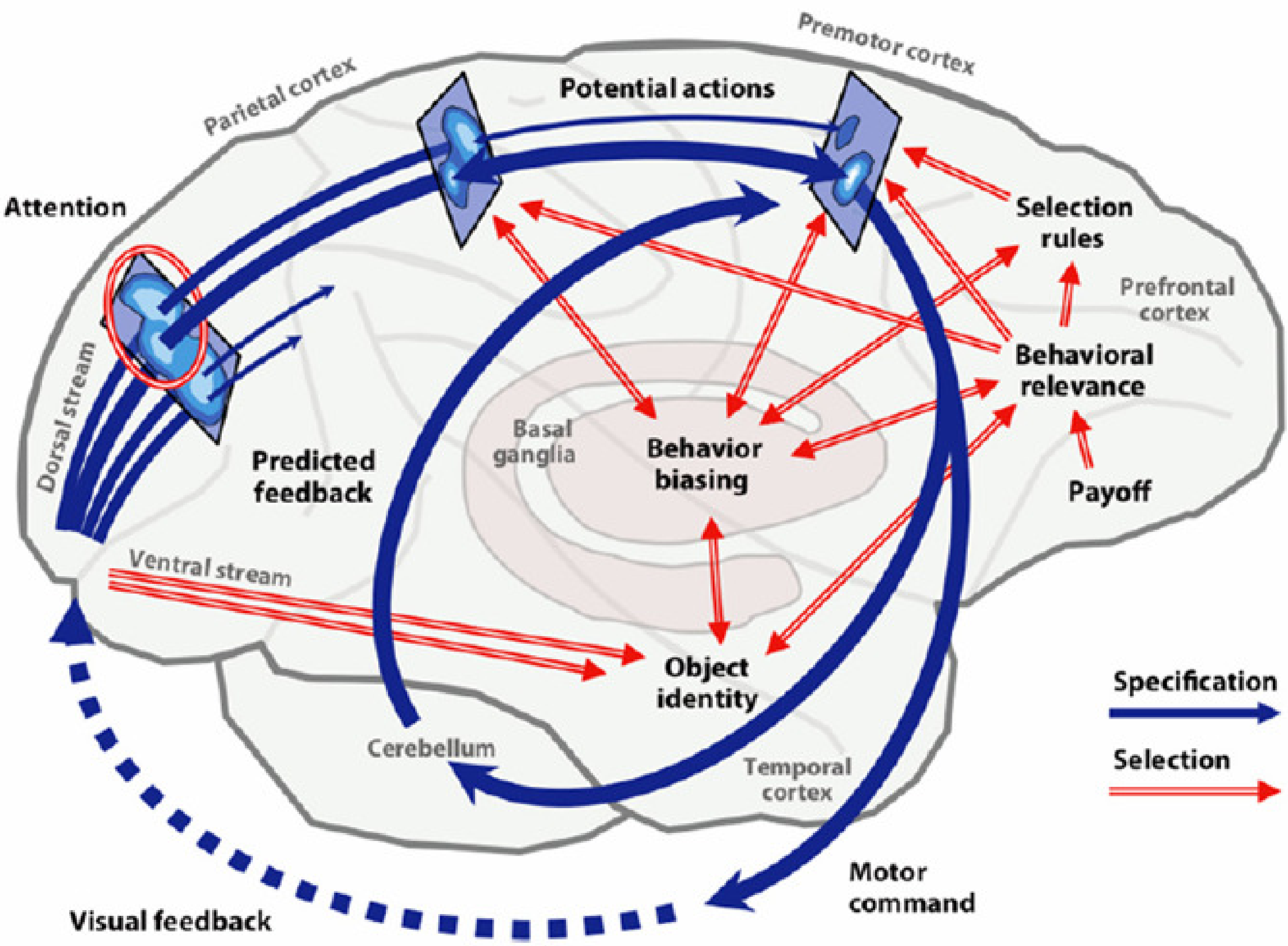
"Life is like playing a violin in a concert while learning to play and creating the score as you are playing." Rabinovic et al, (2012, p. 2)



IMPORTANT FACTS

1- Approx. 80% of Neurons are Excitatory & 20% are Inhibitory

2- Pyramidal neurons have resonant oscillations controlled by the membrane potential, ionic conductances and feedback loops

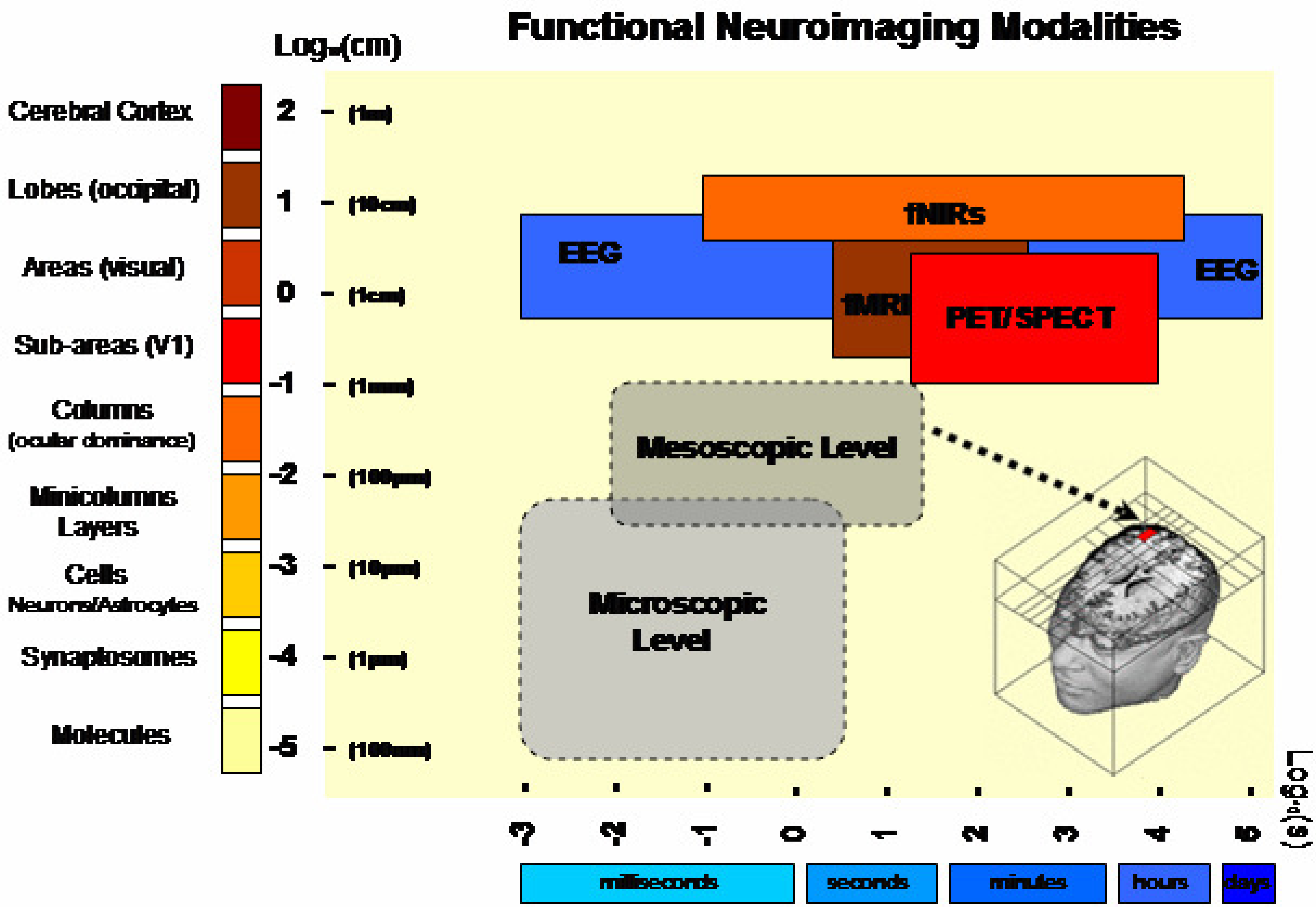
3- The EEG is the Summation of Synaptic Potentials and Changes in the Frequency Spectrum Occur by Changes in Synaptic Potentials

4- Neurons are Connected in Loops and are Self-Organizing & Stable because of Refractoriness of Excitatory Neurons

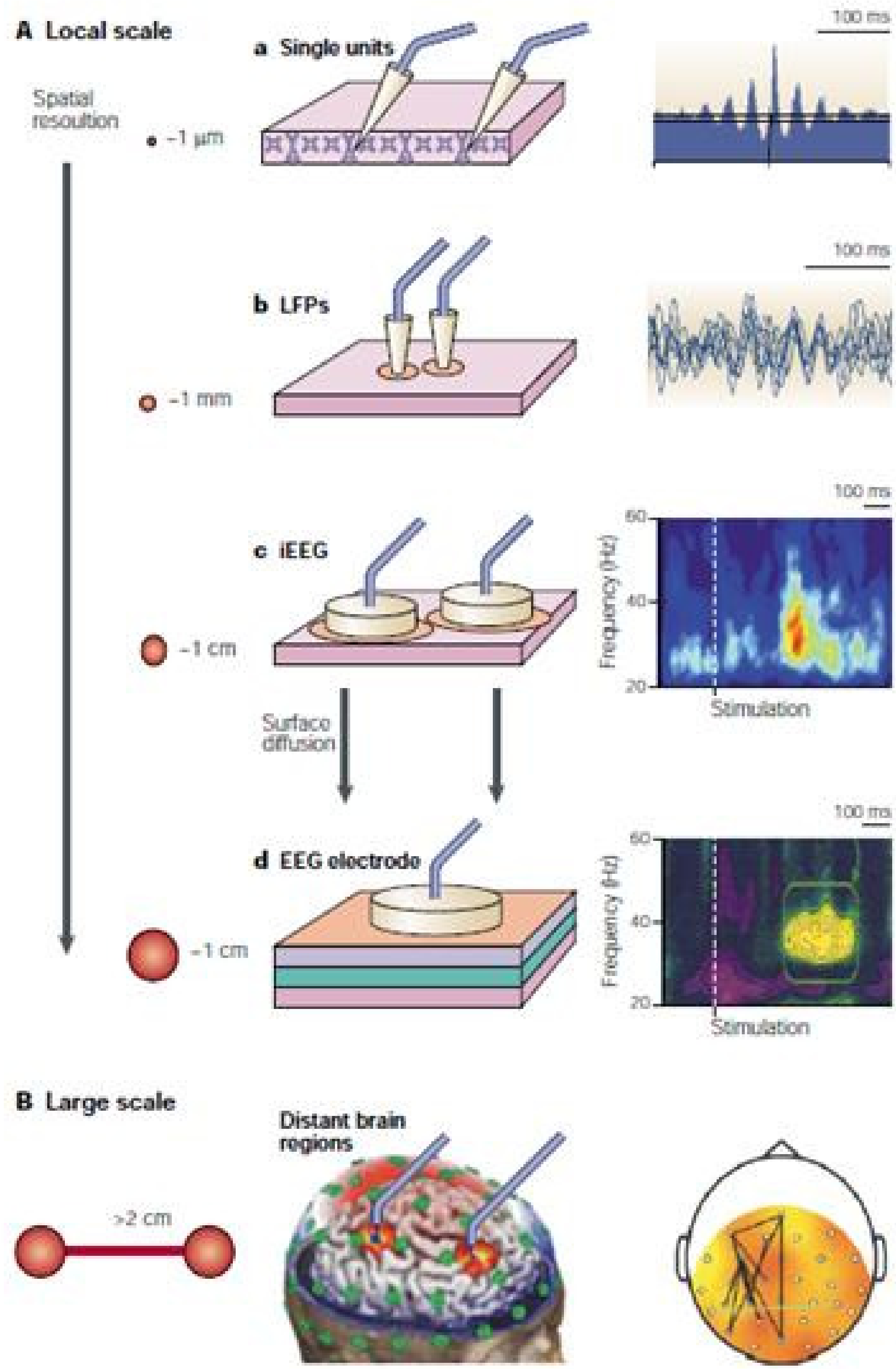
5- Neurons operate in large Modules that are Cross-Frequency Sycnhronized with Phase Shift and Phase Lock as Basic Mechanisms

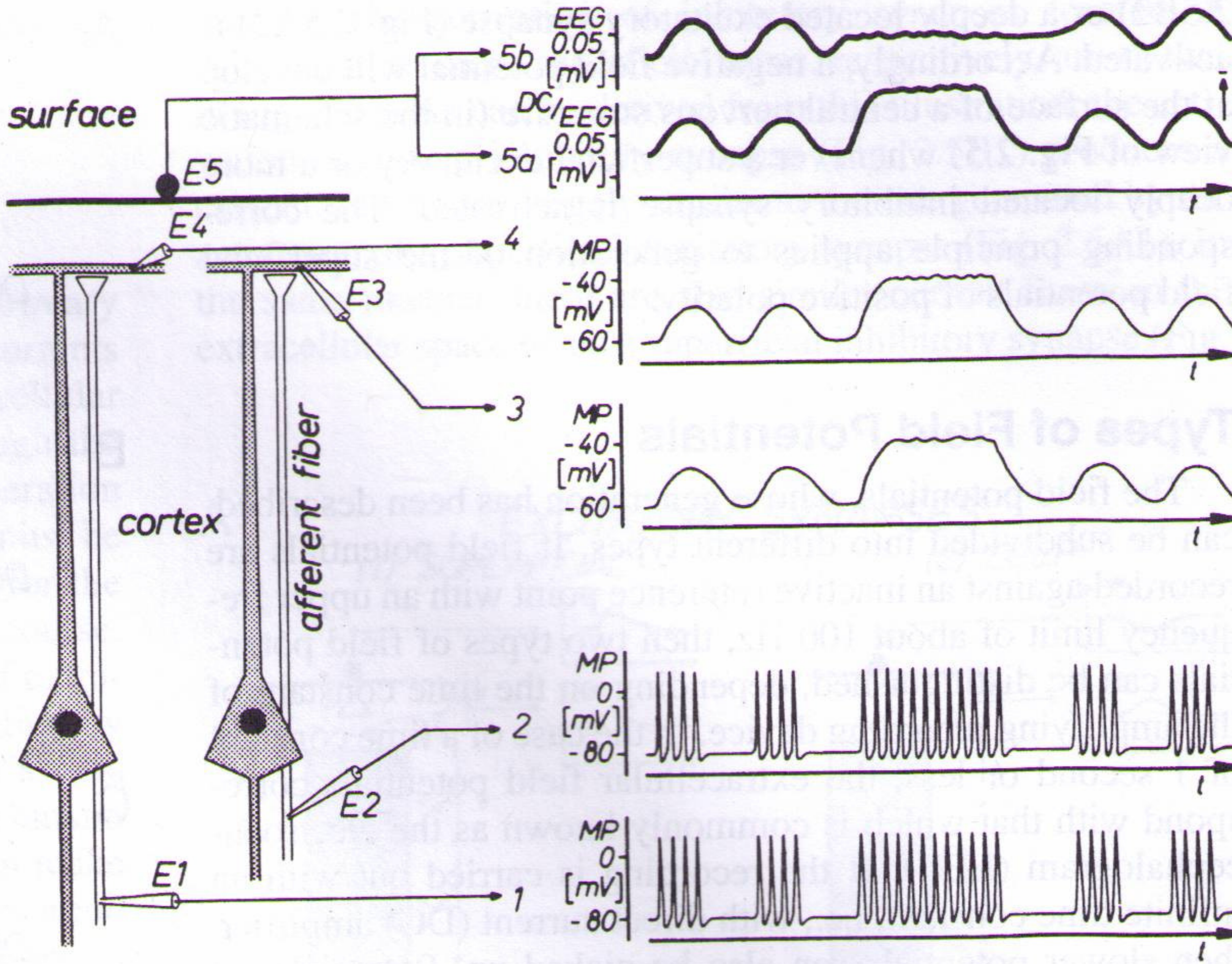
6- EEG Biofeedback is Operant Learning in which a EEG event is followed by a signal that predicts a future reward. This results in the release of Dopamine that alters synapses related to a 'trace' of the EEG event that occurred in the past.

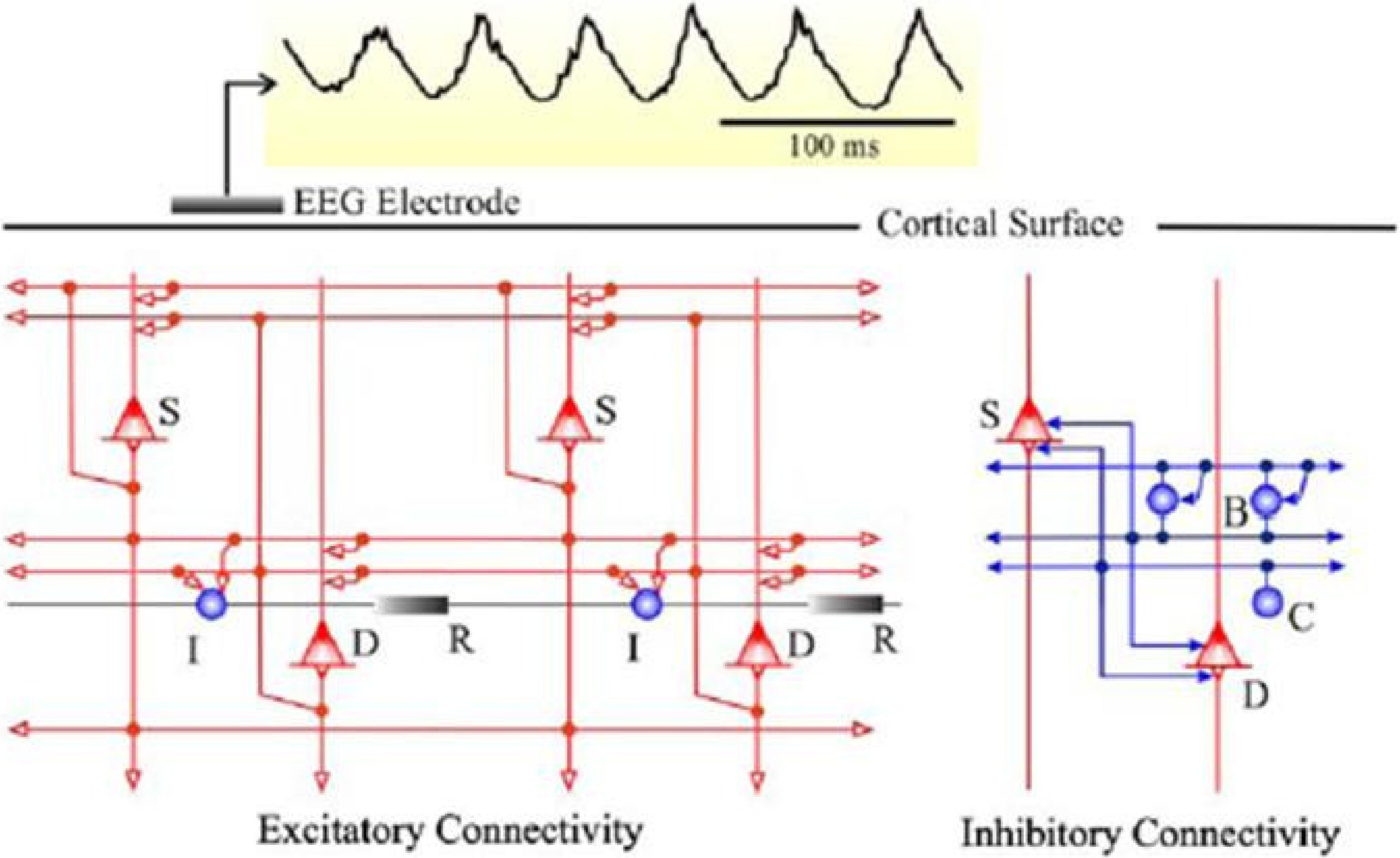
Eric Kandel "In Search of Memory" Norton & Co., 2006 – Nobel Prize 2000
Gyorgy Buzsaki "Rhythms of the Brain", Oxford Univ. Press, 2006



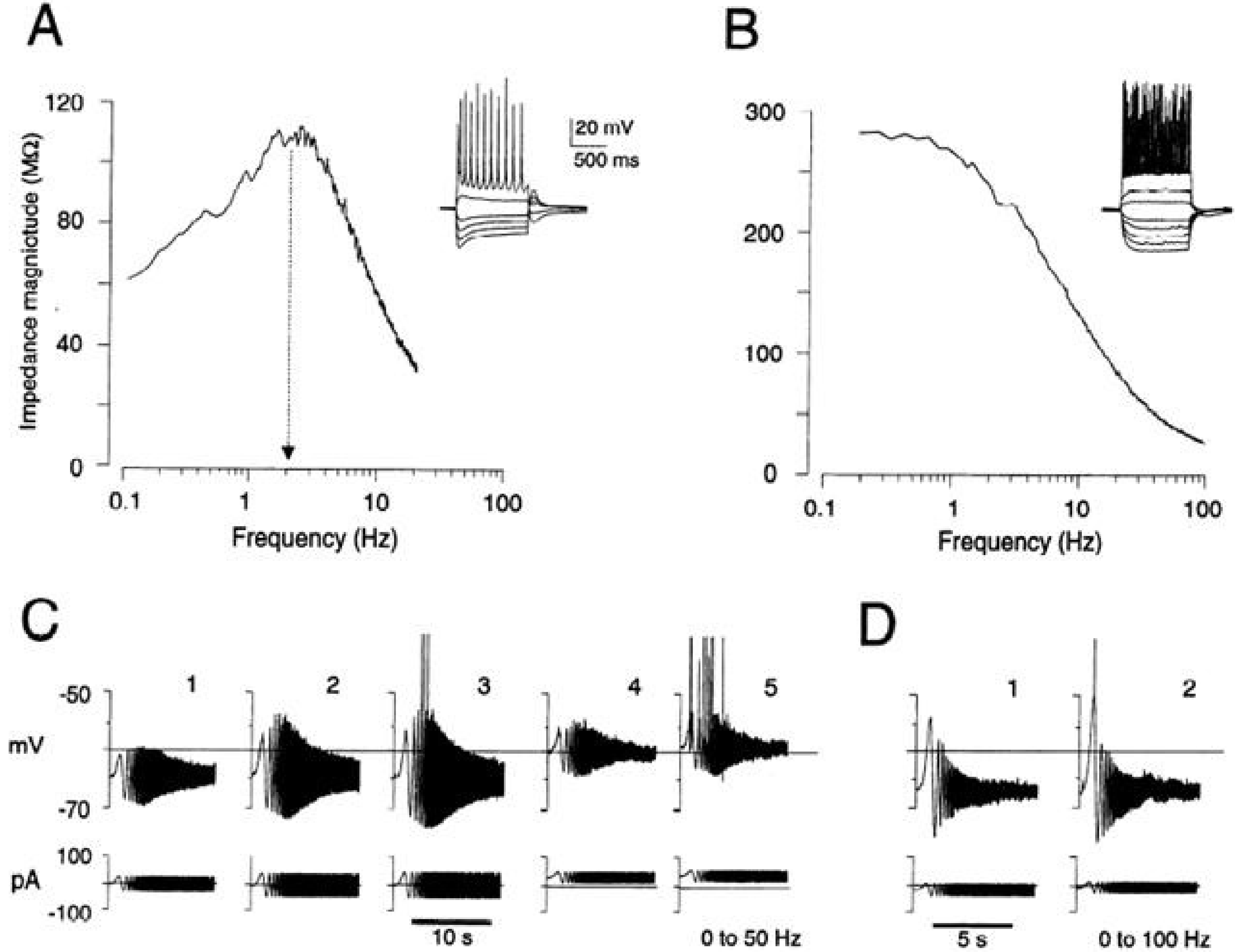
Functional Neuroimaging Modalities
Log(cm)
Cerebral Cortex
Lobes (occipital)
Areas (visual)
Sub-areas (V1)
Columns
(ocular dominance)
Minicolumns
Layers
Cells
Neurons/Astrocytes
Synaptosomes
Molecules
2
1
0
-1
-2
-3
-4
-5
fNIRs
EEG
EEG
fMRI
PET/SPECT
Mesoscopic Level
Microscopic
Level
-3
-2
-1
0
1
2
3
4
5
Log(s)
milliseconds
seconds
minutes
hours
days


A Local scale
Spatial resolution
~1 µm
a Single units
100 ms
b LFPs
~1 mm
100 ms
c iEEG
~1 cm
100 ms
60
Frequency (Hz)
40
20
Stimulation
Surface diffusion
d EEG electrode
~1 cm
100 ms
60
Frequency (Hz)
40
20
Stimulation
B Large scale
>2 cm
Distant brain regions

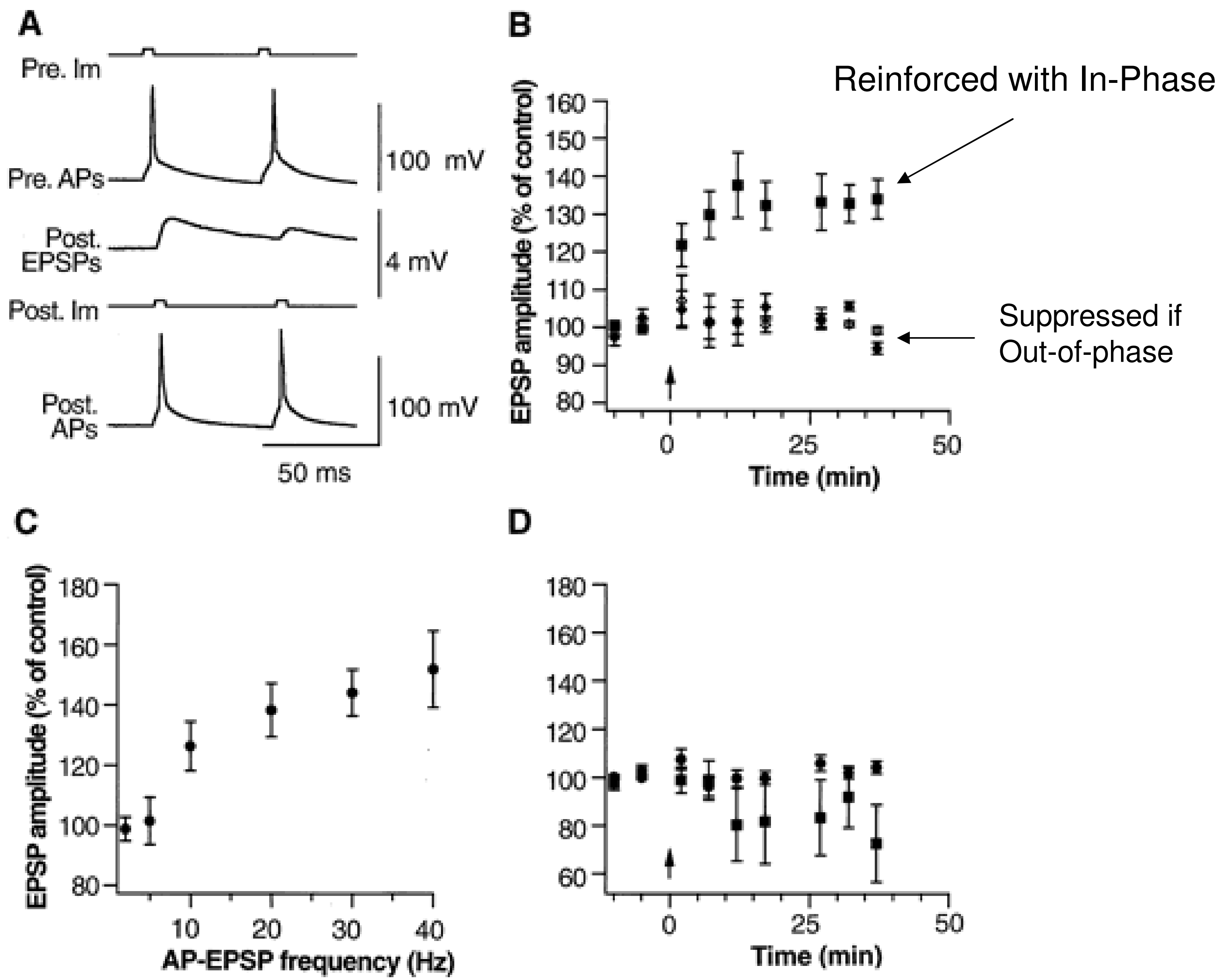

surface
E5
E4
E3
E2
E1
cortex
afferent fiber
5b
5a
4
3
2
1
EEG
0.05
[mV]
DC/EEG
0.05
[mV]
t
MP
-40
[mV]
-60
t
MP
-40
[mV]
-60
t
MP
0
[mV]
-80
t
MP
0
[mV]
-80
t



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



A
B
C
D
Impedance magnitude (MΩ)
Frequency (Hz)
120
80
40
0
0.1
1
10
100
20 mV
500 ms
300
200
100
1
2
3
4
5
-50
mV
-70
100
pA
-100
10 s
0 to 50 Hz
5 s
0 to 100 Hz

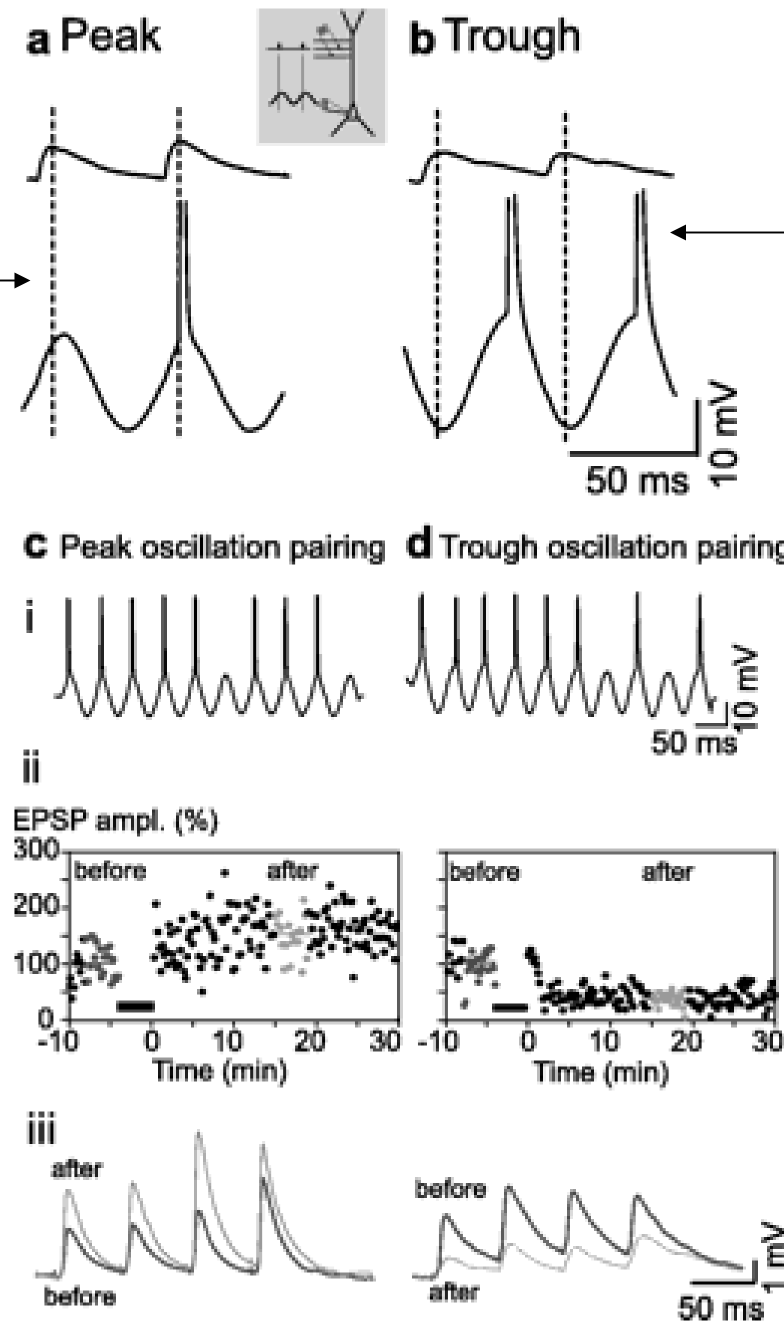


A
Pre. Im
Pre. APs
100 mV
Post. EPSPs
4 mV
Post. Im
Post. APs
100 mV
50 ms
B
Reinforced with In-Phase
Suppressed if Out-of-phase
EPSP amplitude (% of control)
Time (min)
C
EPSP amplitude (% of control)
AP-EPSP frequency (Hz)
D
Time (min)

