EEG and Biofeedback in Mental Health Counseling

applications of neuronal dynamics

Thomas F. Collura, Ph.D., QEEG-D
American Mental Health Counseling Association
July 15, 2011
San Francisco, CA

(c) 2007-11 T. F. Collura, Ph.D.

Neurofeedback

Neurofeedback is a form of biofeedback training that uses the EEG (Electroencephalogram), also known as the "brain wave" as the signal used to control feedback. Sensors applied to the trainee's scalp record the brainwaves, which are converted into feedback signals by a human/machine interface using a computer and software. By using visual, sound, or tactile feedback to produce learning in the brain, it can be used to induce brain relaxation through increasing alpha waves. A variety of additional benefits, derived from the improved ability of the CNS (central nervous system) to modulate the concentration/relaxation cycle and brain connectivity, may also be obtained.

(c) 2007-9 T. F. Collura, Ph.D.

Outline

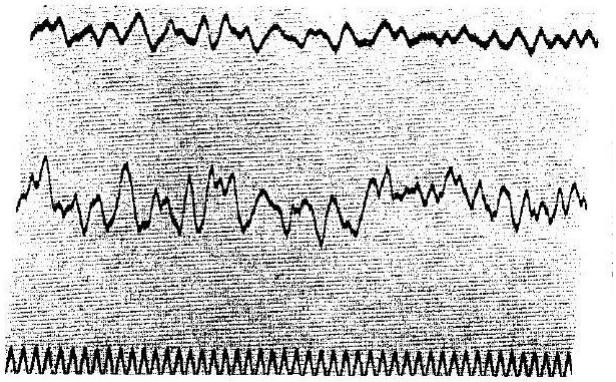
- Electrophysiology
- Instrumentation
- Computerization
- Signal Processing
- User Interfacing
- System Overview

(c) 2007-9 T. F. Collura, Ph.D.

First Human EEG Studies - 1924

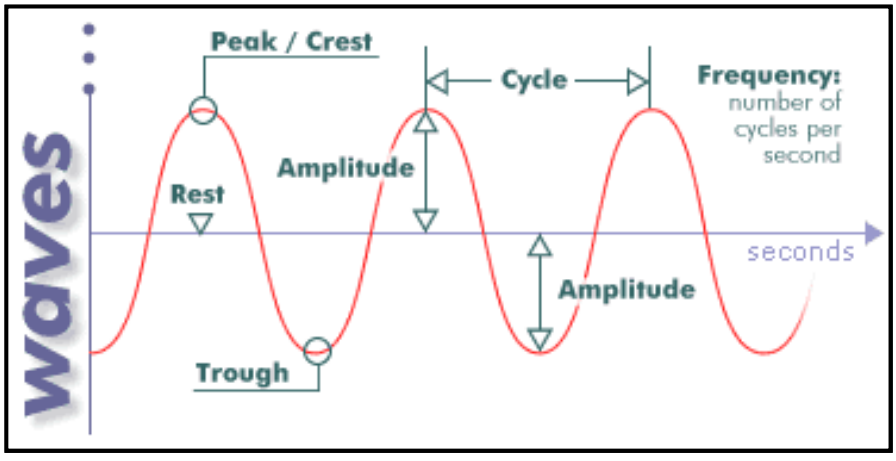
(c) 2007-9 T. F. Collura, Ph.D.

Hans Berger - 1932



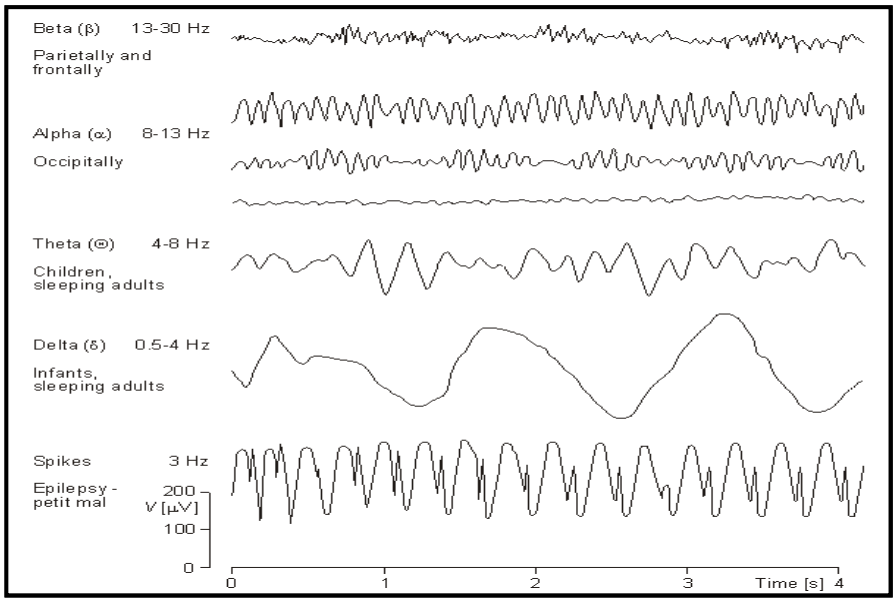
(c) 2007-9 T. F. Collura, Ph.D.

