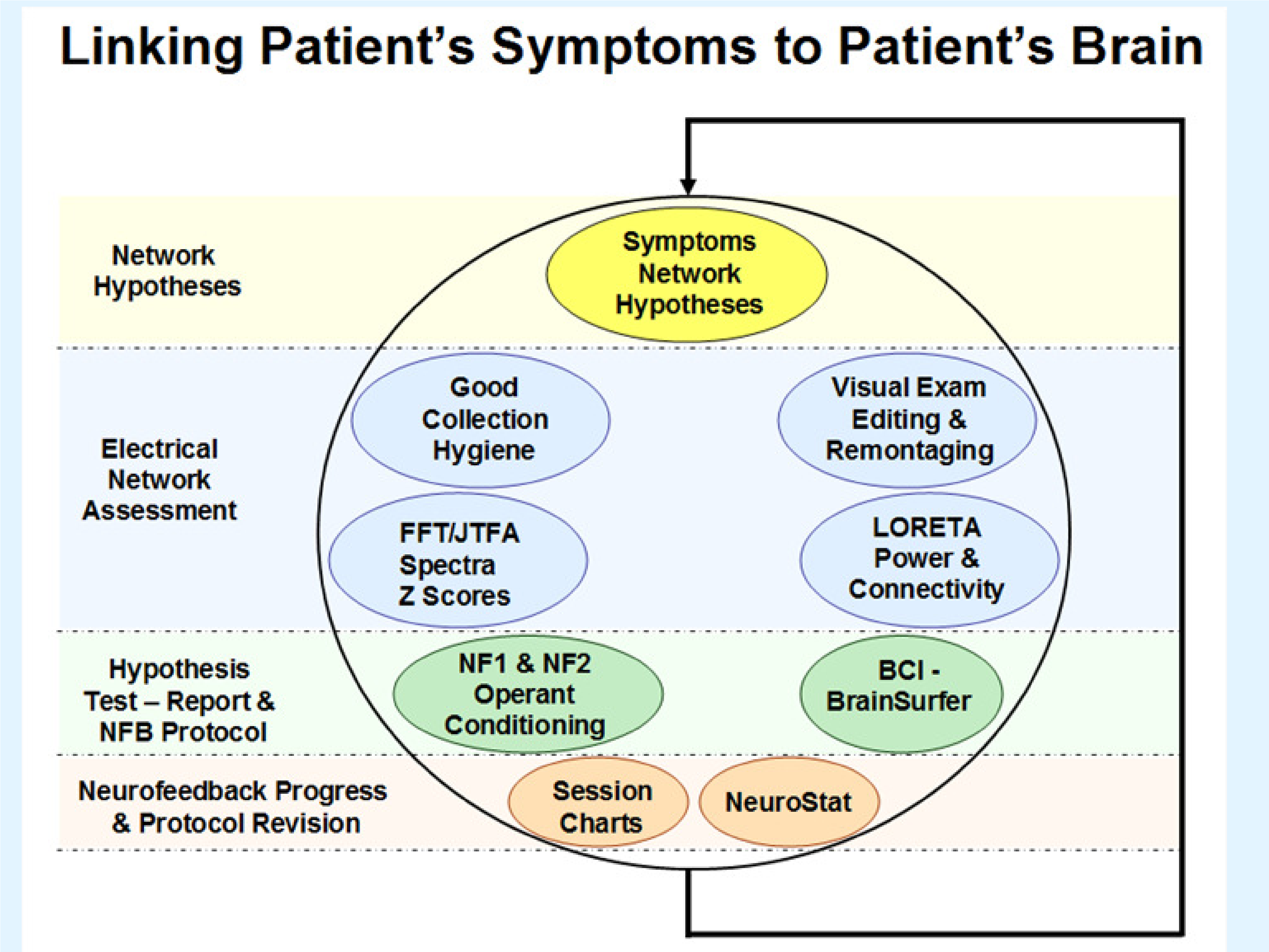
Cross-Validation Birth to 82 Year EEG Normative Database



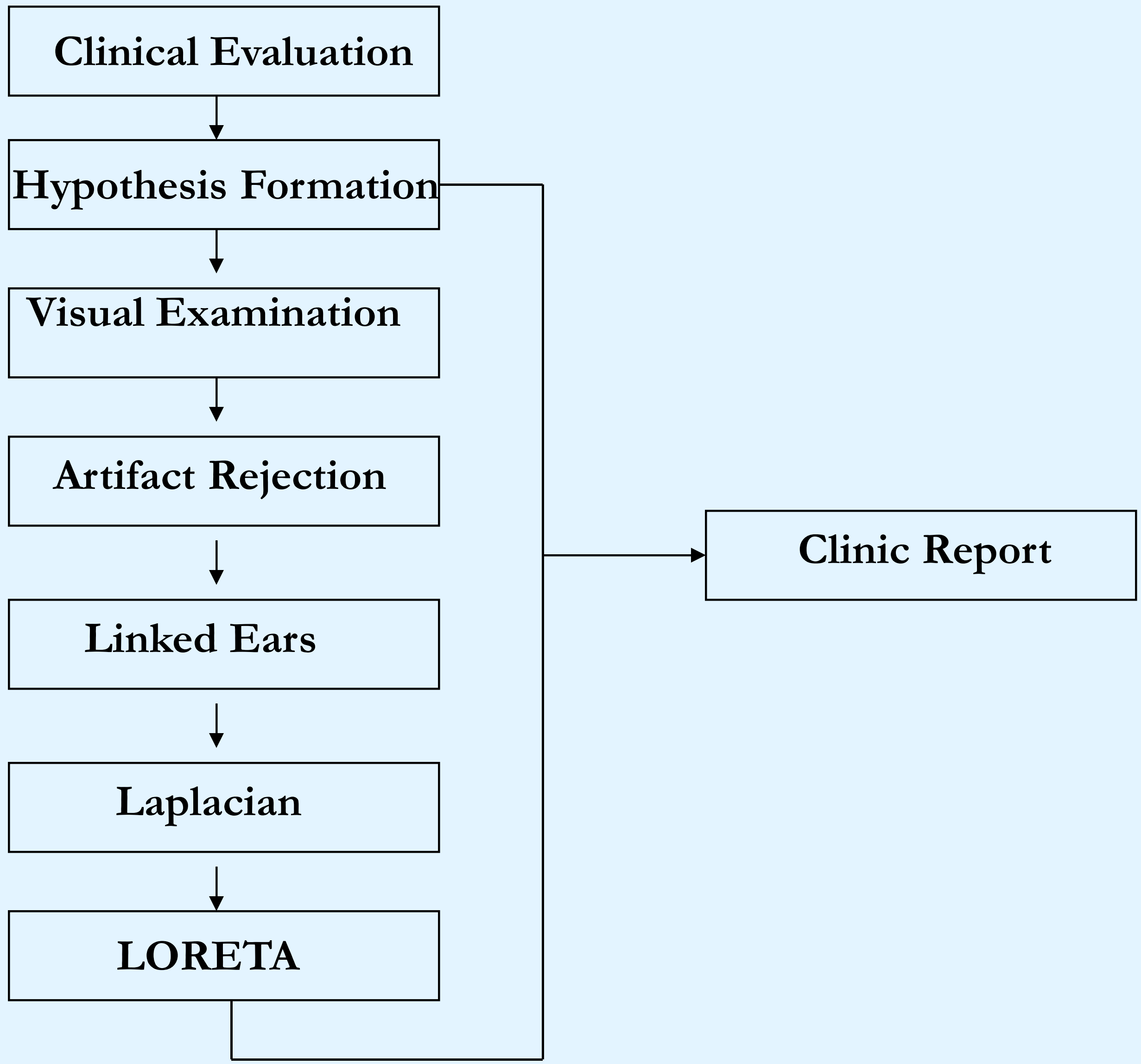
Essential Steps in Helping Patients with Neurological/Psychological Problems

Assess, Address, Reassess …

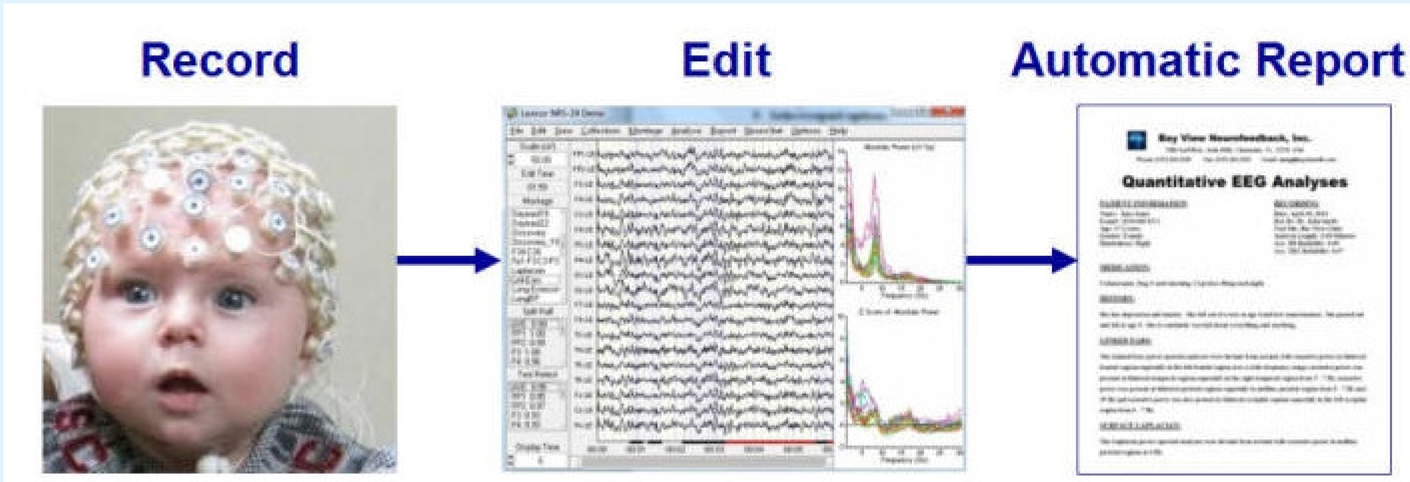



Linking Patient's Symptoms to Patient's Brain
Network Hypotheses
Symptoms Network Hypotheses
Electrical Network Assessment
Good Collection Hygiene
Visual Exam Editing & Remontaging
FFT/JTFA Spectra Z Scores
LORETA Power & Connectivity
Hypothesis Test – Report & NFB Protocol
NF1 & NF2 Operant Conditioning
BCI - BrainSurfer
Neurofeedback Progress & Protocol Revision
Session Charts
NeuroStat

QEEG Report Generation Sequence



Automatic Clinical Report Writer (ACR)



•No Delays with Minimal Expense for a Professional Quality In-House QEEG Clinical Report

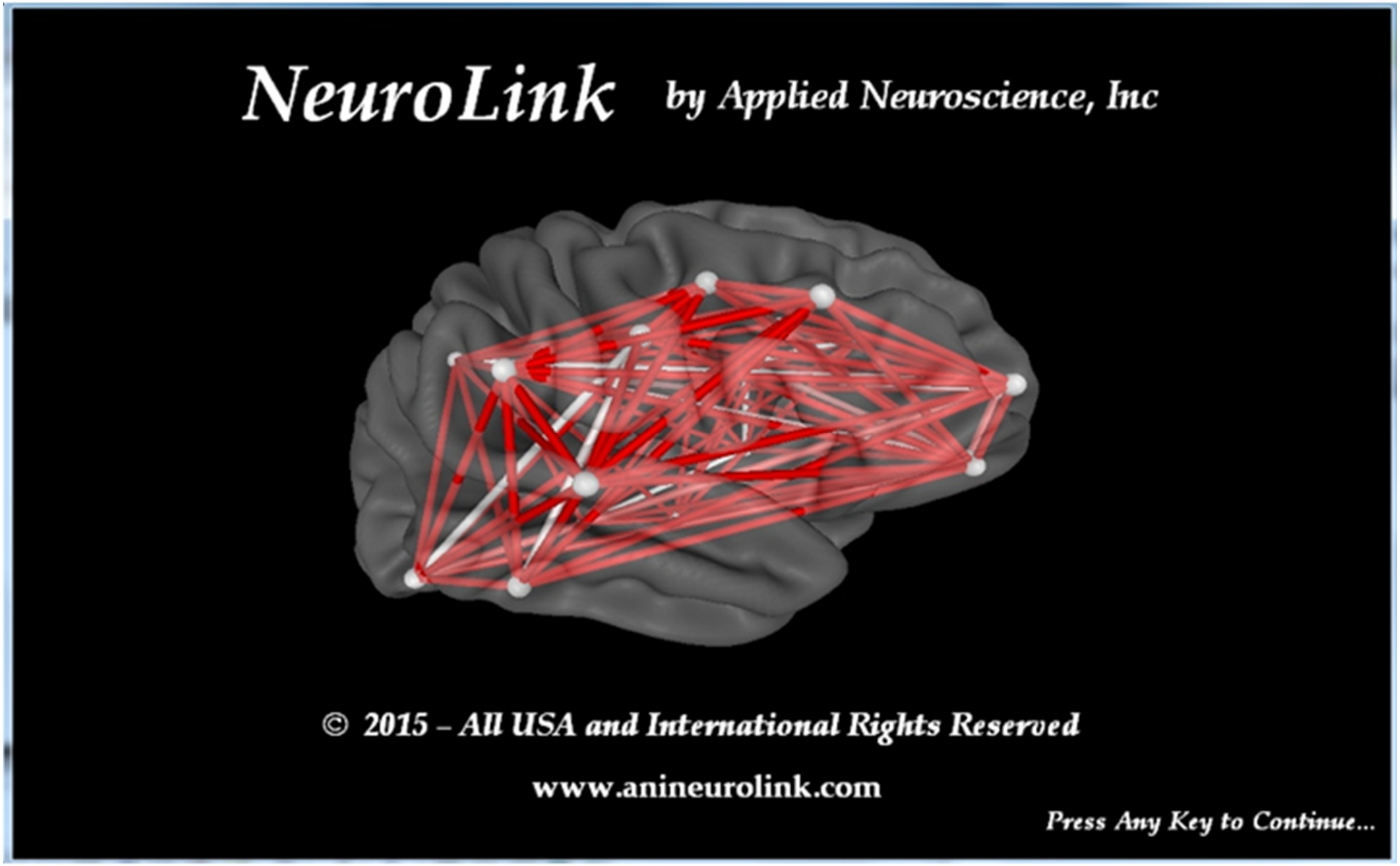
•Less than One Minute to Produce a Professional QEEG Clinical Report, in Microsoft Word format

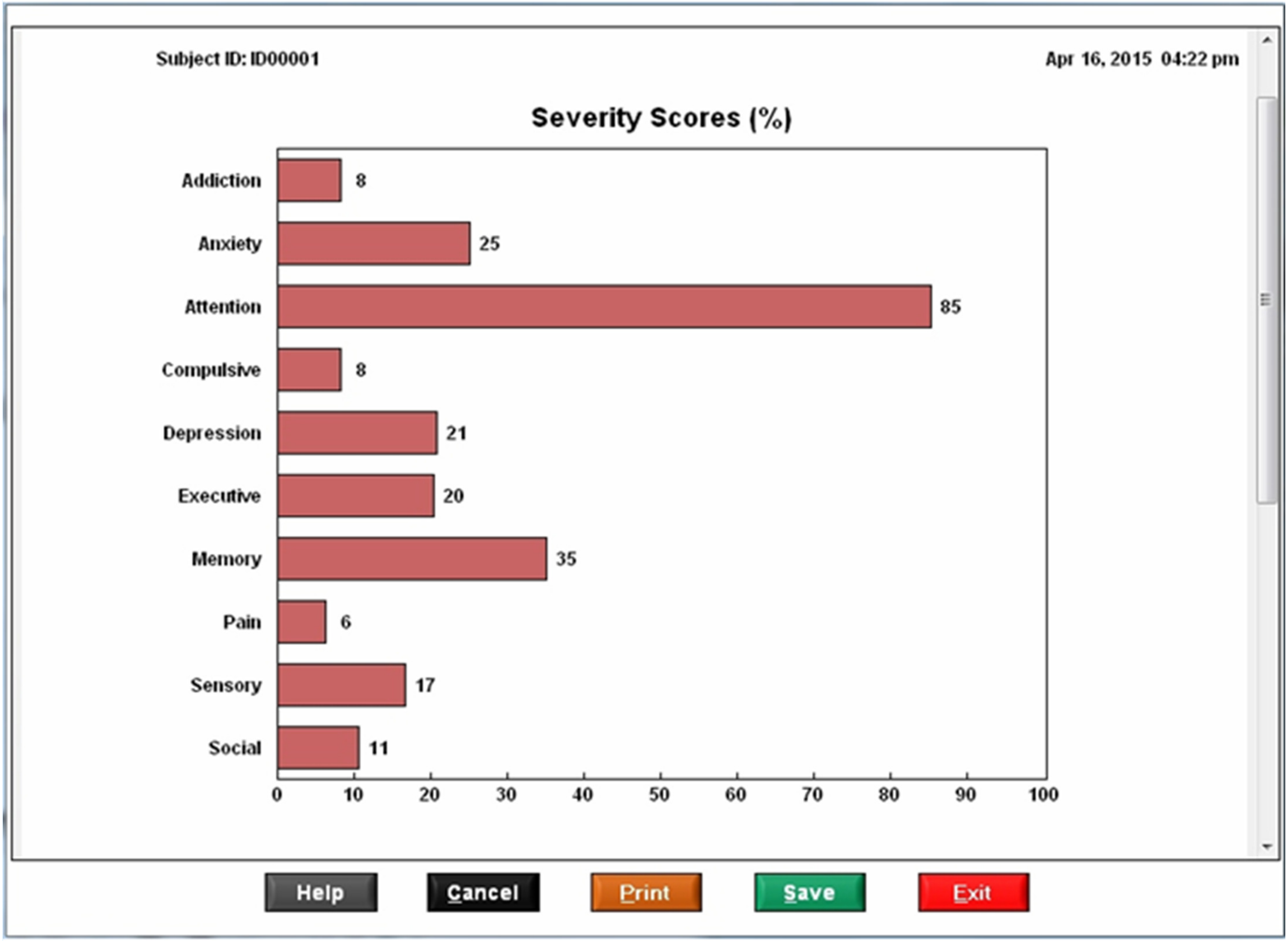
•ACR Provides: Empowerment, Simplicity, Accuracy & Efficiency!