Thalamic Gating to the Neurocortex

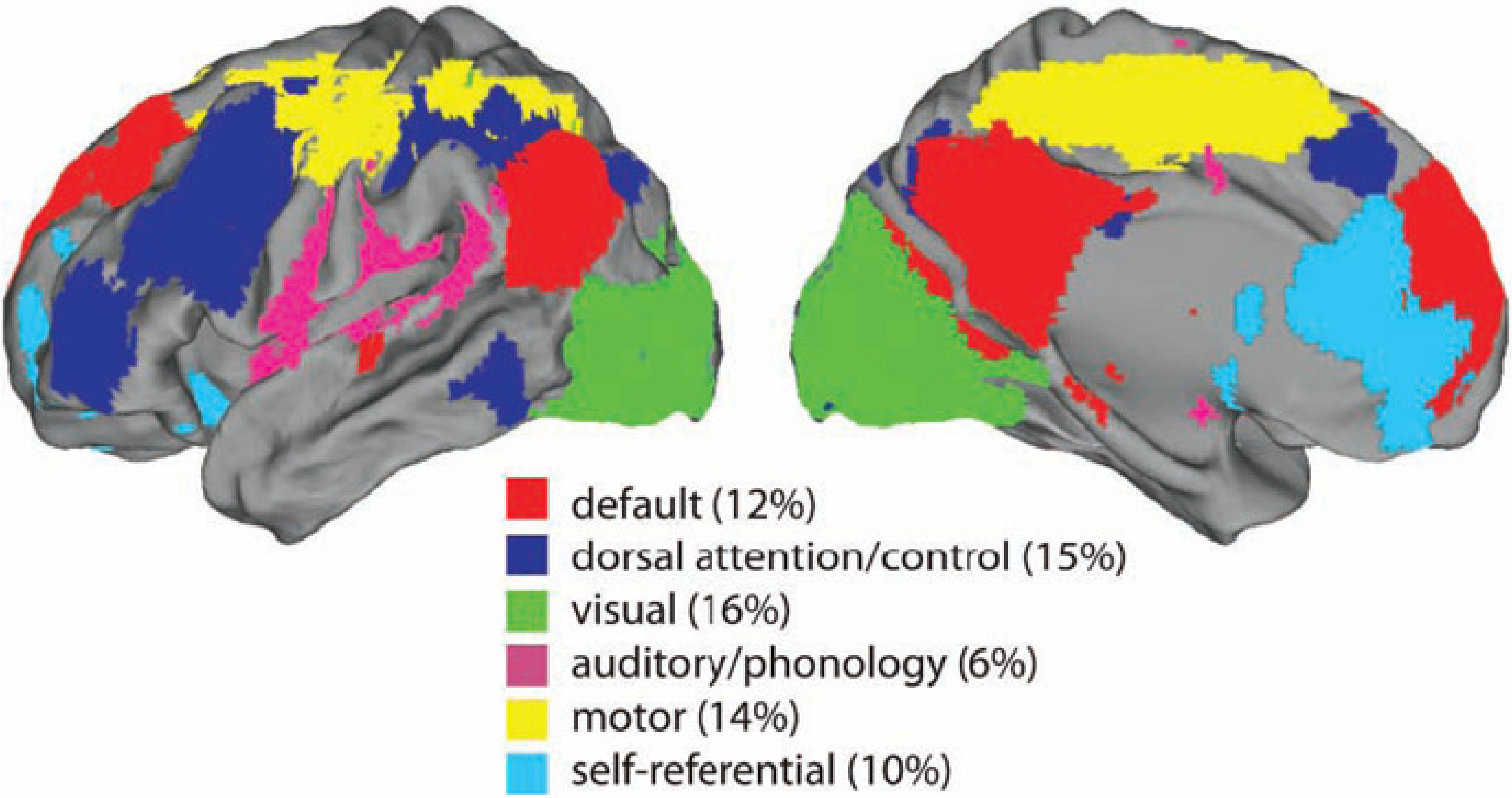
In-Phase is Reinforced

Out-of-Phase is Suppressed

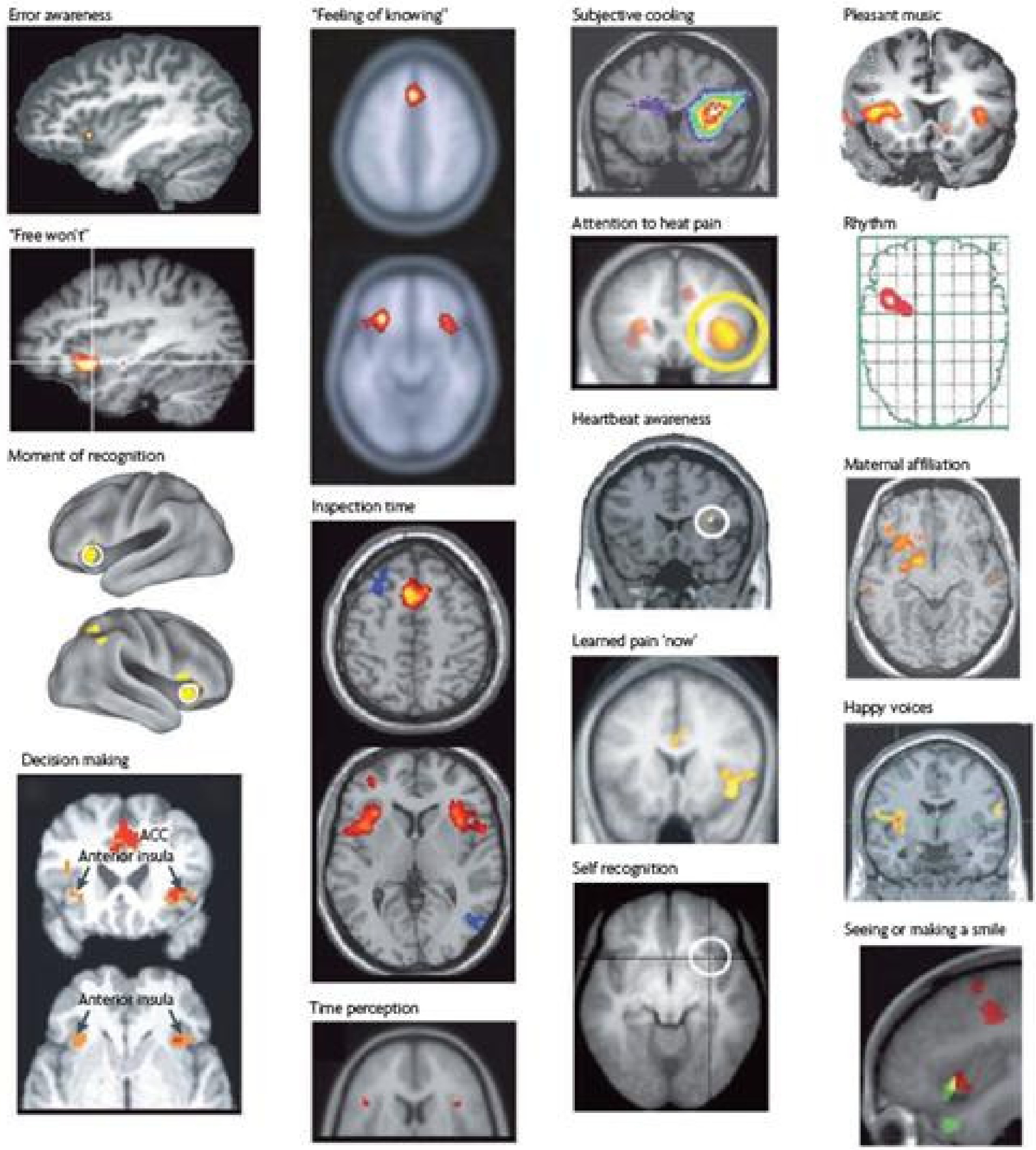


In-Phase is Reinforced

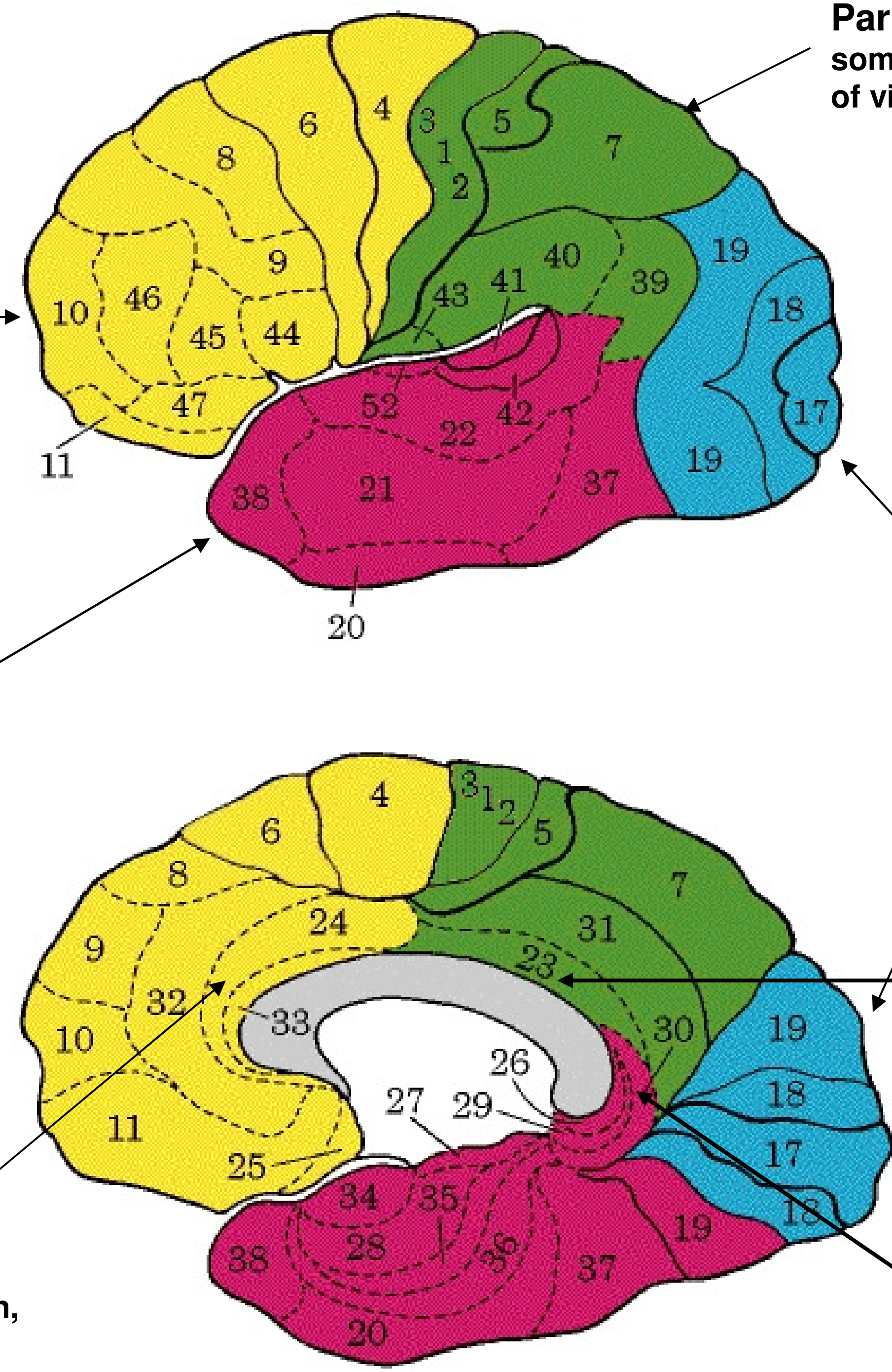
Out-of-Phase is Suppressed



default (12%)
dorsal attention/control (15%)
visual (16%)
auditory/phonology (6%)
motor (14%)
self-referential (10%)


Error awareness
"Free won't"
Moment of recognition
Decision making
ACC
Anterior insula
Anterior insula
"Feeling of knowing"
Inspection time
Time perception
Subjective cooling
Attention to heat pain
Heartbeat awareness
Learned pain 'now'
Self recognition
Pleasant music
Rhythm
Maternal affiliation
Happy voices
Seeing or making a smile

Brodmann Areas



Parietal Lobe
somatosensory perception integration of visual & somatospatial information

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

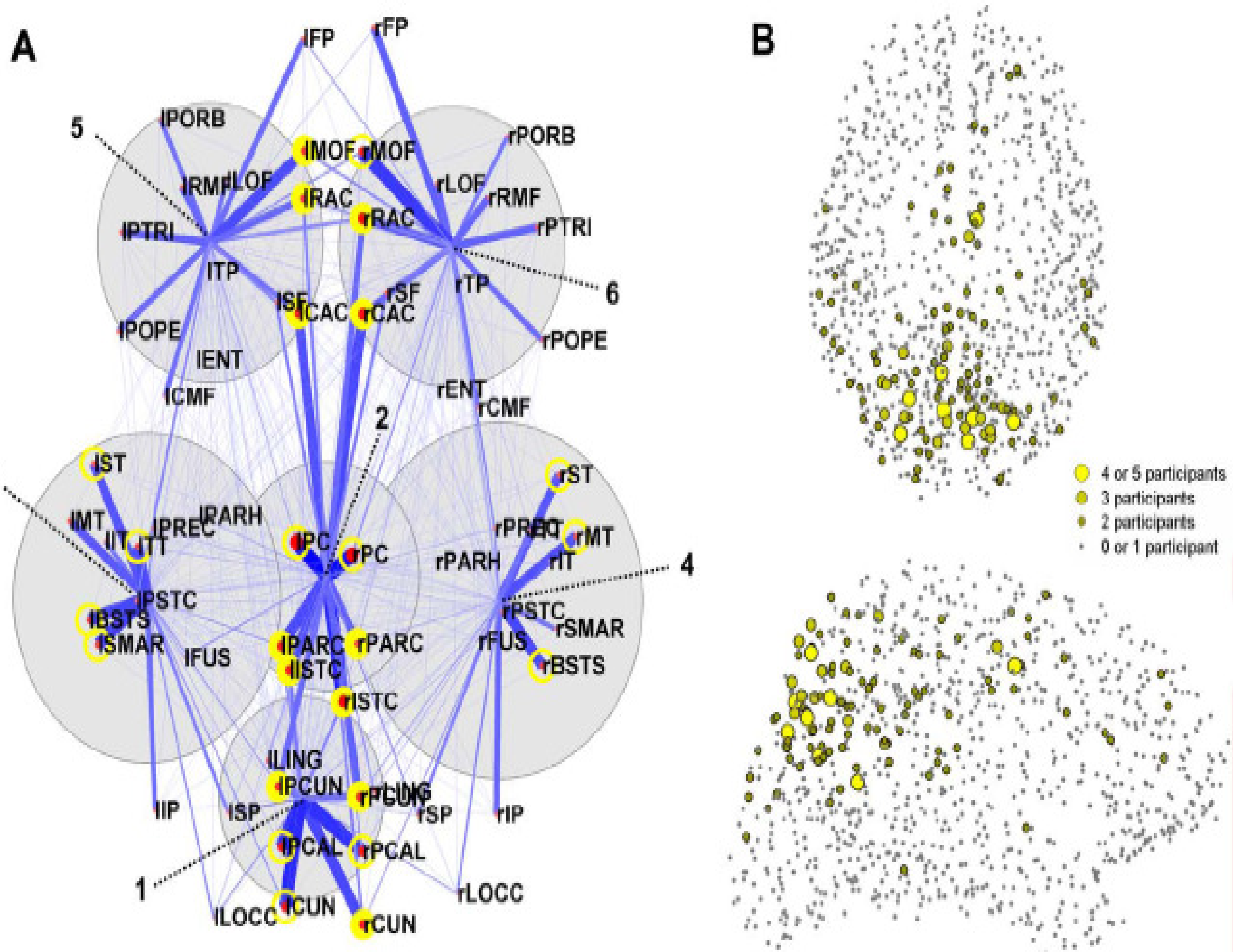
Temporal Lobe
language function and auditory perception involved in long term memory and emotion

Occipital Lobe
Visual perception & Spatial processing

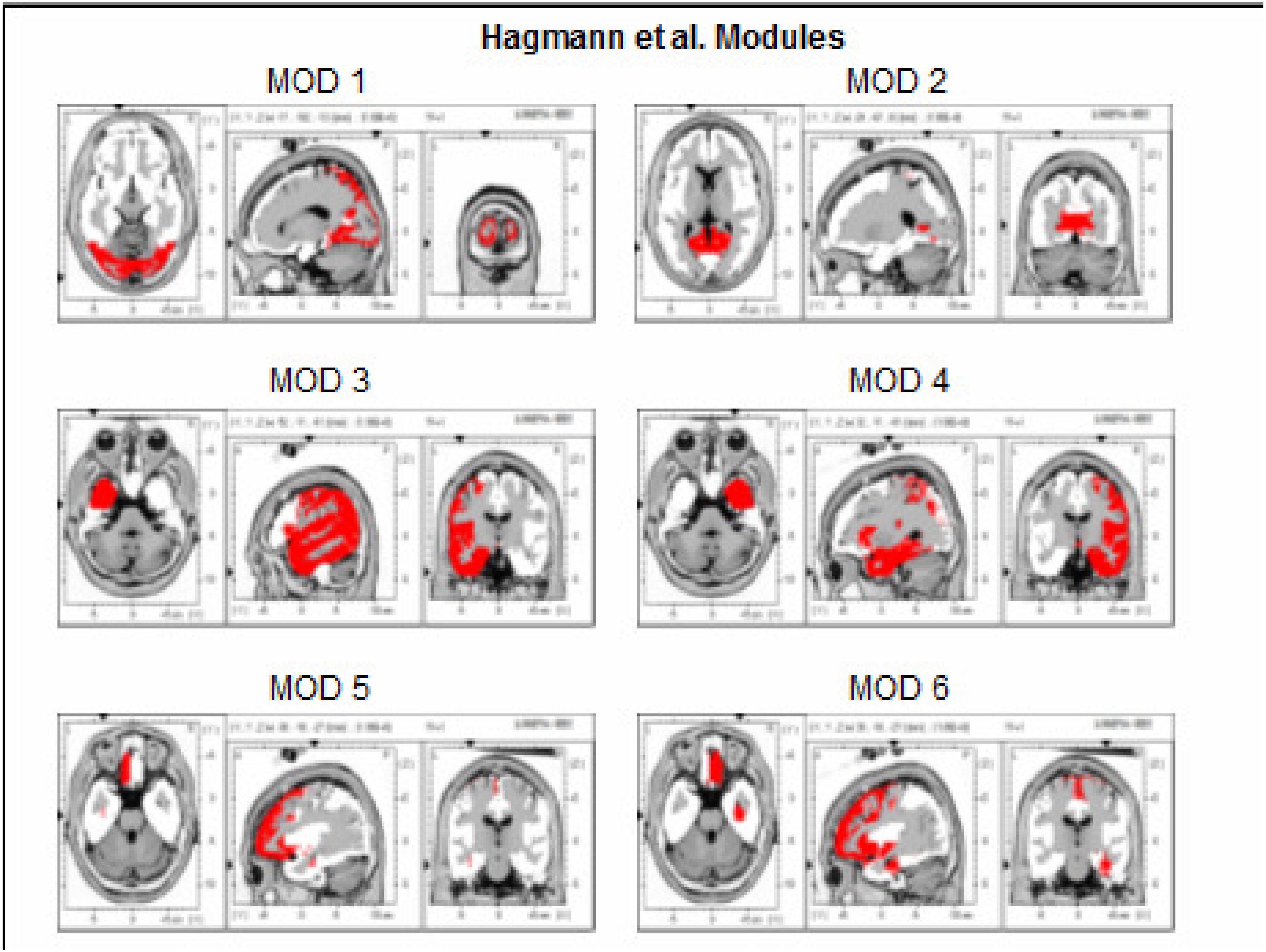
Posterior Cingulate
attention, long-term memory

Anterior Cingulate Gyrus
Volitional movement, attention, long term memory

Parahippocampal Gyrus
Short-term memory, attention

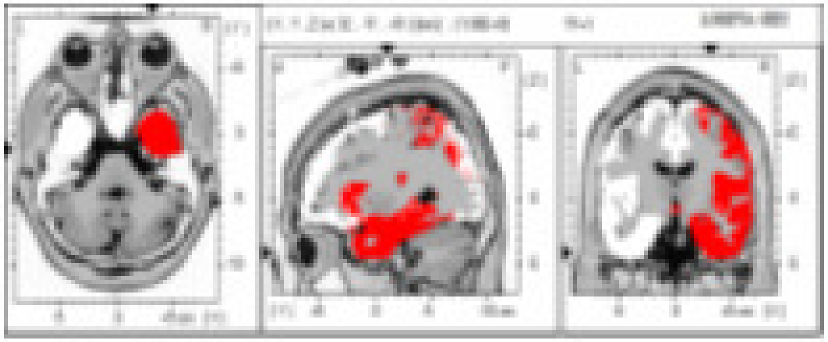


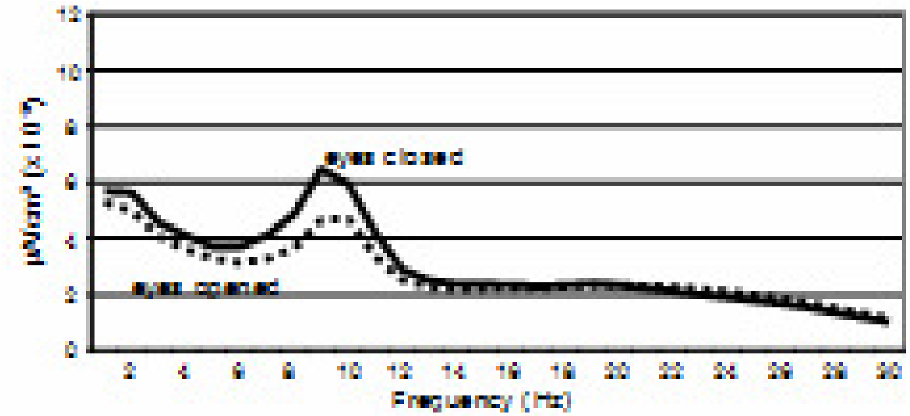
A
lFP
rFP
lPORB
rPORB
lMOF
rMOF
lRMF
lLOF
rLOF
rRMF
lRAC
rRAC
lPTRI
rPTRI
lTP
rTP
lSF
lCAC
rCAC
rSF
lPOPE
rPOPE
lENT
rENT
lCMF
rCMF
5
6
2
3
4
1
lST
rST
lMT
lIT
lTT
lPREC
lPARH
lPC
rPC
rMT
rIT
rPARH
lPSTC
rPSTC
lBSTS
lSMAR
rSMAR
lFUS
lPARC
rPARC
rFUS
lISTC
rBSTS
rISTC
lLING
lPCUN
lIP
lSP
rSP
rIP
lPCAL
rPCAL
rLOCC
lLOCC
lCUN
rCUN
B
4 or 5 participants
3 participants
2 participants
0 or 1 participant