What is a “brain wave”?
What is actually being recorded?



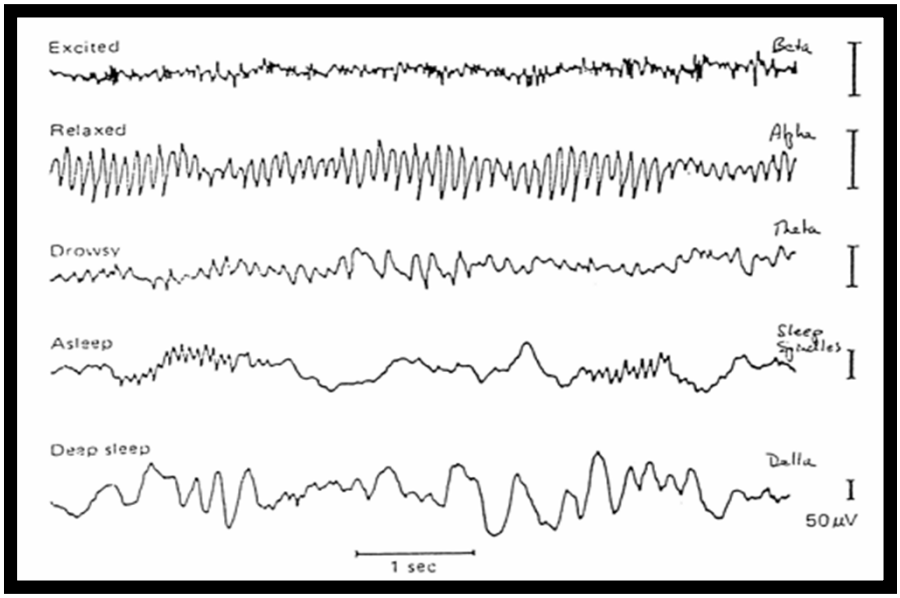
copyright (2011) Stress Therapy Solutions, Inc.

Visual recognition of wave shapes and corresponding frequencies



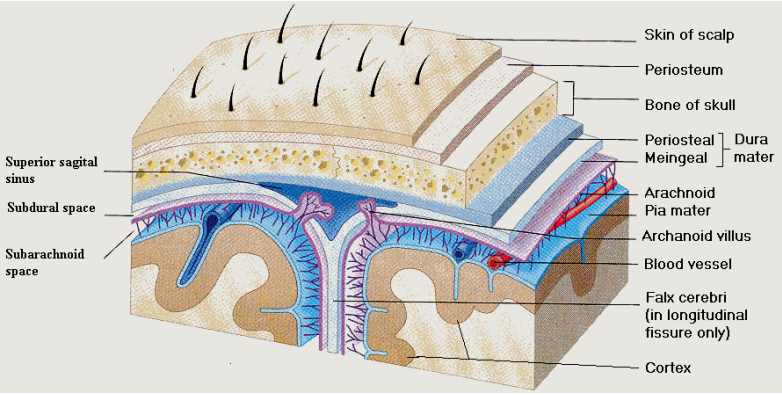
copyright (2011) Stress Therapy Solutions, Inc.

How do we know what these waves mean?



copyright (2011) Stress Therapy Solutions, Inc.

Cortical EEG Sources



(c) 2007-9 T. F. Collura, Ph.D.