•Get Valid Normative Database Comparisons using without Depending on Internet Q-EEG Report Services!

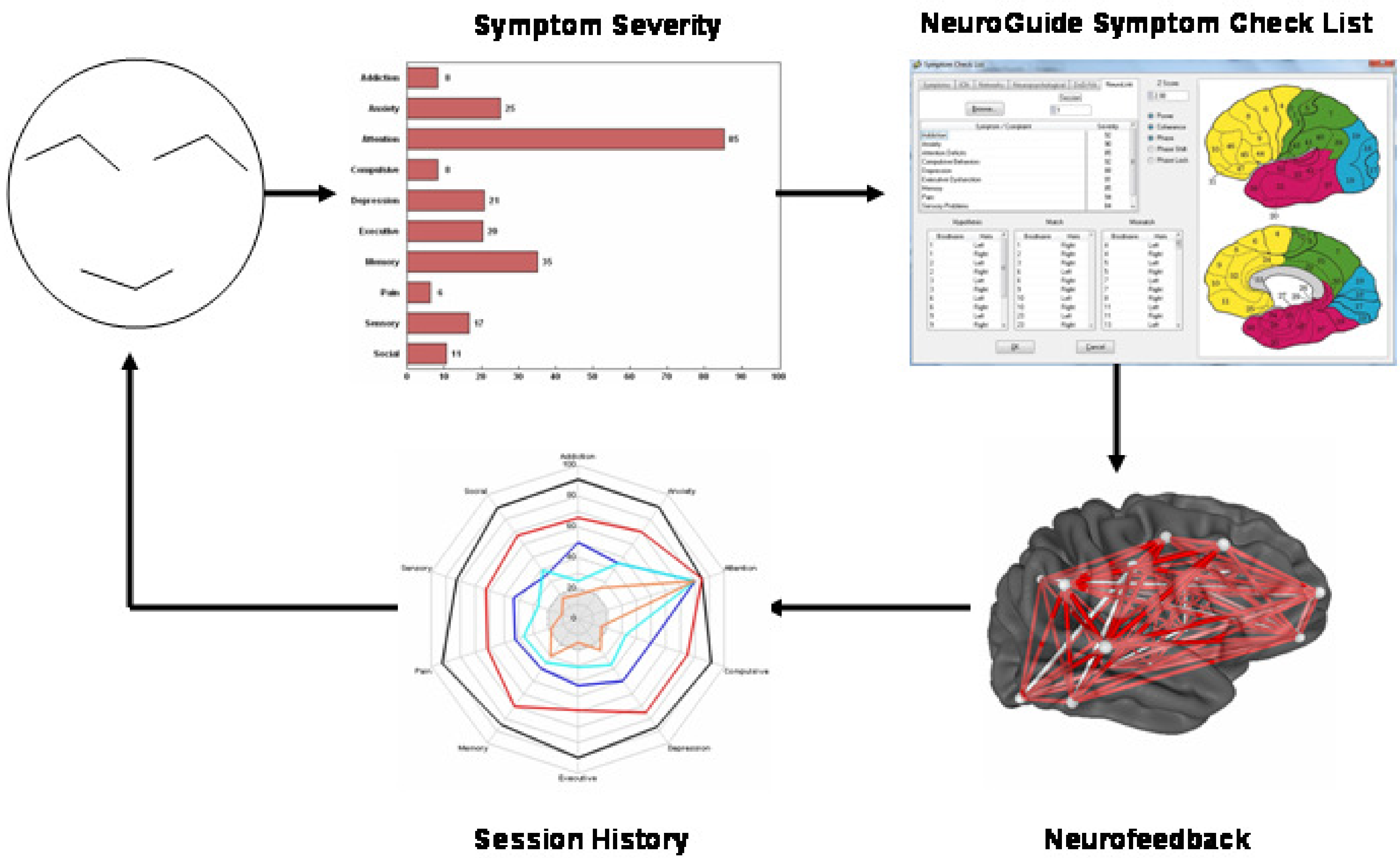
•Get Relevant Content and Displays, plus Helpful NFB Recommendations in Less than a Minute.

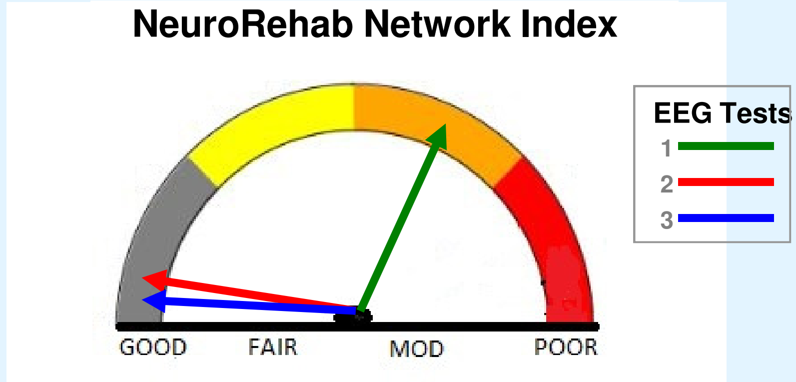
•Increased Productivity by at Least 10 Fold, e.g. Ten Reports in an Hour!


NeuroLink by Applied Neuroscience, Inc
© 2015 – All USA and International Rights Reserved
www.anineurolink.com
Press Any Key to Continue...

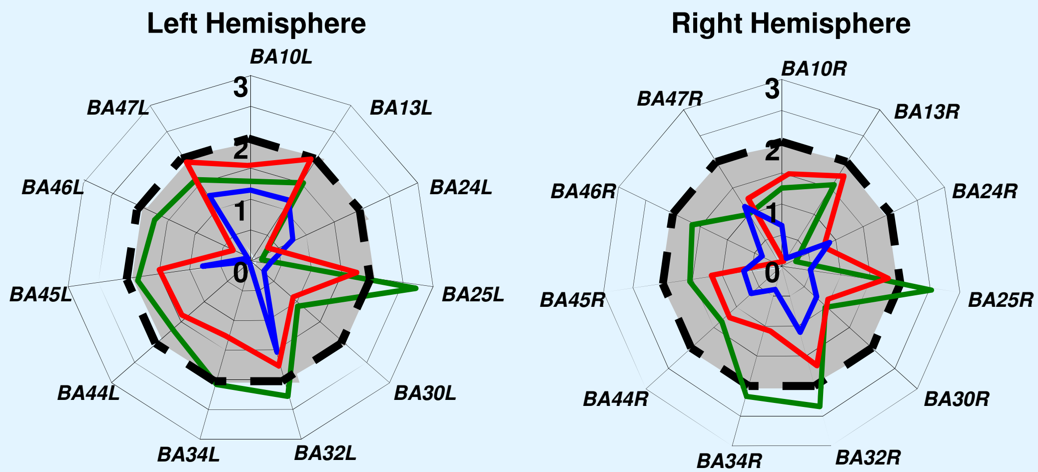

Subject ID: ID00001
Apr 16, 2015 04:22 pm
Severity Scores (%)
Addiction 8
Anxiety 25
Attention 85
Compulsive 8
Depression 21
Executive 20
Memory 35
Pain 6
Sensory 17
Social 11
0 10 20 30 40 50 60 70 80 90 100
Help
Cancel
Print
Save
Exit

NeuroLink and NeuroGuide Integration – Linking Symptoms to the Brain

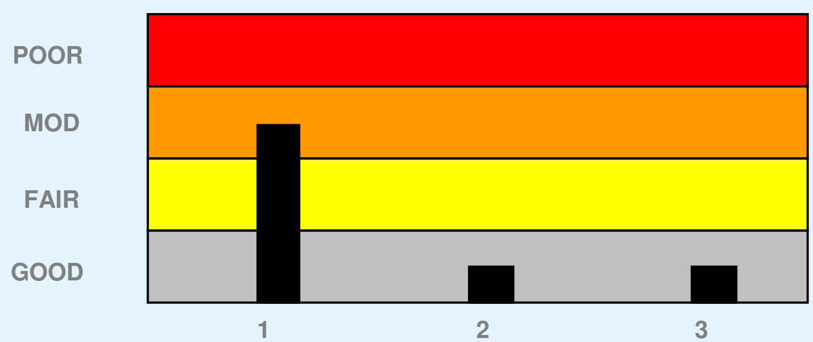


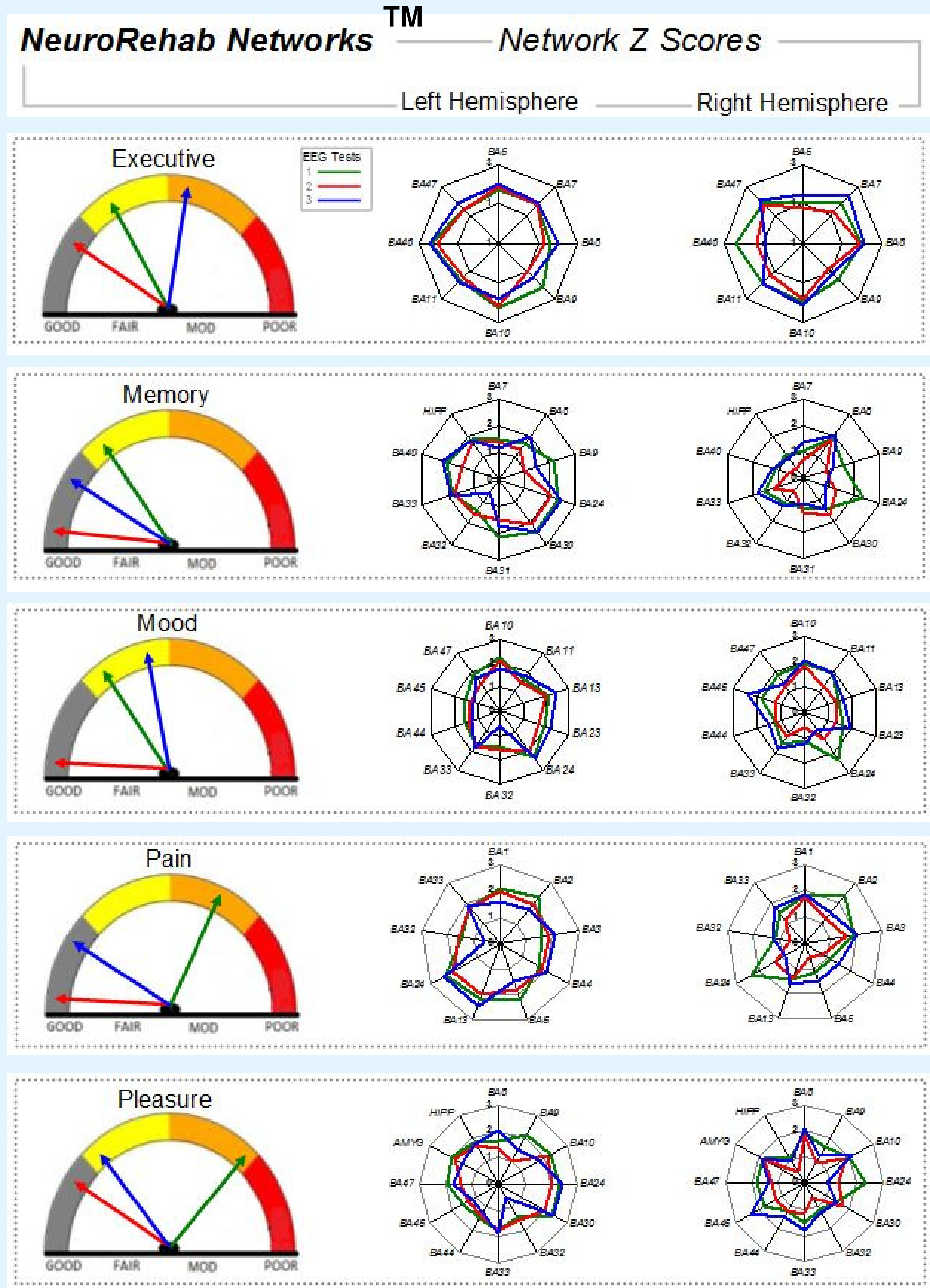


Addiction Network Z Scores



Rehabilitation History

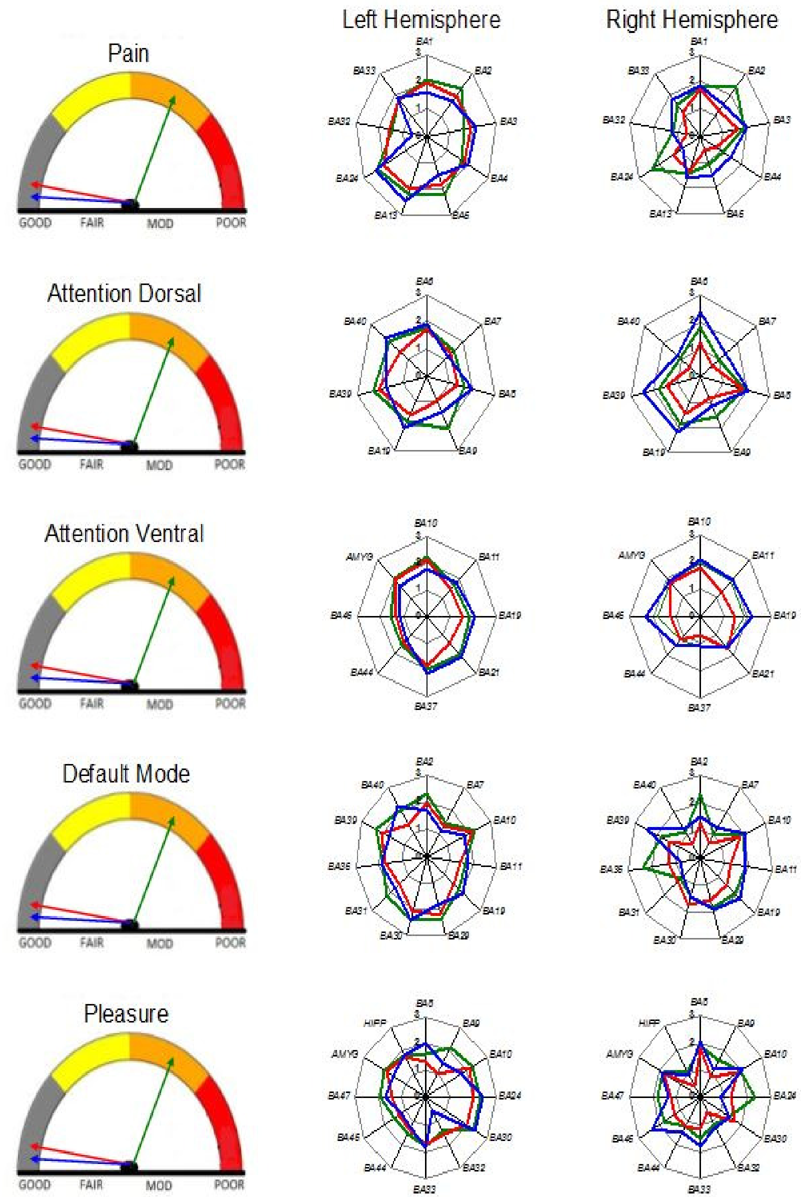




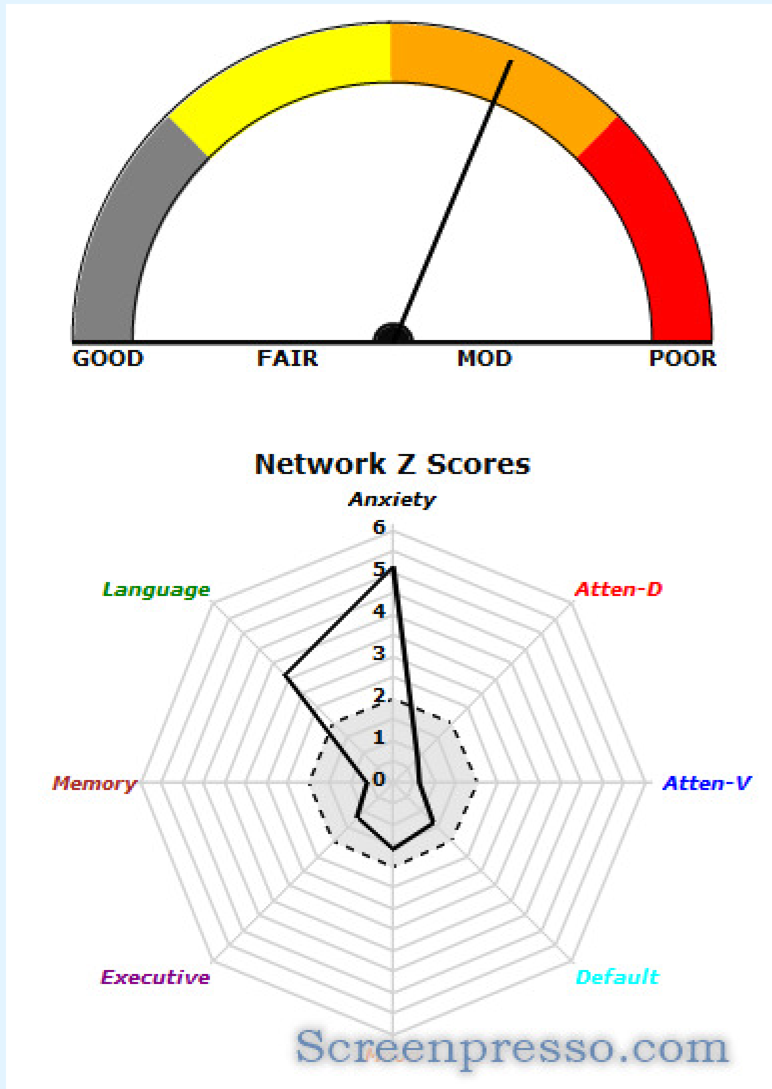
NeuroRehab Networks
TM
Network Z Scores
Left Hemisphere
Right Hemisphere
Executive
EEG Tests
1
2
3
Memory
Mood
Pain
Pleasure
GOOD
FAIR
MOD
POOR