Hagmann et al. Modules
MOD 1
MOD 2
MOD 3
MOD 4
MOD 5
MOD 6

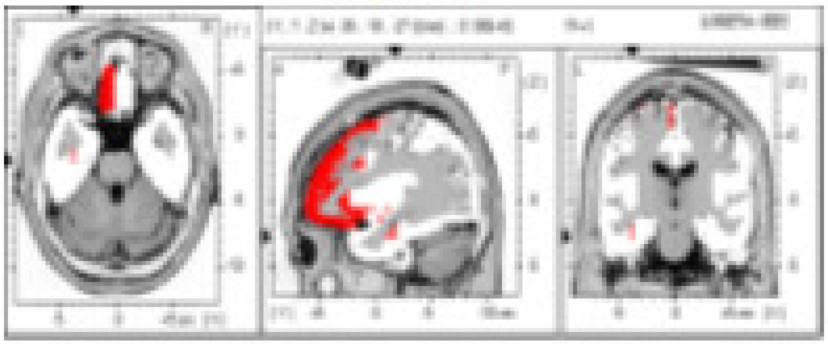
Hagmann et al. Modules

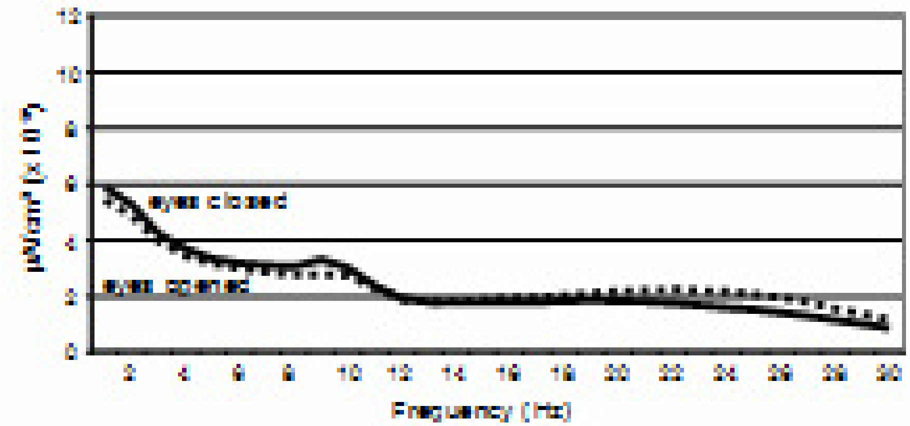
MOD 4



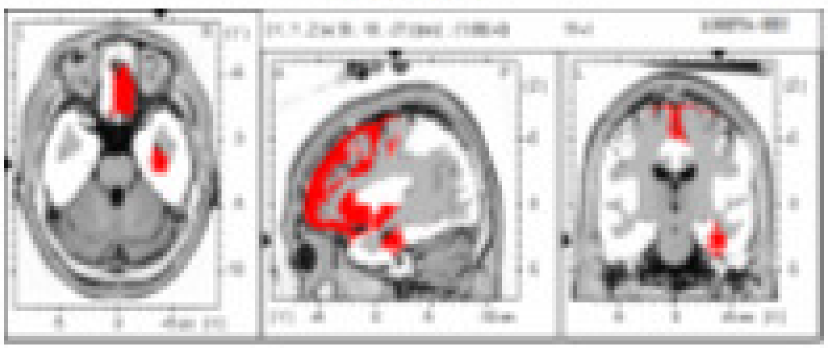


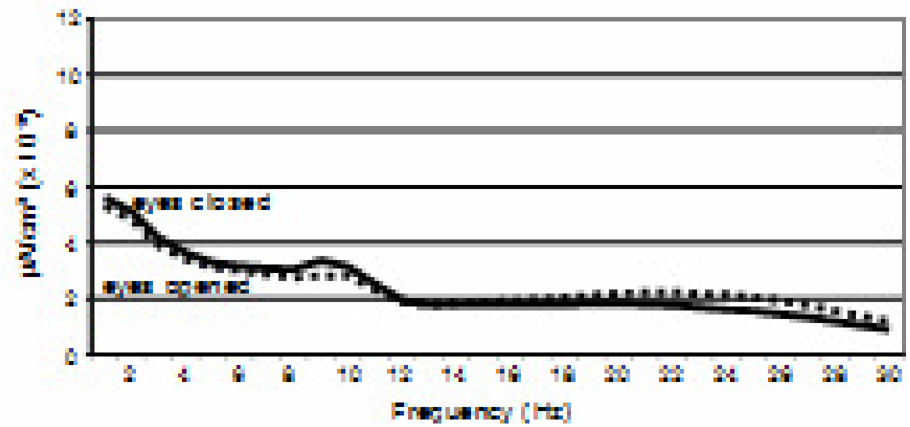
MOD 5





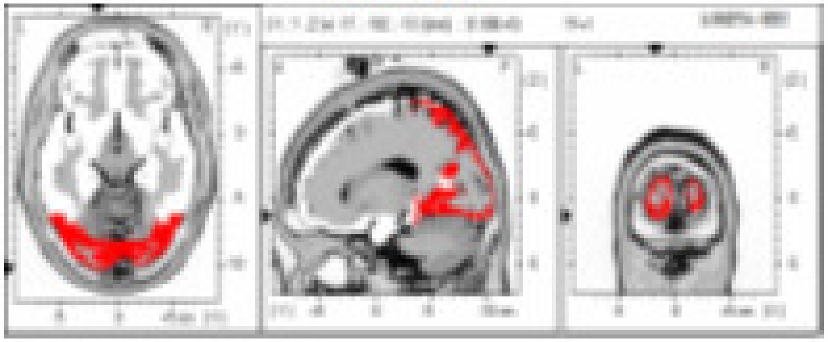
MOD 6

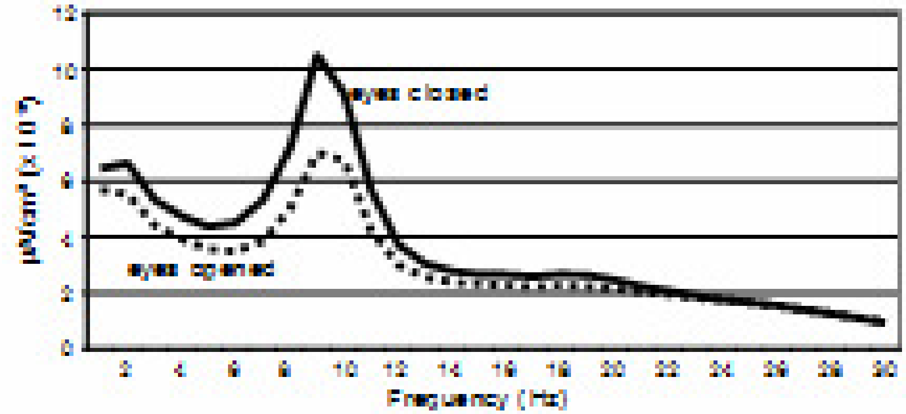




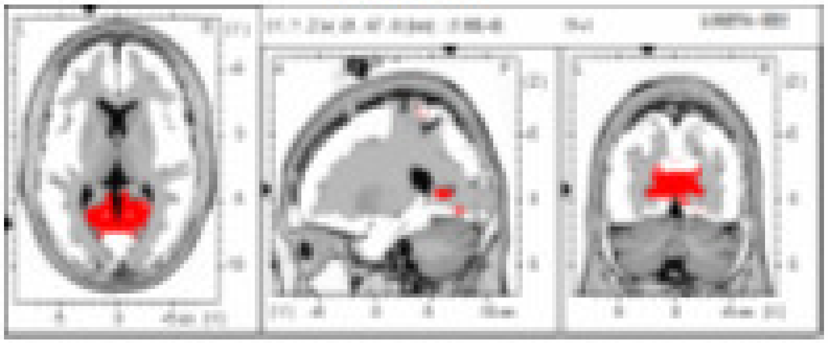
Hagmann et al. Modules

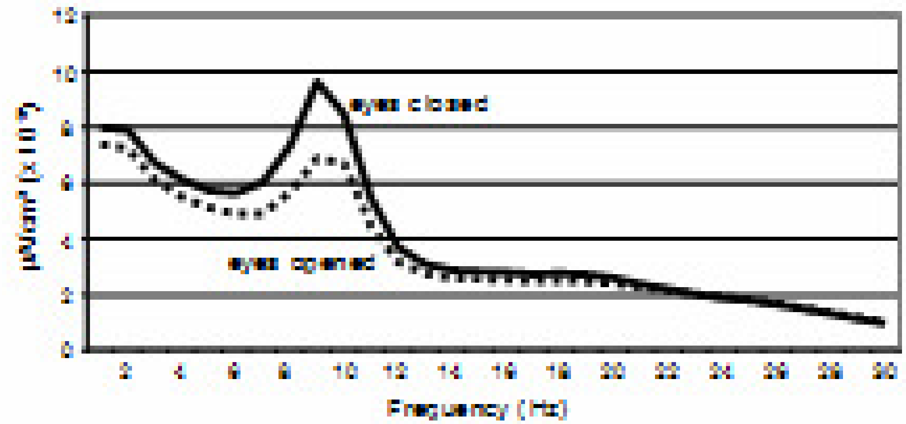
MOD 1



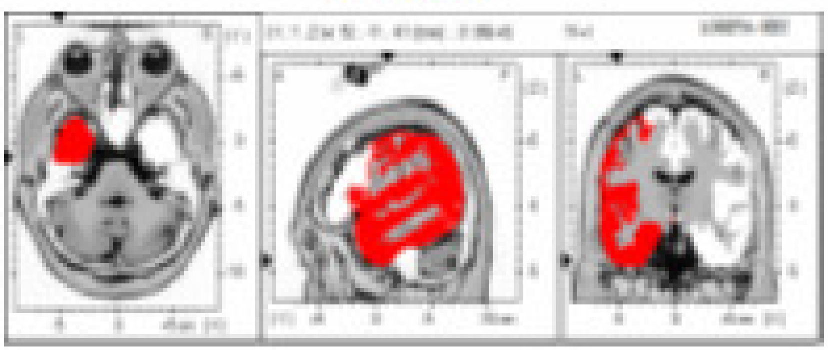


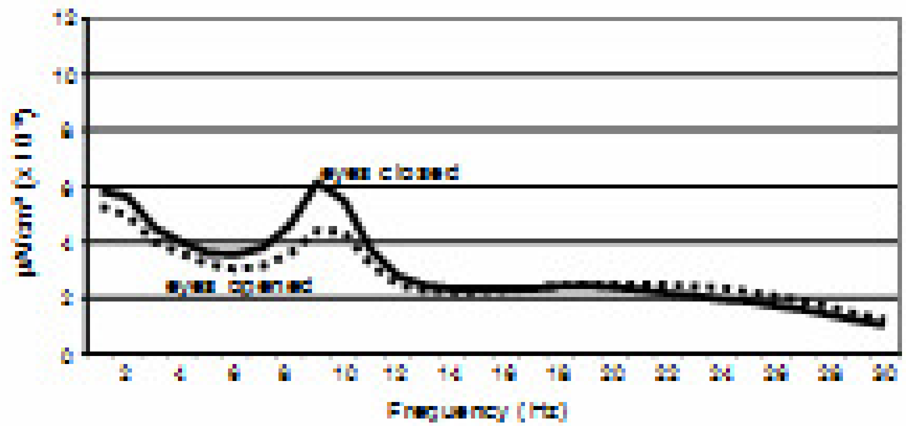
MOD 2

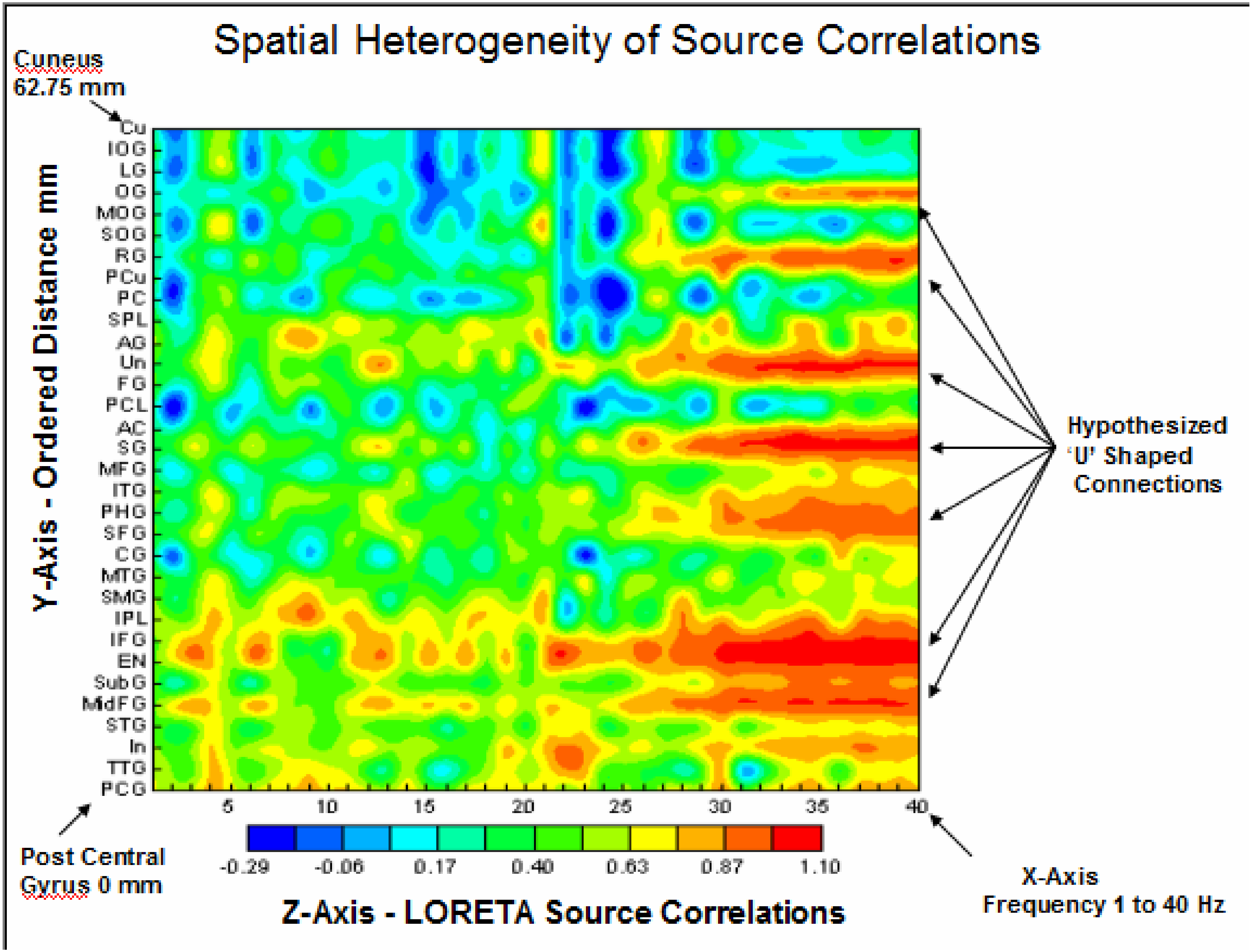




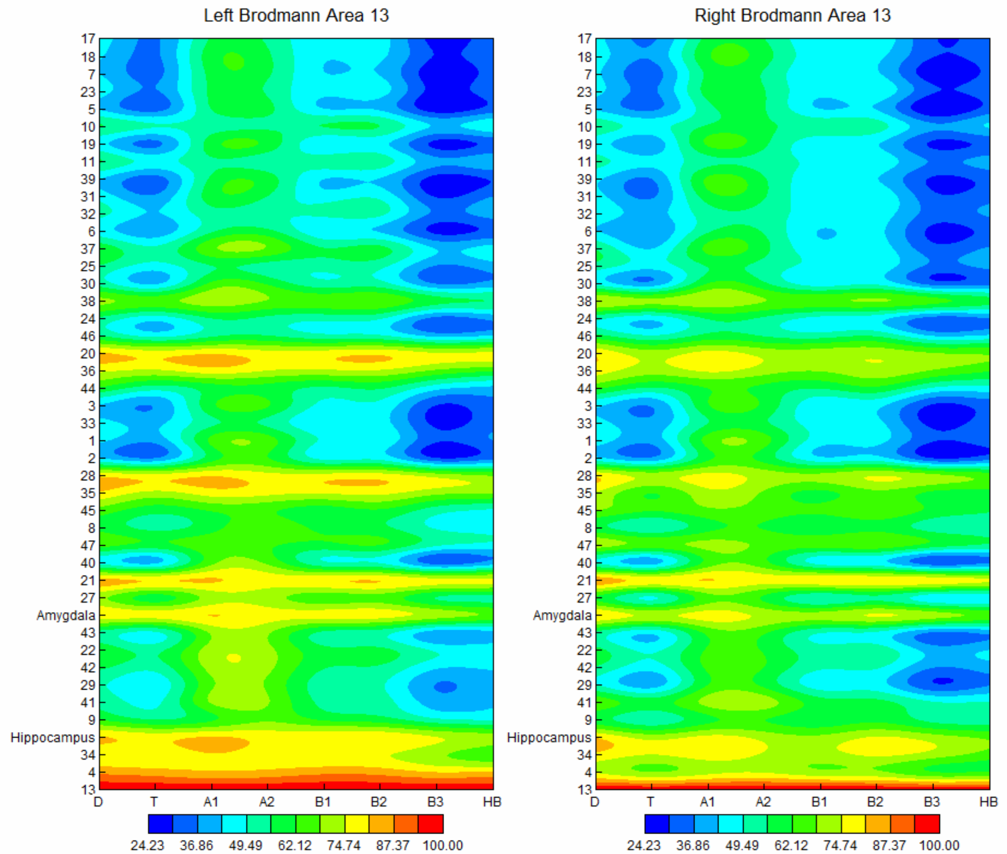
MOD 3



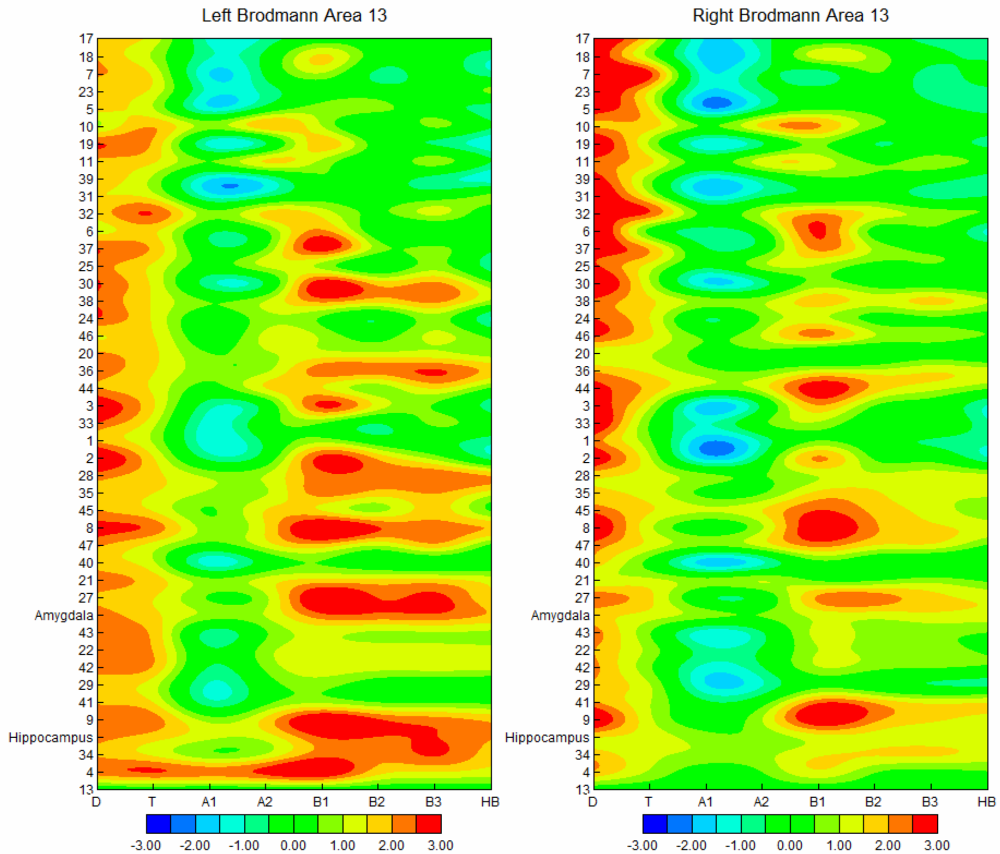


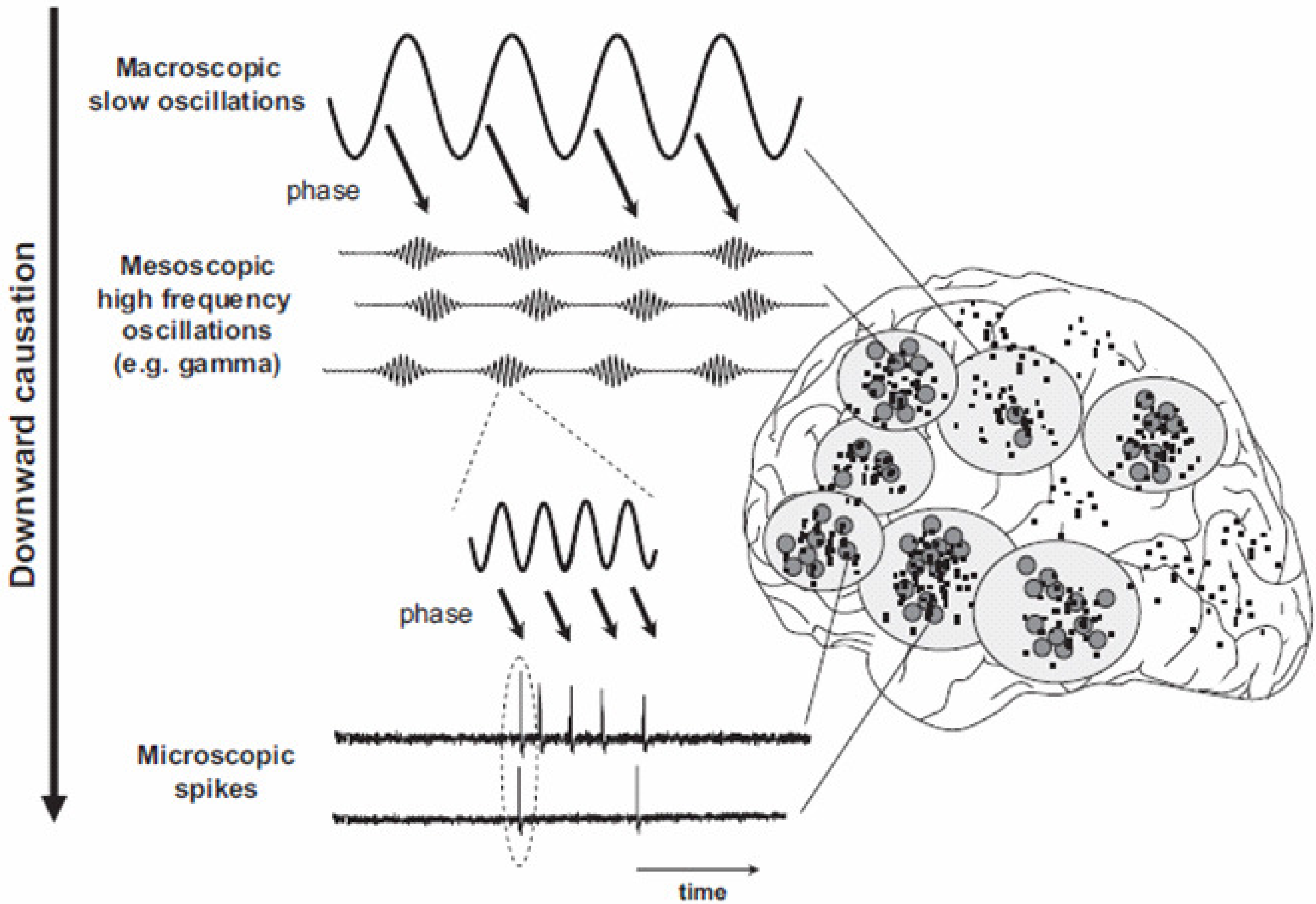

Spatial Heterogeneity of Source Correlations
Cuneus
62.75 mm
Y-Axis - Ordered Distance mm
Cu
IOG
LG
OG
MOG
SOG
RG
PCu
PC
SPL
AG
Un
FG
PCL
AC
SG
MFG
ITG
PHG
SFG
CG
MTG
SMG
IPL
IFG
EN
SubG
MidFG
STG
In
TTG
PCG
5
10
15
20
25
30
35
40
Hypothesized
'U' Shaped
Connections
-0.29
-0.06
0.17
0.40
0.63
0.87
1.10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

LORETA Coherence

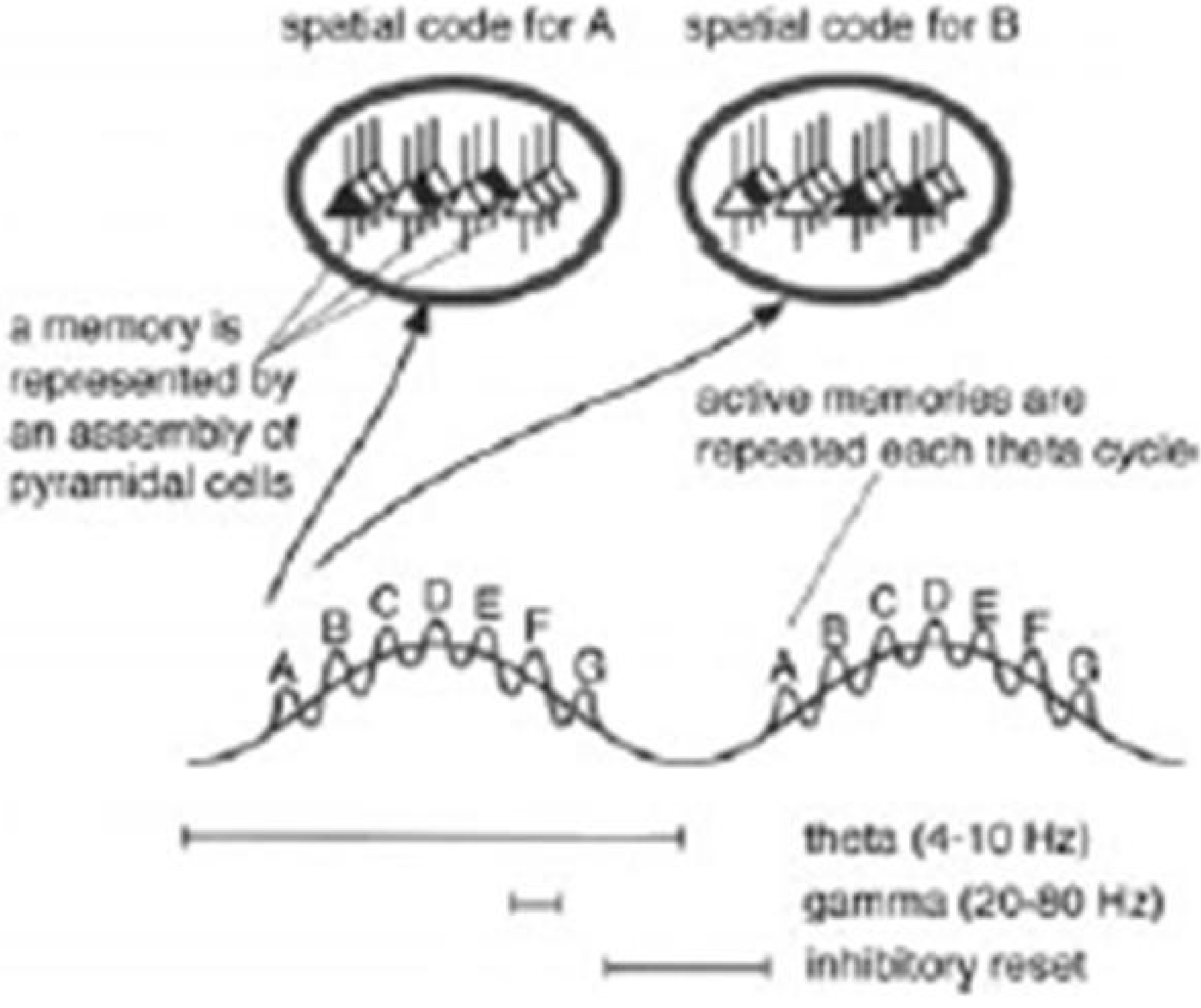


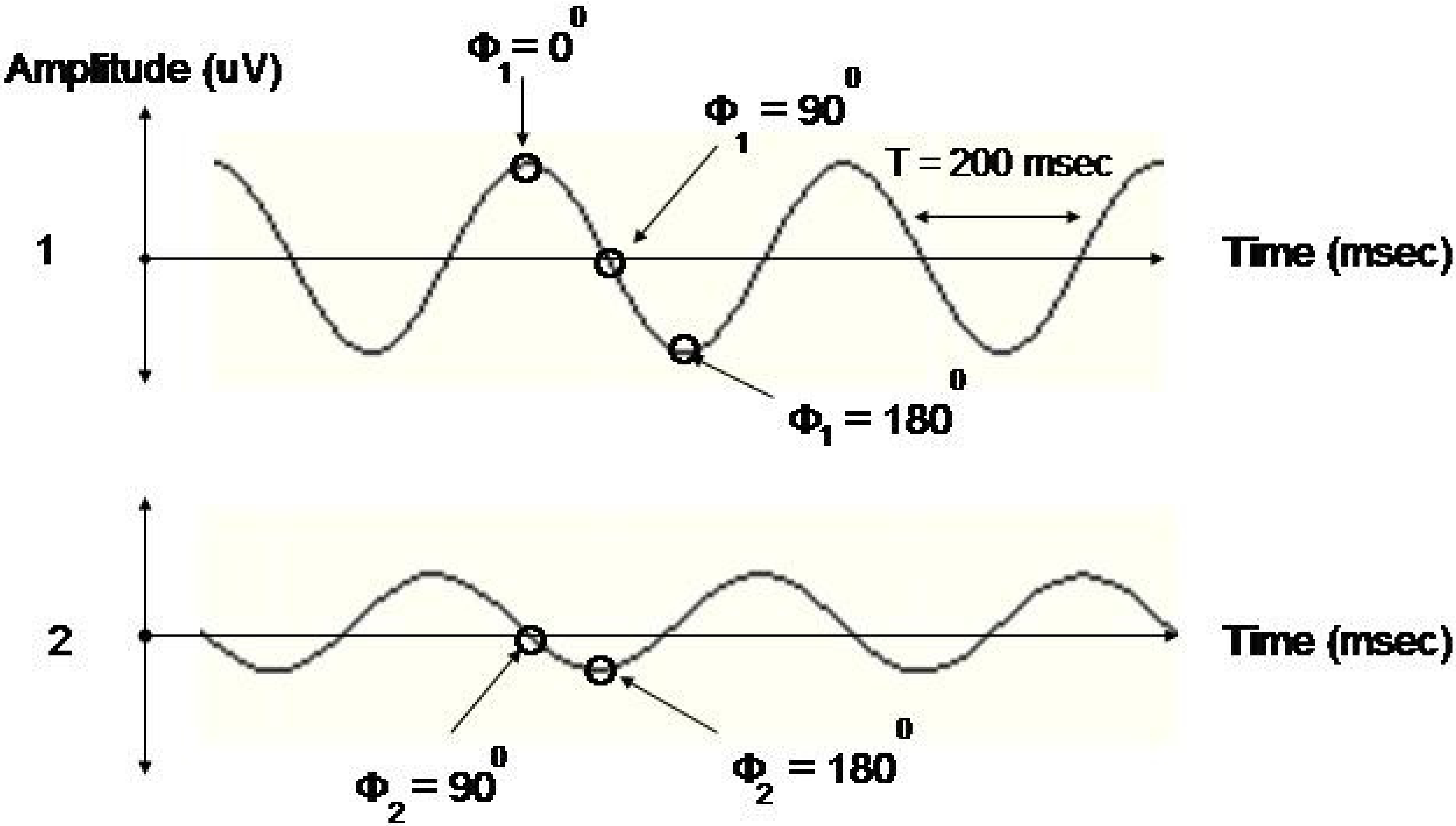
Z Scored LORETA Coherence



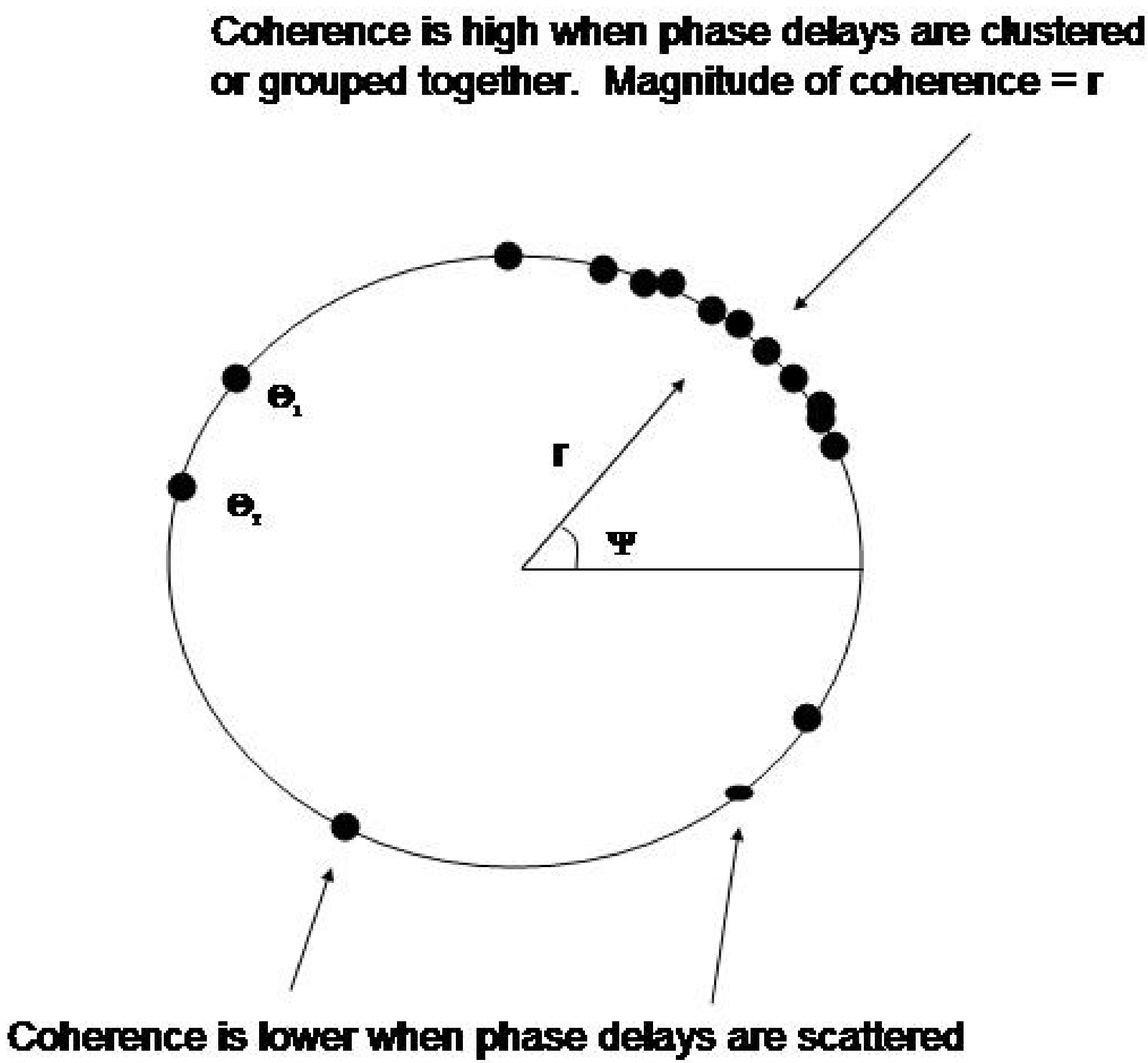


Downward causation
Macroscopic
slow oscillations
phase
Mesoscopic
high frequency
oscillations
(e.g. gamma)
phase
Microscopic
spikes
time


spatial code for A
spatial code for B
a memory is represented by an assembly of pyramidal cells
active memories are repeated each theta cycle
A
B
C
D
E
F
G
theta (4-10 Hz)
gamma (20-80 Hz)
inhibitory reset

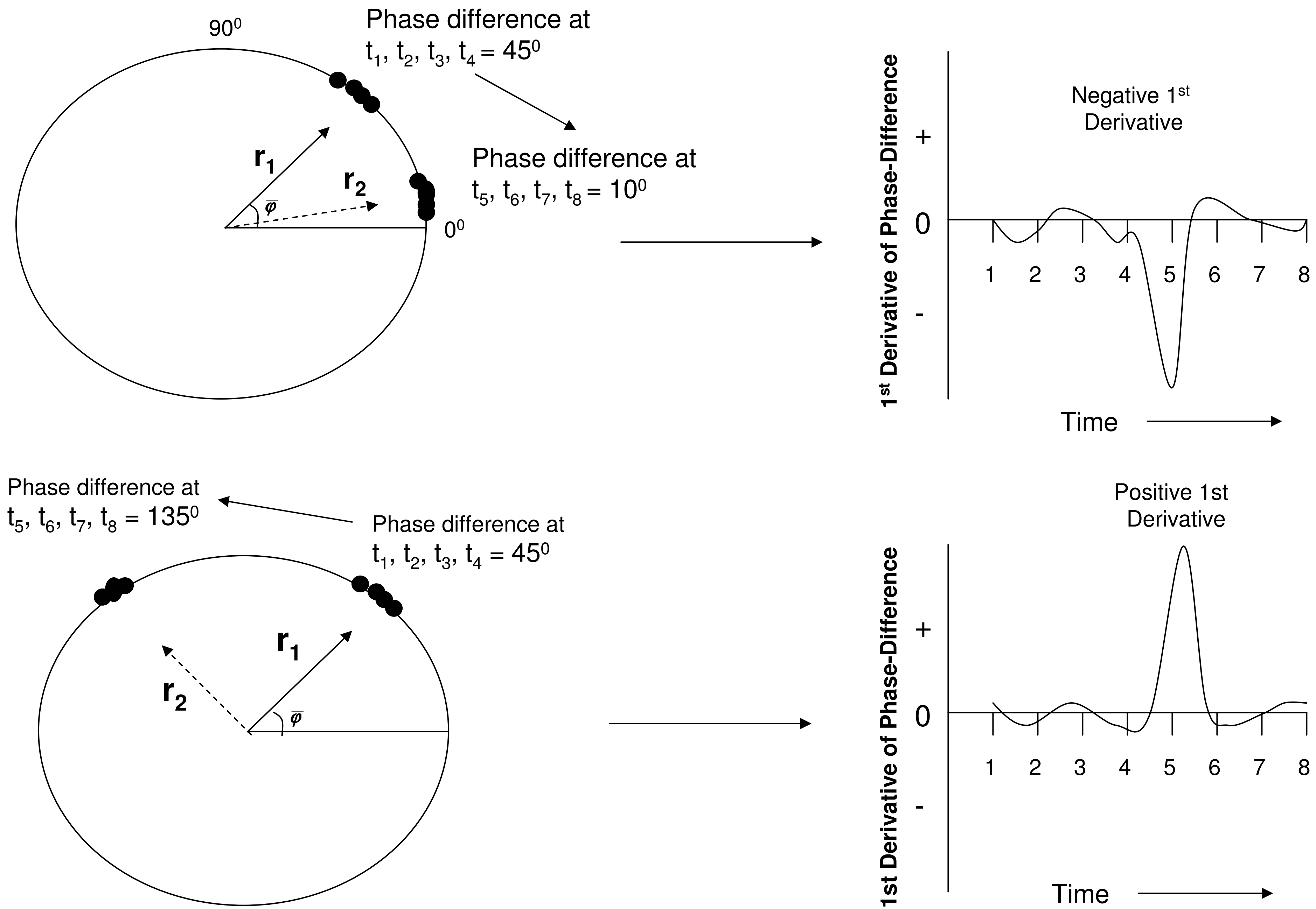


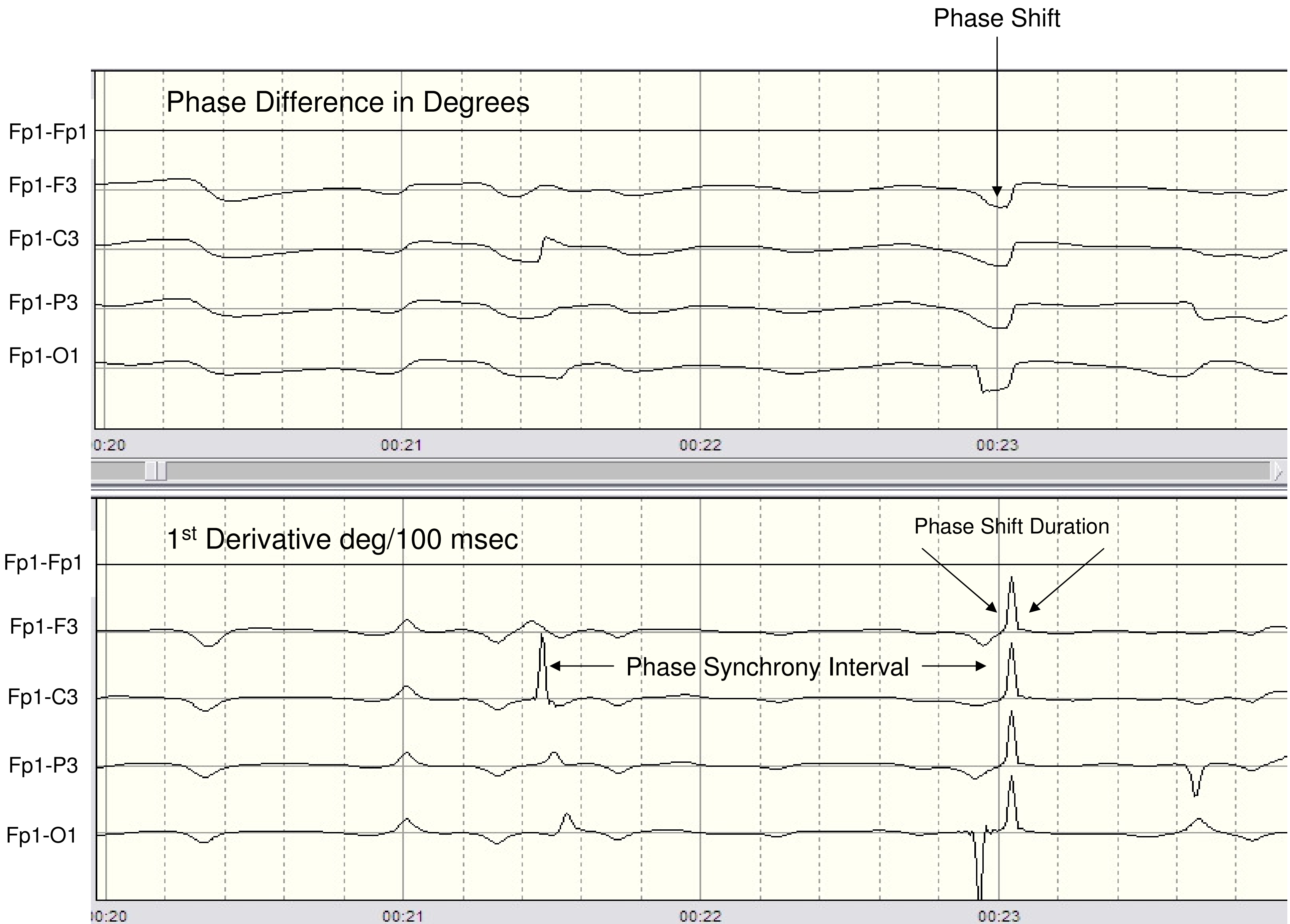
Phase Difference = $\Phi_1 - \Phi_2 = 90^0$

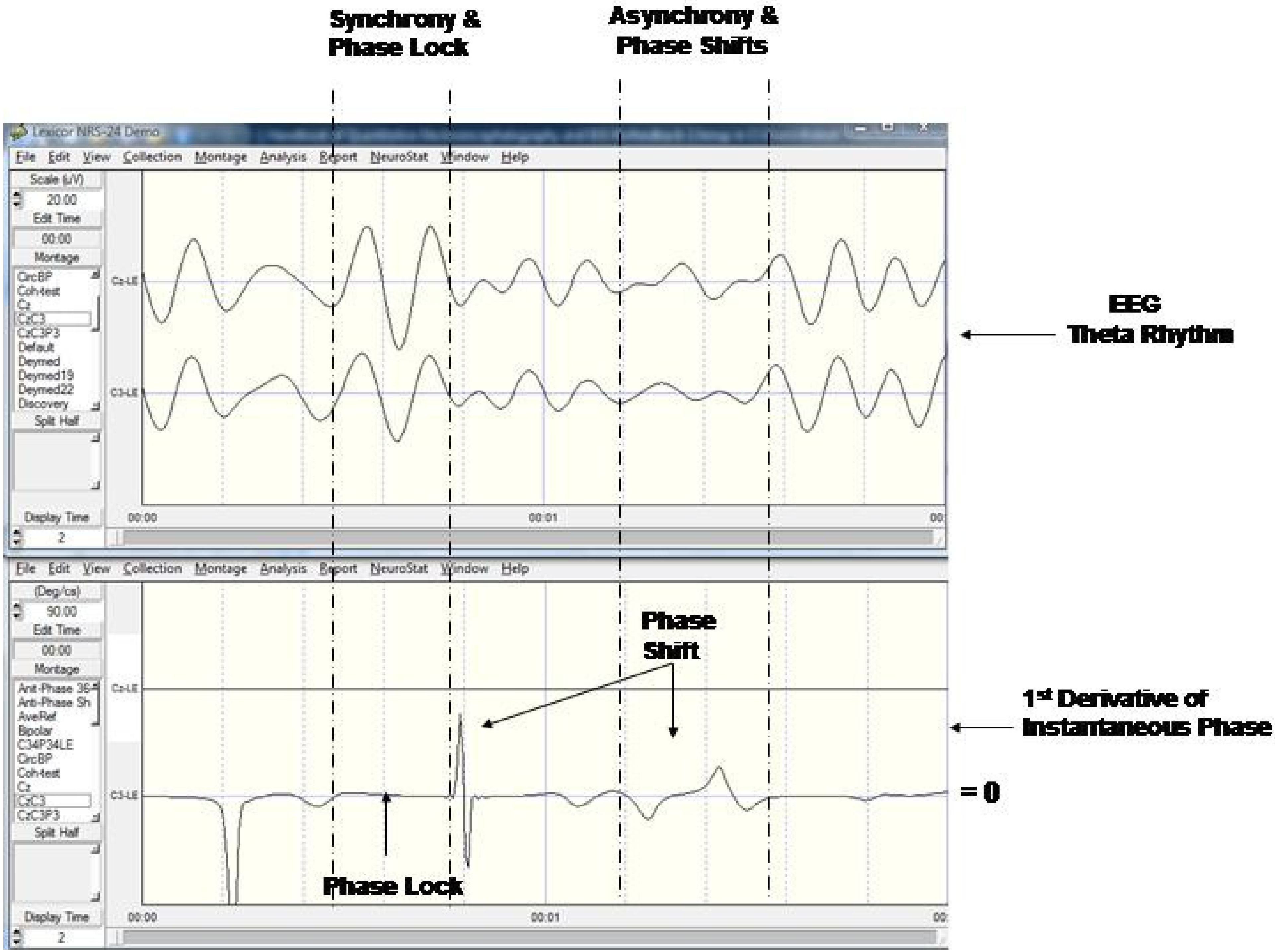


Coherence is high when phase delays are clustered or grouped together. Magnitude of coherence = r
θ_1
θ_2
r
Ψ
Coherence is lower when phase delays are scattered

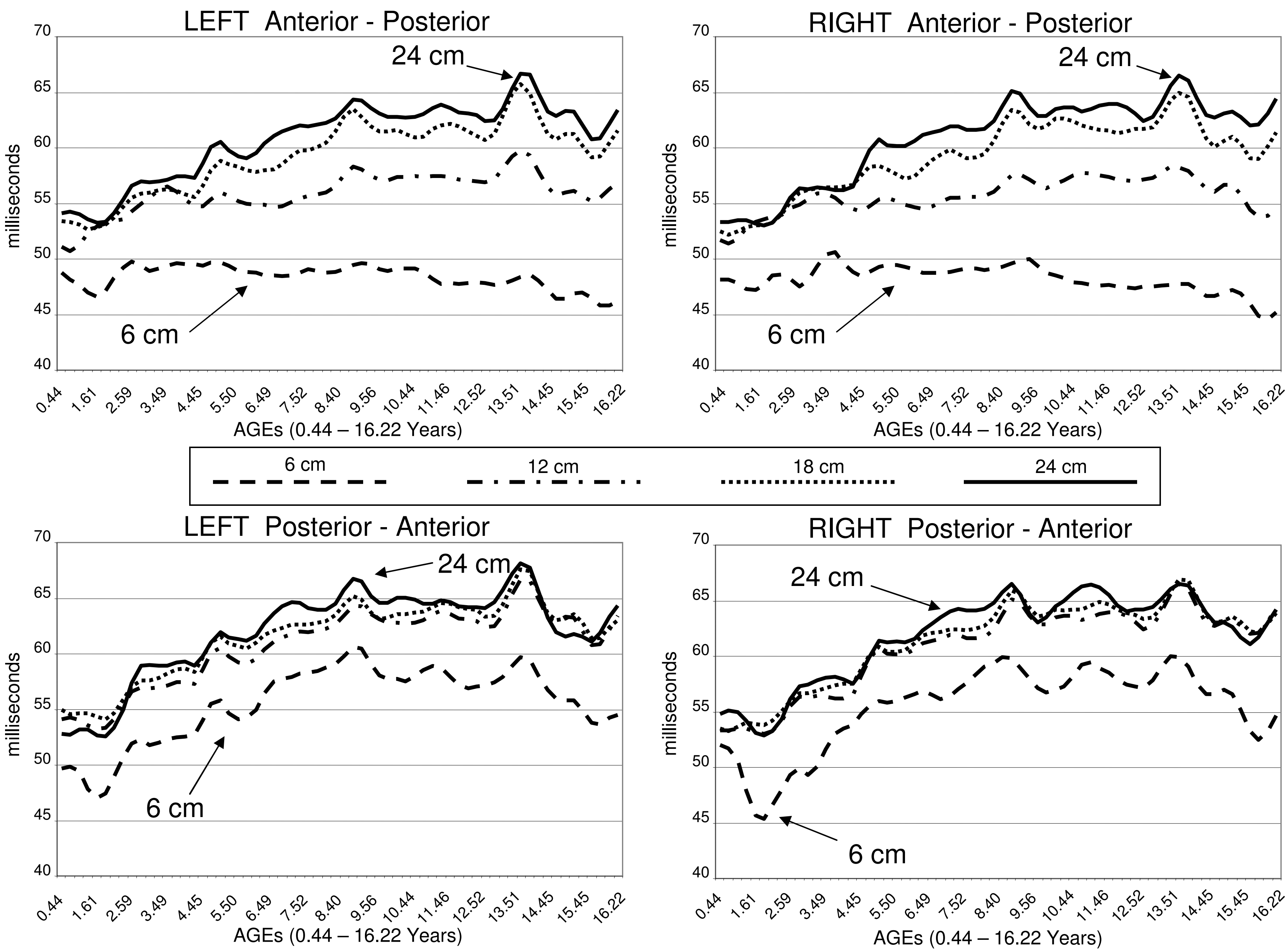
EEG Phase Reset as a Phase Transition in the Time Domain