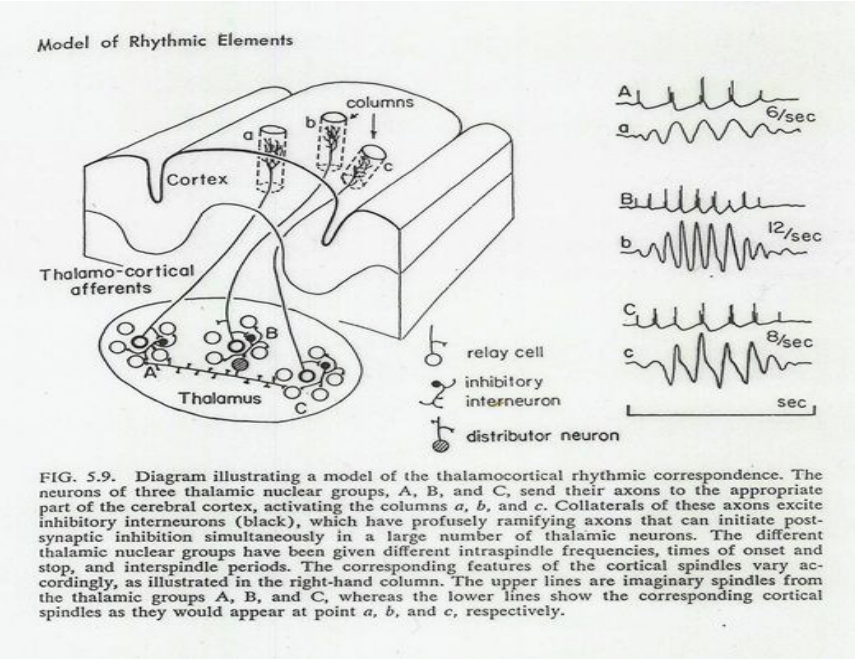
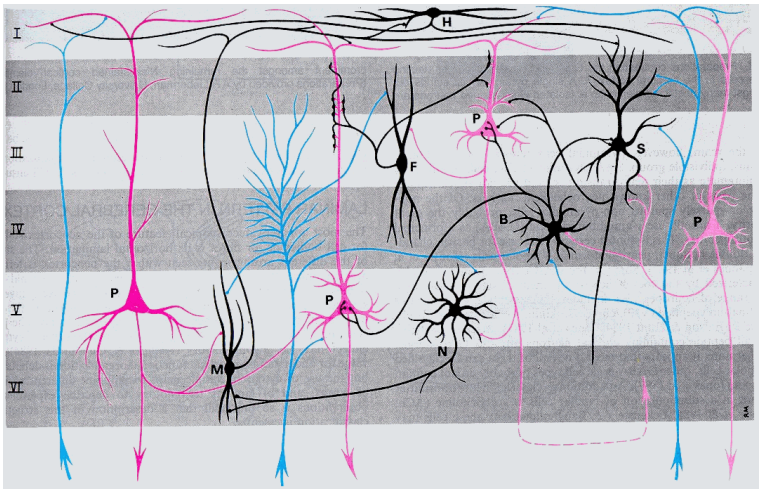


FIG. 5.9. Diagram illustrating a model of the thalamocortical rhythmic correspondence. The neurons of three thalamic nuclear groups, A, B, and C, send their axons to the appropriate part of the cerebral cortex, activating the columns *a*, *b*, and *c*. Collaterals of these axons excite inhibitory interneurons (black), which have profusely ramifying axons that can initiate post-synaptic inhibition simultaneously in a large number of thalamic neurons. The different thalamic nuclear groups have been given different intraspindle frequencies, times of onset and stop, and interspindle periods. The corresponding features of the cortical spindles vary accordingly, as illustrated in the right-hand column. The upper lines are imaginary spindles from the thalamic groups A, B, and C, whereas the lower lines show the corresponding cortical spindles as they would appear at point *a*, *b*, and *c*, respectively.

copyright (2011) Stress Therapy Solutions, Inc.

Cortical Layers



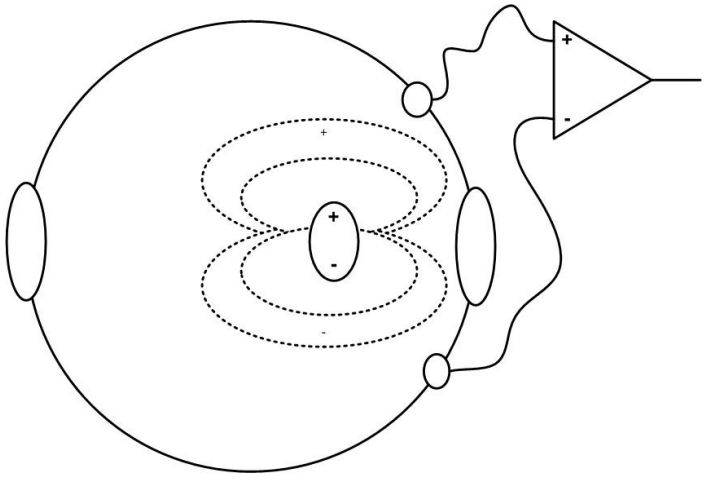
(c) 2007-9 T. F. Collura, Ph.D.