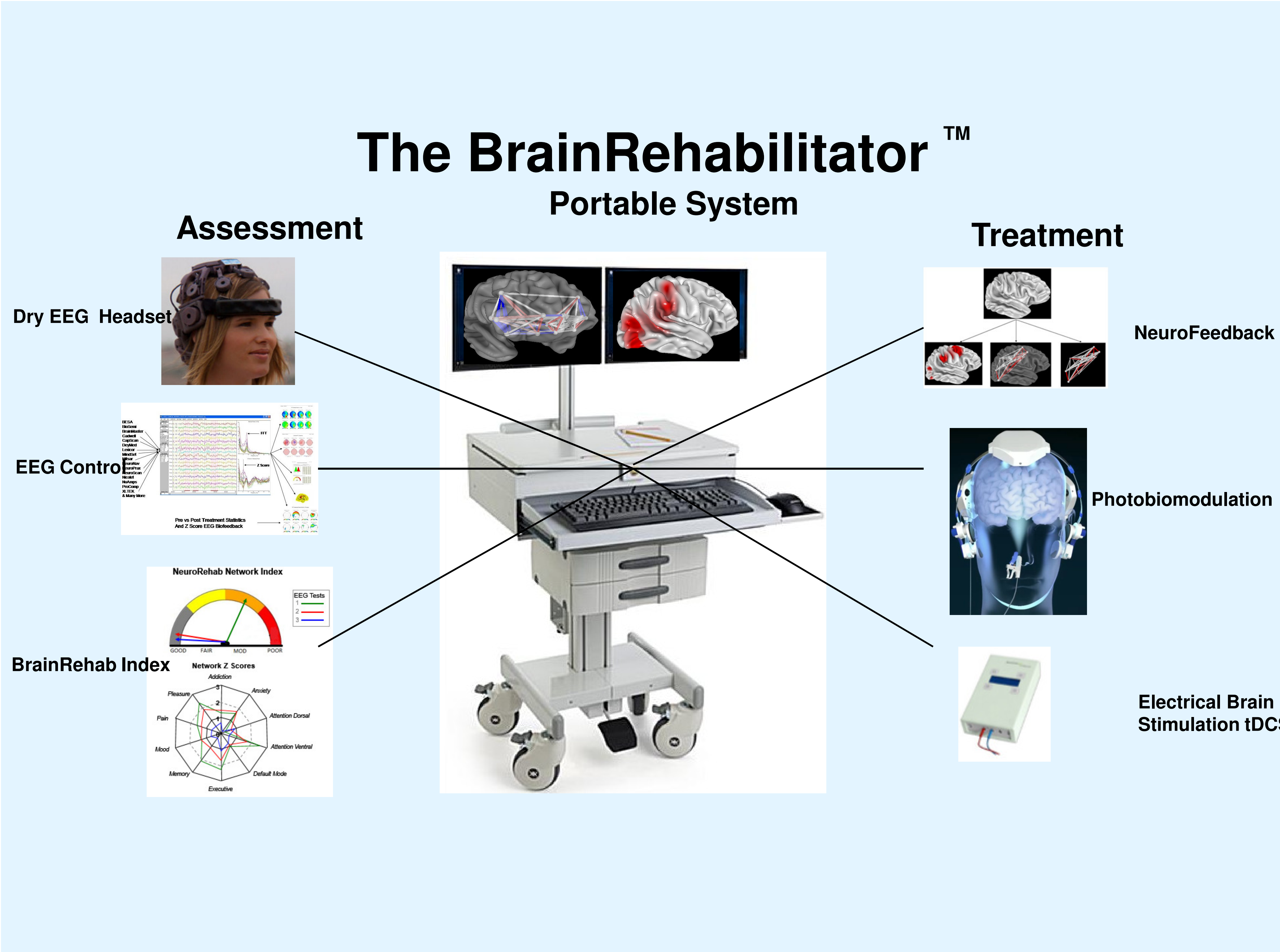
NeuroRehab Networks

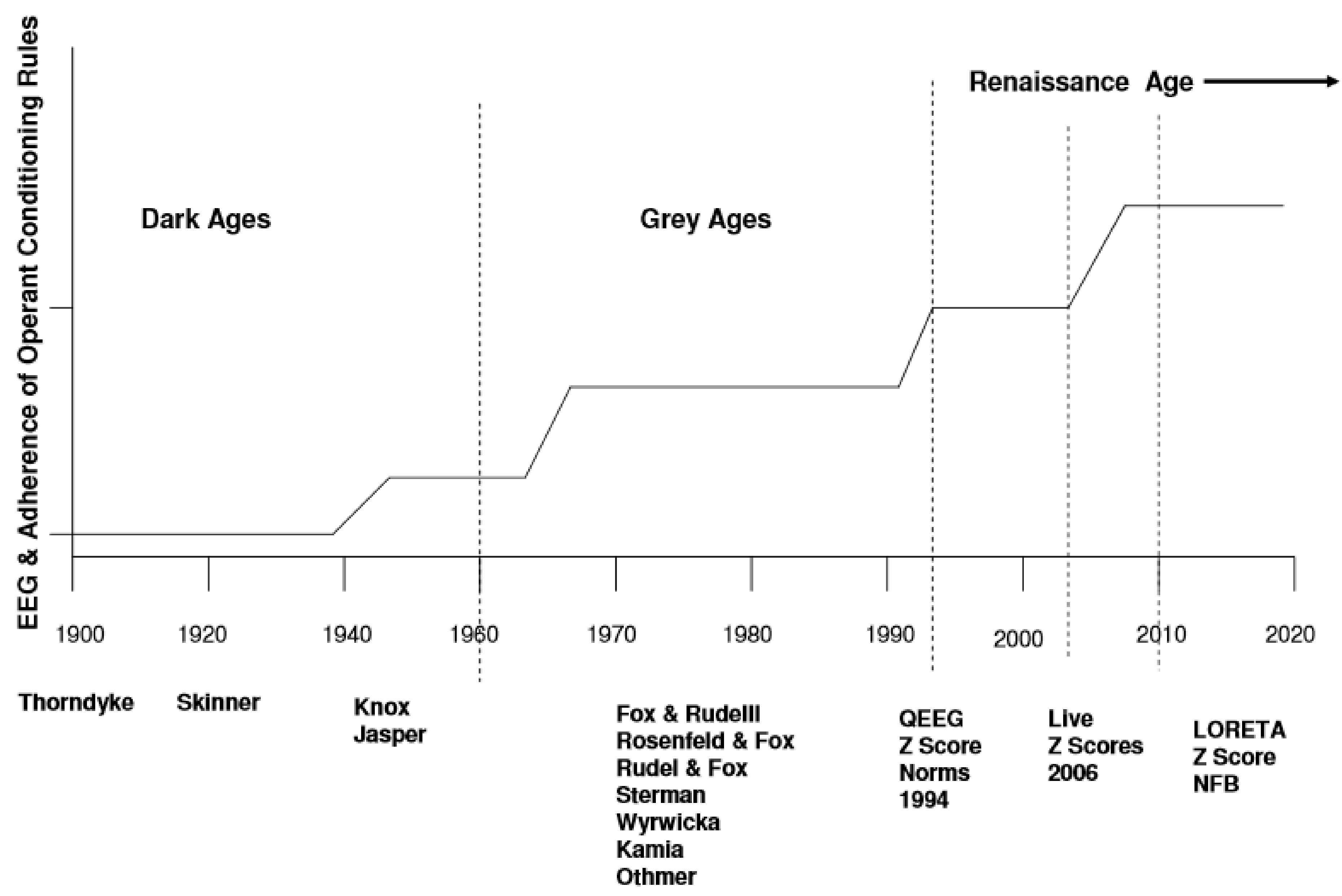
Network Z Scores



The BrainRehab Index




The BrainRehabilitator ™
Portable System
Assessment
Treatment
Dry EEG Headset
EEG Control
Pre vs Post Treatment Statistics
And Z Score EEG Biofeedback
BrainRehab Index
NeuroRehab Network Index
EEG Tests
1
2
3
GOOD
FAIR
MOD
POOR
Network Z Scores
Addiction
Anxiety
Attention Dorsal
Attention Ventral
Default Mode
Executive
Memory
Mood
Pain
Pleasure
NeuroFeedback
Photobiomodulation
Electrical Brain
Stimulation tDC


EEG & Adherence of Operant Conditioning Rules
Renaissance Age
Dark Ages
Grey Ages
1900
1920
1940
1960
1970
1980
1990
2000
2010
2020
Thorndyke
Skinner
Knox
Jasper
Fox & Rudelll
Rosenfeld & Fox
Rudel & Fox
Sterman
Wyrwicka
Kamia
Othmer
QEEG
Z Score
Norms
1994
Live
Z Scores
2006
LORETA
Z Score
NFB

What is the Future for Z Score Neurofeedback?

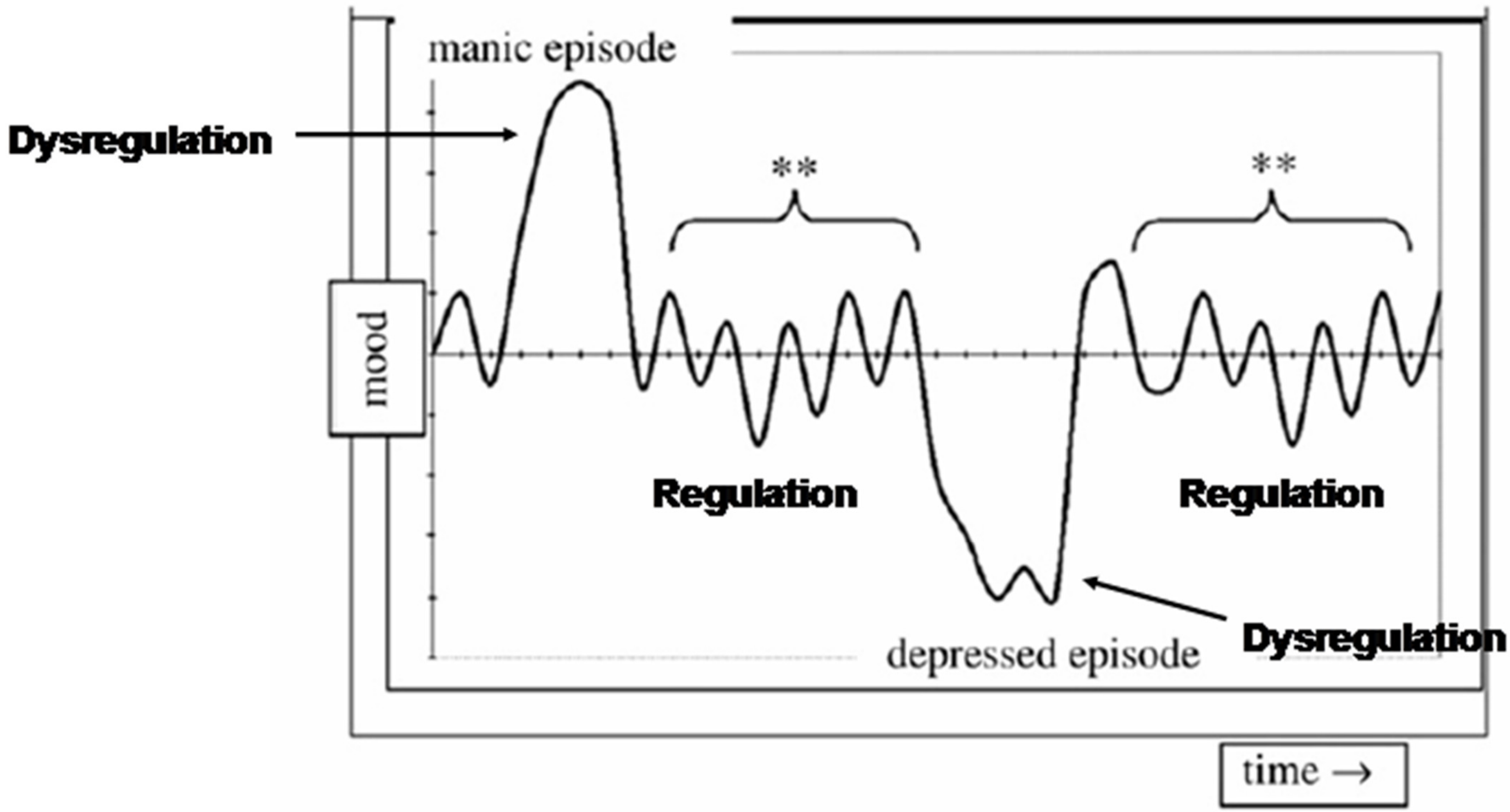
1- Expanding Number or Clinicians Using Z Score NFB

2- Expanding Number of Metrics:
- a- Effective Connectivity
- b- Cross-Frequency Coherence
- c- Cross-Frequency Effective Connectivity
- d- Phase Amplitude Cross-Frequency Coupling
- e- swLORETA – Individualized MRI & NFB