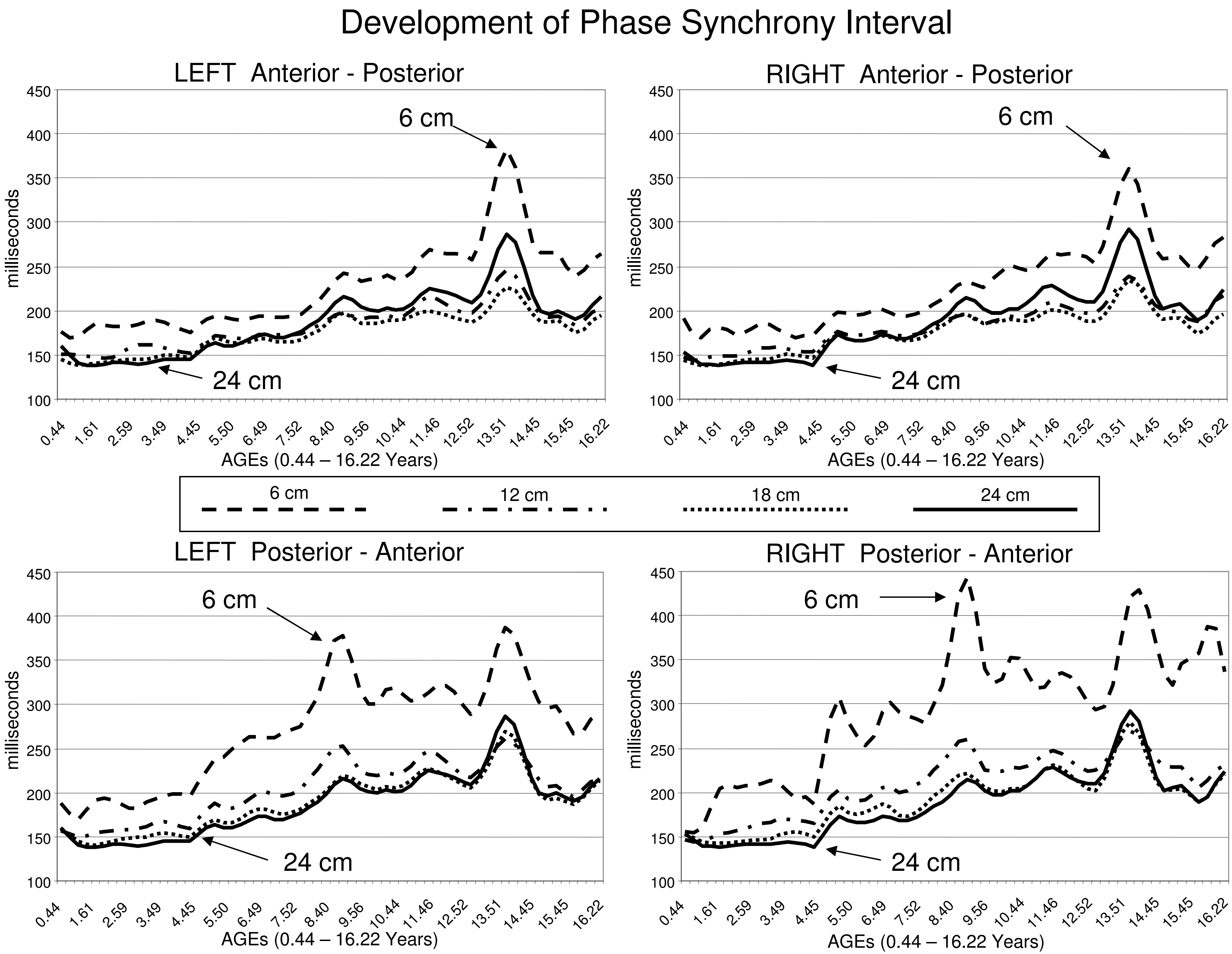



Phase Shift
Phase Difference in Degrees
Fp1-Fp1
Fp1-F3
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23
1st Derivative deg/100 msec
Phase Shift Duration
Fp1-Fp1
Fp1-F3
Phase Synchrony Interval
Fp1-C3
Fp1-P3
Fp1-O1
0:20
00:21
00:22
00:23


Synchrony & Phase Lock
Asynchrony & Phase Shifts
EEG Theta Rhythm
Phase Shift
1st Derivative of Instantaneous Phase
= 0
Phase Lock
Lexicor NRS-24 Demo
File Edit View Collection Montage Analysis Report NeuroStat Window Help
Scale (uV)
20.00
Edit Time
00:00
Montage
CircBP
Coh-test
Cz
CzC3
CzC3P3
Default
Deymed
Deymed19
Deymed22
Discovery
Split Half
Display Time
2
Cz-LE
C3-LE
00:00
00:01
(Deg/cs)
90.00
Anti-Phase 36
Anti-Phase Sh
AveRef
Bipolar
C34P34LE

Development of Phase Shift Duration





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
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.

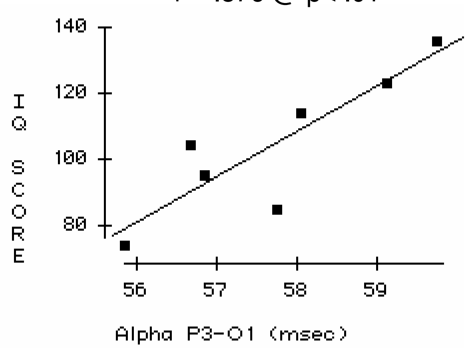
INTELLIGENCE AND EEG PHASE RESET:
A TWO COMPARTMENTAL MODEL OF PHASE SHIFT AND LOCK

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

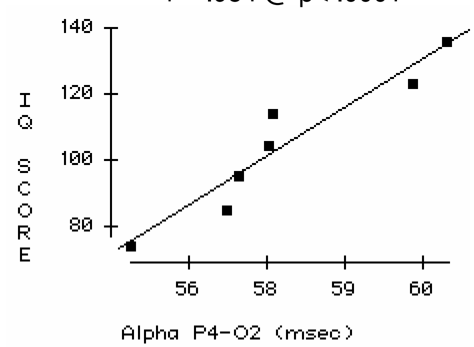
EEG and NeuroImaging Laboratory, Applied Neuroscience Research Institute.
St. Petersburg, Fl1 and Department of Neurology, University of South Florida
College of Medicine, Tampa, Fl.2

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

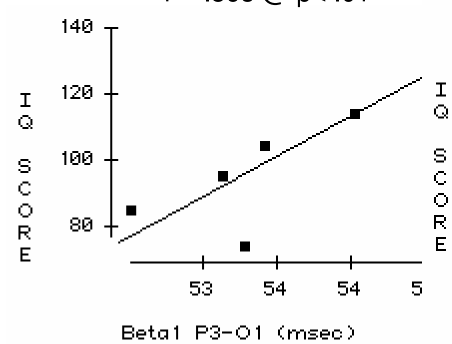
IQ = 78 + 13.78 x (msec)
r = .876 @ p< .01



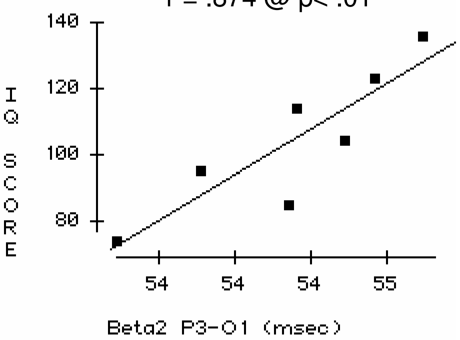
IQ = 70 +11.85 x (msec)
r = .954 @ p< .0001



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

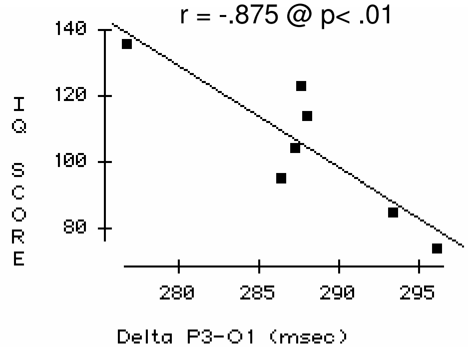


IQ = 68 + 34.40 x (msec)
r = .874 @ p< .01

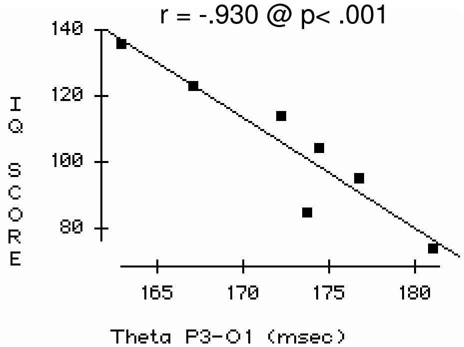


Regressions & Correlations of Phase Locking Interval Short Distances (6 cm)

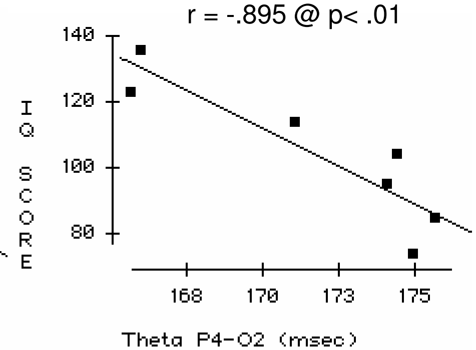
IQ = 143 - 3.11 x (msec)
r = -.875 @ p< .01



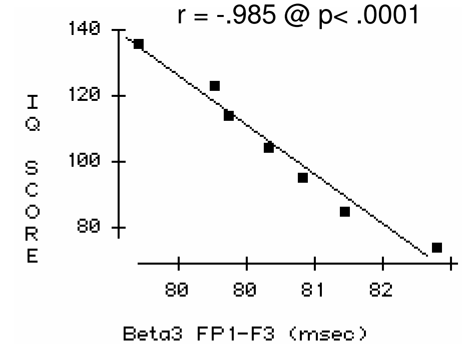
IQ = 142 - 3.36 x (msec)
r = -.930 @ p< .001

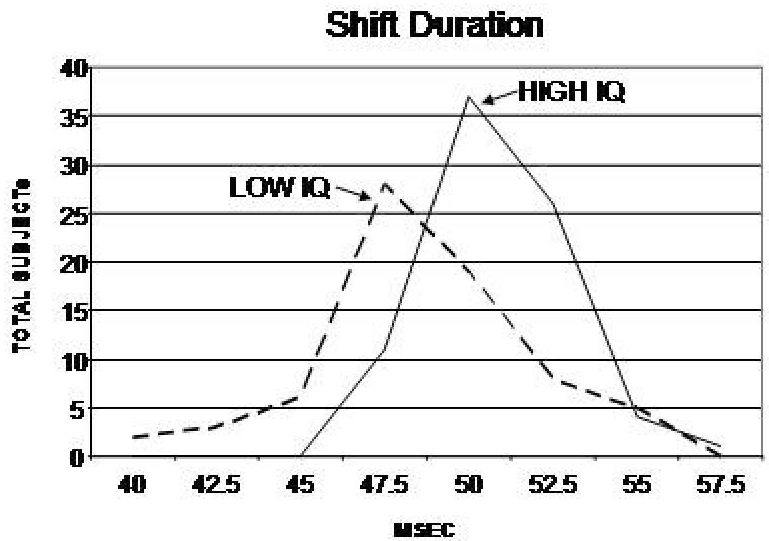


IQ = 132 - 4.57 x (msec)
r = -.895 @ p< .01

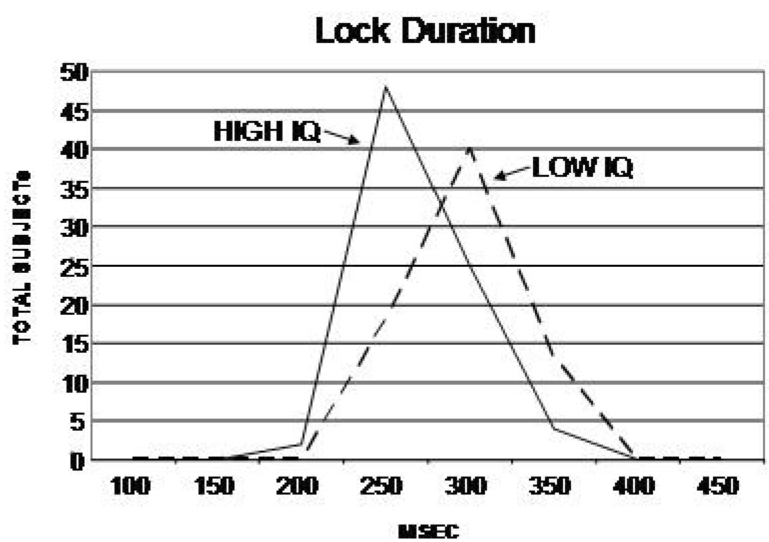


IQ = 140 - 20.08 x (msec)
r = -.985 @ p< .0001



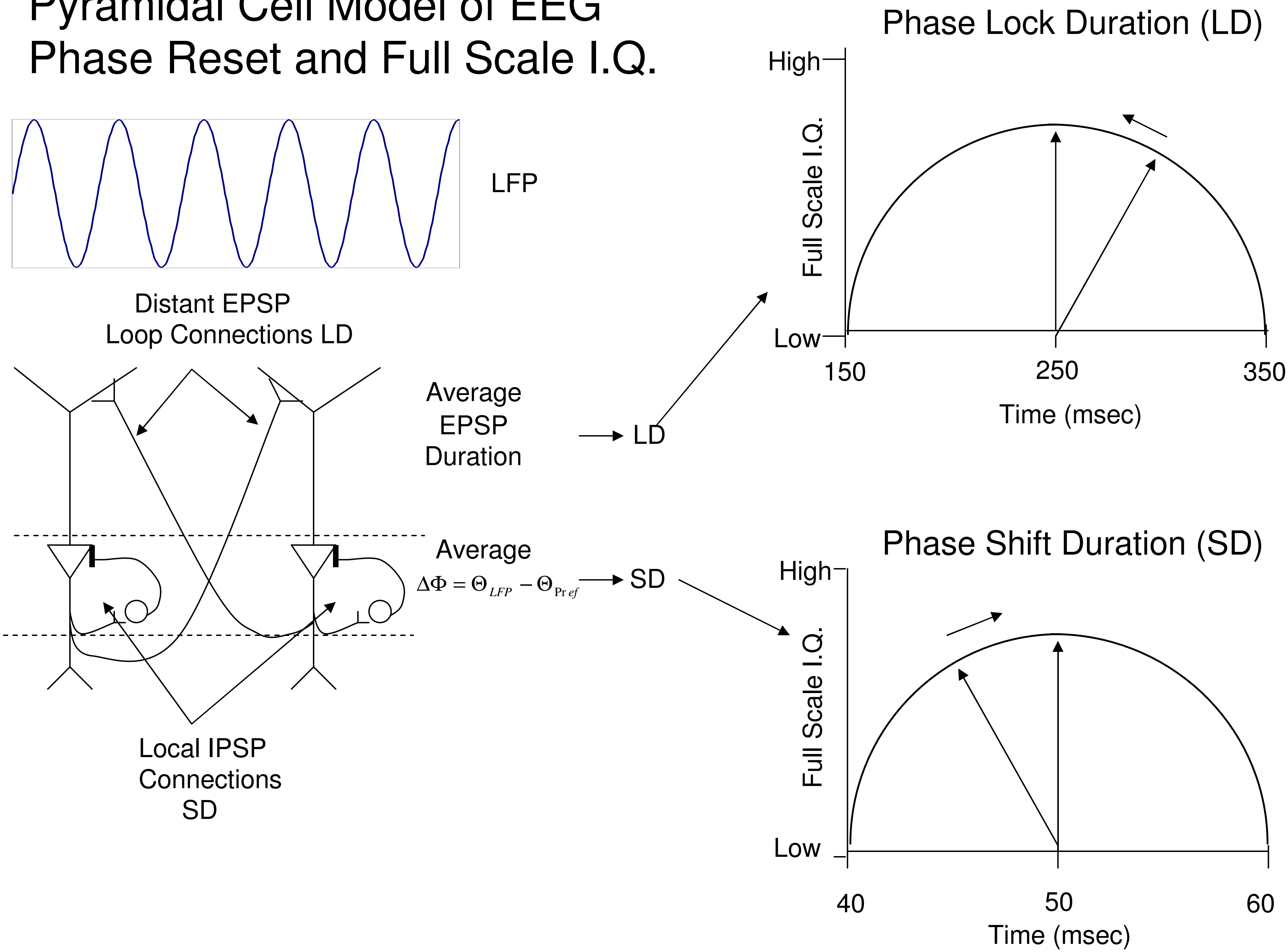


Shift Duration
HIGH IQ
LOW IQ
TOTAL SUBJECTS
0
5
10
15
20
25
30
35
40
40
42.5
45
47.5
50
52.5
55
57.5
MSEC



Lock Duration
HIGH IQ
LOW IQ
TOTAL SUBJECTS
0
5
10
15
20
25
30
35
40
45
50
100
150
200
250
300
350
400
450
MSEC

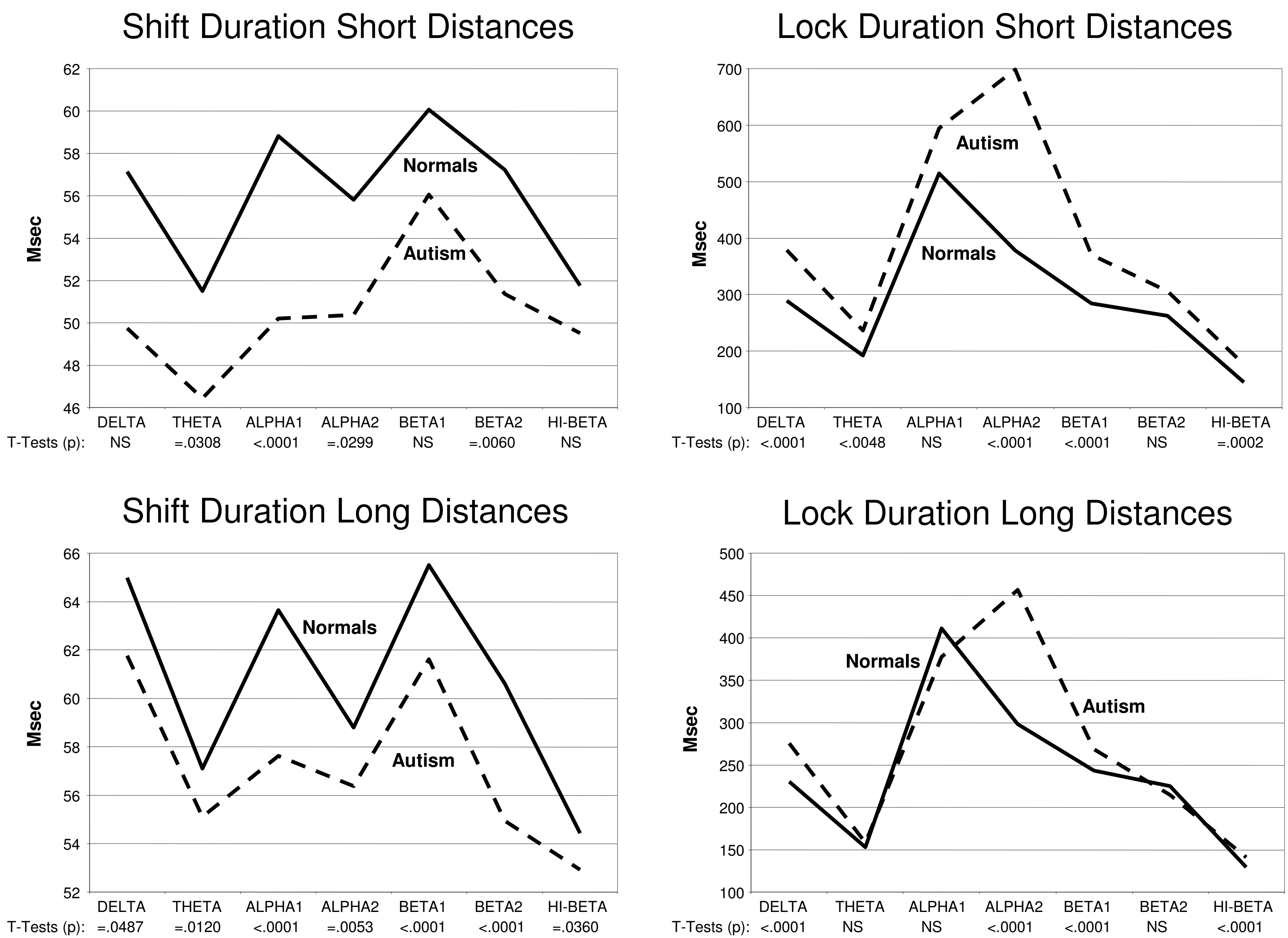
Pyramidal Cell Model of EEG Phase Reset and Full Scale I.Q.

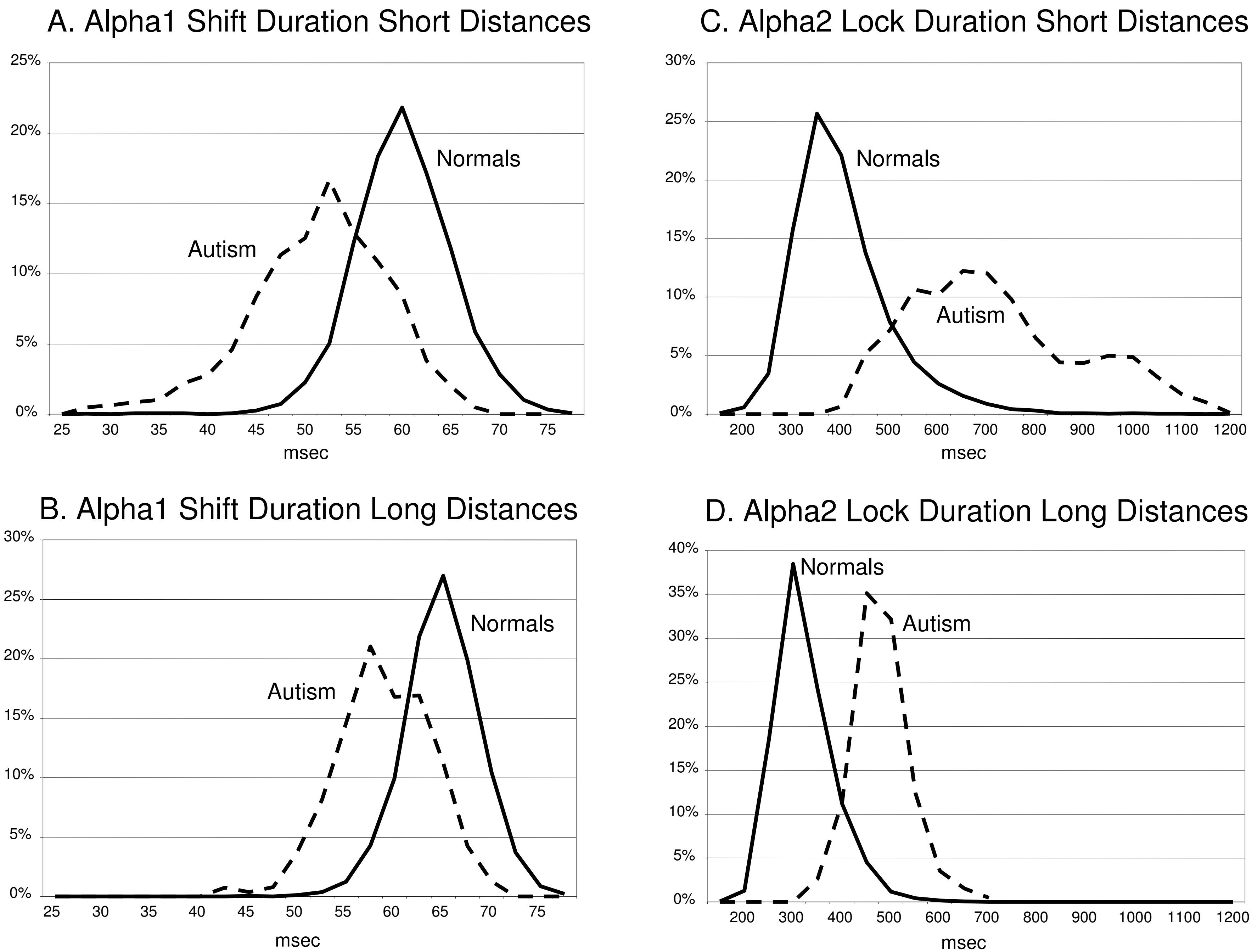


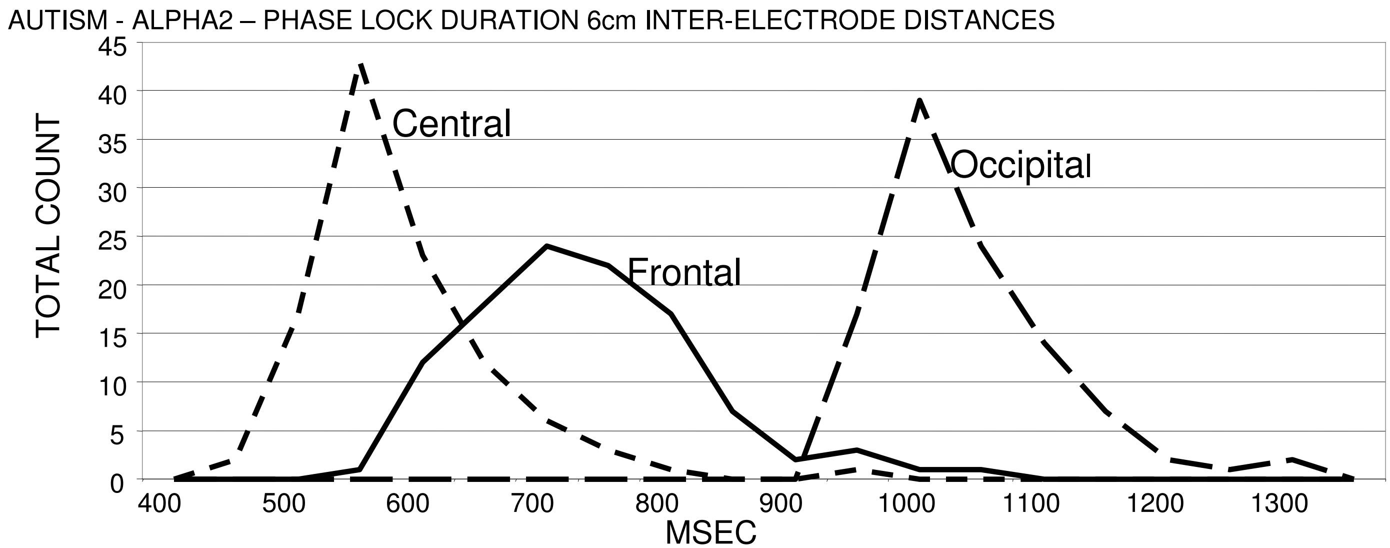
AUTISM AND EEG PHASE RESET: A UNIFIED THEORY OF DEFICIENT GABA MEDIATED INHIBITION IN THALAMO-CORTICAL CONNECTIONS

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


Shift Duration Short Distances
Msec
62
60
58
56
54
52
50
48
46
Normals
Autism
DELTA THETA ALPHA1 ALPHA2 BETA1 BETA2 HI-BETA
T-Tests (p): NS =.0308 <.0001 =.0299 NS =.0060 NS
Lock Duration Short Distances
Msec
700
600
500
400
300
200
100
Autism
Normals
DELTA THETA ALPHA1 ALPHA2 BETA1 BETA2 HI-BETA
T-Tests (p): <.0001 <.0048 NS <.0001 <.0001 NS =.0002
Shift Duration Long Distances
Msec
66
64
62
60
58
56
54
52
Normals
Autism
DELTA THETA ALPHA1 ALPHA2 BETA1 BETA2 HI-BETA
T-Tests (p): =.0487 =.0120 <.0001 =.0053 <.0001 <.0001 =.0360
Lock Duration Long Distances
Msec
500
450
400
350
300
250
200
150
100
Normals
Autism
DELTA THETA ALPHA1 ALPHA2 BETA1 BETA2 HI-BETA
T-Tests (p): <.0001 NS NS <.0001 <.0001 NS <.0001

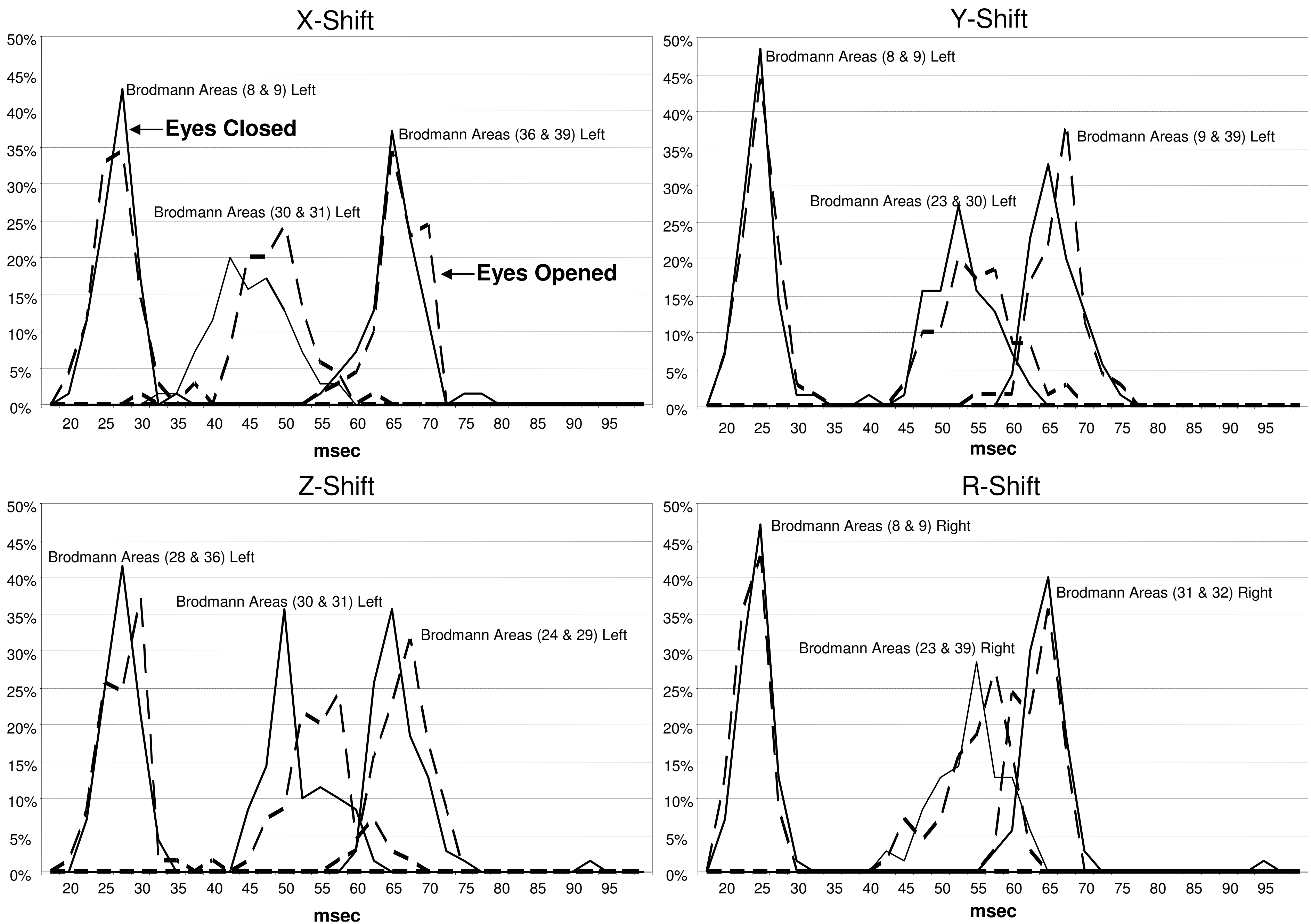

A. Alpha1 Shift Duration Short Distances
25%
20%
15%
10%
5%
0%
25
30
35
40
45
50
55
60
65
70
75
msec
Normals
Autism
C. Alpha2 Lock Duration Short Distances
30%
25%
20%
15%
10%
5%
0%
200
300
400
500
600
700
800
900
1000
1100
1200
msec
Normals
Autism
B. Alpha1 Shift Duration Long Distances
30%
25%
20%
15%
10%
5%
0%
25
30
35
40
45
50
55
60
65
70
75
msec
Normals
Autism
D. Alpha2 Lock Duration Long Distances
40%
35%
30%
25%
20%
15%
10%
5%
0%
200
300
400
500
600
700
800
900
1000
1100
1200
msec
Normals
Autism


AUTISM - ALPHA2 – PHASE LOCK DURATION 6cm INTER-ELECTRODE DISTANCES
TOTAL COUNT
0
5
10
15
20
25
30
35
40
45
400
500
600
700
800
900
1000
1100
1200
1300
MSEC
Central
Frontal
Occipital