EEG Generation Mechanisms

- Primary mechanism of brain is inhibition
- Rhythms generated when inhibition is relaxed
- Allows thalamocortical reverberation
- Relaxation at cortical level, and at thalamic level
- Allows populations to oscillate in synchrony

(c) 2007-9 T. F. Collura, Ph.D.

Sample EEG Computation



(c) 2007-9 T. F. Collura, Ph.D.

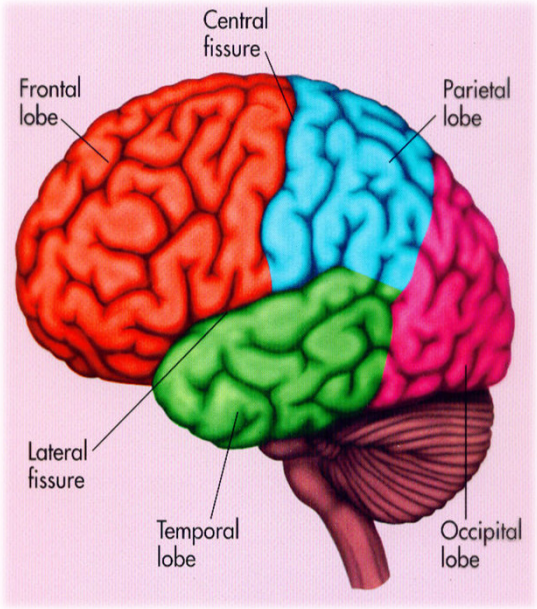
General function of each lobe

Occipital
- Vision

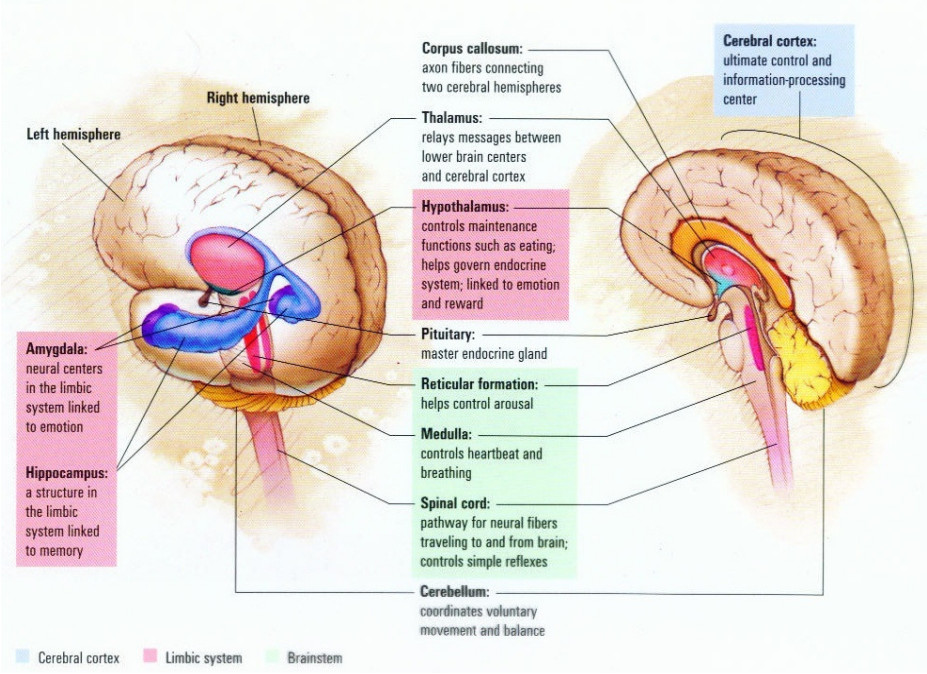
Temporal
- Auditory
- Memory

Parietal
- Touch
- Attention, Integration

Frontal
- Motor
- Executive Function (goal-oriented, plan, sequence)