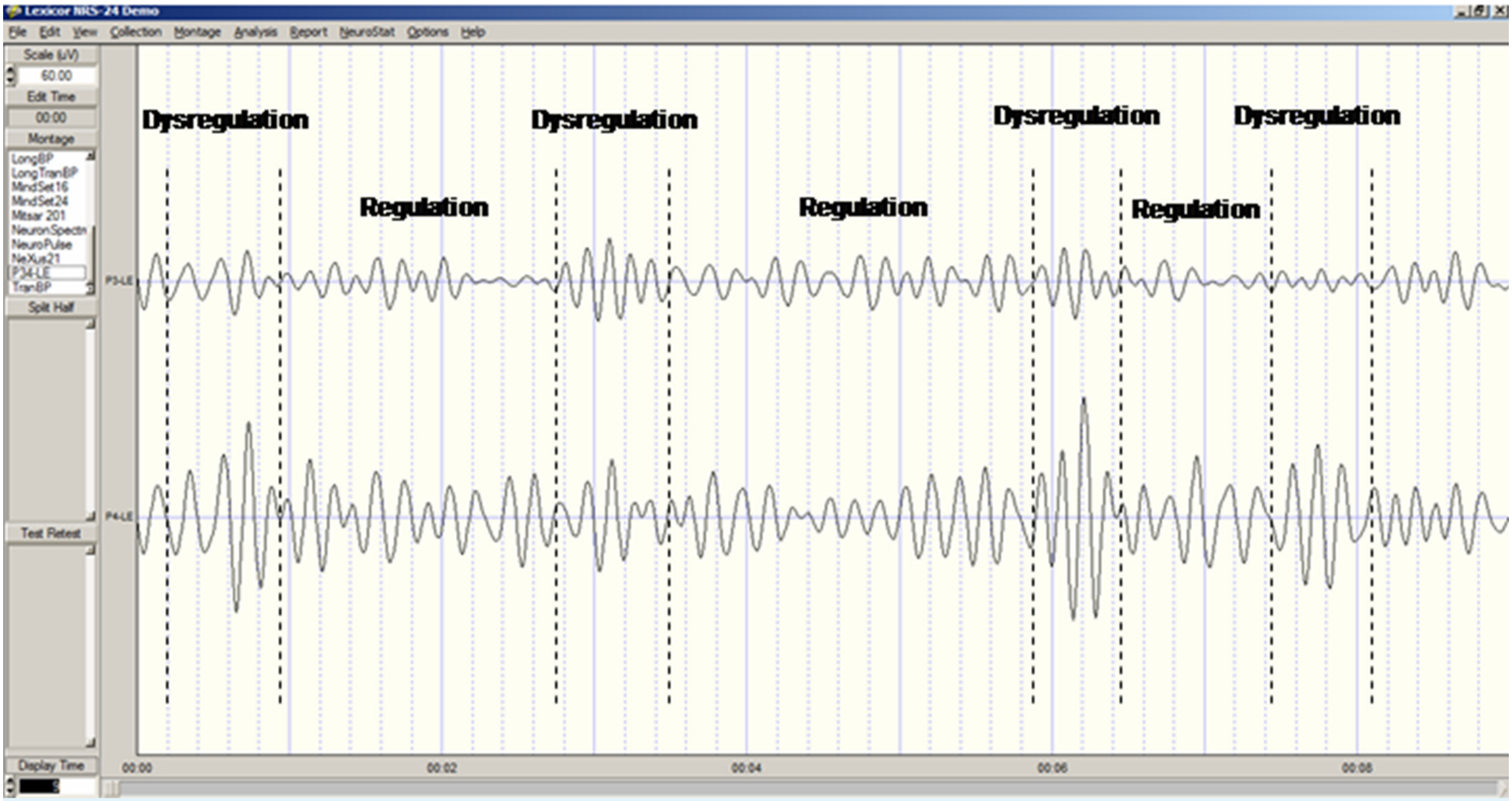
3- New Brain Imaging Technology

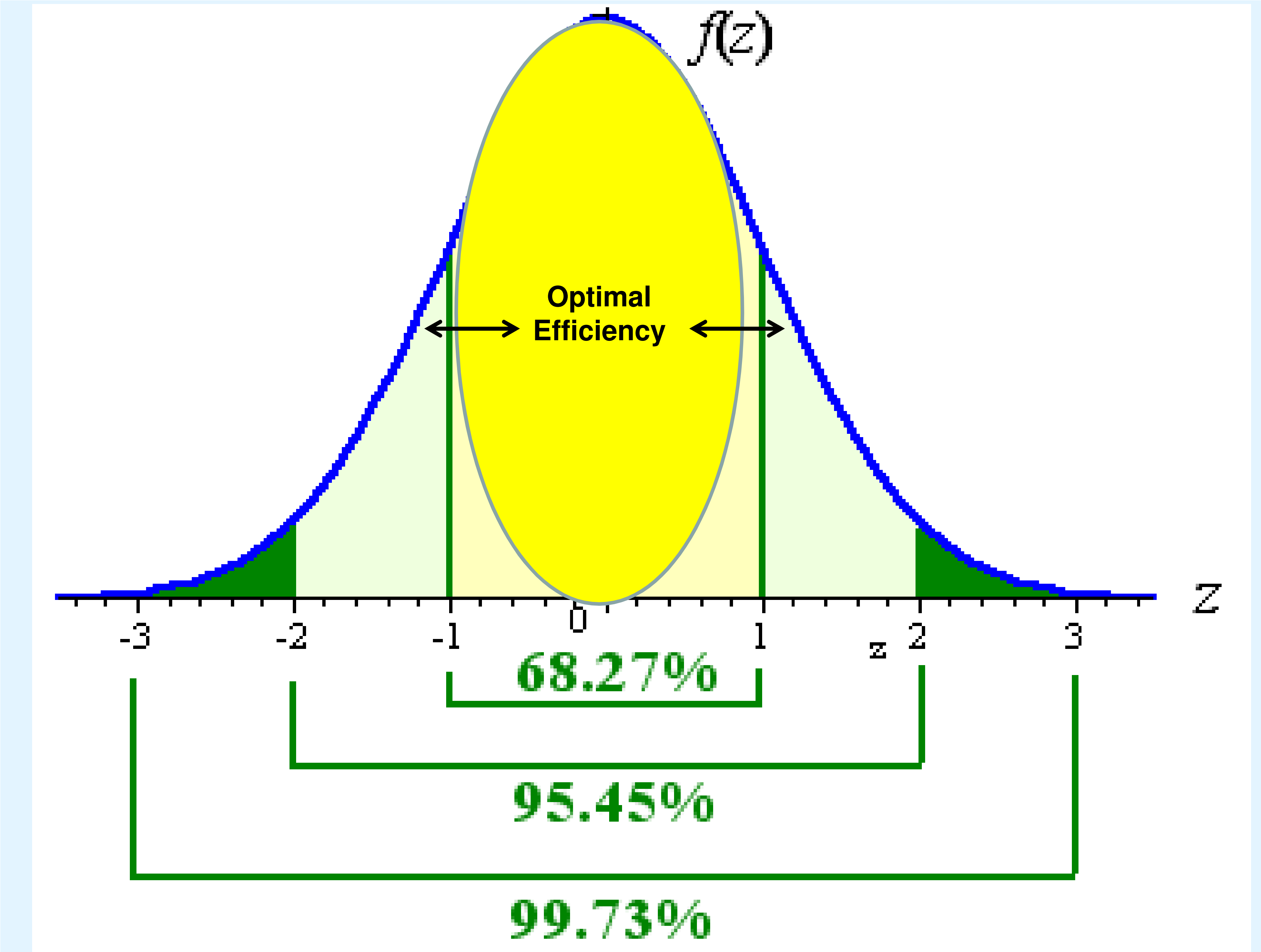
4- Smart Phone and Tablet Techology

Moment-to-Moment “Regulation” and “Dysregulation”

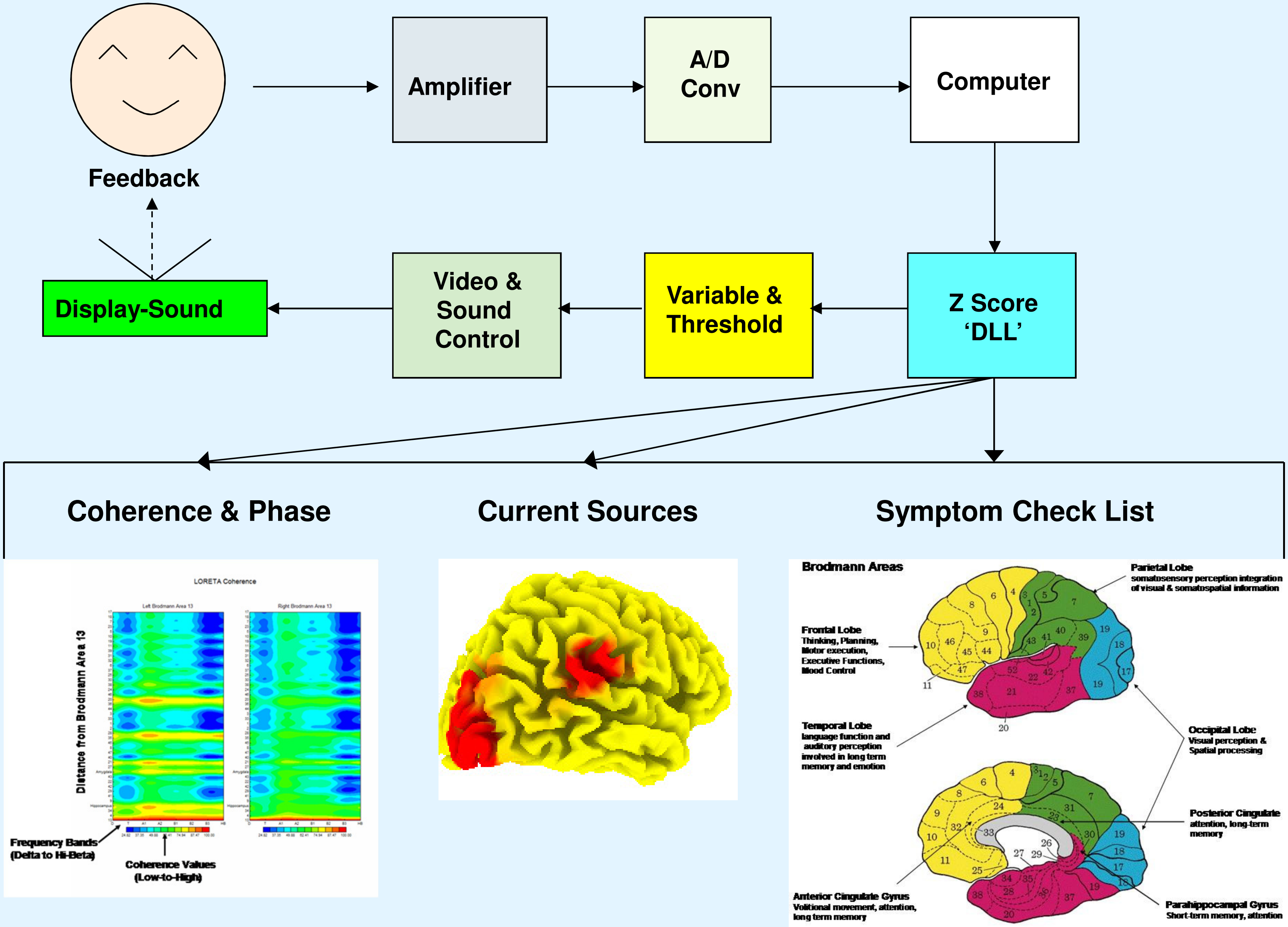


TBI Demo Right Parietal Lobe Alternating Degrees of Regulation Biofeedback's Goal is to Reduce the Frequency, Duration and Intensity of Dysregulation




f(z)
Optimal
Efficiency
Z
-3
-2
-1
0
1
z
2
3
68.27%
95.45%
99.73%

Neuroimaging Neurofeedback - Fort Campbell



LMU
KLINIKUM DER UNIVERSITÄT MÜNCHEN
DEPARTMENT OF PSYCHIATRY
INSTITUTE OF CLINICAL RADIOLOGY

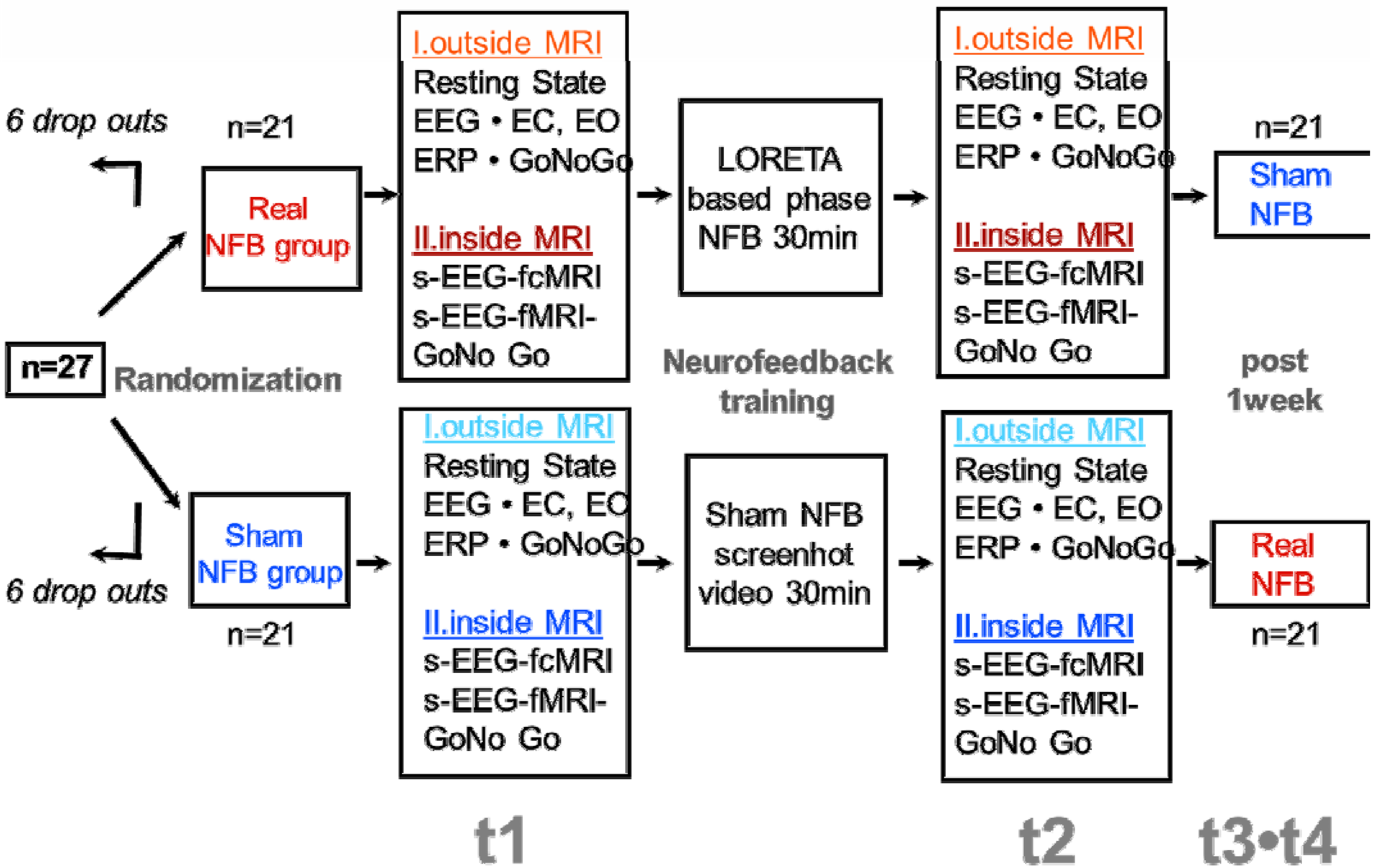
The impact of source-localized EEG phase neurofeedback on brain activity

A double-blinded placebo-controlled study using simultaneously EEG-fMRI – preliminary results

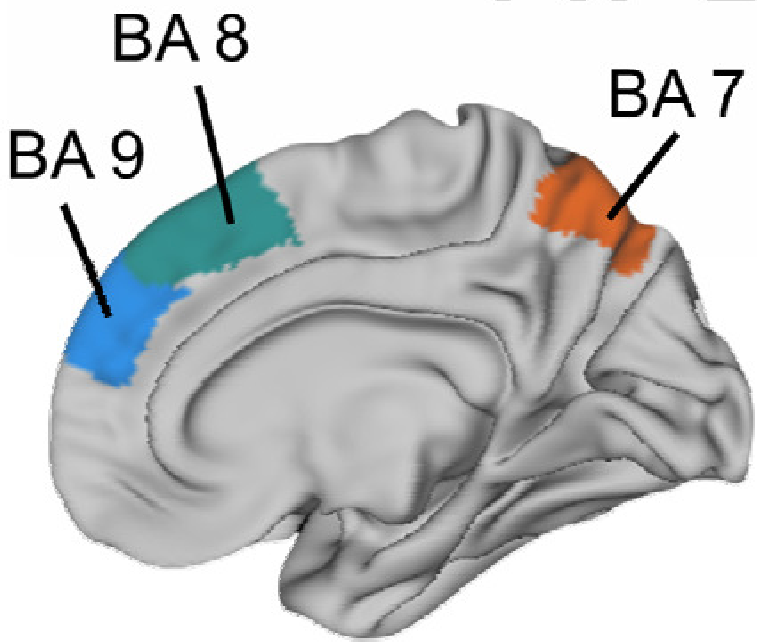
Daniel Keeser

Valerie Kirsch, Boris Rauchmann, Brian Stamm, Paul Reidler, Robert Thatcher, Susanne Karch, Oliver Pogarell, Birgit Ertl-Wagner

s-EEG-fcMRI neurofeedback study design



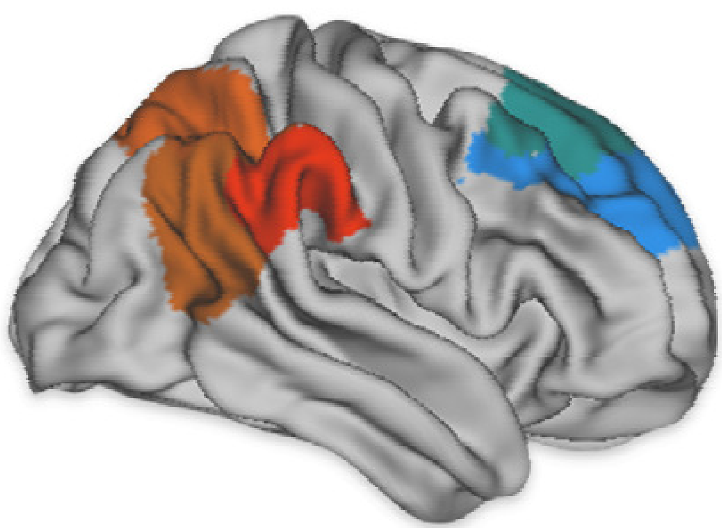
NFB protocol

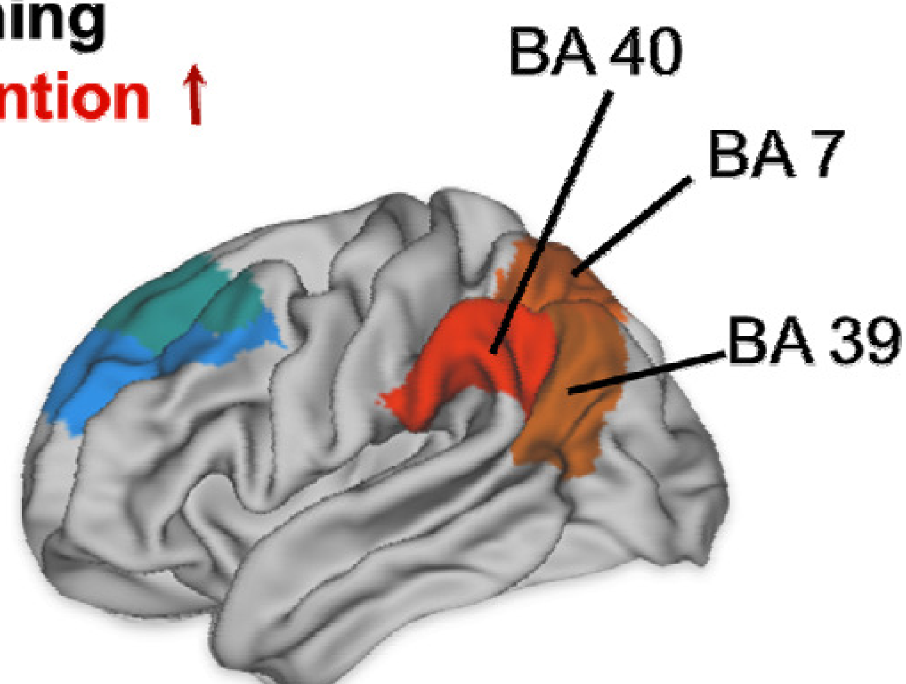


Alpha 1 (8-10 Hz)
Alpha 2 (10-12 Hz)
Beta 1 (12-15 Hz)