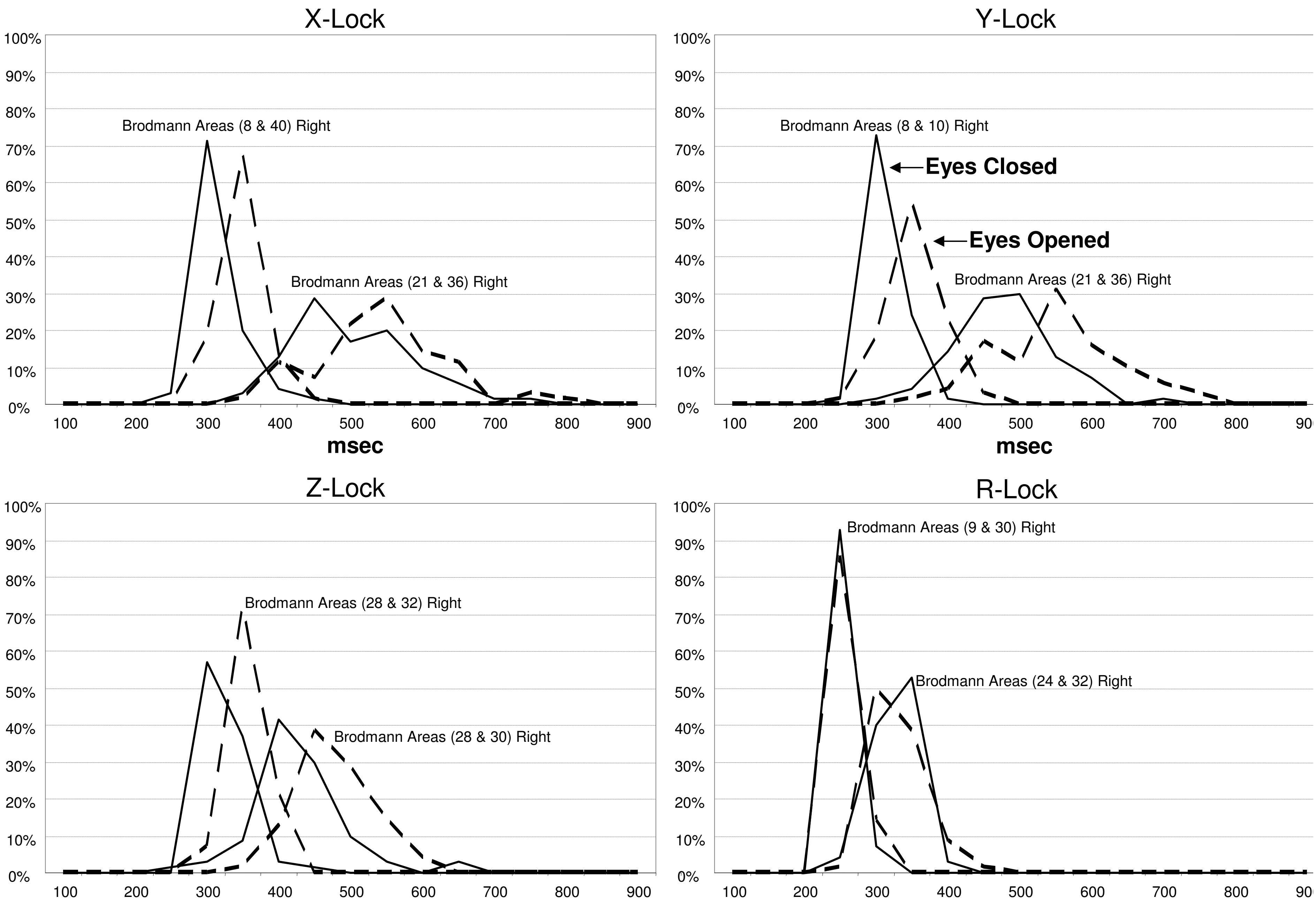
TEMPORAL QUANTA AND EEG LORETA PHASE RESET

Thatcher, R.W. North, D.M. and Biver, C. J.
EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, Fl

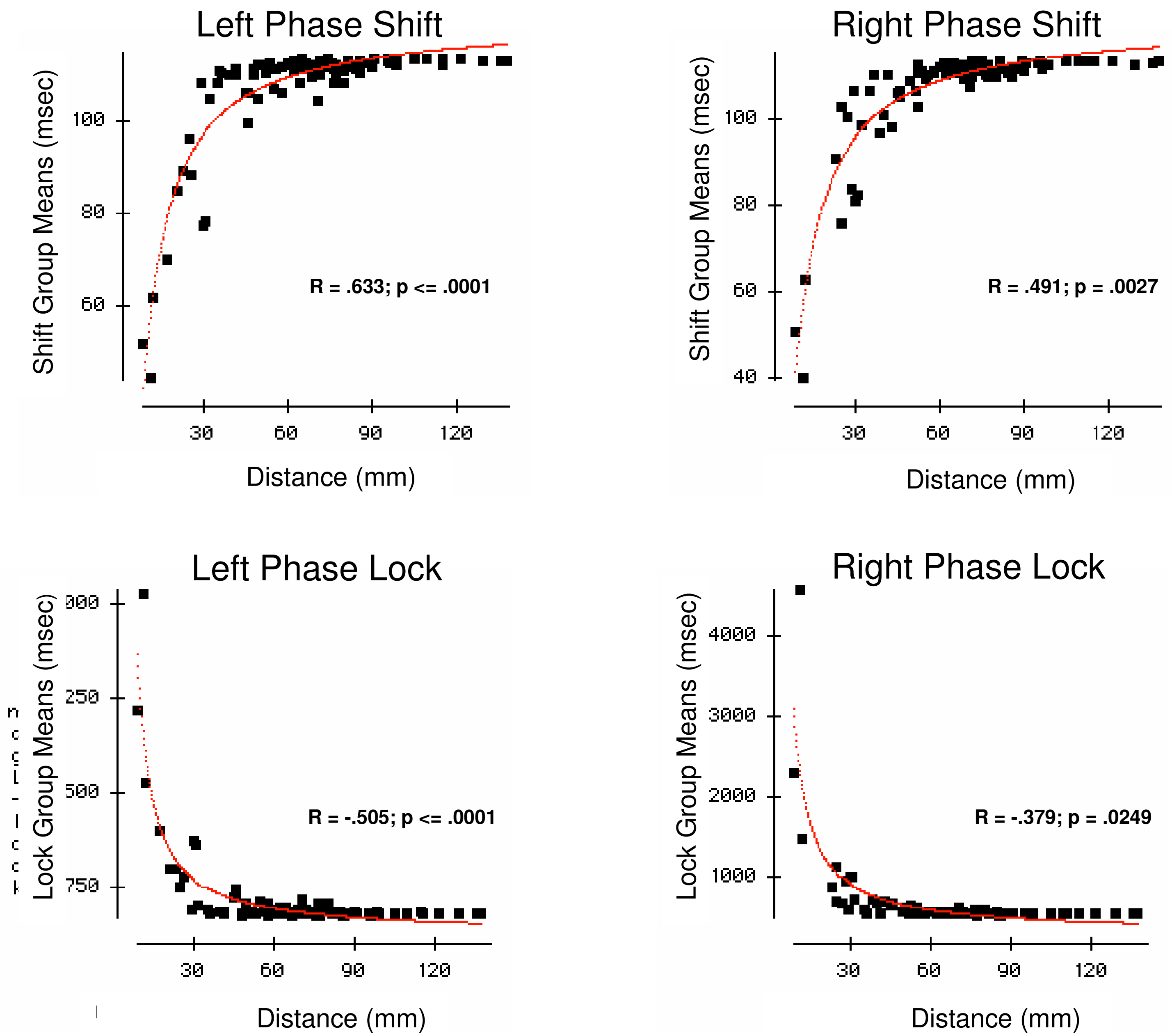
Phase Reset Shift Duration LORETA Default Brain Brodmann Area Pairs



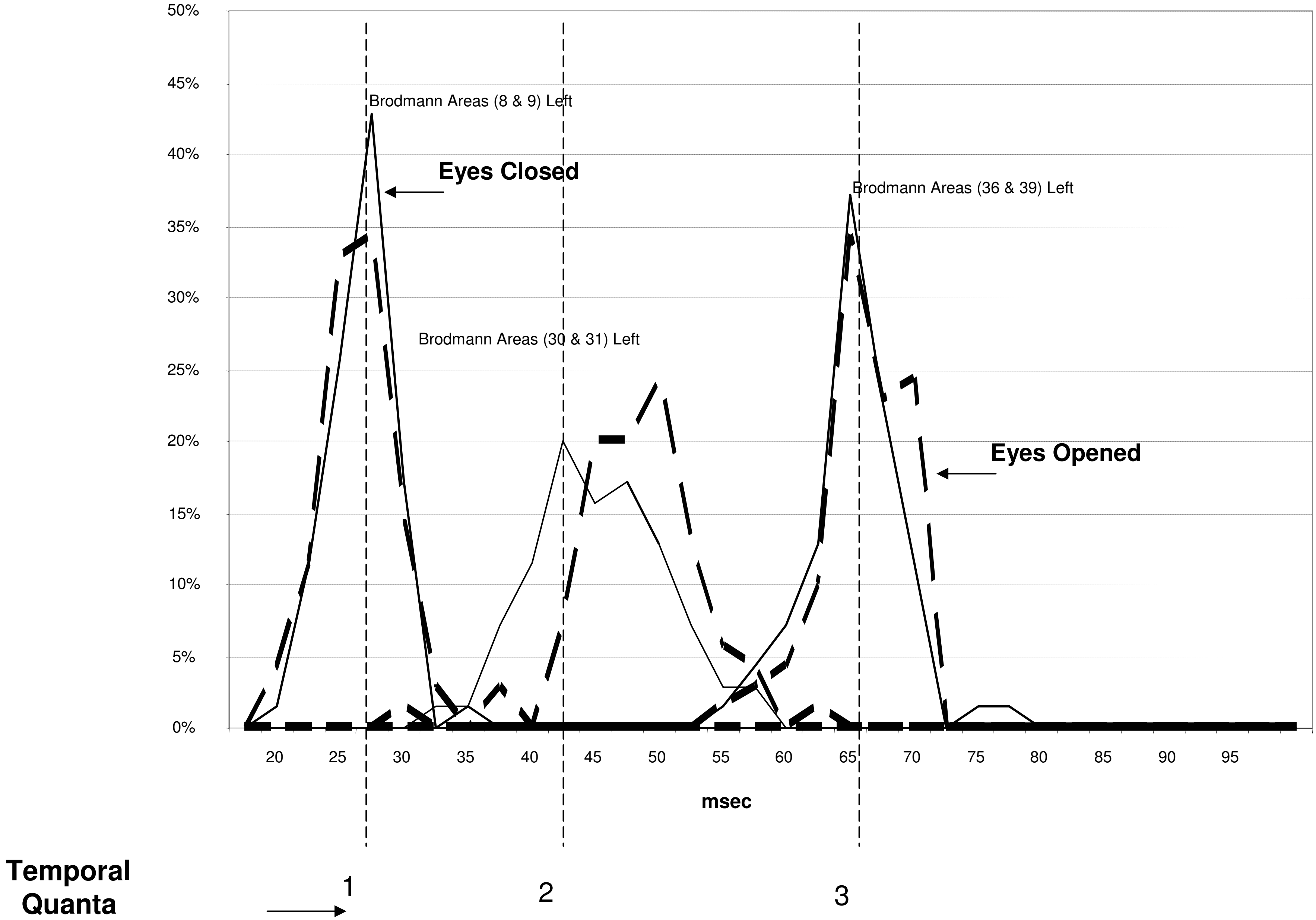
Phase Reset Lock Duration LORETA Default Brain Brodmann Area Pairs



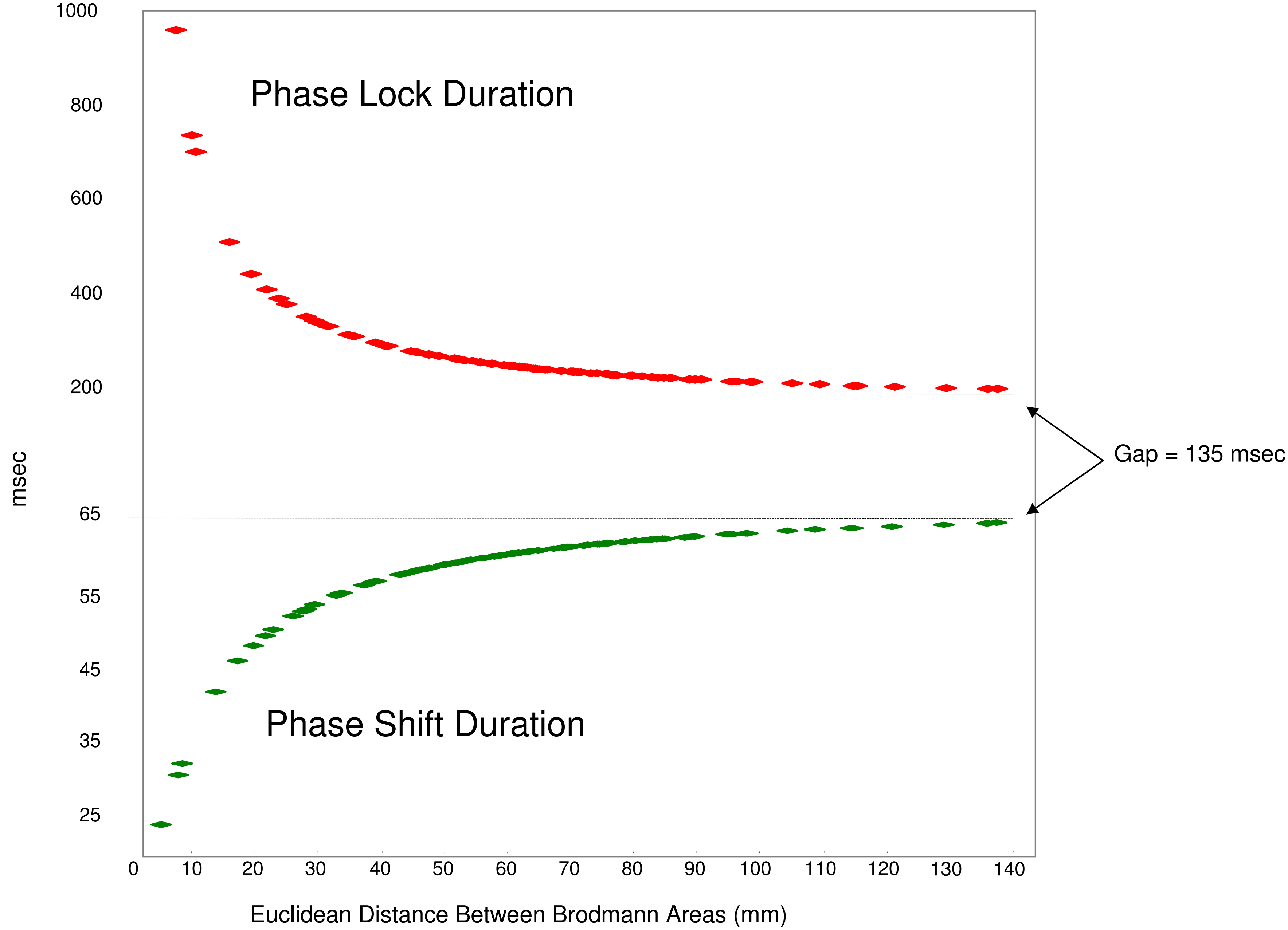
Relations Between Phase Reset Shift & Lock Means and the Euclidean Distance Between Voxels

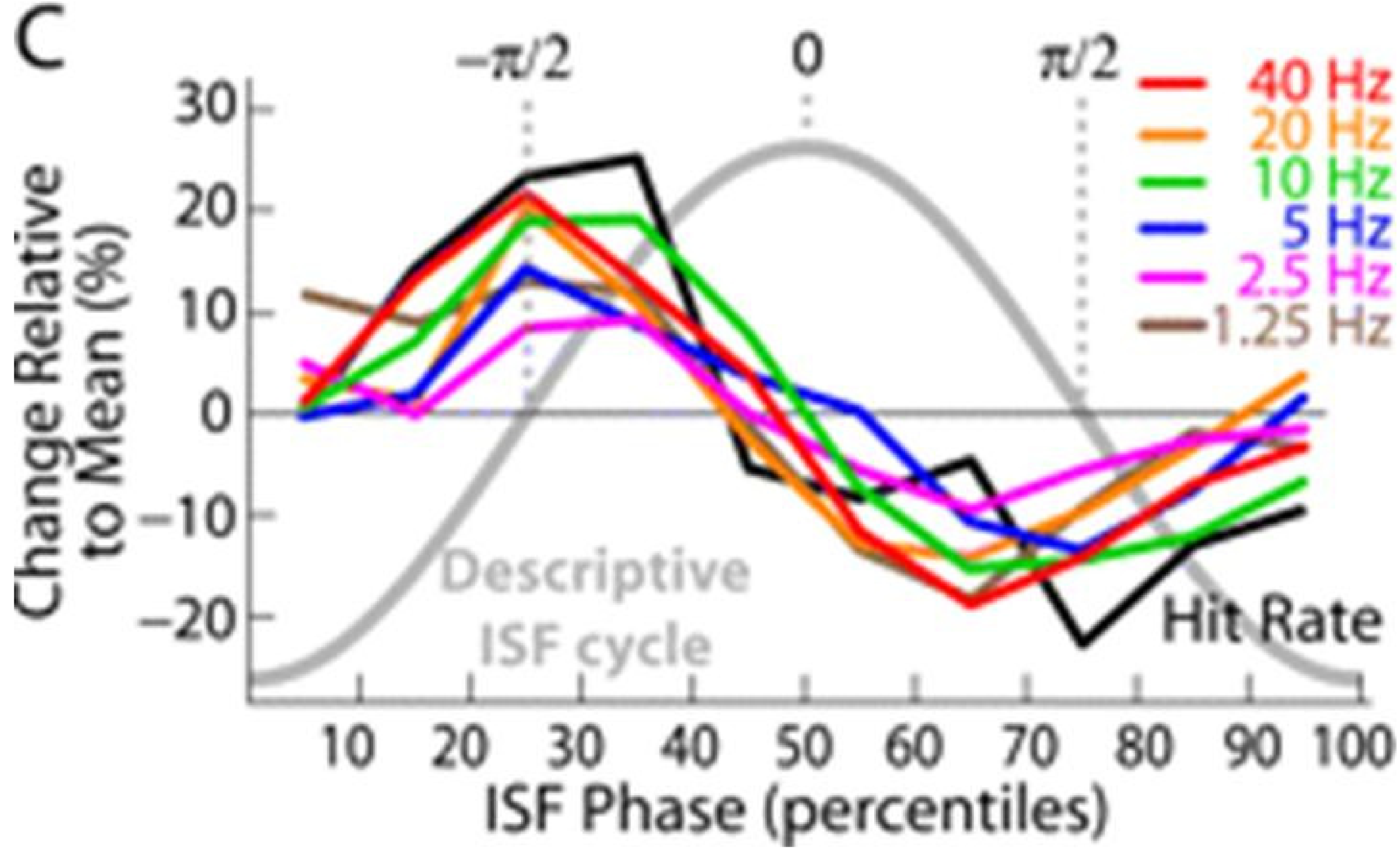


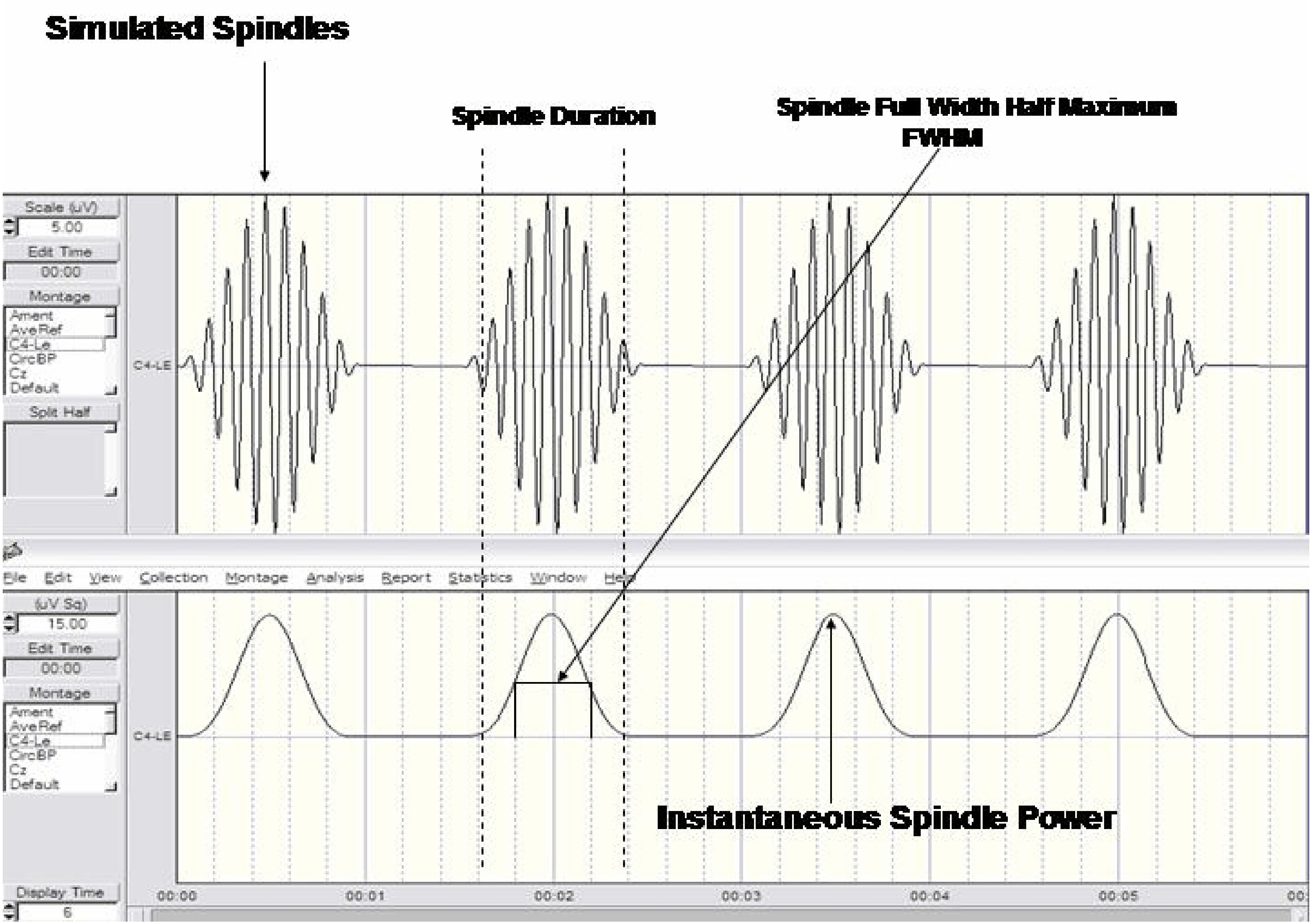
A Quanta Phase Shift Durations: N = 140 Under Each Quanta Duration



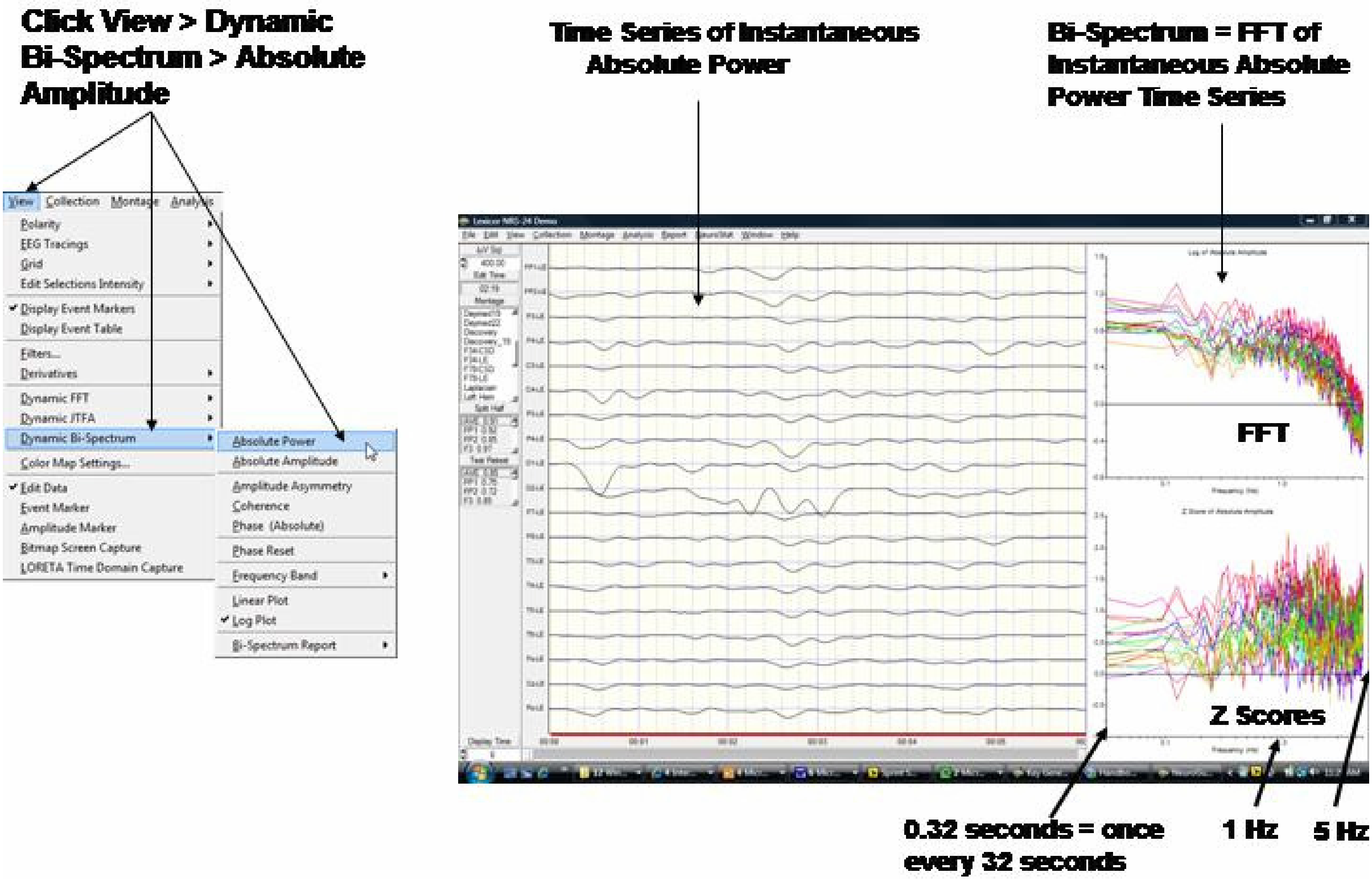
B **Non-Linear Exponential Brodmann Area Distances: Shift vs Lock**



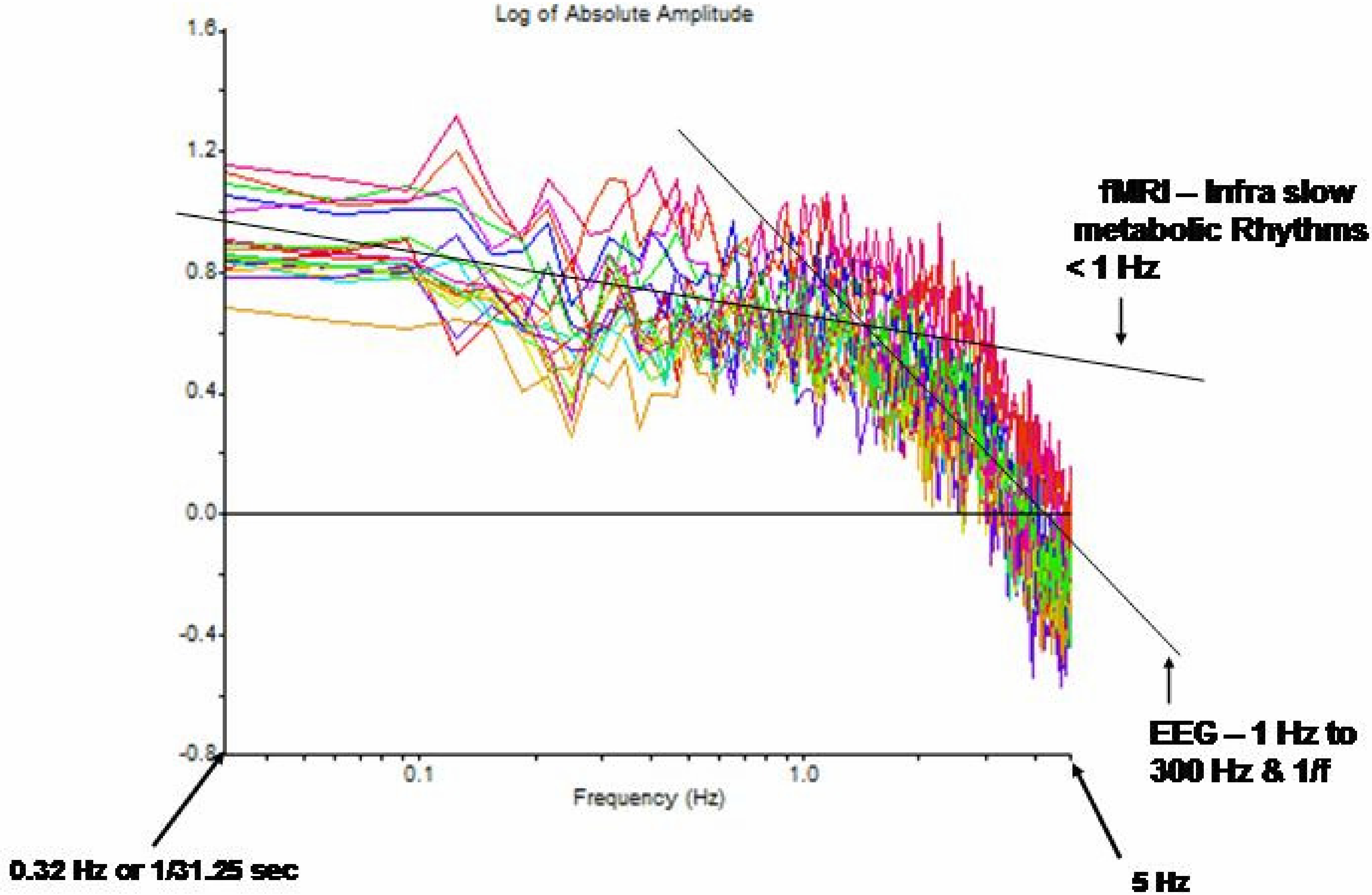

C
−π/2
0
π/2
40 Hz
20 Hz
10 Hz
5 Hz
2.5 Hz
1.25 Hz
30
20
10
0
−10
−20
Change Relative to Mean (%)
Descriptive ISF cycle
Hit Rate
10
20
30
40
50
60
70
80
90
100
ISF Phase (percentiles)



Simulated Spindles
Spindle Duration
Spindle Full Width Half Maximum
FWHM
Scale (uV)
5.00
Edit Time
00:00
Montage
Ament
AveRef
C4-Le
CircBP
Cz
Default
Split Half
C4-LE
File Edit View Collection Montage Analysis Report Statistics Window Help
(uV Sq)
15.00
Edit Time
00:00
Montage
Ament
AveRef
C4-Le
CircBP
Cz
Default
C4-LE
Instantaneous Spindle Power
Display Time
6
00:00
00:01
00:02
00:03
00:04
00:05


Click View > Dynamic Bi-Spectrum > Absolute Amplitude
Time Series of Instantaneous Absolute Power
Bi-Spectrum = FFT of Instantaneous Absolute Power Time Series
View
Collection
Montage
Analysis
Polarity
EEG Tracings
Grid
Edit Selections Intensity
Display Event Markers
Display Event Table
Filters...
Derivatives
Dynamic FFT
Dynamic JTFA
Dynamic Bi-Spectrum
Color Map Settings...
Edit Data
Event Marker
Amplitude Marker
Bitmap Screen Capture
LORETA Time Domain Capture
Absolute Power
Absolute Amplitude
Amplitude Asymmetry
Coherence
Phase (Absolute)
Phase Reset
Frequency Band
Linear Plot
Log Plot
Bi-Spectrum Report
FFT
Z Scores
0.32 seconds = once every 32 seconds
1 Hz
5 Hz

Two Compartments of the Frequency Spectrum of Bursts in EEG Absolute Amplitude

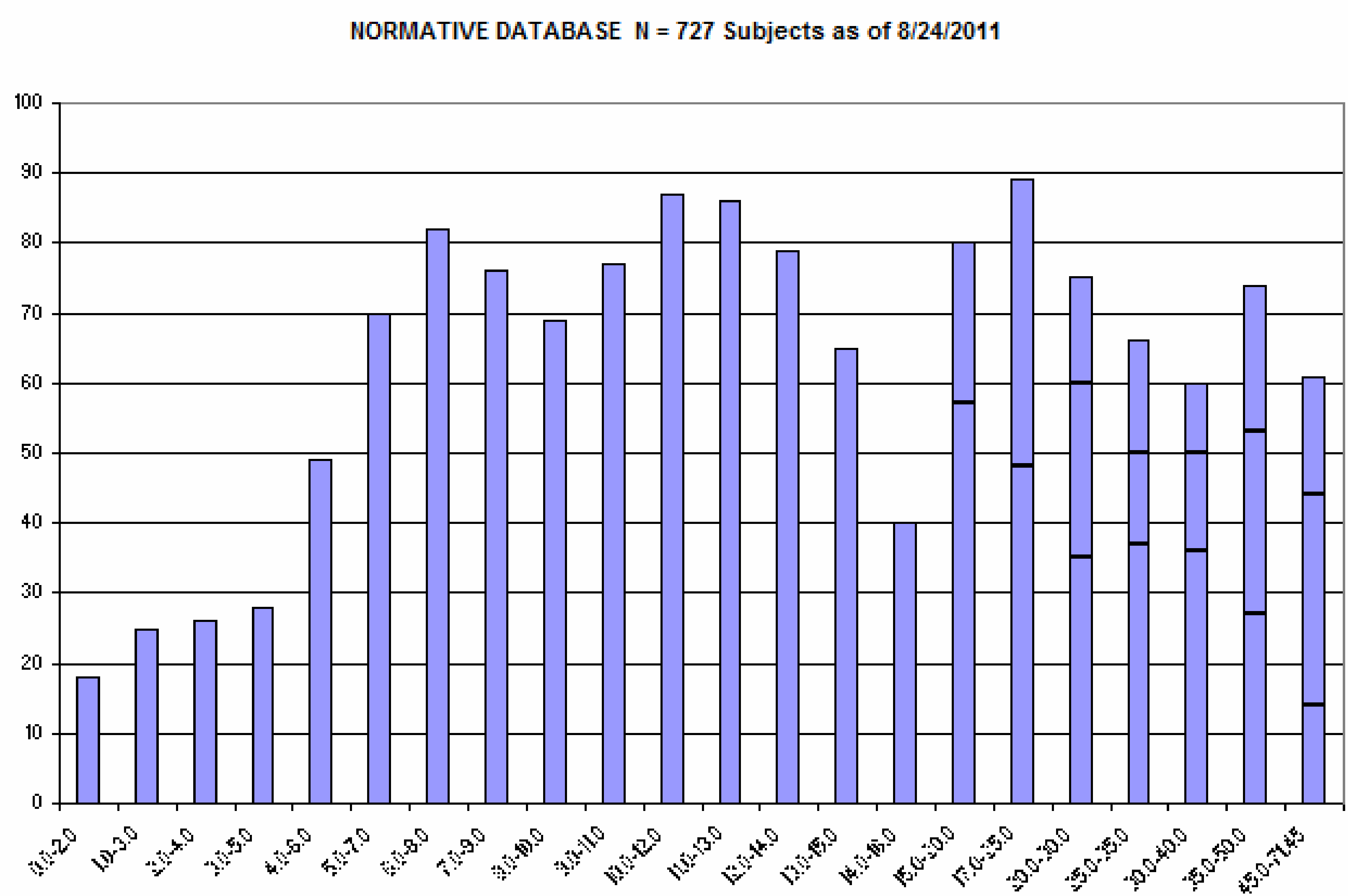


Published as a chapter in "Introduction to QEEG and Neurofeedback: Advanced Theory and Applications" Thomas Budzinsky, H. Budzinski, J. Evans and A. Abarbanel editors, Academic Press, San Diego, Calif, 2008.