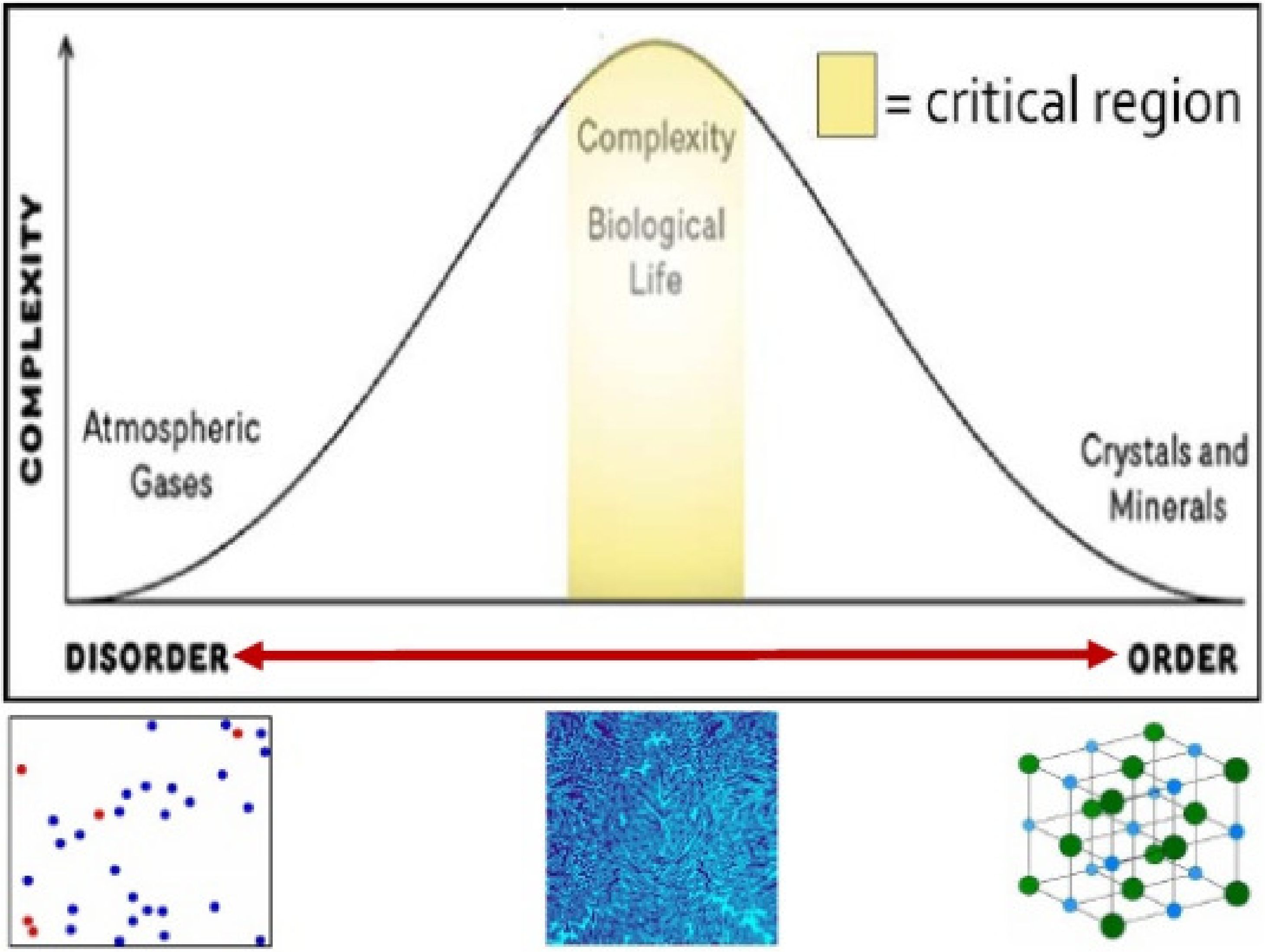
EEG phase training

Attention ↑

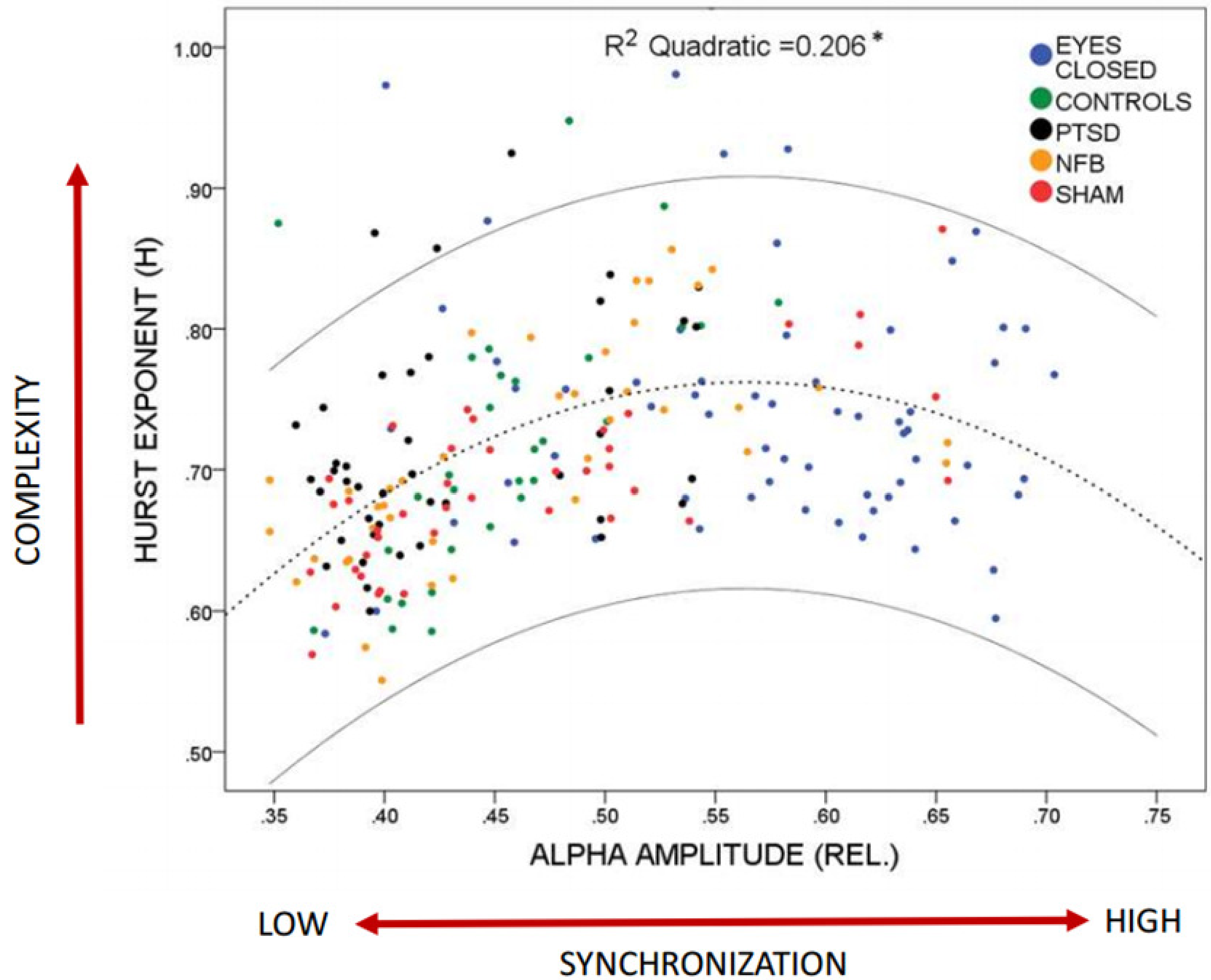




The Theory of Self-Organised Criticality

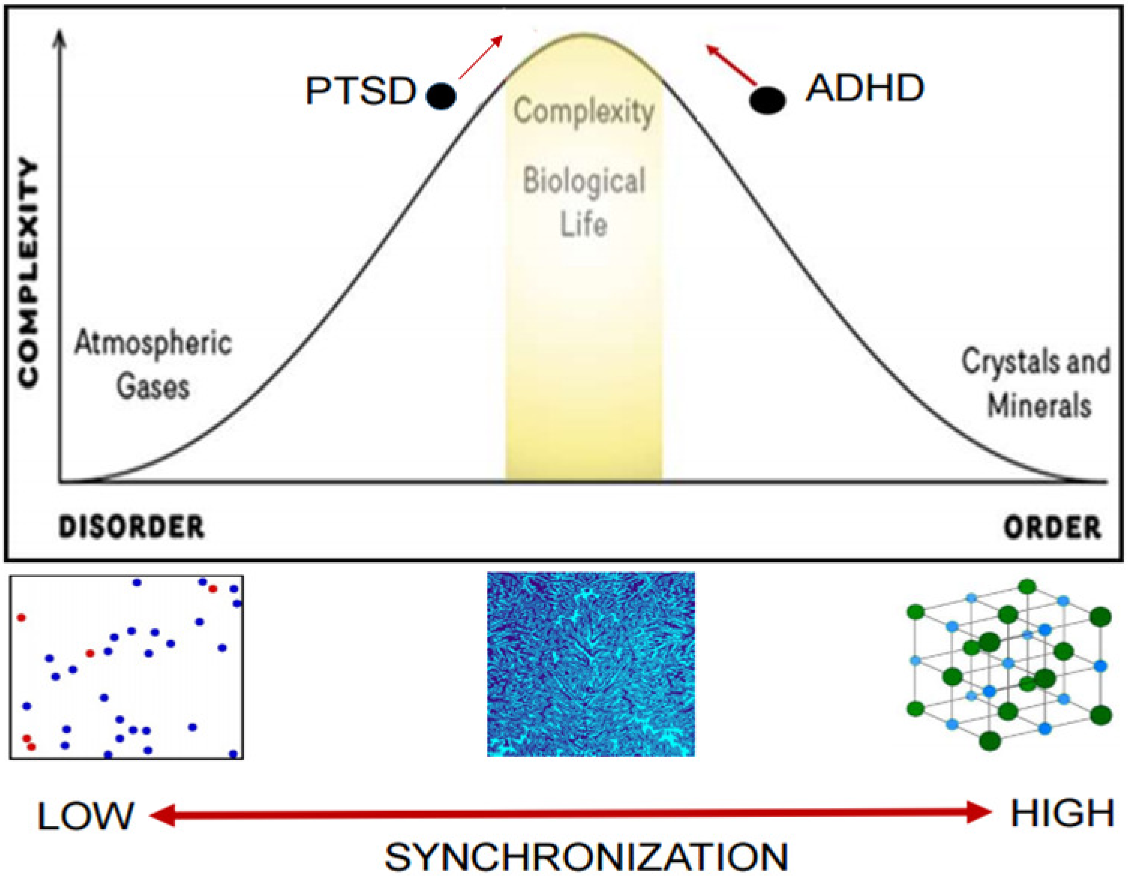


Tuning-pathological-brain-oscillations-Thomas Ros- 2016



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

Self-Organised Criticality: a potential mechanism?



Tuning-pathological-brain-oscillations-Thomas Ros- 2016

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HUMAN NEUROSCIENCE

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doi: 10.3389/fnhum.2014.01008

Tuning pathological brain oscillations with neurofeedback: a systems neuroscience framework

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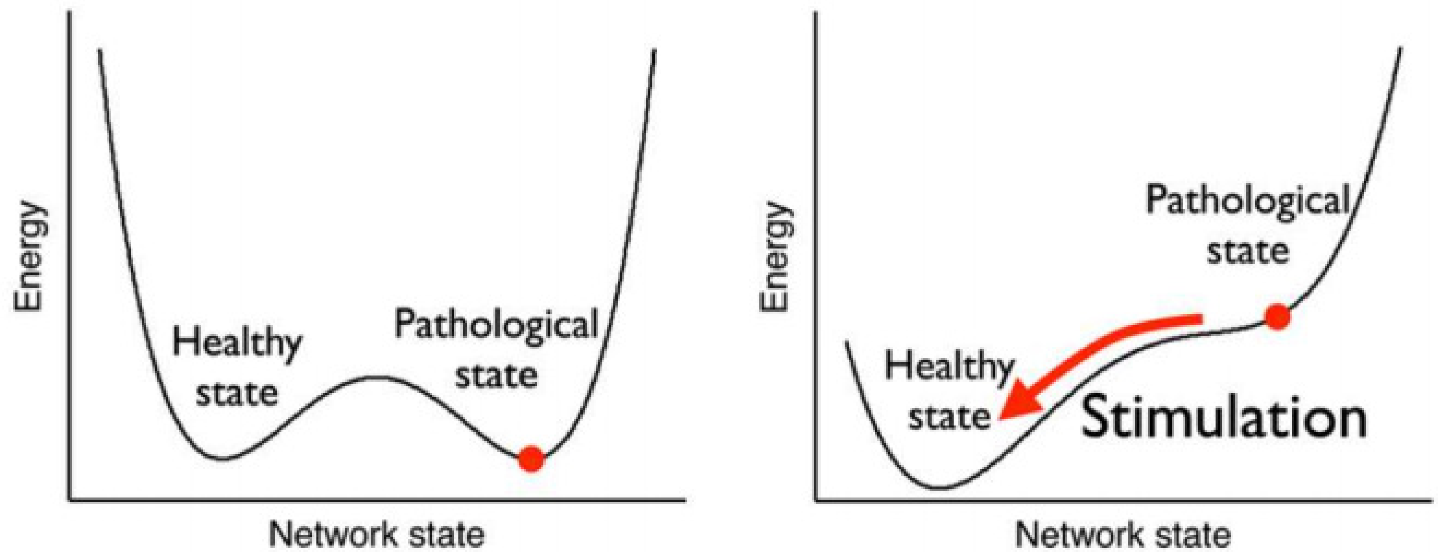


Select a Network or Symptoms, Frequency and Metric

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Network	Severity
Addiction	0
Anxiety	0
Attention - Dorsal	0
Attention - Ventral	0
Attention - Emotional	0
Default Mode	0
Executive Function	0
Face, Object Recognition	0
Language	0
Memory - Emotion	0
Mirror Neuron	0
Mood	0
Pain	0
Pleasure	0
Salience	0
Schizophrenia	0
Working Memory	0
DTI - Frontal Limbic	0
DTI - Frontal Occipital	0
DTI - Frontal Parietal	0
DTI - Frontal Temporal	0
DTI - Local Frontal	0
DTI - Local Limbic	0
DTI - Local Occipital	0
DTI - Local Parietal	0
DTI - Local Temporal	0
Hagmann Module 1 (Vision)	0
Hagmann Module 2 (Attention, Working Memory)	0
Hagmann Module 3 (Auditory, Language, Memory)	0
Hagmann Module 4 (Auditory, Language, Memory)	0
Hagmann Module 5 (Executive, Sequential Planning)	0
Hagmann Module 6 (Executive, Social Skills)	0
Isocortex Hippocampocentric	0
Isocortex Olfactocentric	0
Mesocortex Hippocampocentric	0
Mesocortex Olfactocentric	0
Mesulam - Emotional Memory	0
Mesulam - Executive Function	0
Mesulam - Face/Object Indentification	0
Mesulam - Language	0
Mesulam - Spatial Attention	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Intrinsic Connectivity Network	Severity
ICN 1 (Limbic, Medial-Temporal, Emotion)	0
ICN 2 (Reward, Emotion)	0
ICN 4 (Language, Executive)	0
ICN 6 (Premotor, Supplemental Motor)	0
ICN 7 (Visual-Spatial Processing)	0
ICN 8, 17 (Primary Sensory Motor)	0
ICN 9 (Parietal)	0
ICN 10 (Picture Naming, Visual Tracking)	0
ICN 11, 12 (Visual System)	0
ICN 13 (Default Mode Network)	0
ICN 15 (Right Hemisphere, Attention, Reasoning, Memory)	0
ICN 16 (Auditory, Music)	0
ICN 18 (Left Hemisphere, Language)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Neuropsychological Diagnosis	Severity
Agnosia of Action Apperceptive	0
Agnosia of Action Associative	0
Agnosia Auditory Apperceptive	0
Agnosia Auditory Associative	0
Agnosia Auditory Space	0
Agnosia Prosopagnosia (Face)	0
Agnosia Social Emotional	0
Agnosia Social of Action - Theory of Mind	0
Agnosia Somatosensory Autotopagnosia	0
Agnosia Somatosensory Finger	0

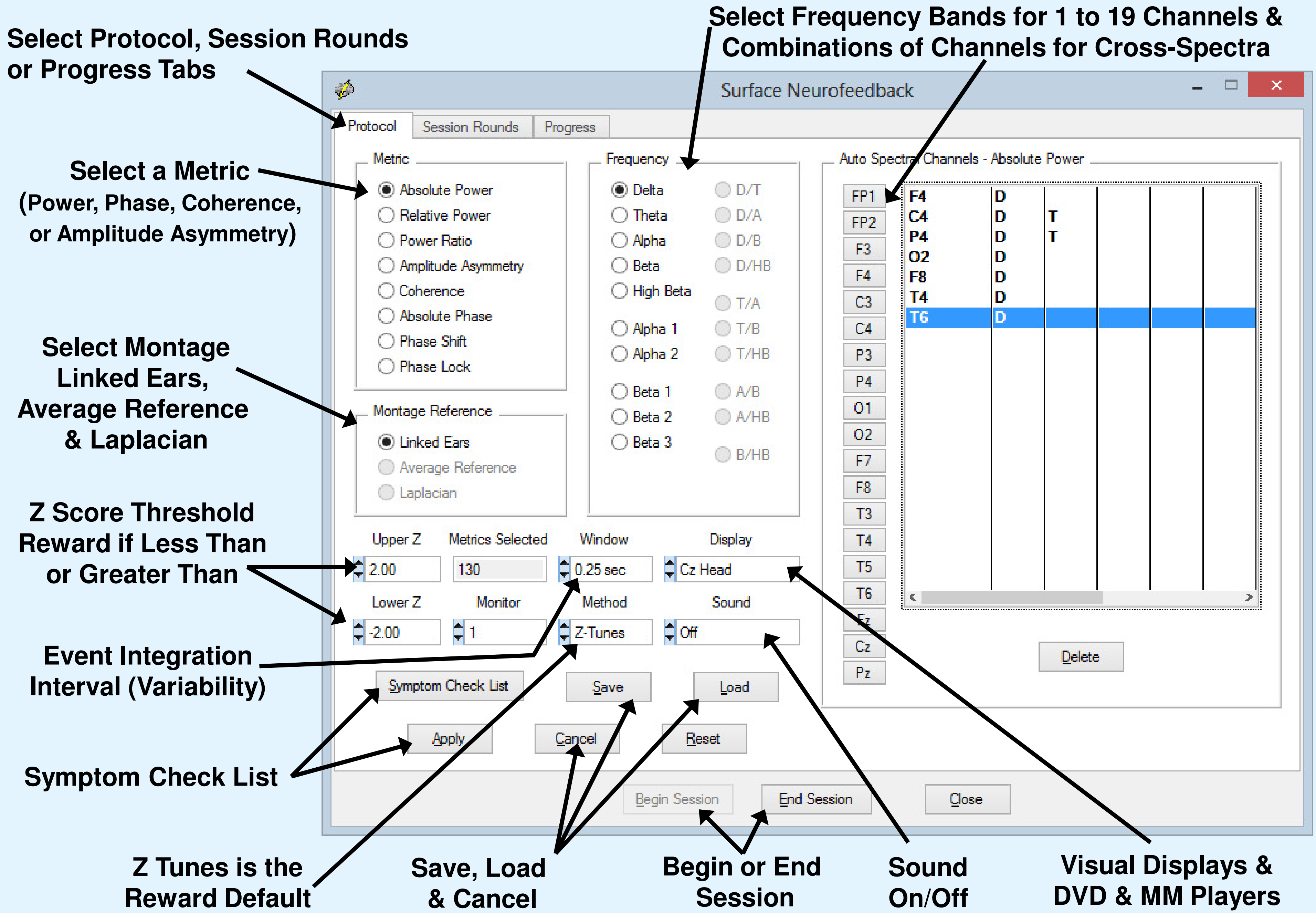
Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Attention - Re-Experiences Intrusive Memories	0
Attention - Emotional Numbing	0
Attention - Distracting Pain	0
Attention - Difficulty Multi-Tasking	0
Attention - Worsens with Emotional Stress	0
Attention - Dissociative Episodes	0
Attention - Worsens With Withdrawl Symptoms	0
Chronic Pain - Neuropathic	0
Chronic Pain - Musculoskeletal	0
Chronic Pain - Diffuse Pain (Entire Body)	0

Symptoms | ICN | Networks | Neuropsychological | DoD/VA

Symptom / Complaint	Severity
Anosognosia - Denial of a Problem	0
Anxiety	0
Attention Deficits - Easily Distractible	0
Auditory Sequencing Problems	0
Balance Problems	0
Blurred Vision	0
Chronic Pain	0
Compulsive Behaviors and/or Thoughts	0
Concentration Problems	0
Decreased Tactile or Skin Sensitivity	0
Delusional	0
Depression (Sad & Blue)	0
Difficulty Comprehending Social Cues	0
Dyscalculia - Problems Calculating	0
Dyslexia - Letter Reversal	0
Executive Function Problems	0
Face Recognition Problems	0
Failure to Initiate Actions	0
Hyperactive and/or Agitation	0
Impulsive Behaviors	0
Insensitive to Others Emotional Expressions	0
Insensitive to Other's Feelings	0
Low Motivation	0
Low Threshold for Anger & Loss of Control	0
Migrane Headaches	0
Mood Swings	0
Multi-Tasking Problems	0
Obsessive Thoughts about Self	0
Obsessive Thoughts and/or Hyper Focused	0
Oppositional Defiant Conduct	0
Orientation in Space Problems	0
Perception of Letters Problems	0
Poor Judgement	0
Poor Skilled Motor Movements	0
Poor Social Skills	0
Receptive Language Problems	0
Recognizing Objects by Touch Problems	0
Self-Esteem Problems	0
Sequential Planning Problems	0
Short-Term Memory Problems	0
Slow Reader	0
Slowness of Thought - Easily Confused	0
Spatial Perception Problems	0
Speech Articulation Problems	0
Substance Abuse	0
Symptoms of Fibromyalgia	0
Word Finding Problems	0

Z Score Neurofeedback Panel



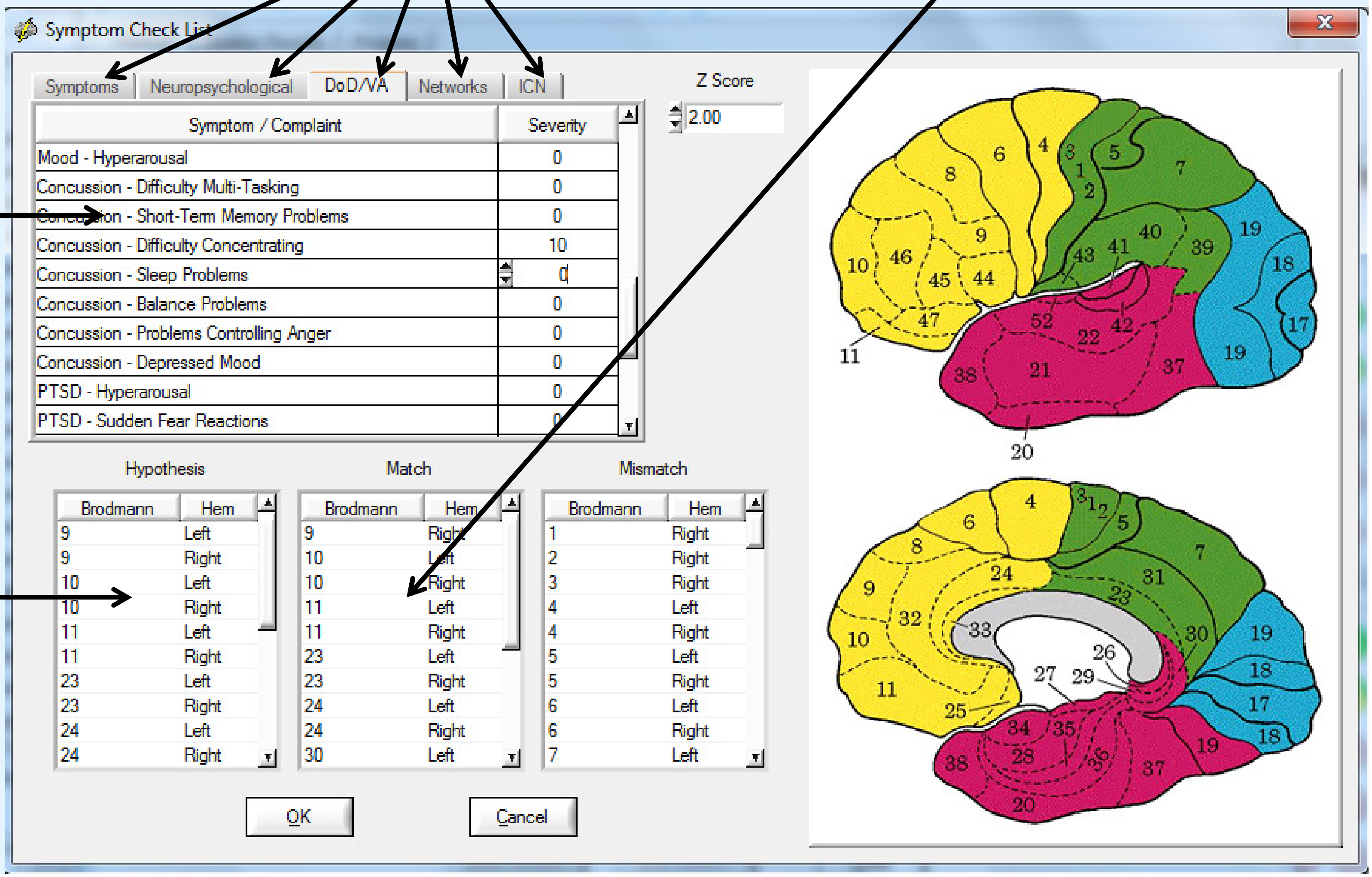
Neuroimaging Neurofeedback Symptom Check List

Click Symptoms or Neuropsychological Diagnoses or DoD/VA List or Networks & Severity

List of Matching Brodmann Areas

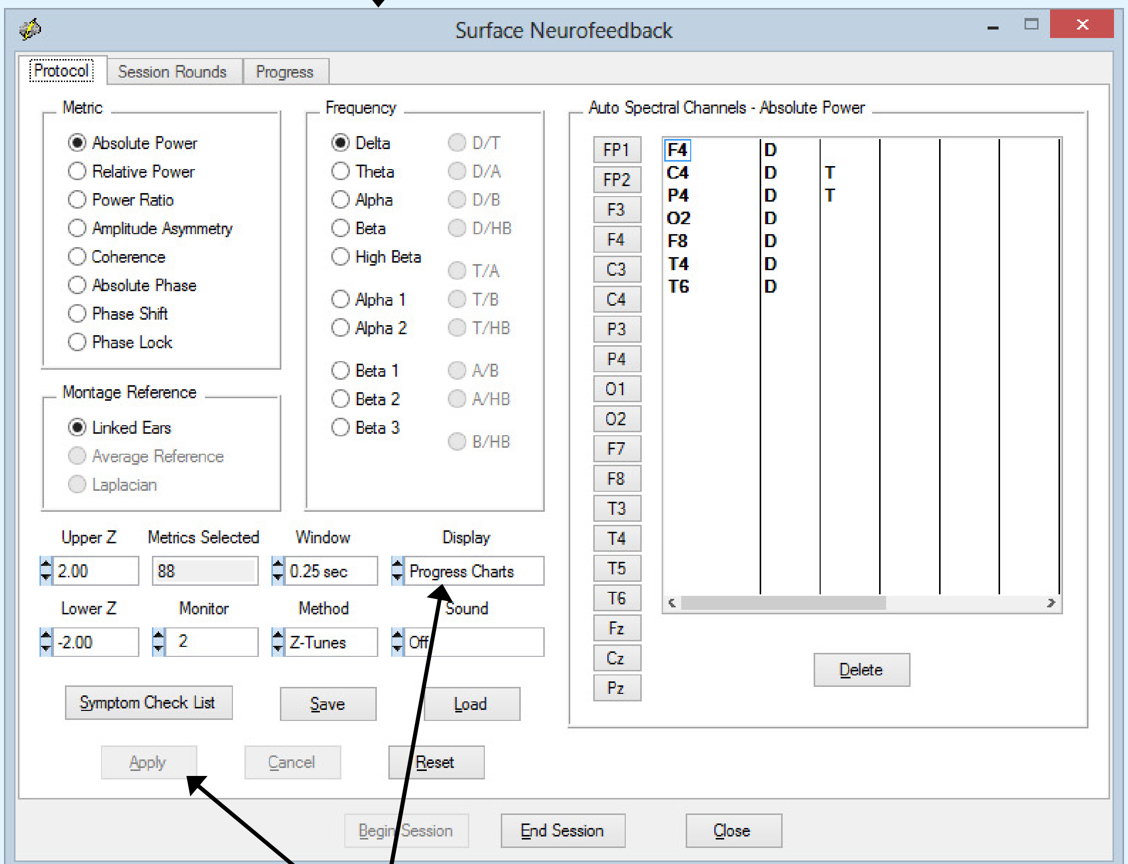
List of Symptoms

Anatomical Hypotheses

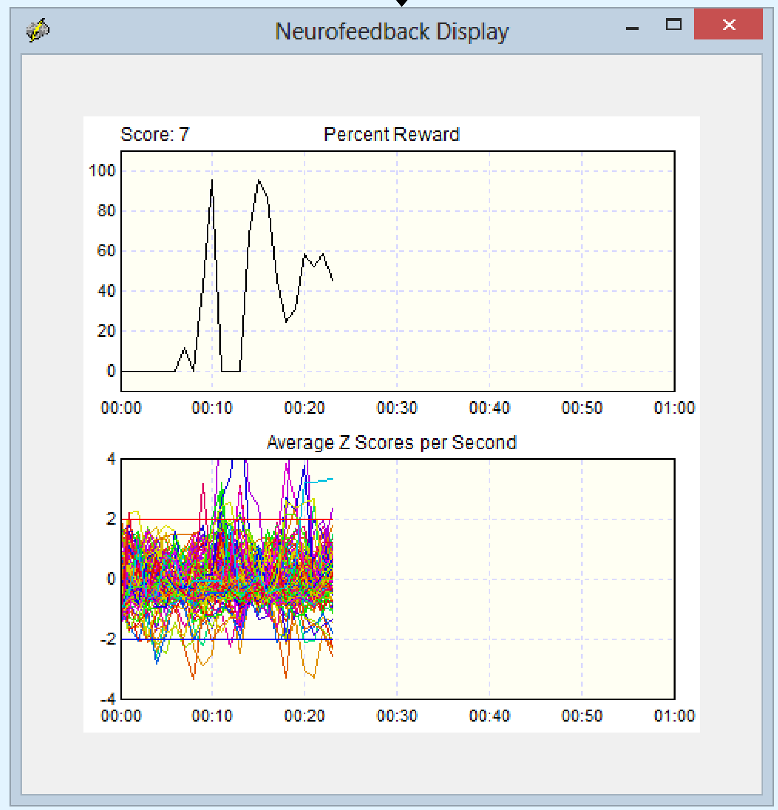


Use the Progress Chart as a Feedback Display

Neurofeedback Setup Panel



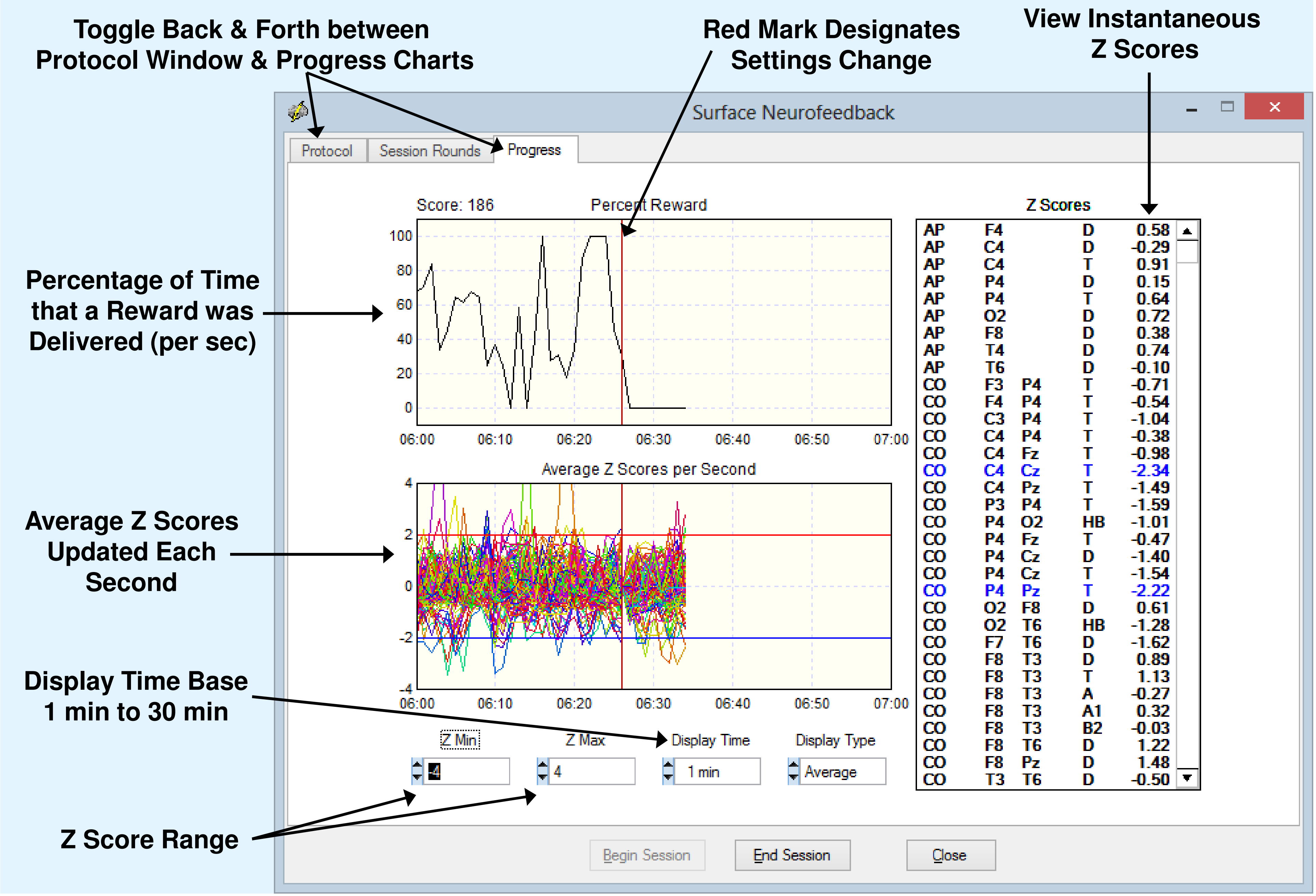
Move the Display to the Client's Monitor