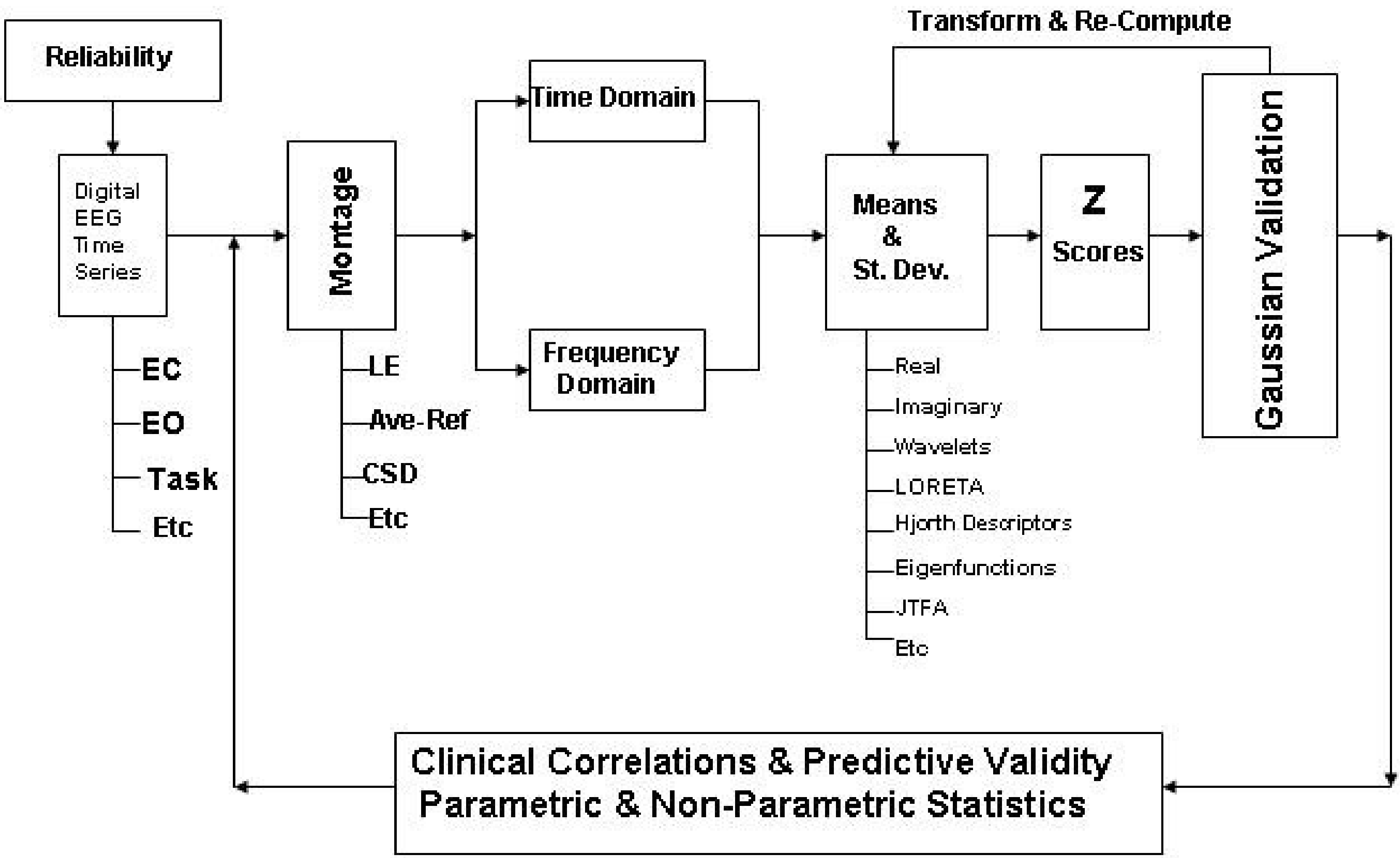
HISTORY OF THE SCIENTIFIC STANDARDS OF QEEG NORMATIVE DATABASES

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].

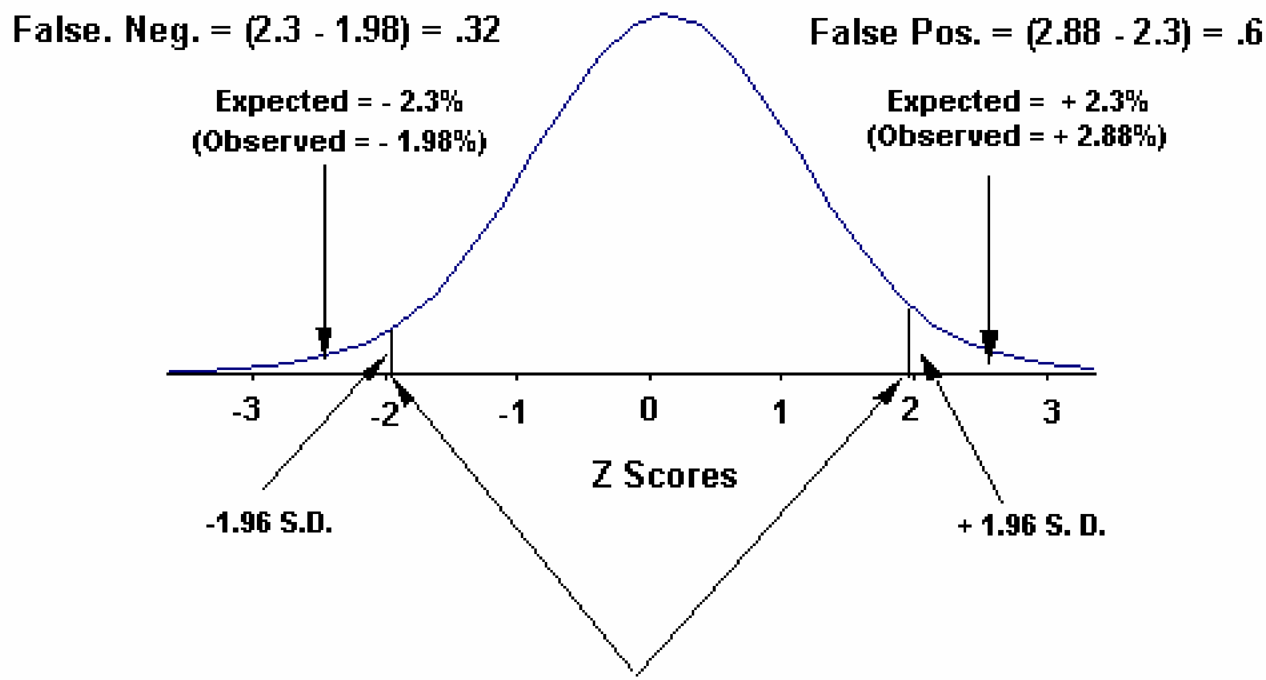

NORMATIVE DATABASE N = 727 Subjects as of 8/24/2011
100
90
80
70
60
50
40
30
20
10
0

Normative Database Validation Steps



Sensitivity Based on Deviation from Gaussian

Cross-Validation Accuracy N = 625 Subjects

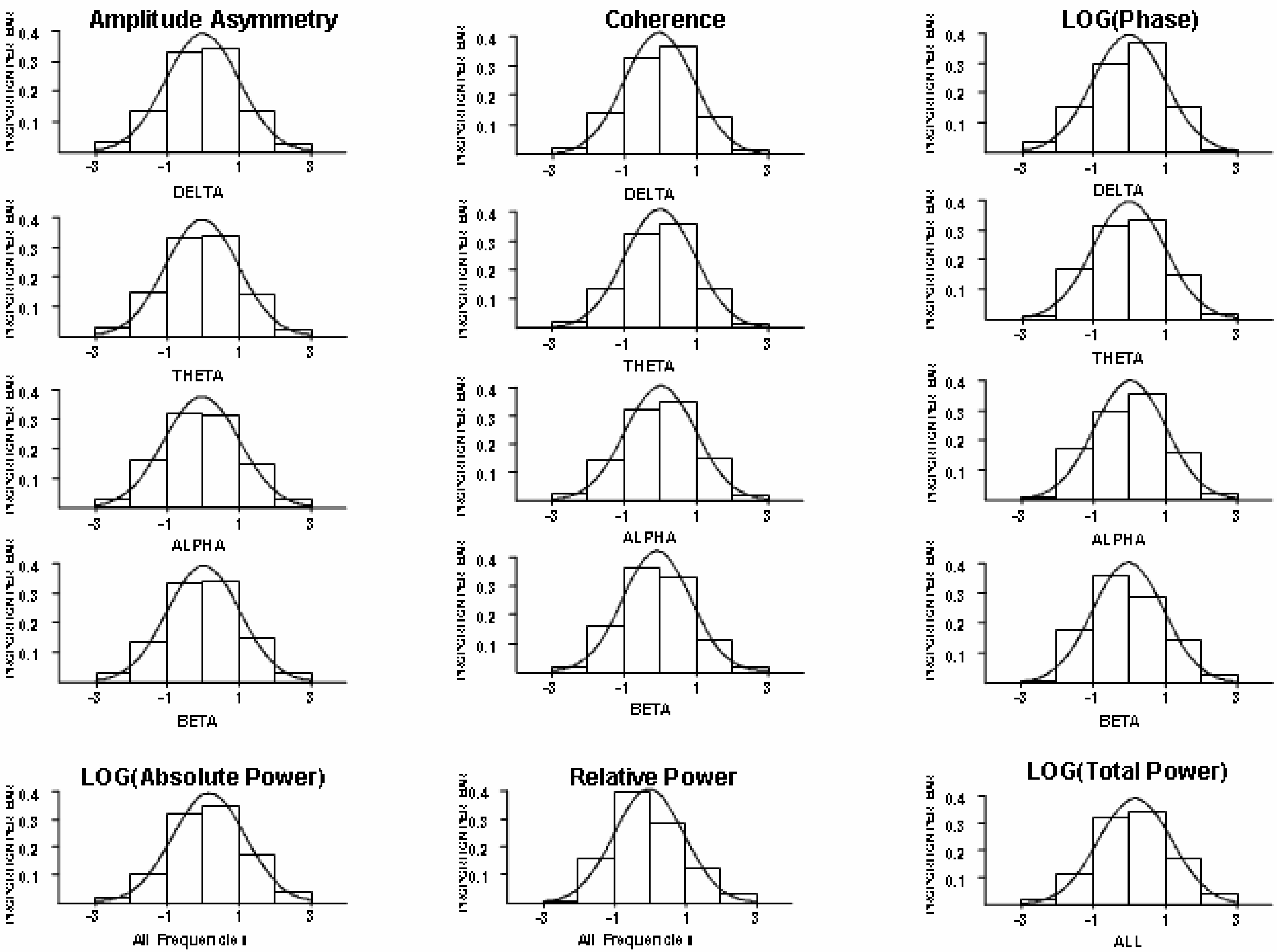


True Positive = (100 - (1.98 + 2.88) = 95.14%

$$\text{Sensitivity} = \frac{TP}{TP + (FP + FN)} = \frac{95.14}{95.14 + 1.0} = 98.96\%$$

$$\text{Specificity} = \frac{TN}{TN + (FP + FN)} = \text{Undefined}$$

Cross-Validation Birth to 82 Year EEG Normative Database



FFT Normative Database Sensitivities

2 STDEVs	CALC SENSITIVITY: FP=TP/(TP+FP) or FN=TP/(TP+FN)		
AGES	(+/- 2 SD)	(>= 2 SD)	(<= -2 SD)
0-5.99	0.95448265	0.9771774	0.97730526
6-9.99	0.95440363	0.9772031	0.97720054
10-12.99	0.9543997	0.97724346	0.97715624
13-15.99	0.95440512	0.97723601	0.97716911
16-ADULT	0.9543945	0.97718143	0.97721307
ALL	0.95442375	0.97720714	0.97721661

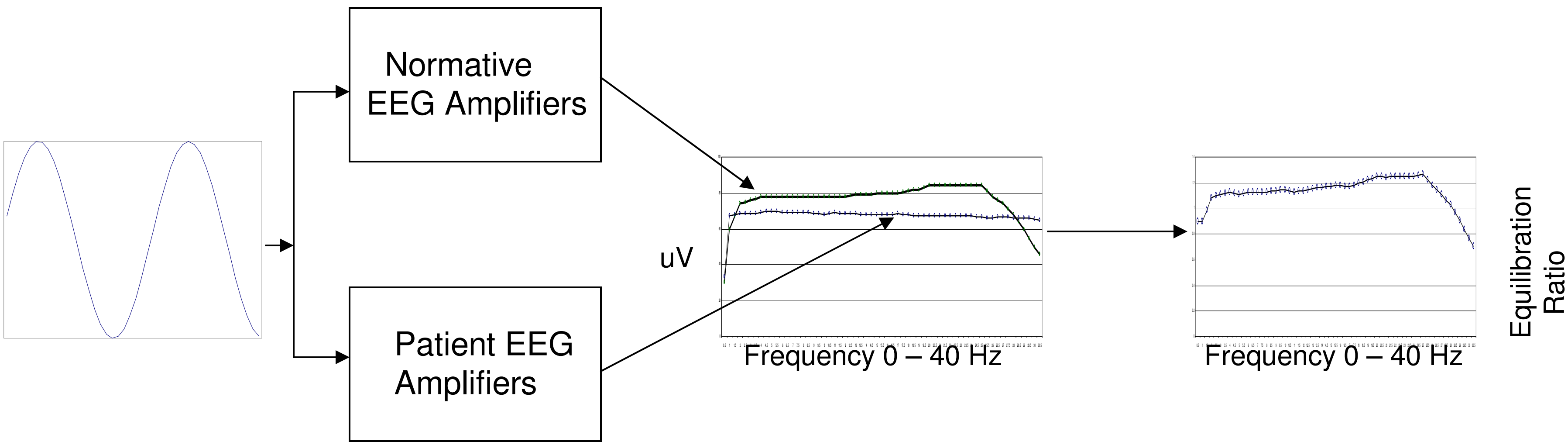
+/- 2 Std. Dev.

3 STDEVs	CALC SENSITIVITY: FP=TP/(TP+FP) or FN=TP/(TP+FN)		
AGES	(+/- 3 SD)	(>= 3 SD)	(<= -3 SD)
0-5.99	0.99743898	0.99871123	0.99872774
6-9.99	0.99744112	0.99871611	0.99872501
10-12.99	0.99744688	0.99873171	0.99871518
13-15.99	0.99743186	0.99871951	0.99871234
16-ADULT	0.99743835	0.99870216	0.99873619
ALL	0.99744002	0.99871716	0.99872286

+/- 3 Std. Dev.

Normative Database Amplifier Matching – Microvolt Sine Waves 0 to 40 Hz

Equilibration Ratios to Match Frequency Responses



Cross-Validation of NeuroGuide vs NxLink

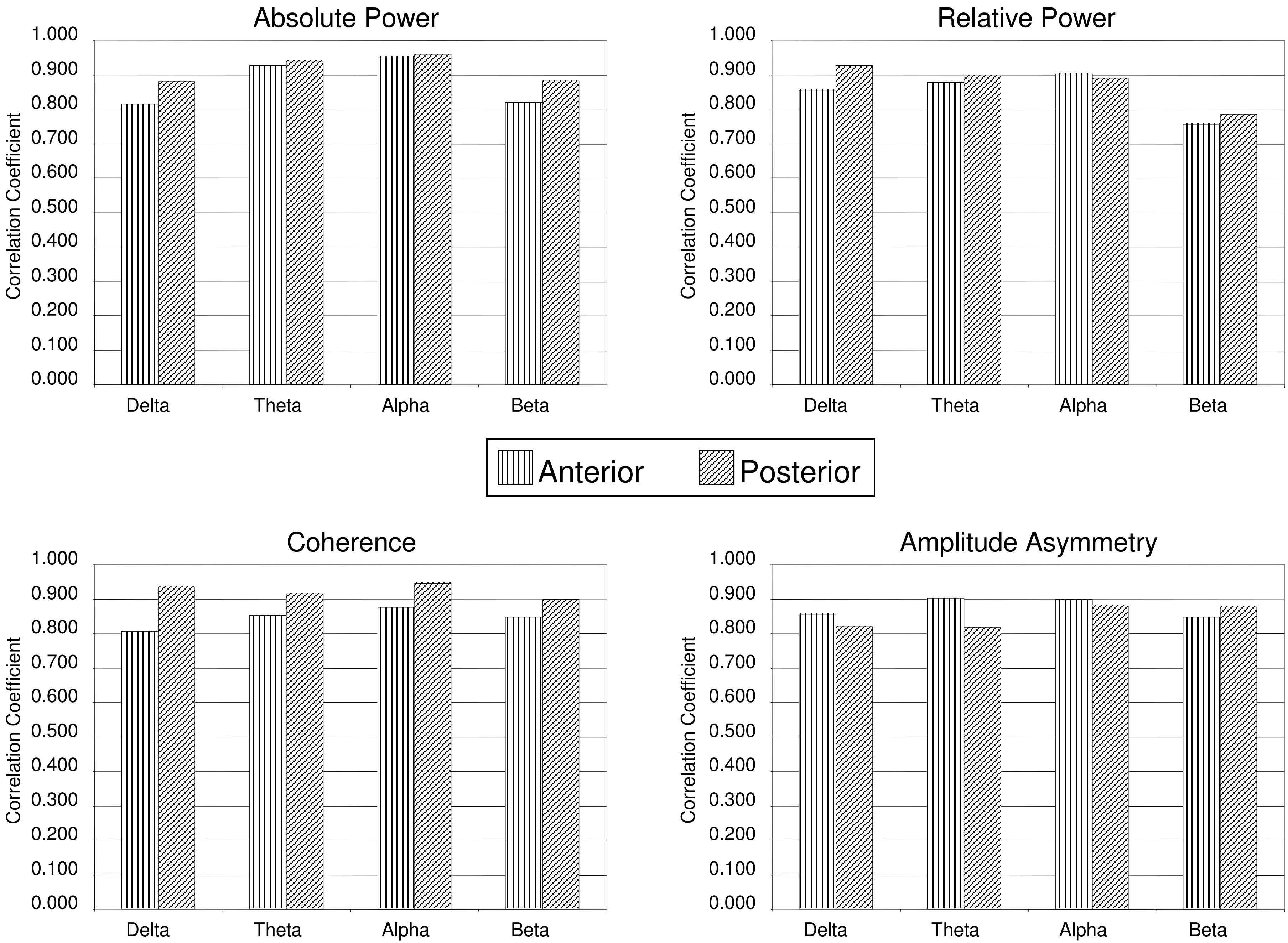
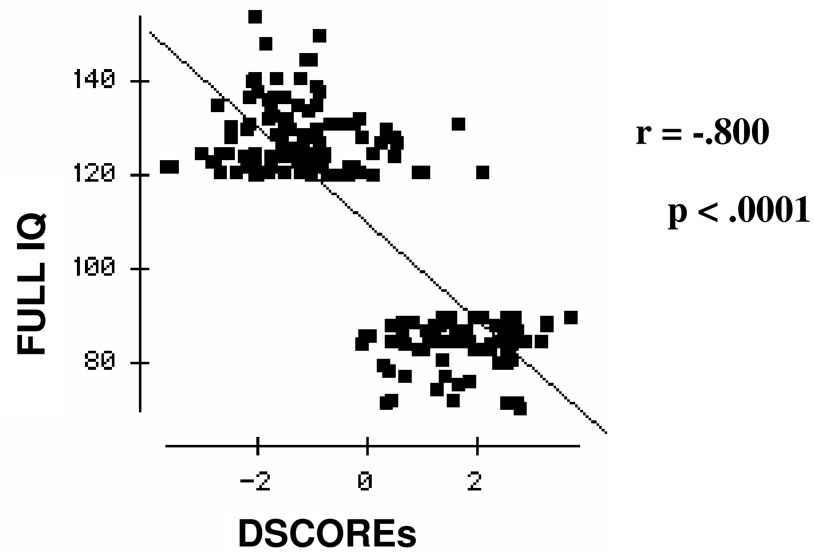


Table IV
List of "Gold Standards" by which to judge
QEEG Normative databases

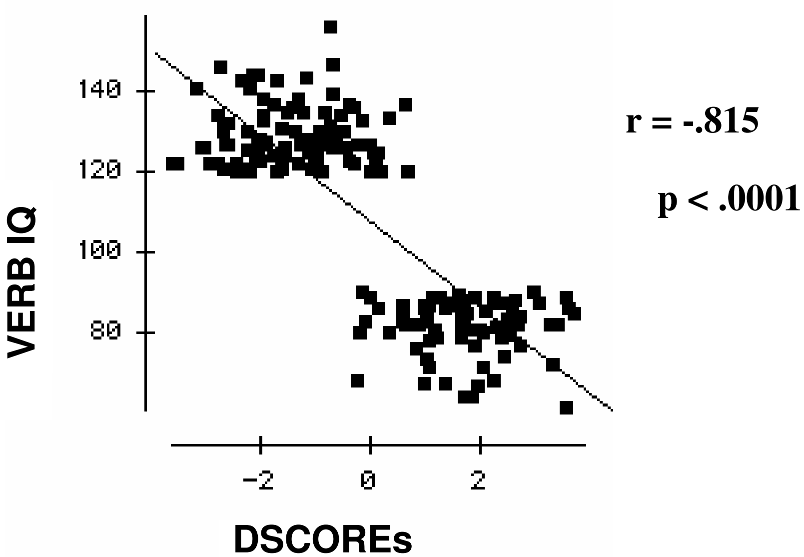
	Standards	Yes	No
1	Peer reviewed publications		
2	Amplifier Matching		
3	Artifact Rejection		
4	Test Re-Test Reliability		
5	Inclusion/exclusion criteria		
6	Adequate Sample size per age group		
7	Approximation to a Gaussian		
8	Cross-Validation		
9	Clinical Correlation		
10	FDA Registered		

Correlations between DSCOREs with FULL IQ, VERB IQ, & PERF IQ

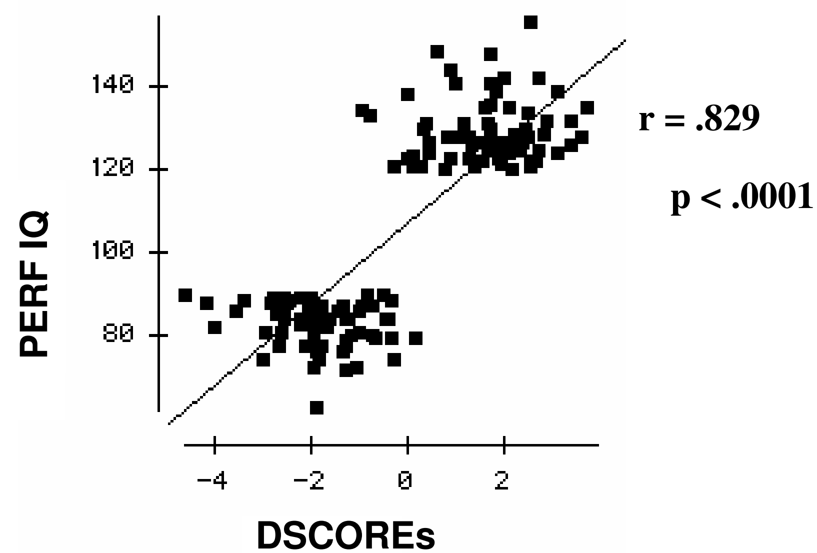
FULL IQ Discriminant Scores with FULL IQ



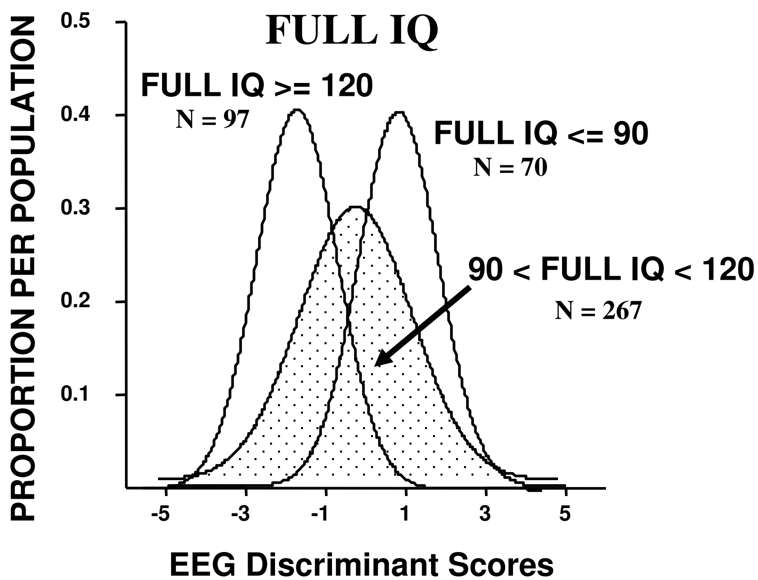
VERB IQ Discriminant Scores with VERB IQ

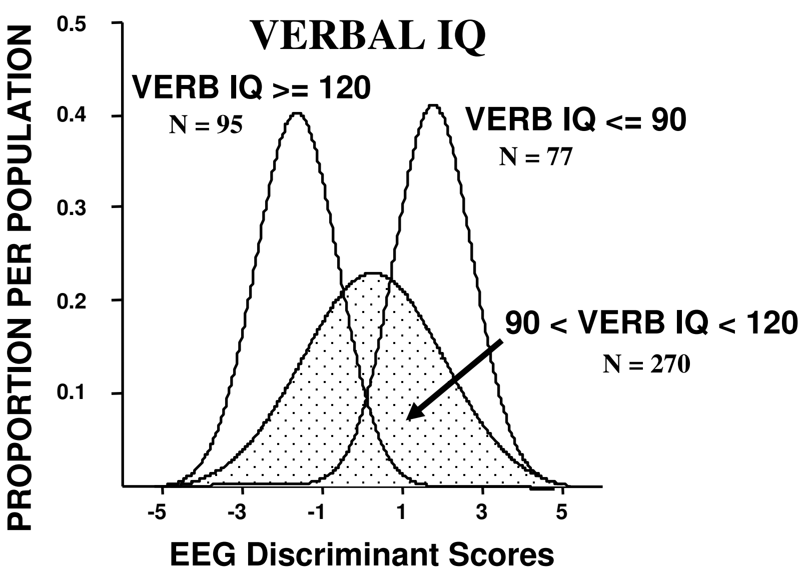


PERF IQ Discriminant Scores with PERF IQ



Histograms of Discriminant Functions using IQ Score Measures





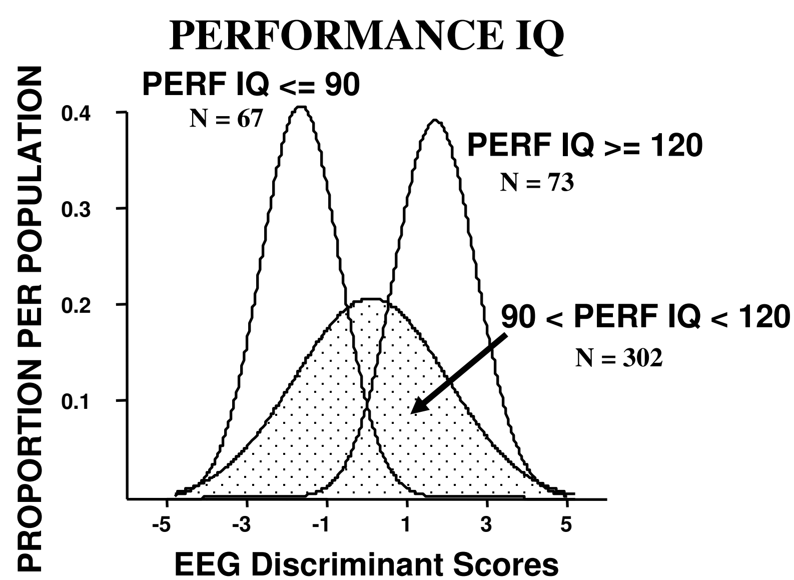


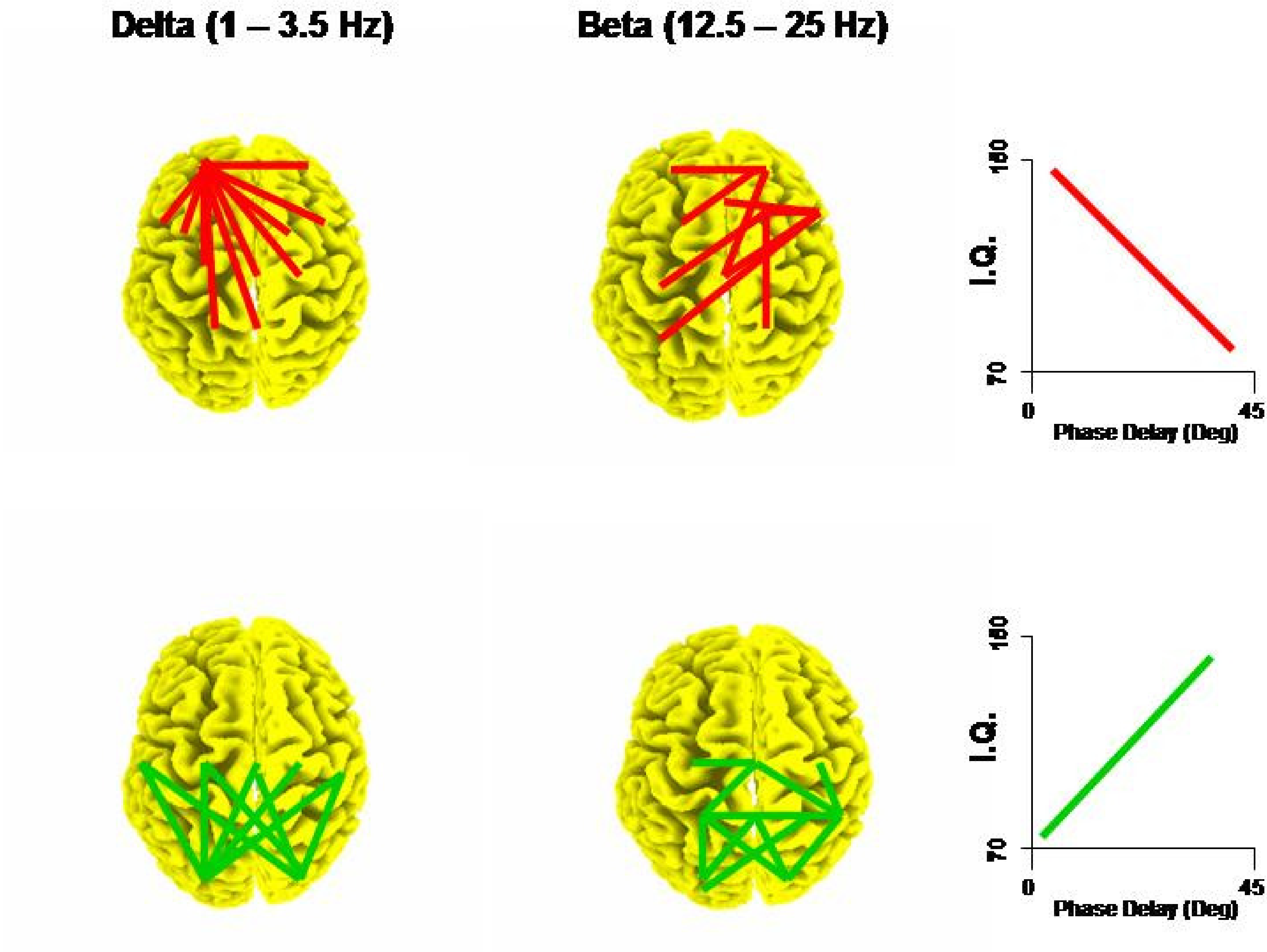
TABLE VII.