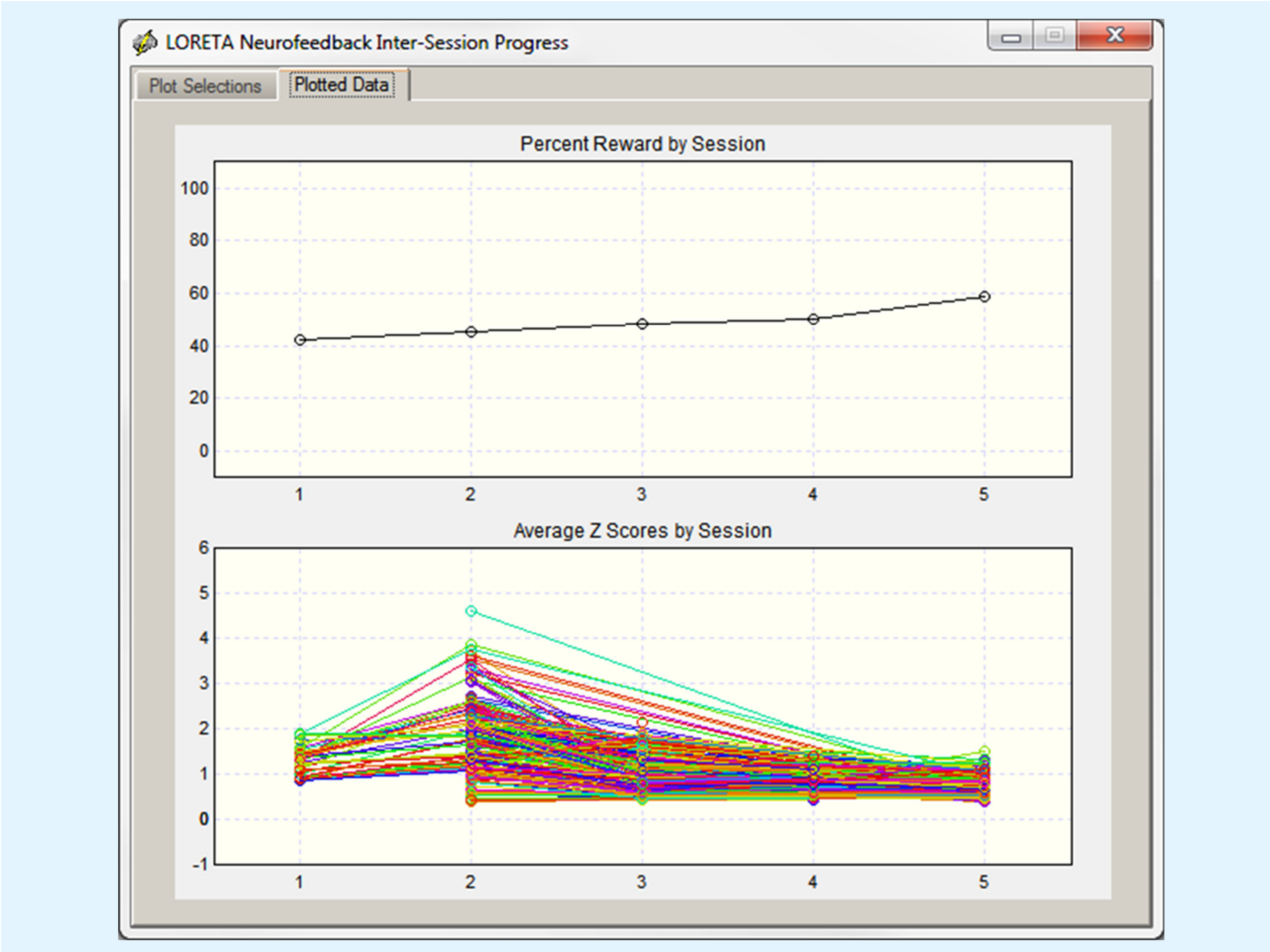


Select Progress Charts as Feedback to a Client and then Click Apply

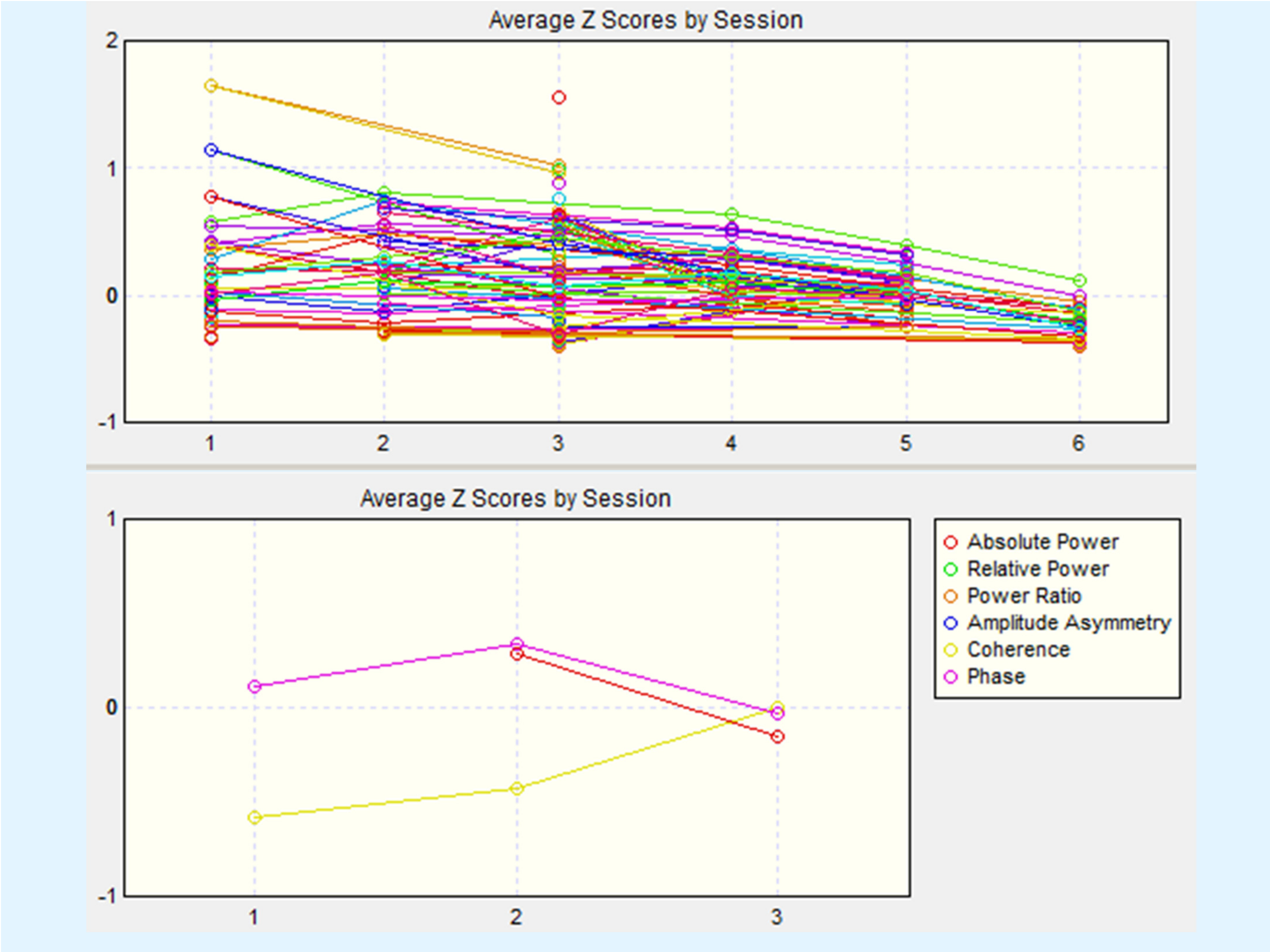
Move to the Client's Monitor

Progress Charts to be Monitored by the Clinician During Neurofeedback





LORETA Neurofeedback Inter-Session Progress
Plot Selections
Plotted Data
Percent Reward by Session
100
80
60
40
20
0
1
2
3
4
5
Average Z Scores by Session
6
5
4
3
2
1
0
-1
1
2
3
4
5

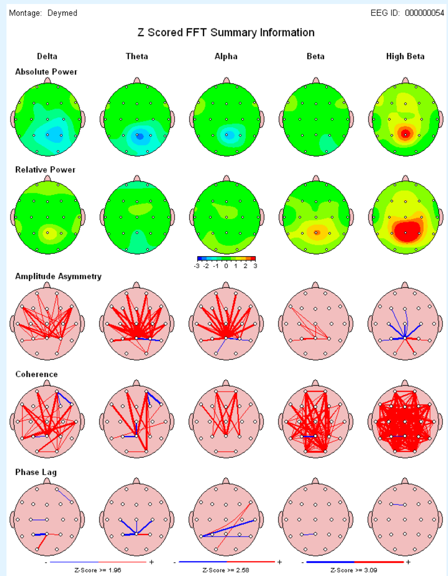


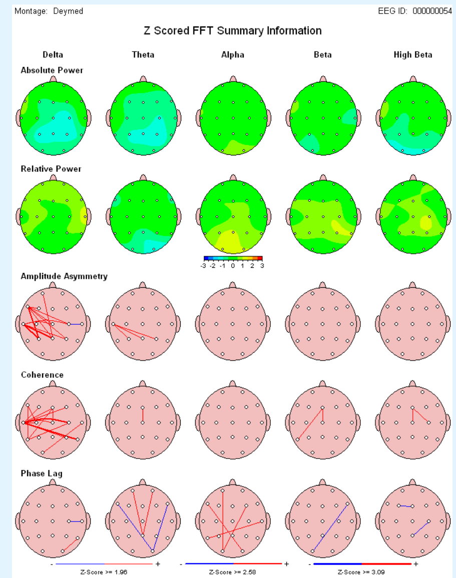
Average Z Scores by Session
2
1
0
-1
1
2
3
4
5
6
Average Z Scores by Session
1
0
-1
1
2
3
Absolute Power
Relative Power
Power Ratio
Amplitude Asymmetry
Coherence
Phase

Examples of Surface EEG Changes After EEG Neurofeedback

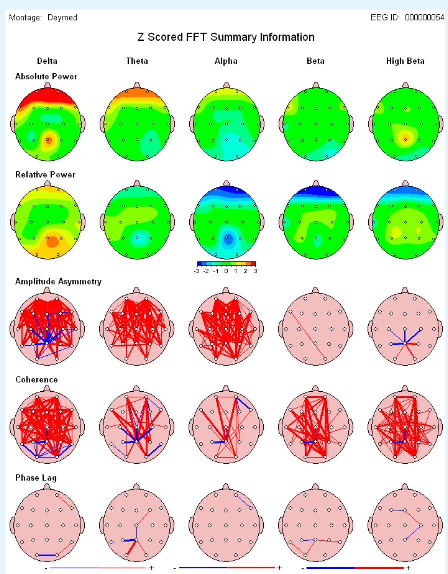
Pre-Treatment | Post – 10 Treatments

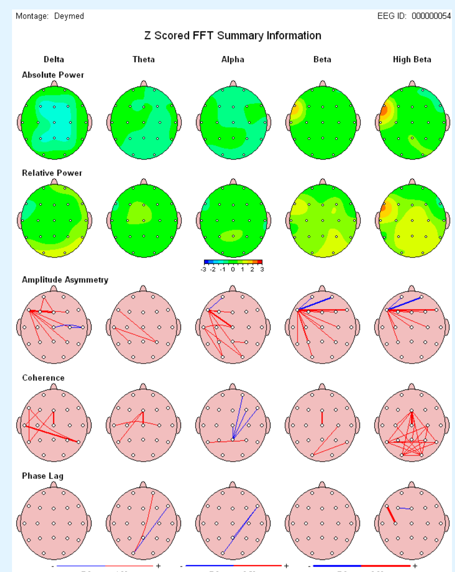
TBI Subject #1





TBI Subject #2



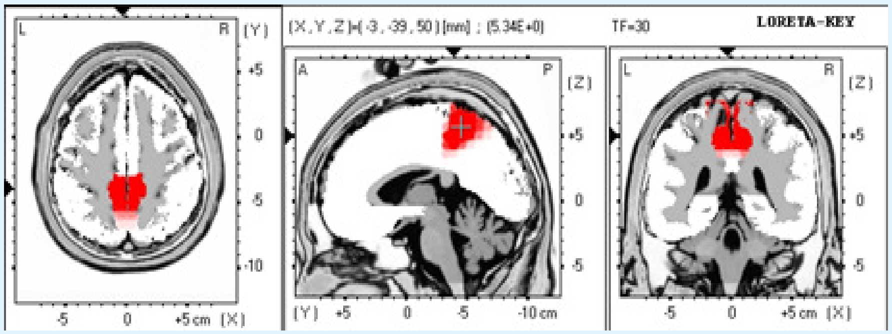


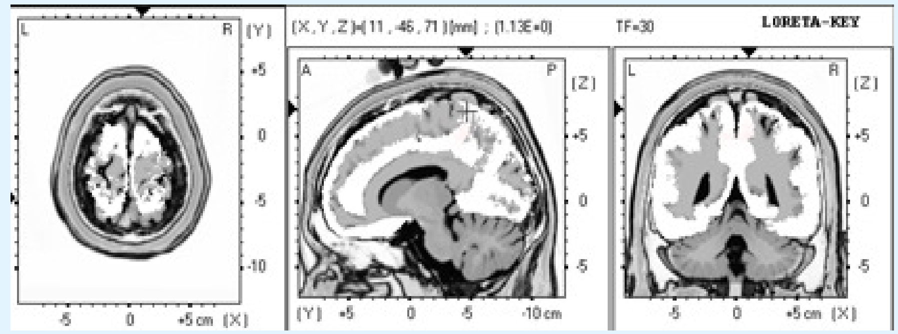
Examples of Electrical Neuroimaging After Neurofeedback

Pre-Treatment

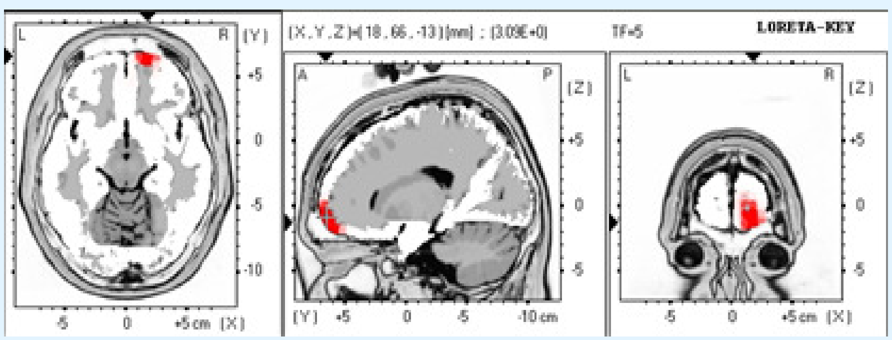
Post – 10 Treatments

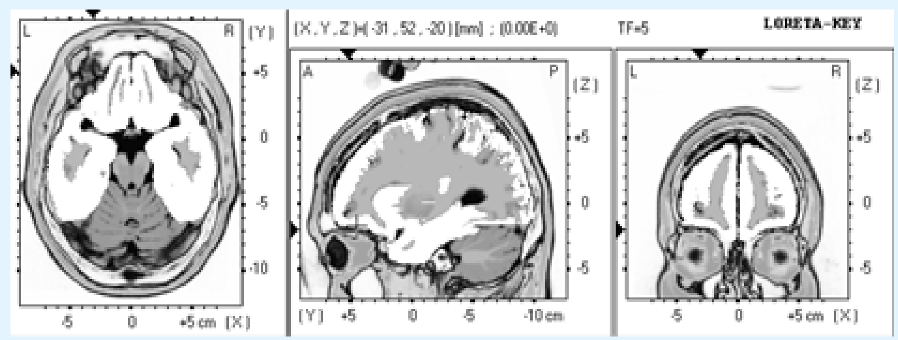
S #1

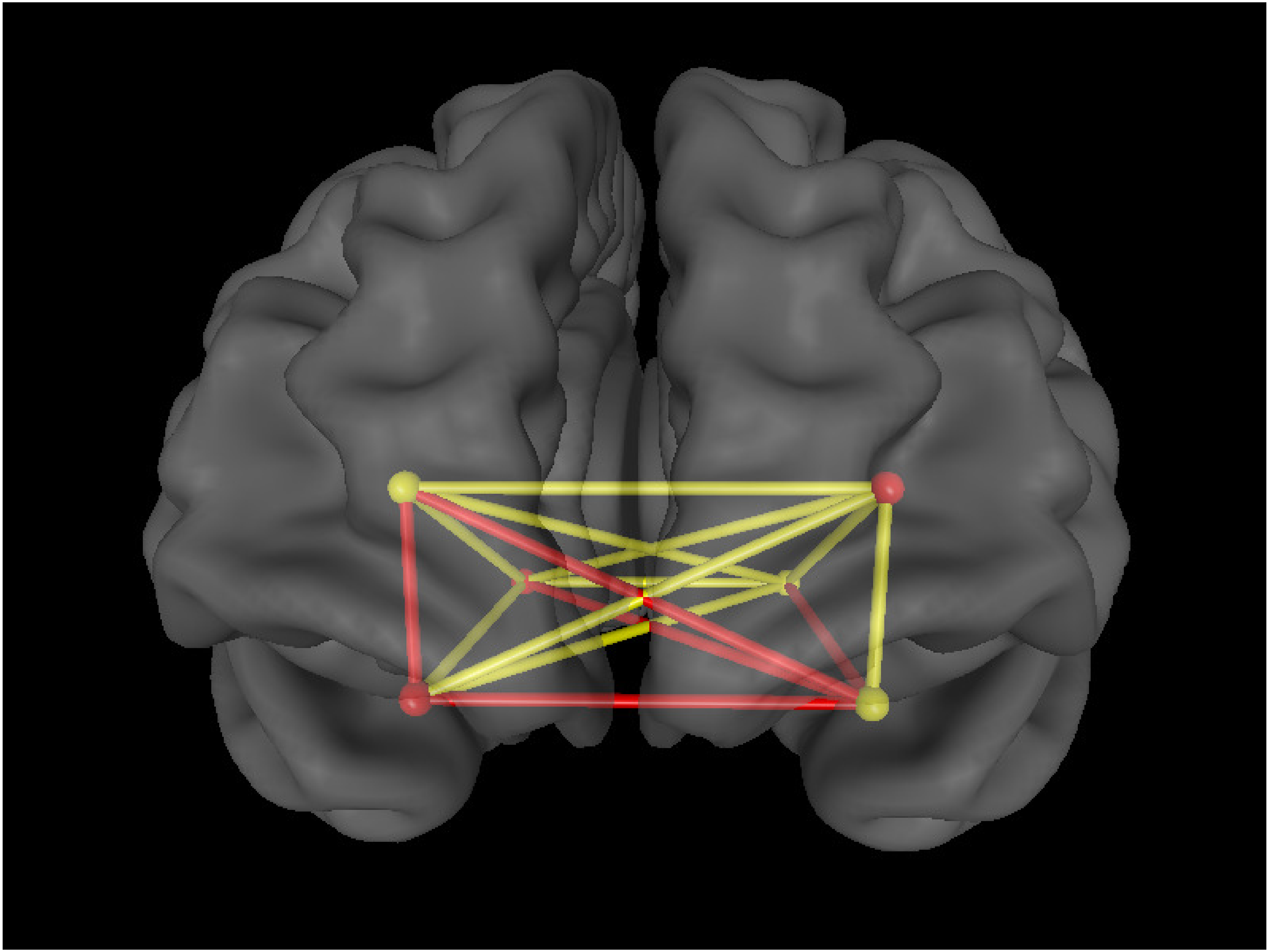


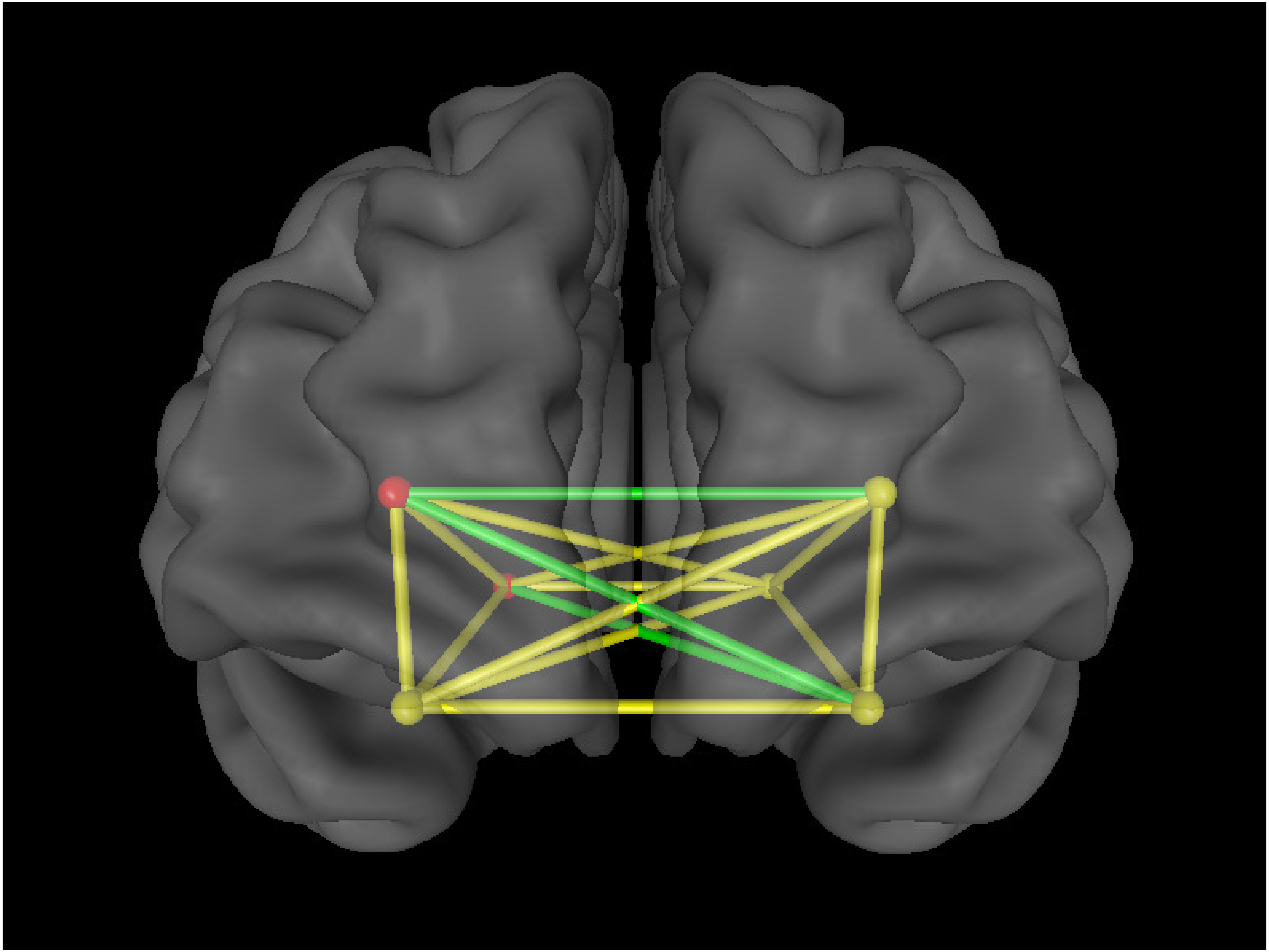


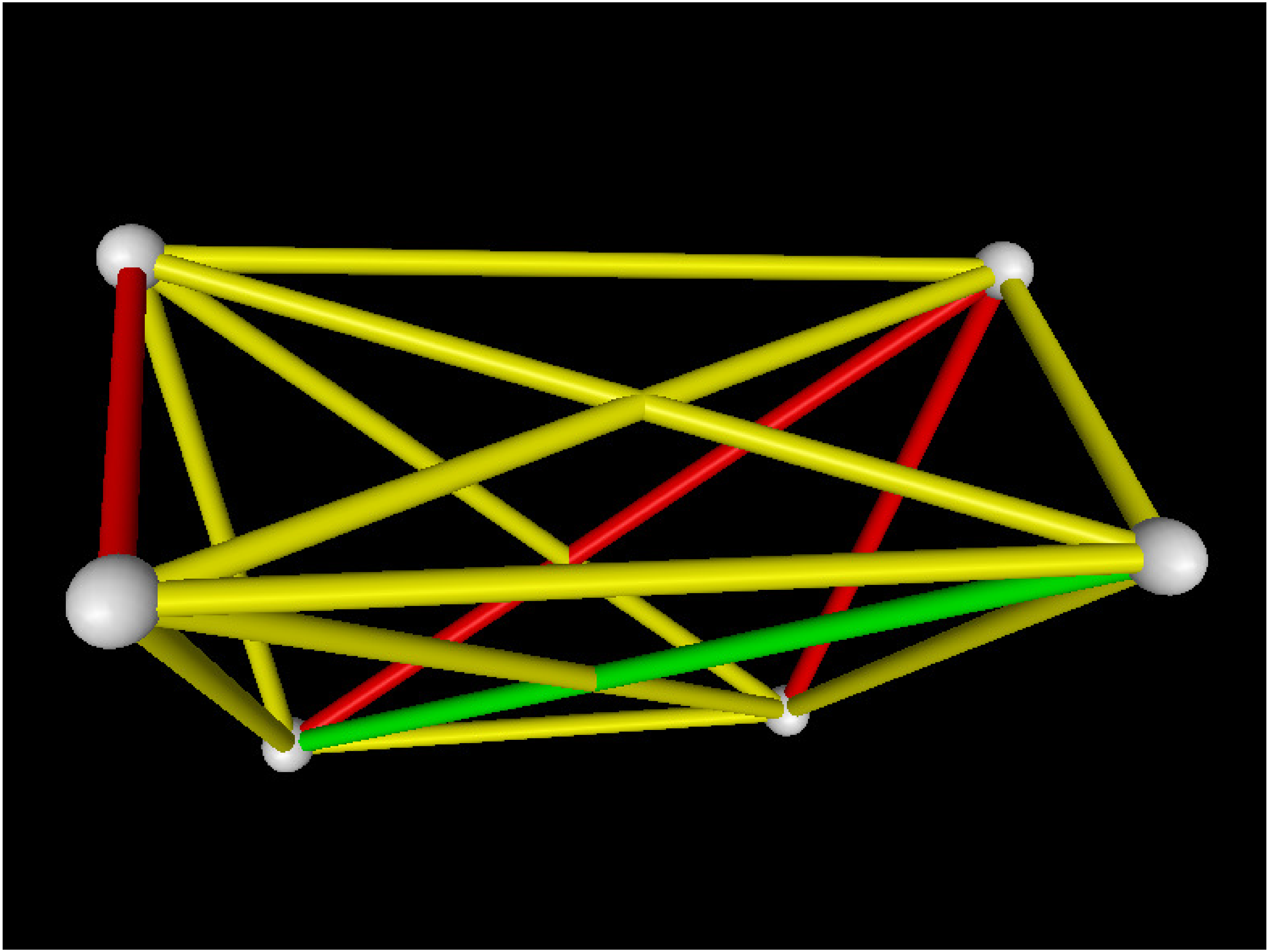
S #2

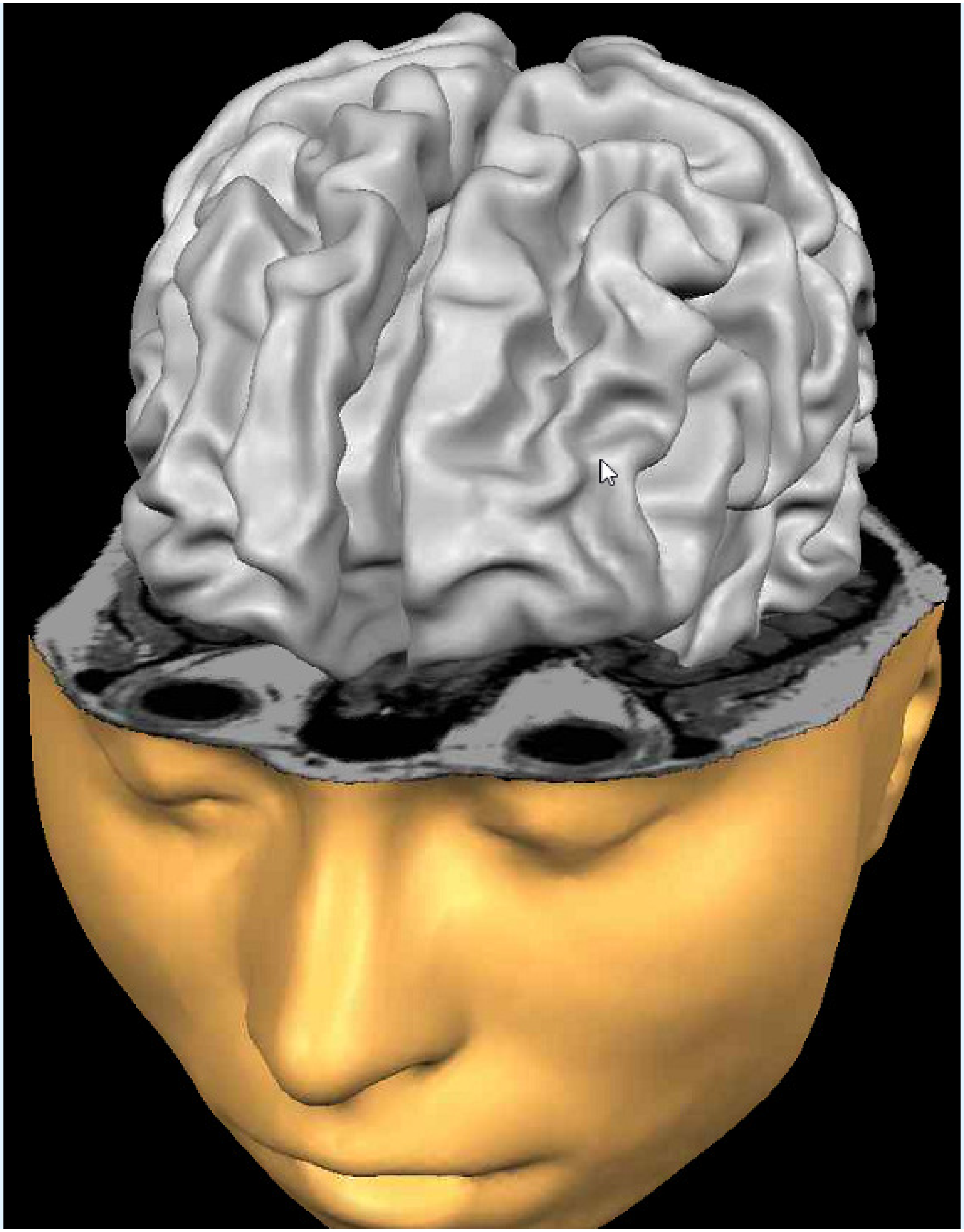


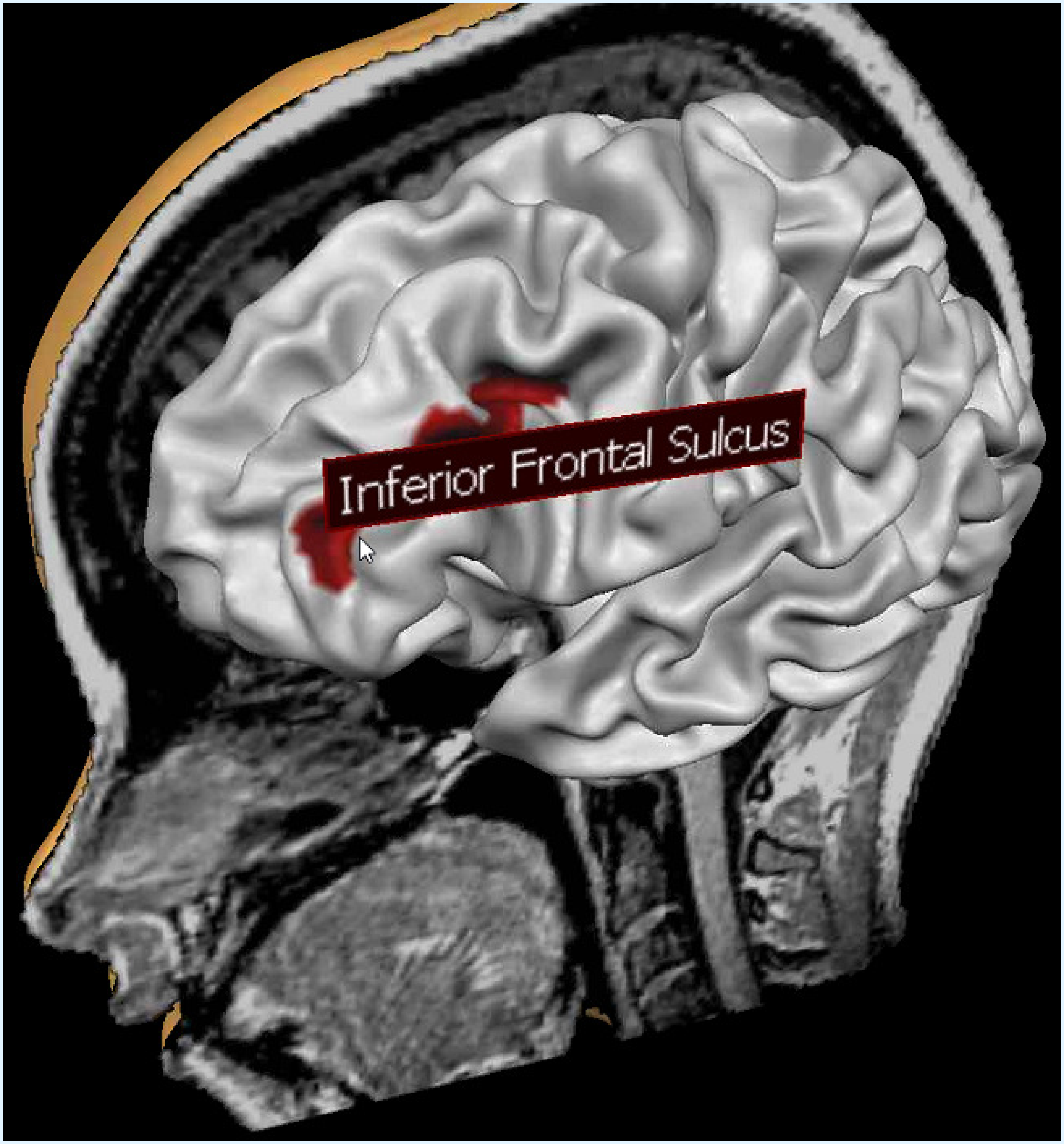











Inferior Frontal Sulcus