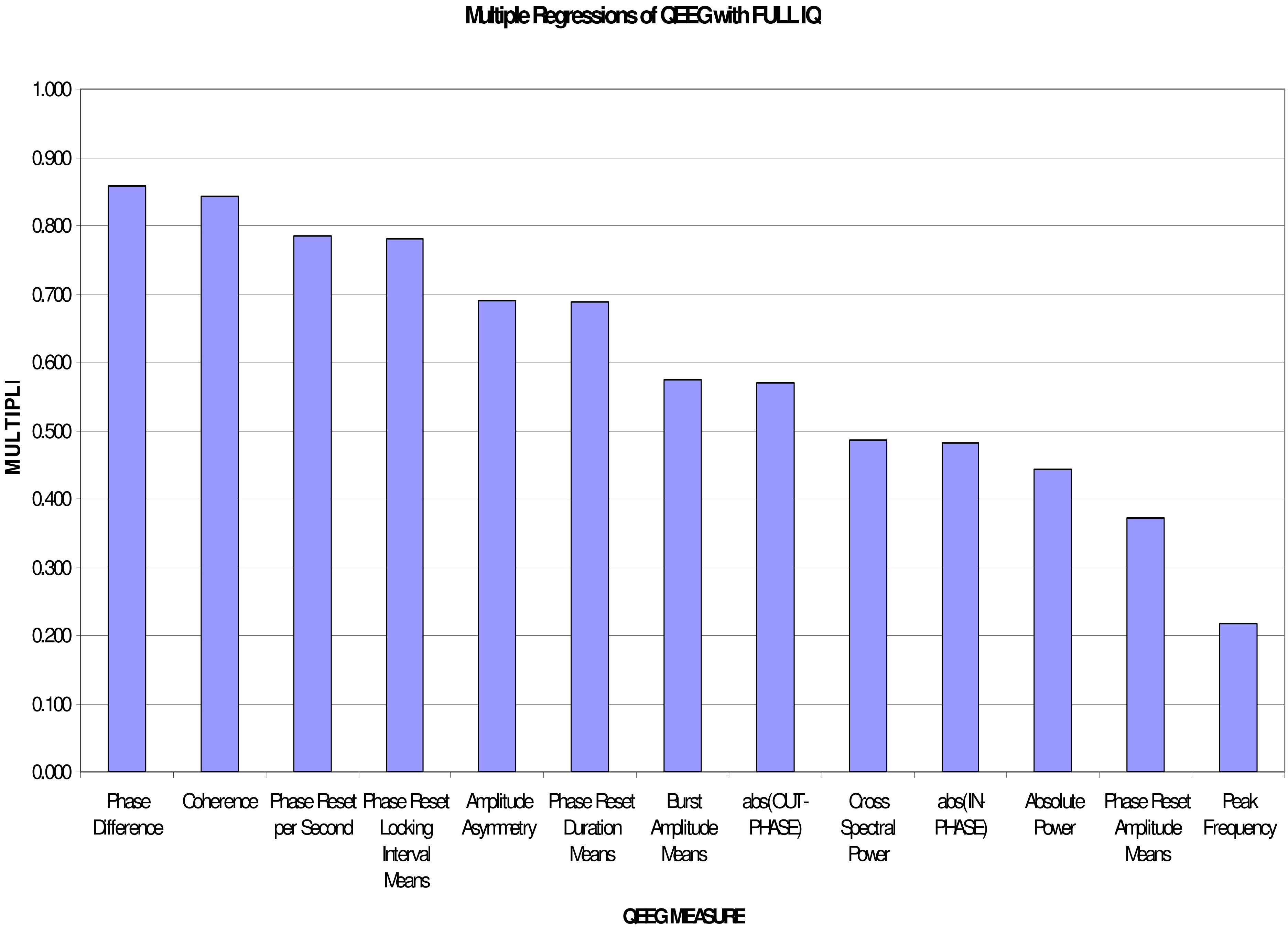
Correlations @ $p < .05$ of Significant T-Test Variables with IQ SCOREs

<u>DQFULL</u>	Absolute Power		Coherence		Absolute Phase	
Frequency:	POS +	NEG -	POS +	NEG -	POS +	NEG -
DELTA	8	0	1	58	20	10
THETA	1	0	1	39	13	3
ALPHA	6	0	2	24	13	2
BETA	7	0	0	14	13	6
HI-BETA	0	0	0	30	5	9
TOTAL	22	0	4	165	64	30

<u>DQVERB</u>	Absolute Power		Coherence		Absolute Phase	
Frequency:	POS +	NEG -	POS +	NEG -	POS +	NEG -
DELTA	6	0	0	49	11	13
THETA	3	0	0	37	0	6
ALPHA	4	0	0	42	3	16
BETA	2	0	0	10	1	7
HI-BETA	0	0	0	6	1	13
TOTAL	15	0	0	144	16	55

<u>DQPERF</u>	Absolute Power		Coherence		Absolute Phase	
Frequency:	POS +	NEG -	POS +	NEG -	POS +	NEG -
DELTA	10	0	1	74	36	4
THETA	3	0	2	40	28	3
ALPHA	16	0	18	9	16	0
BETA	11	0	0	25	19	1
HI-BETA	2	0	0	53	7	1
TOTAL	42	0	21	201	106	9


Delta (1 – 3.5 Hz)
Beta (12.5 – 25 Hz)
I.Q.
150
70
0
45
Phase Delay (Deg)
I.Q.
150
70
0
45
Phase Delay (Deg)


Multiple Regressions of QEEG with FULL IQ
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
MULTIPLI
Phase Difference
Coherence
Phase Reset per Second
Phase Reset Locking Interval Means
Amplitude Asymmetry
Phase Reset Duration Means
Burst Amplitude Means
abs(OUT-PHASE)
Cross Spectral Power
abs(IN-PHASE)
Absolute Power
Phase Reset Amplitude Means
Peak Frequency
QEEG MEASURE

Essentials of Operant Conditioning

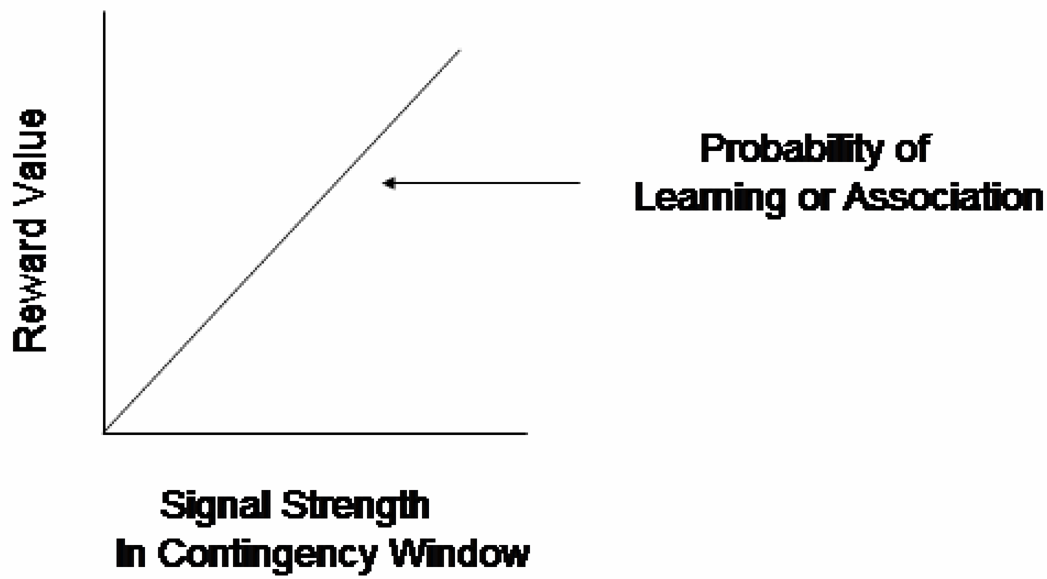
1- Specificity – Reinforce EEG events in hubs/modules in networks related to the patient's symptoms. Minimize compensatory hubs/modules.

2- The 'Feedback Signal' must predict a large & significant future reward

3- Discrete and novel feedback signals increase the probability of linking the signal and a future reward, i.e., "contingency"

4- The interval of time between the spontaneous 'emitted EEG event' & the 'feedback signal' can not be too short, approx. < 250 msec? or too long approx. 20 sec?

Principles of Operant Learning

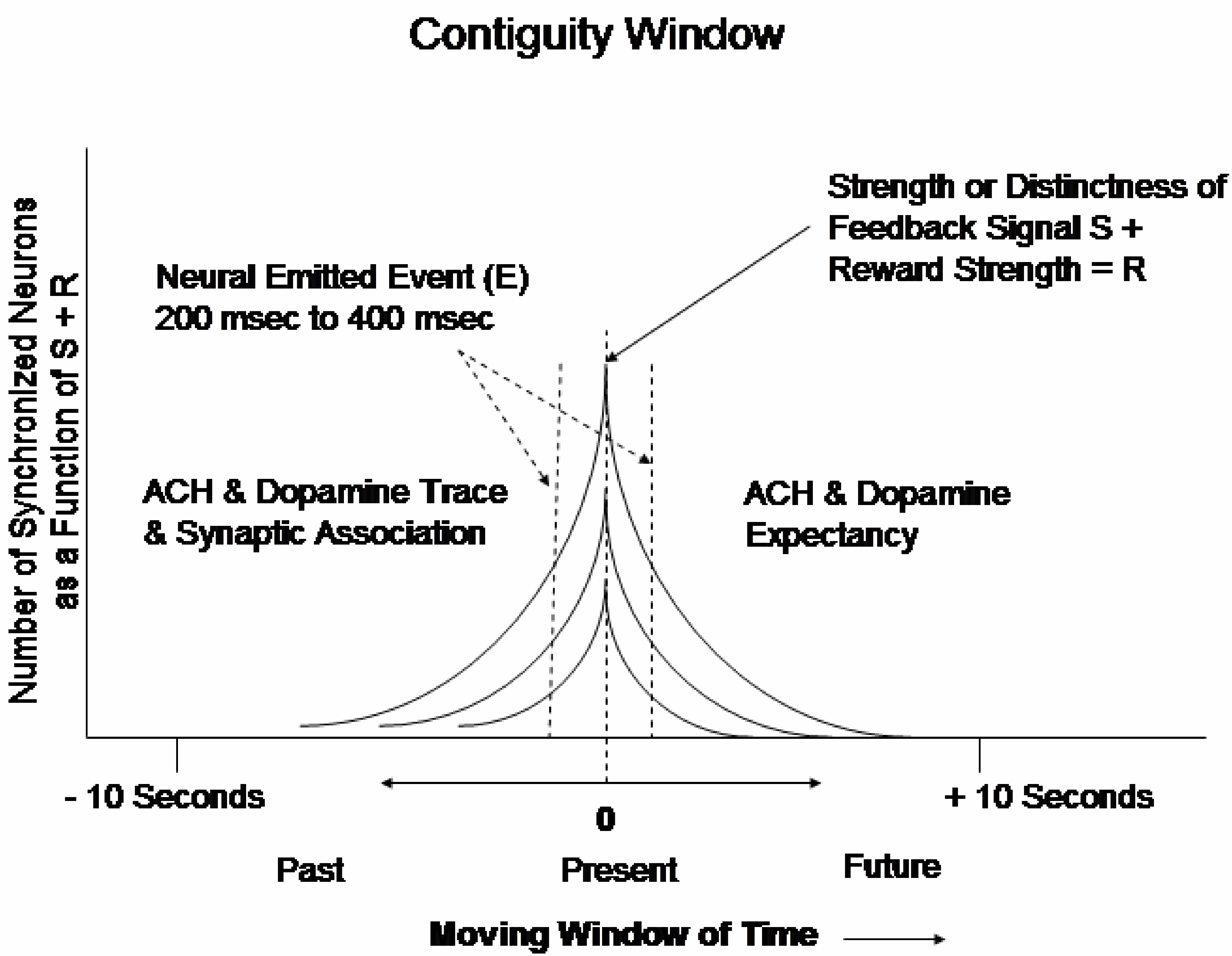


A General Theory of EEG Operant Conditioning and Z Score Biofeedback

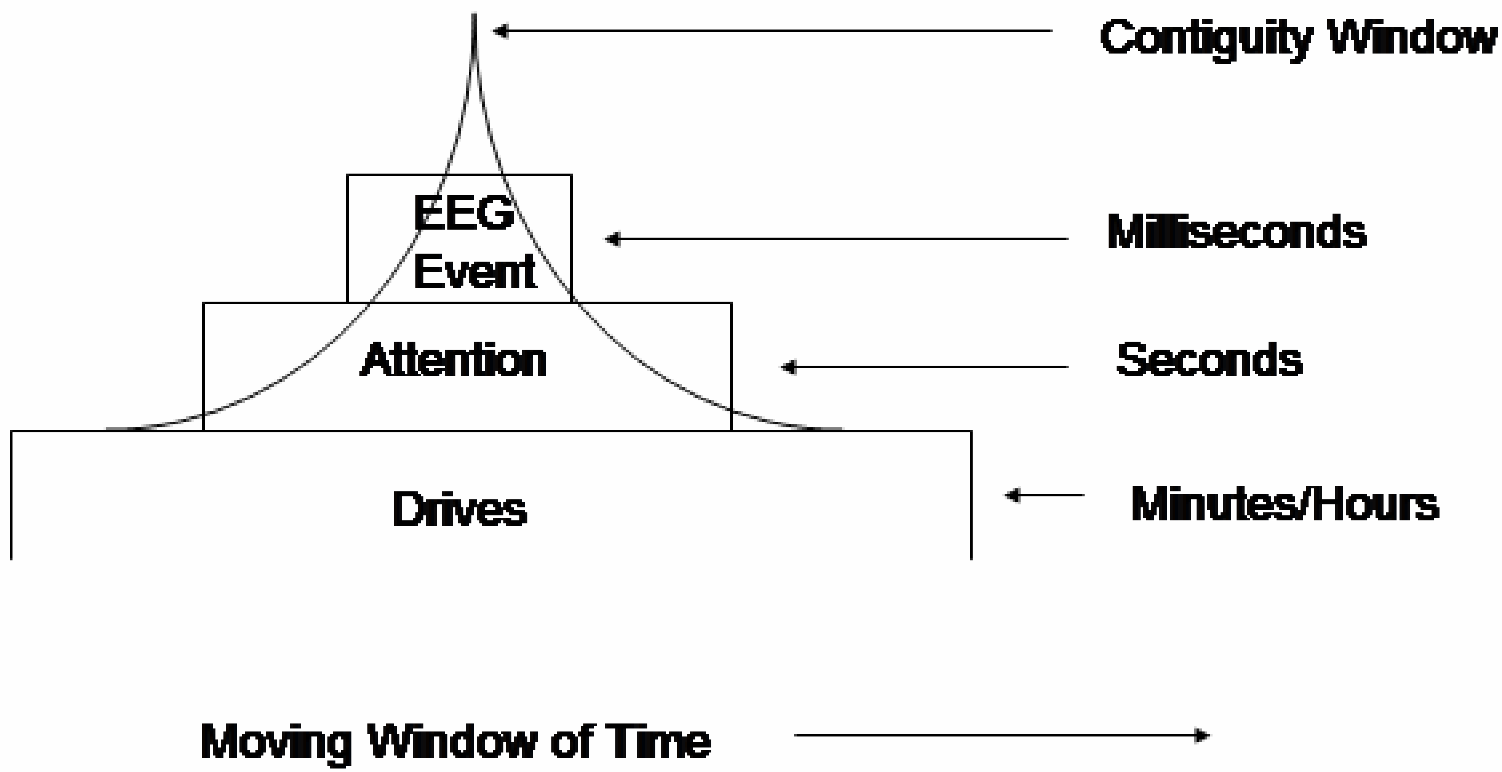
Principles

1- Specificity of EEG Event (E) = Neural State Interval (I)
2- Contiguity Window (C) = Time period preceding and following a E
3- Contingency of Reward Signal (S) = Feedback signal time locked to E
4- Reward Strength (R) = Value of the reward if N successes occur in an interval of time, e.g., toys, candy, cookies, money, etc.

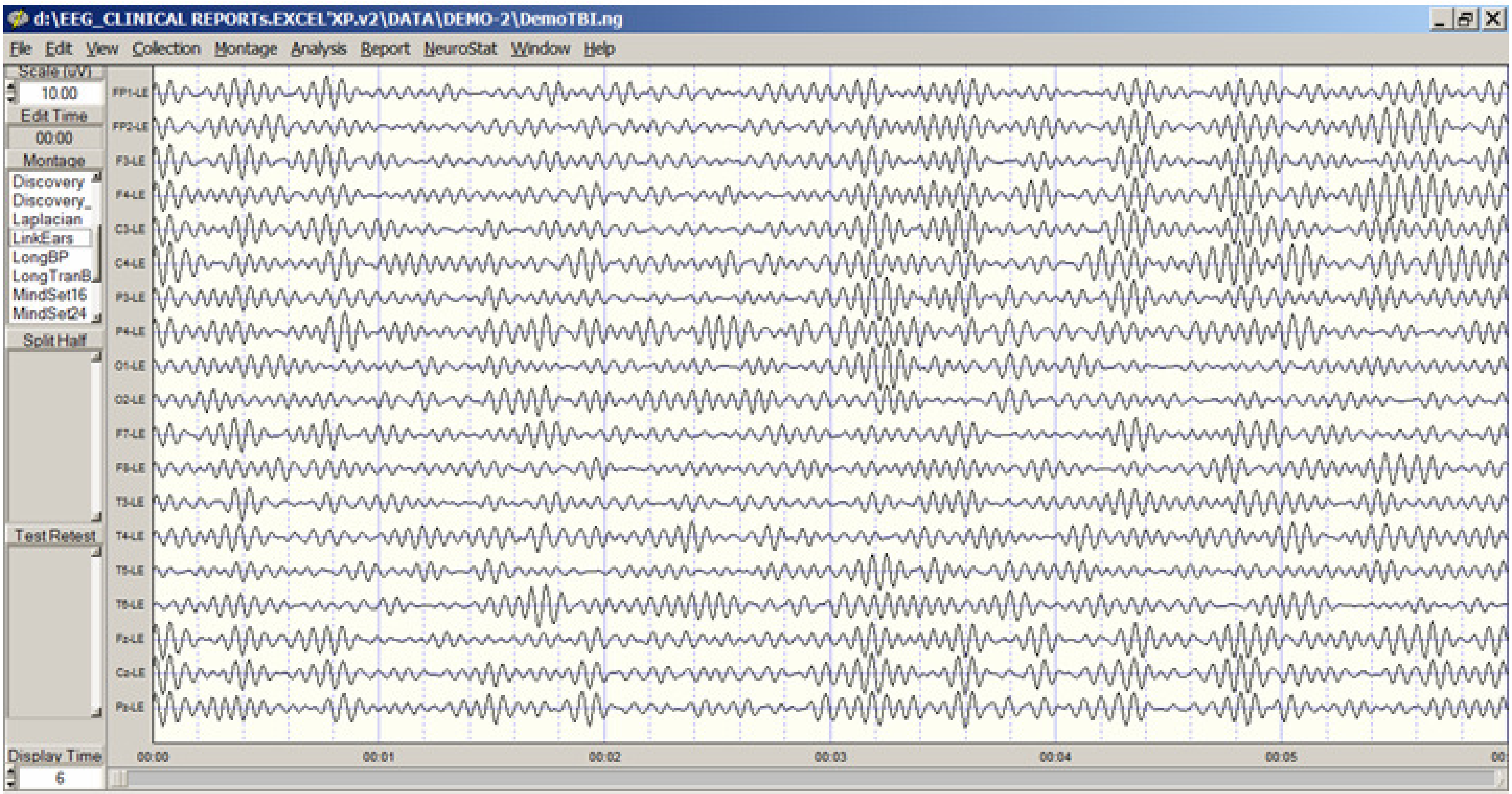
Category	Measurement
Specificity of EEG Event (E)	**Z Scores and Brodmann areas linked to symptoms**
Contiguity Window (C)	**Time preceding/following E (msec – sec)**
Contingency of Reward Signal (S)	**Feedback signal time locked to E (msec)**
Reward Strength (R)	**Ordinal or Nominal measure**


Contiguity Window
Strength or Distinctness of
Feedback Signal S +
Reward Strength = R
Neural Emitted Event (E)
200 msec to 400 msec
ACH & Dopamine Trace
& Synaptic Association
ACH & Dopamine
Expectancy
Number of Synchronized Neurons
as a Function of S + R
- 10 Seconds
0
+ 10 Seconds
Past
Present
Future
Moving Window of Time

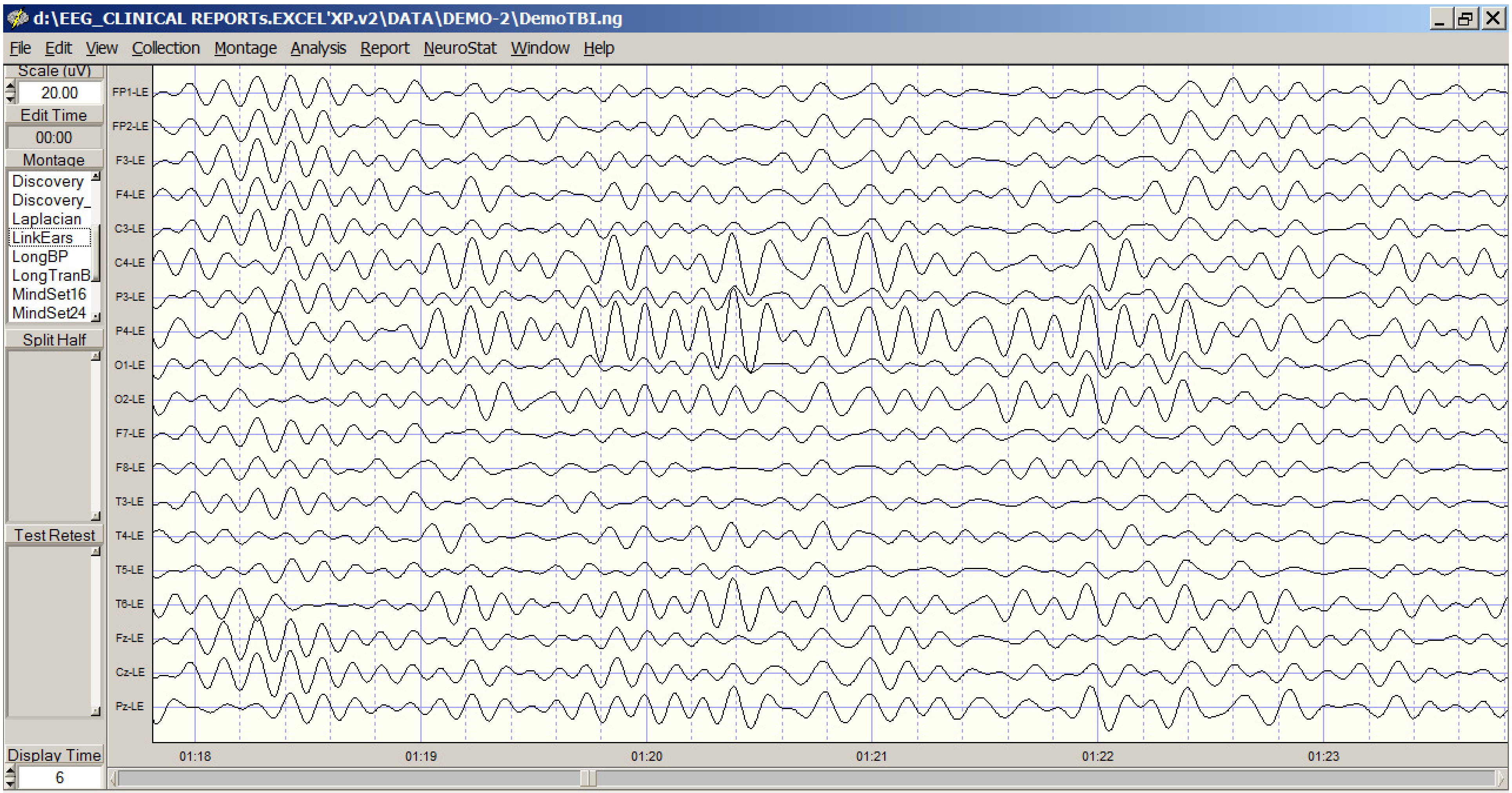
Nested Neural State Intervals



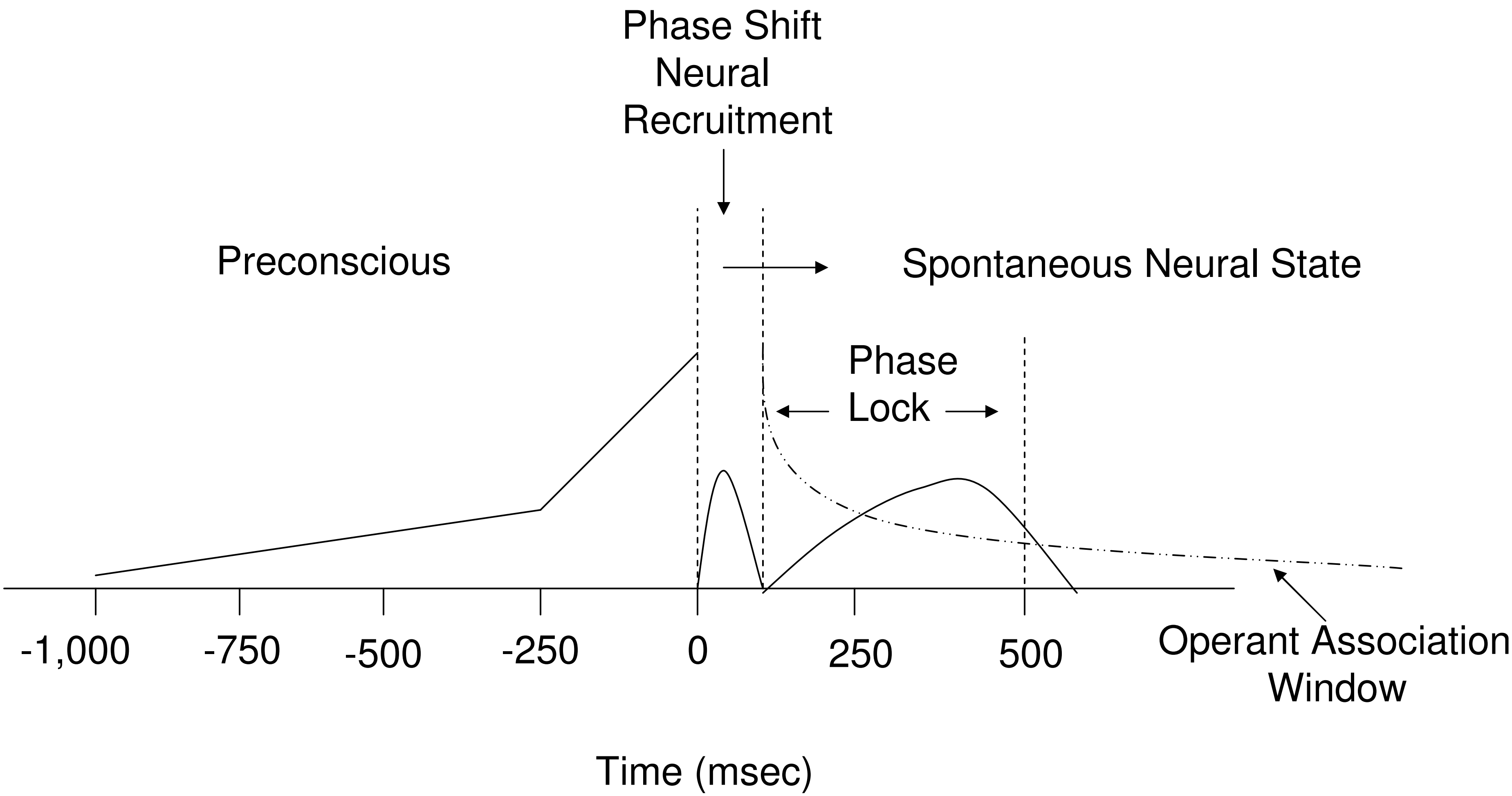
Example of Bursts of SMR (13 – 18 Hz) in the Human EEG
Burst Duration approx. 200 msec to 400 msec



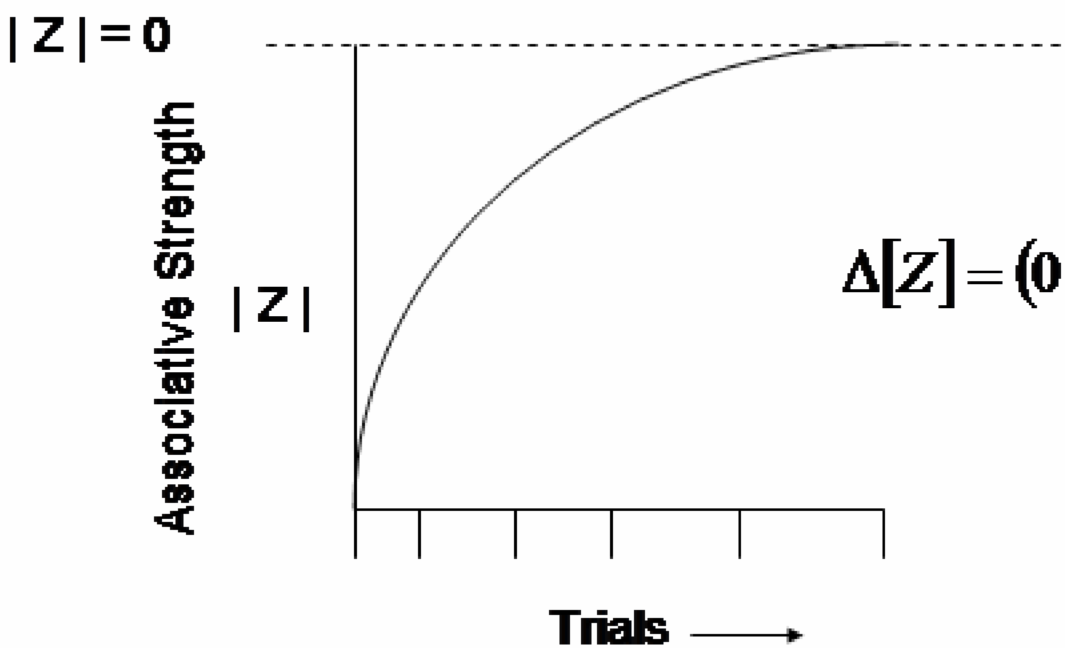
Example of Bursts of Theta Rhythms (4 – 8 Hz) in the Human EEG
Burst Duration approx. 200 msec to 600 msec



Moving Window of Operant Learning Quanta

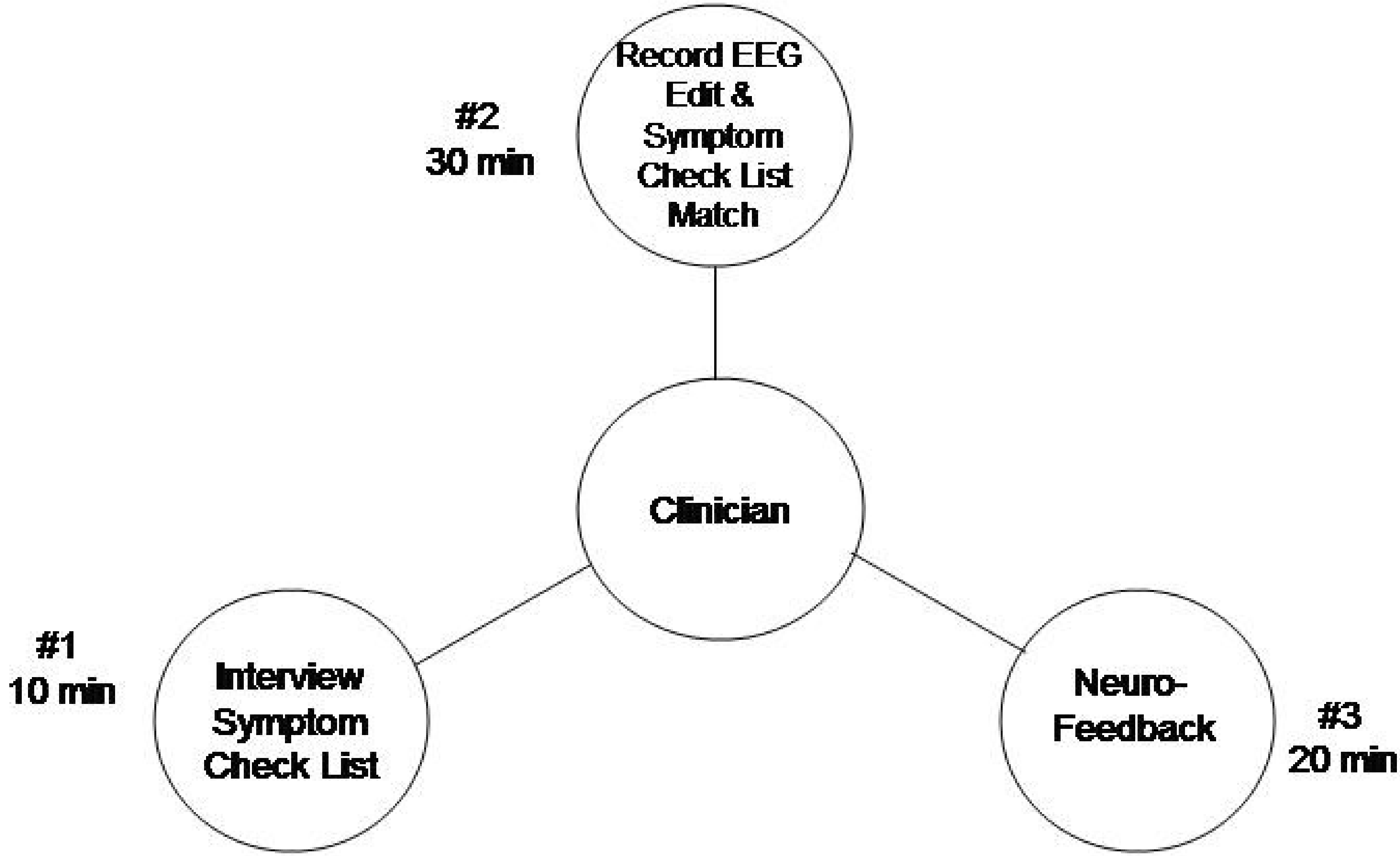


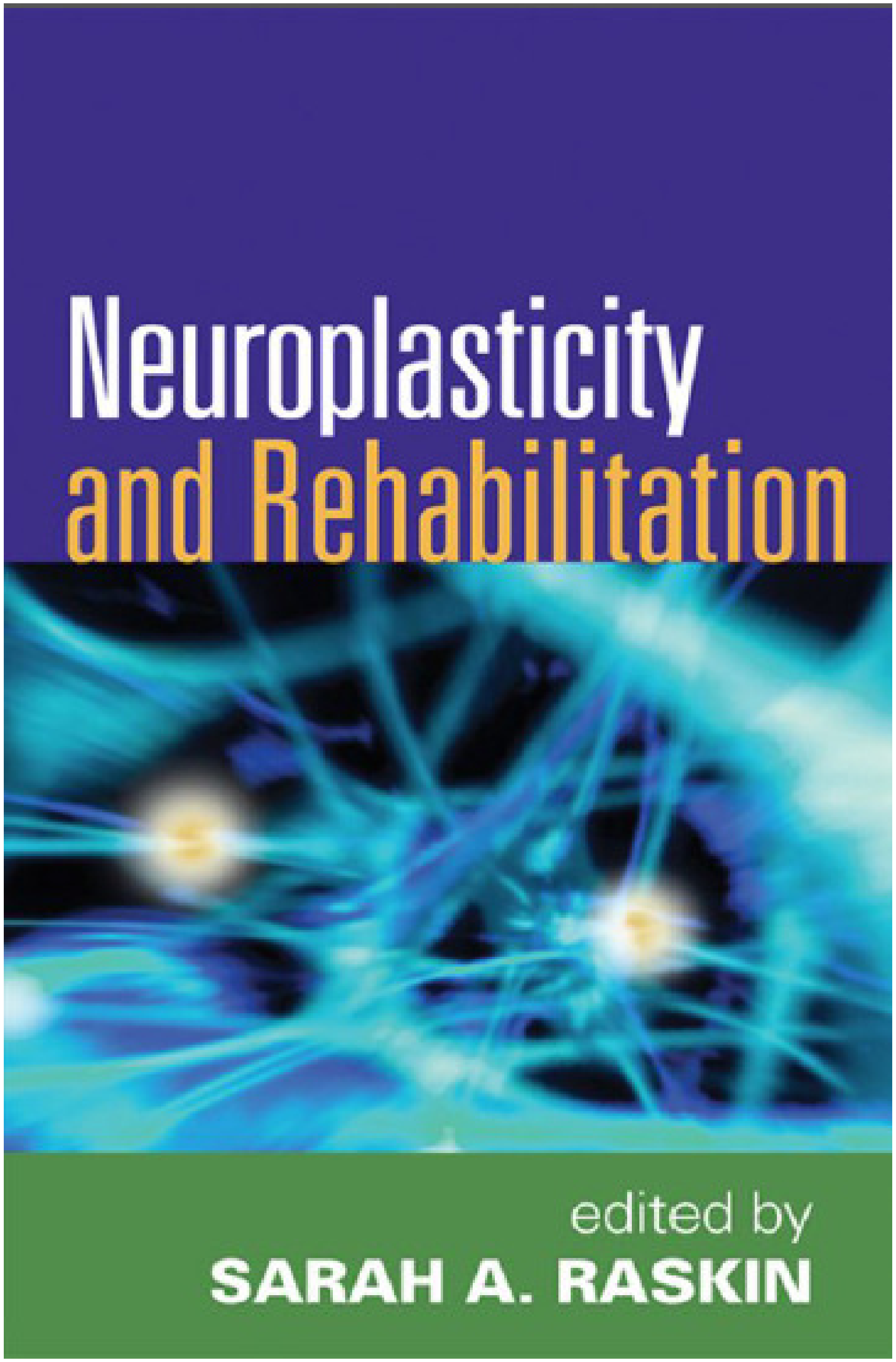
Predictive Error



$$\Delta[Z] = (0 - [Z])$$

Seamless QEEG and Neurofeedback – approx. 50 – 60 minutes for a single Session in four Steps from Clinical Interview to QEEG to Neurotherapy





1- "Behavioral approaches emphasize compensation" (p. 21)

2- "Restorative approaches emphasize improving weak or lost function" (p. 21)

"A compensation occurs when a
Noninjured brain region takes over
The function of the injured region.
True recovery involves improvement
In function in an injured area." (p. 22)

Z Score Neurofeedback Panel

Select Frequency Bands & 1 to 19 Channels & Combinations of Channels for Cross-Spectra

Settings or Progress Chart Tabs

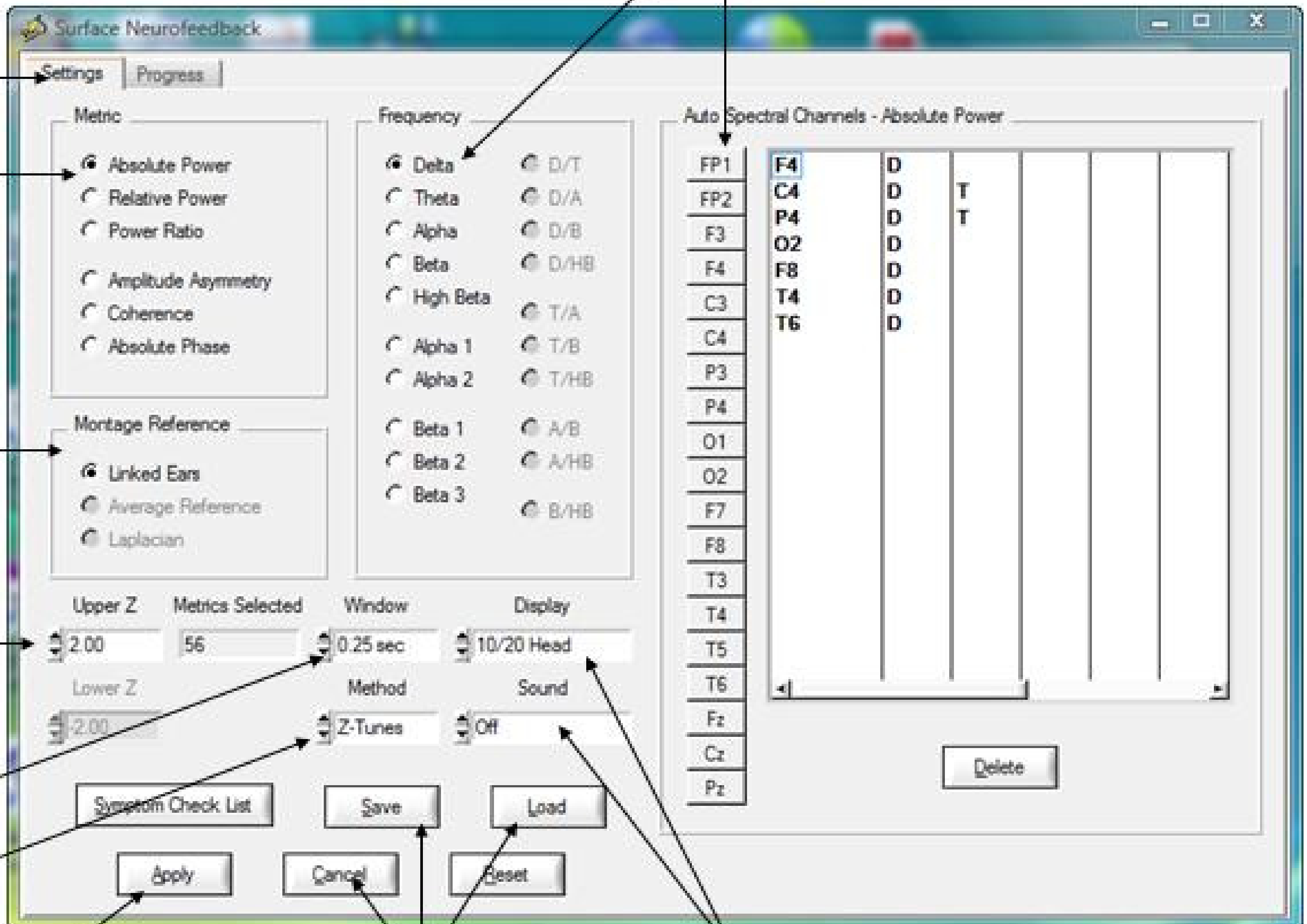
Select Power or Coherence, Phase Amp. Asym

Select Montage Laplacian, Ave. Ref & Linked Ears

Z Score Threshold Reward if Less Than Or greater than

Event Integration Interval (Variability)

Z Tunes is the Reward Default



Symptom Check List

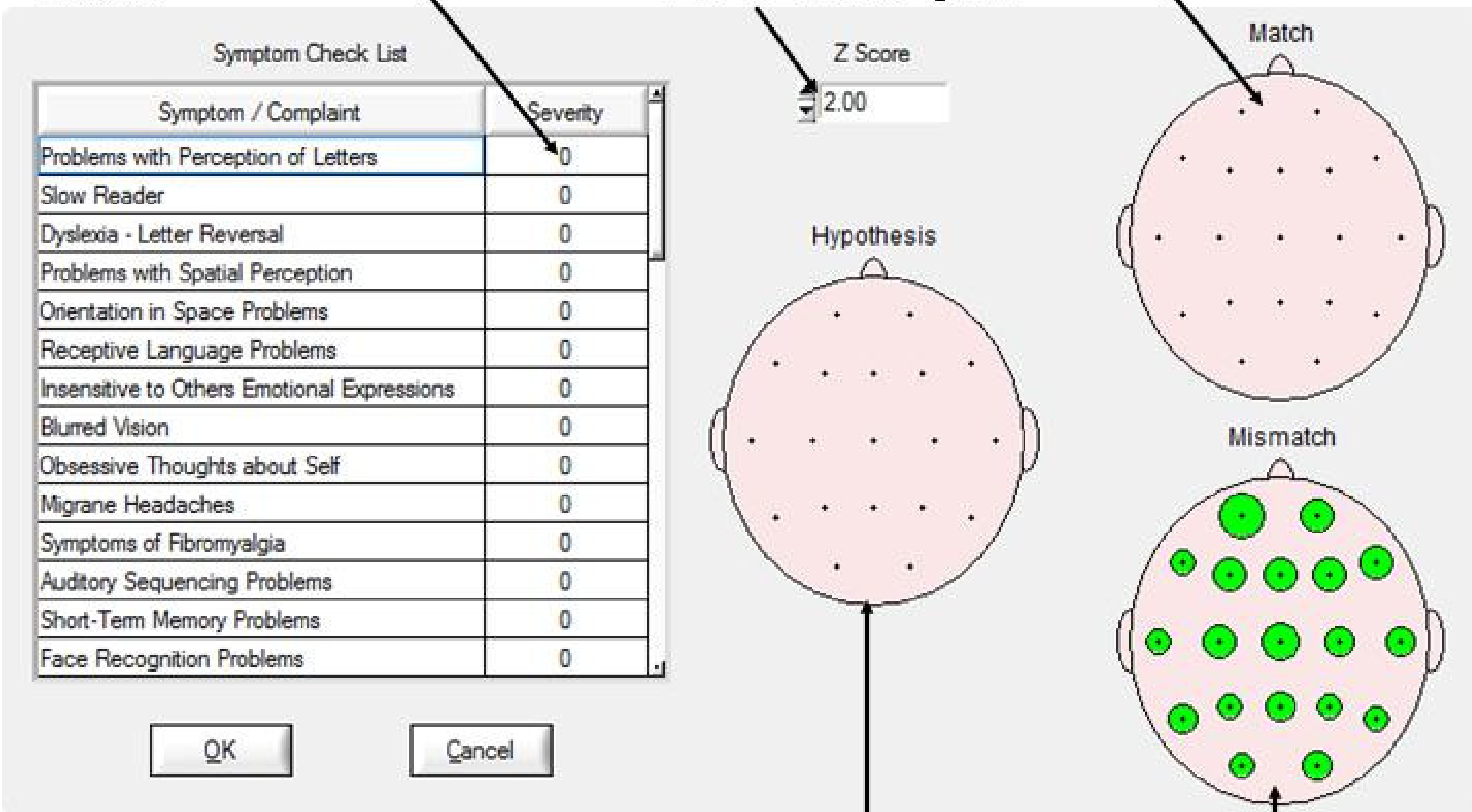
Save, Load & Cancel

Sound on/off & Visual Displays & DVD/Flash

Double click the Severity of a Symptom and Grade Severity 1 to 10.

Set the Z score threshold from the QEEG Analyses

Match to Symptoms & QEEG Z Scores

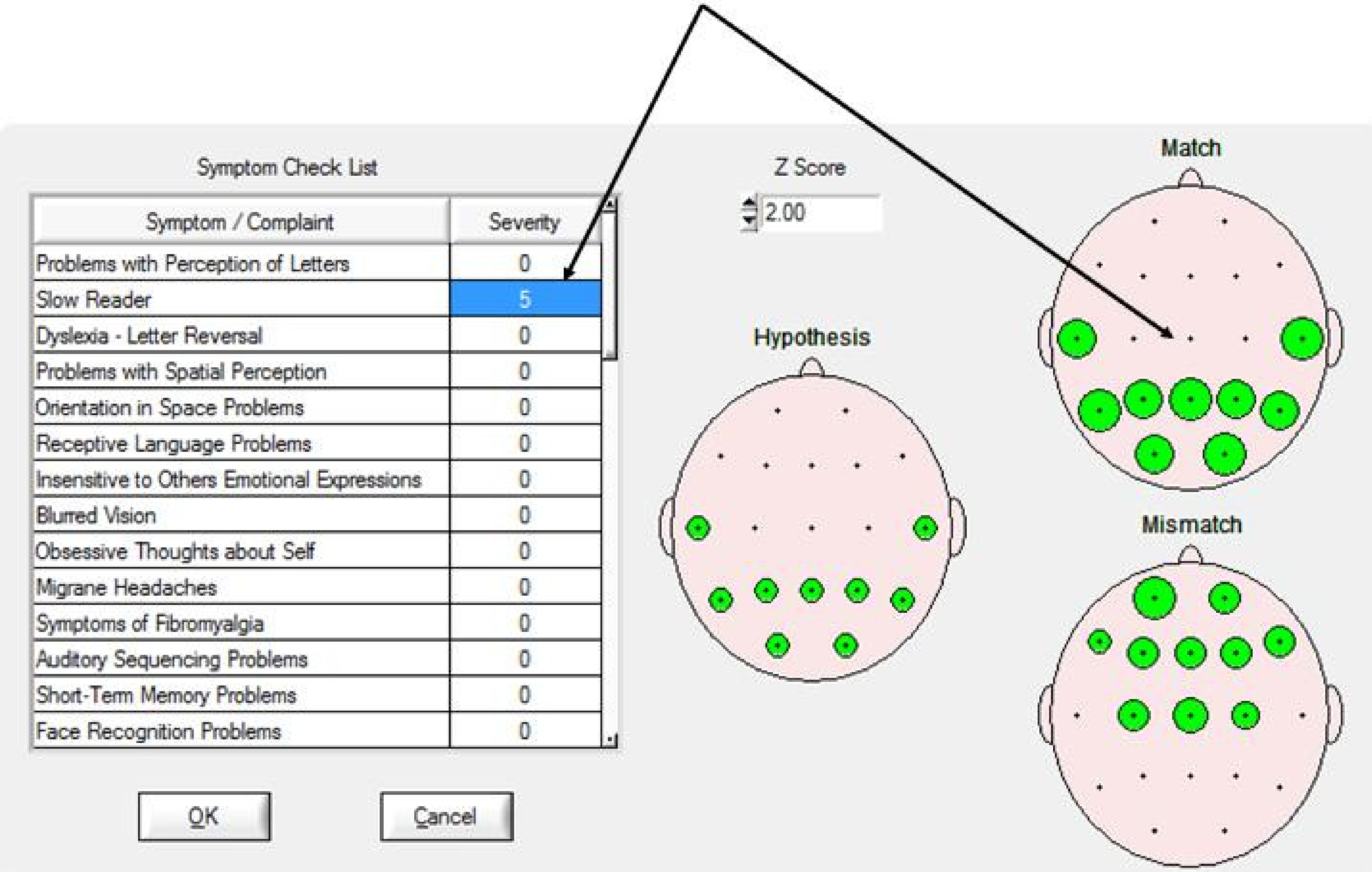


Symptom / Complaint	Severity
Problems with Perception of Letters	0
Slow Reader	0
Dyslexia - Letter Reversal	0
Problems with Spatial Perception	0
Orientation in Space Problems	0
Receptive Language Problems	0
Insensitive to Others Emotional Expressions	0
Blurred Vision	0
Obsessive Thoughts about Self	0
Migrane Headaches	0
Symptoms of Fibromyalgia	0
Auditory Sequencing Problems	0
Short-Term Memory Problems	0
Face Recognition Problems	0

Symptom Check List Hypotheses

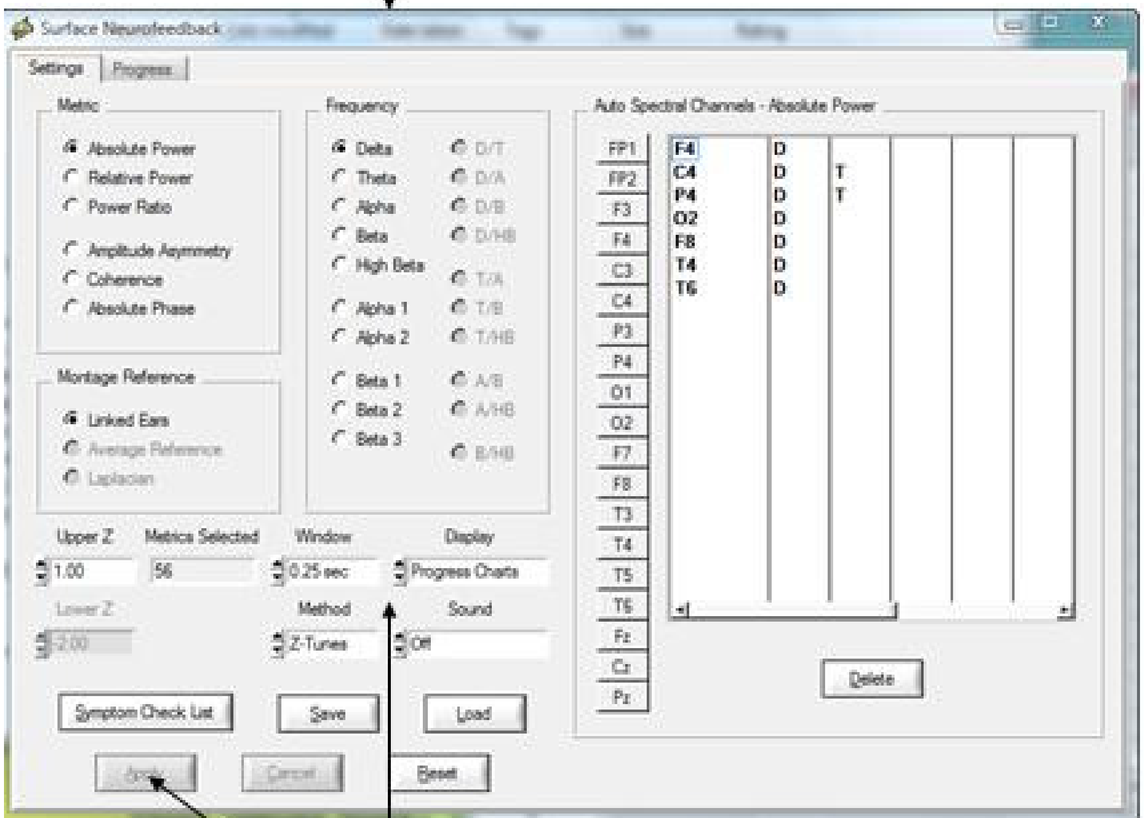
Mismatch of Symptoms & QEEG Z Scores

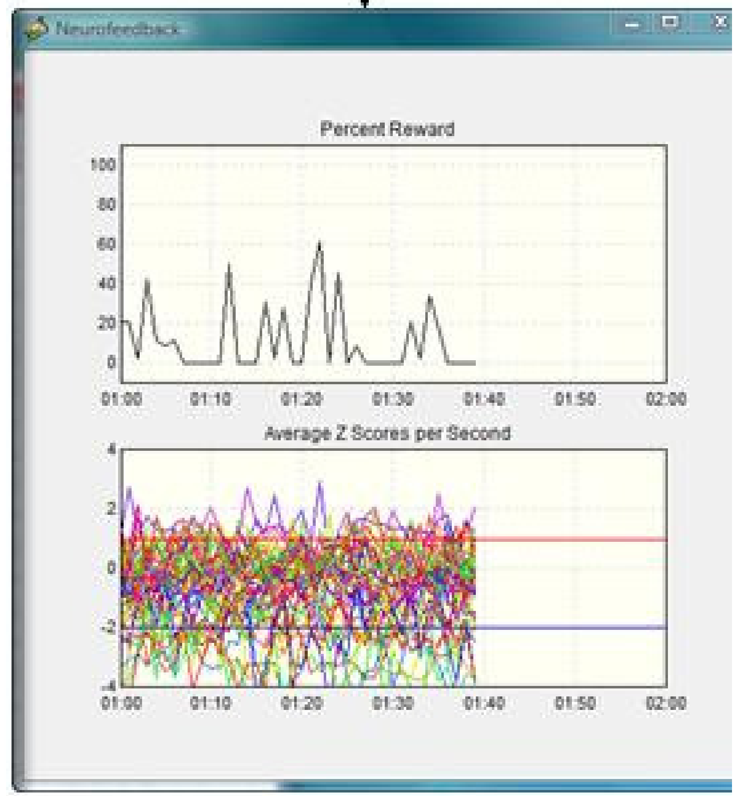
Example of a Slow Reader Symptom Check List Hypotheses and the Test Of the Hypothesis using QEEG Z Scores. Note how the mismatch items Move to the match 10/20 head display as Symptoms are matched



Use the Progress Chart as a Feedback Display and Move the Display to the Client's Monitor

Neurofeedback Setup Panel





Move to the Client's Monitor

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

Progress Charts to be Monitored by the Clinician During Neurofeedback

Toggle back & forth between to Settings Window & Progress Charts

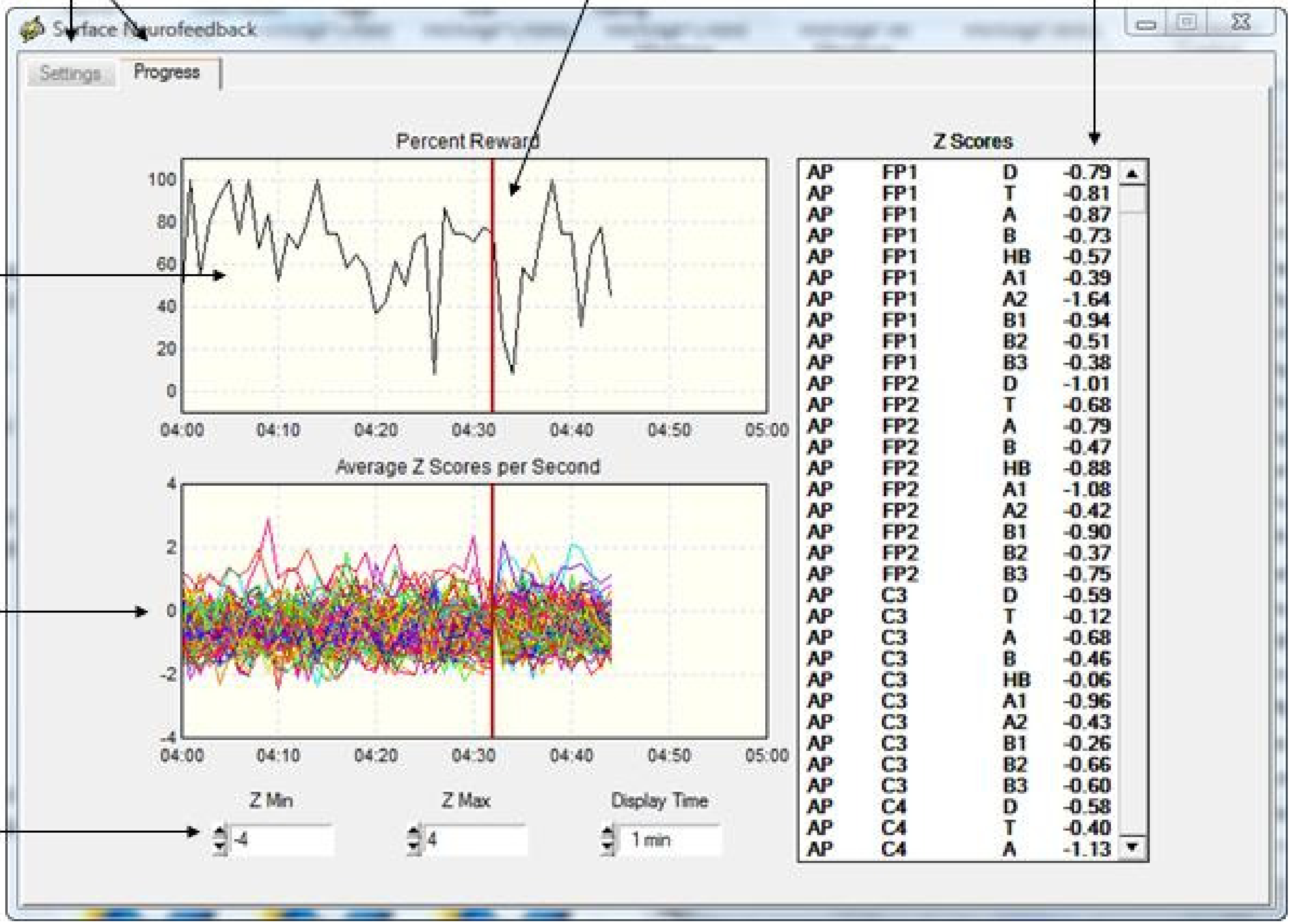
Red Mark Designates Settings Change

View Instantaneous Z Scores

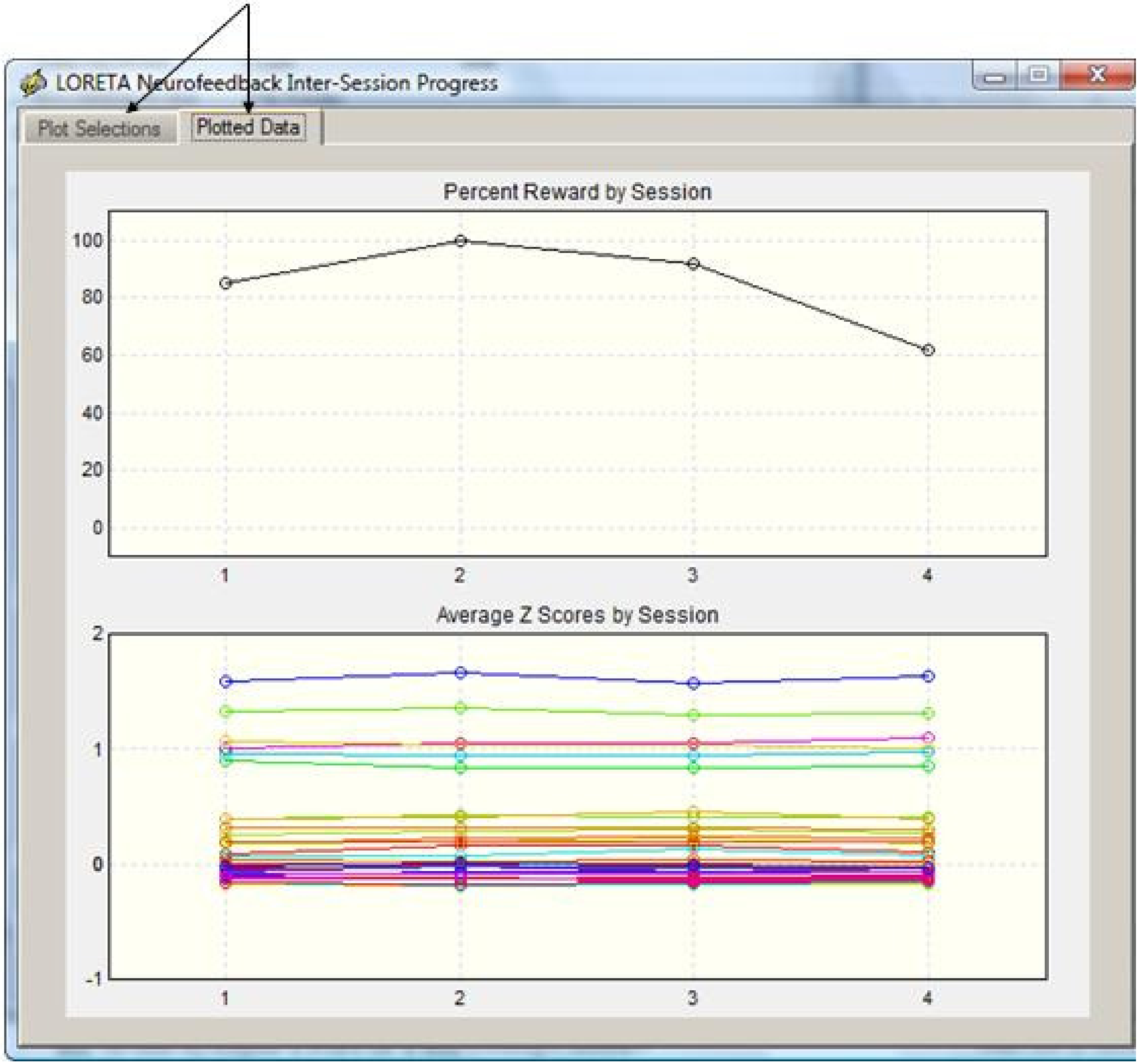
Percentage of Time that a Reward was Delivered (per sec)

Average Z Scores Updated Each Second

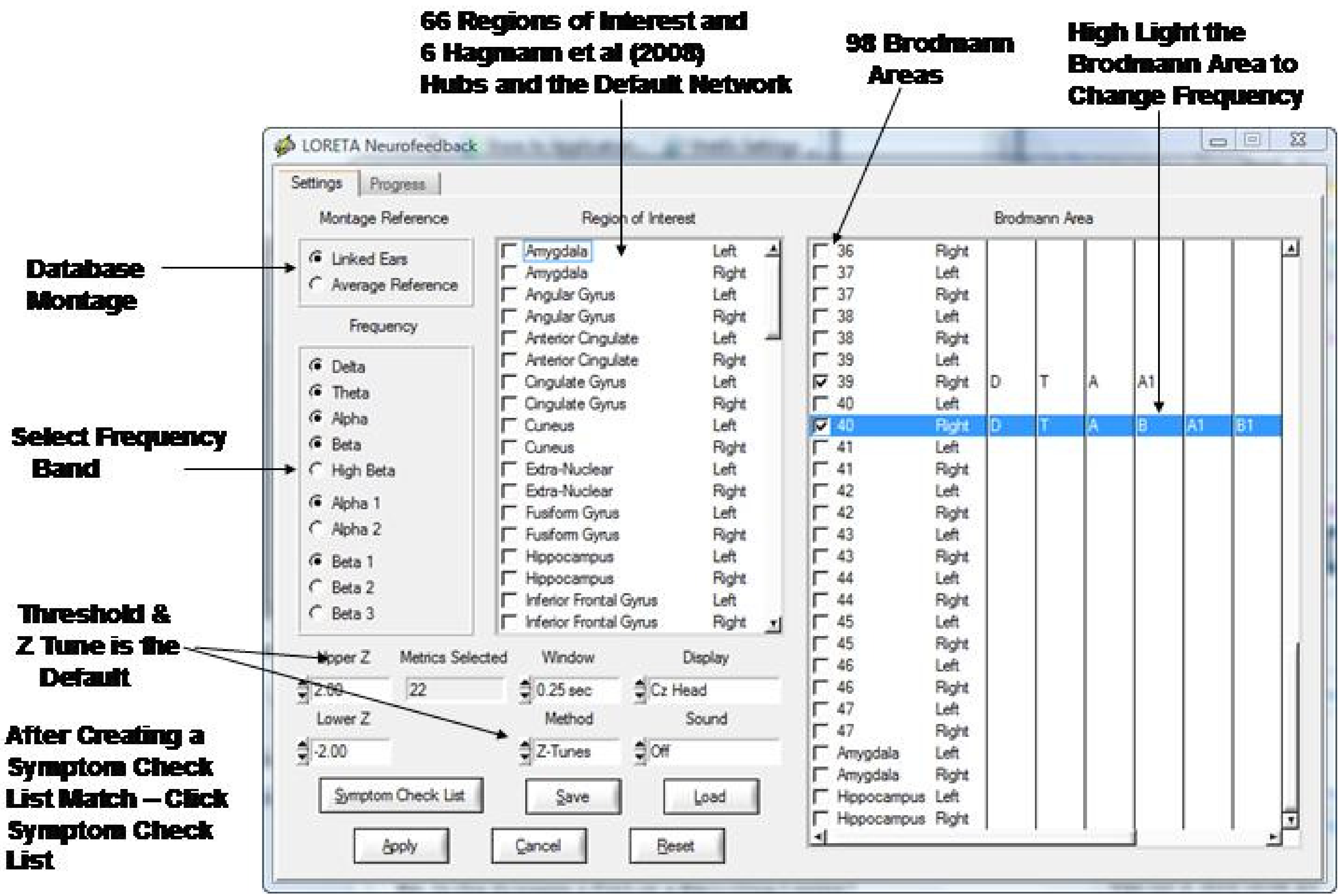
Z Score Range & Display Time Base 1 min to 30 min

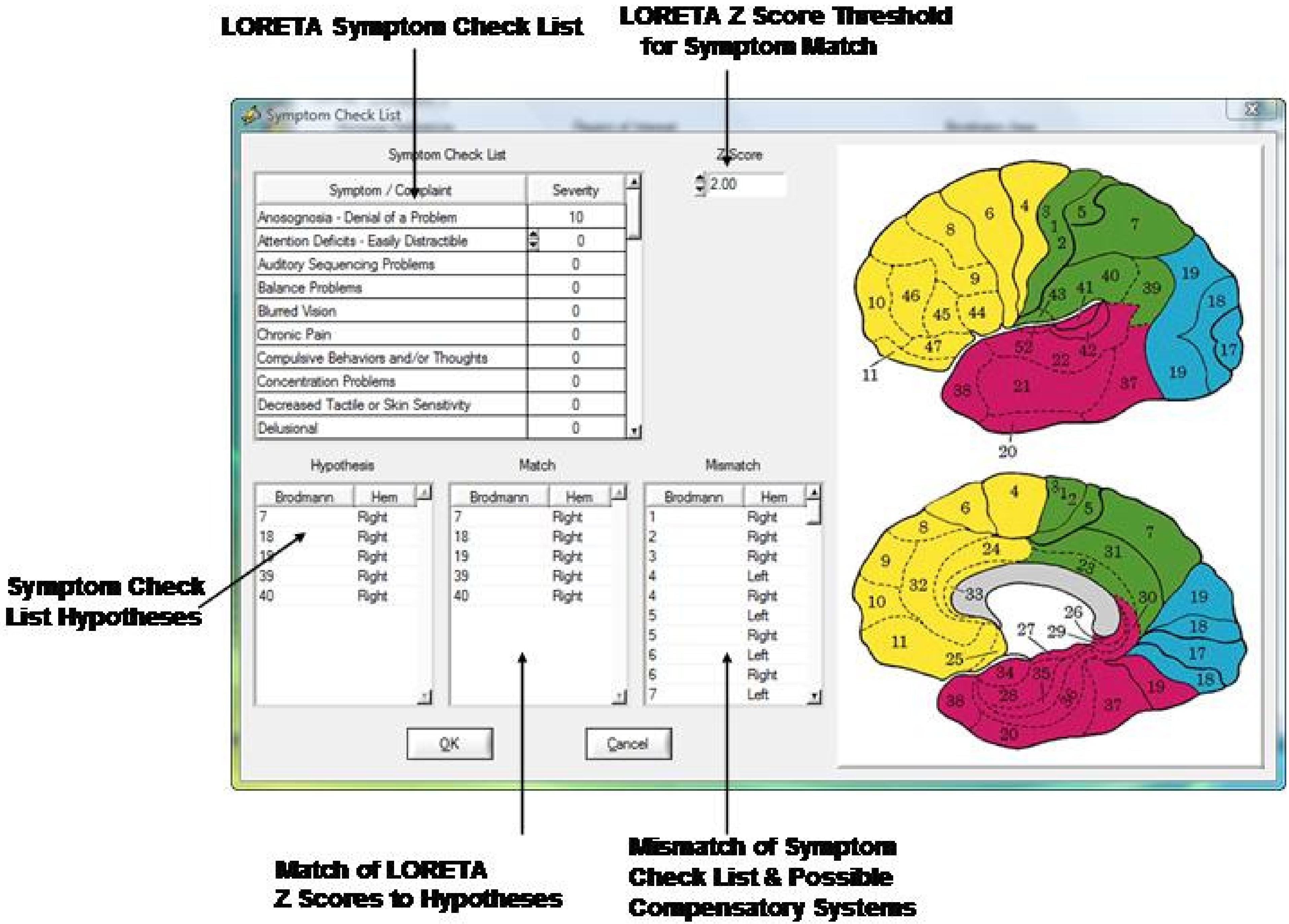


After Plot Selections then Click Plotted Data to View the Inter-Session Progress Charts



LORETA Neurofeedback Setup Panel





LORETA Symptom Check List
LORETA Z Score Threshold for Symptom Match
Symptom Check List
Symptom / Complaint
Severity
Anosognosia - Denial of a Problem 10
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
Z Score
2.00
Hypothesis
Match
Mismatch
Brodmann Hem
7 Right
18 Right
19 Right
39 Right
40 Right
1 Right
2 Right
3 Right
4 Left
4 Right
5 Left
5 Right
6 Left
6 Right
7 Left
OK
Cancel
Symptom Check List Hypotheses
Match of LORETA Z Scores to Hypotheses
Mismatch of Symptom Check List & Possible Compensatory Systems