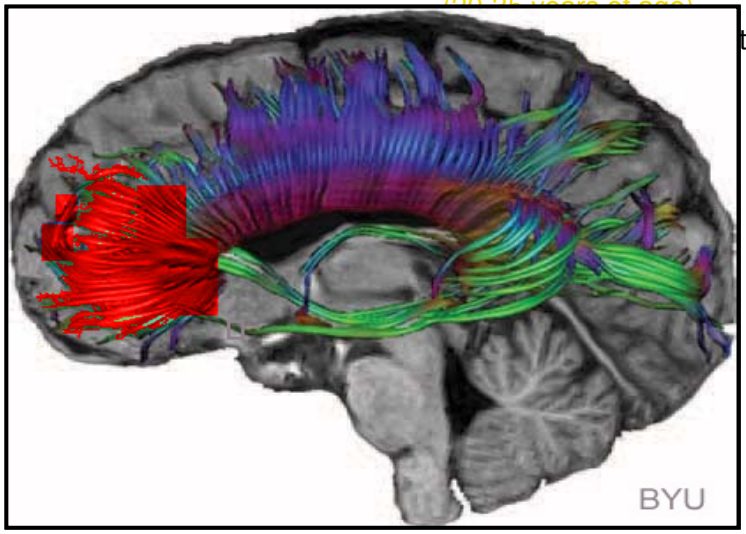


copyright (2011) Stress Therapy Solutions, Inc.

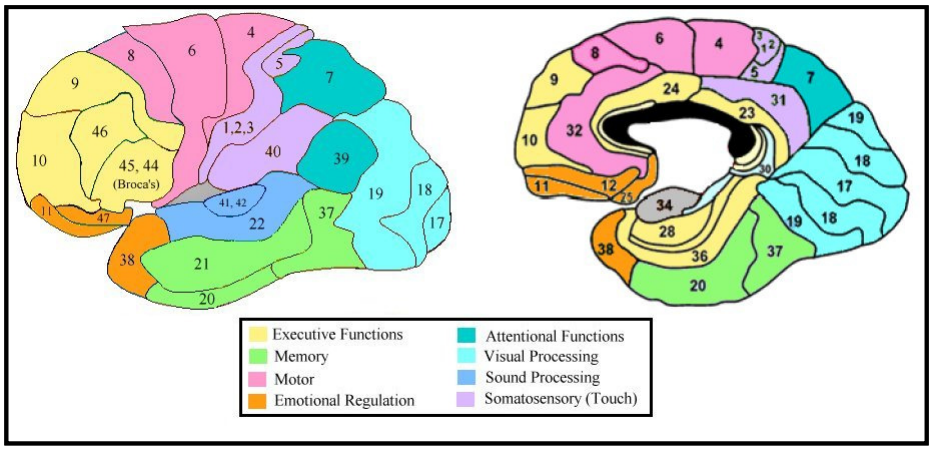


copyright (2011) Stress Therapy Solutions, Inc.

Functional connectivity in adulthood

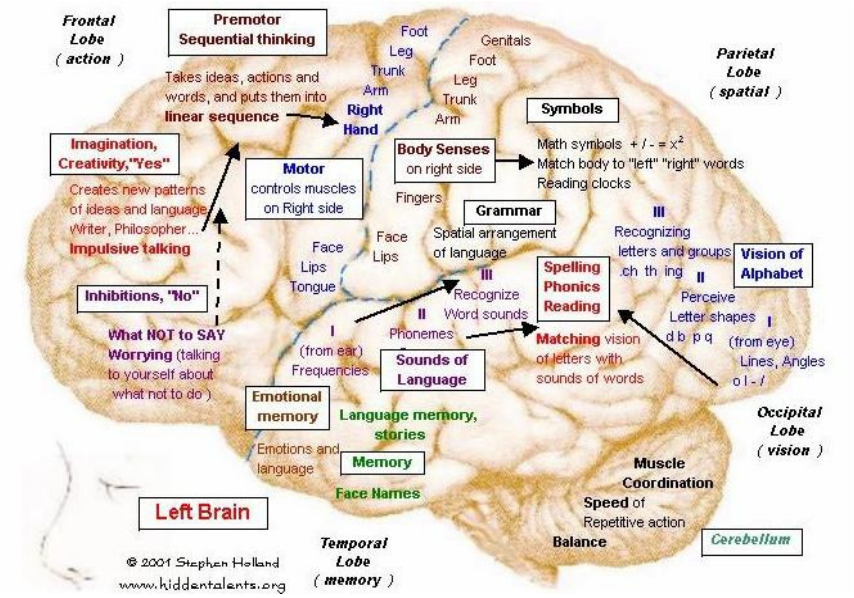


copyright (2011) Stress Therapy Solutions, Inc.



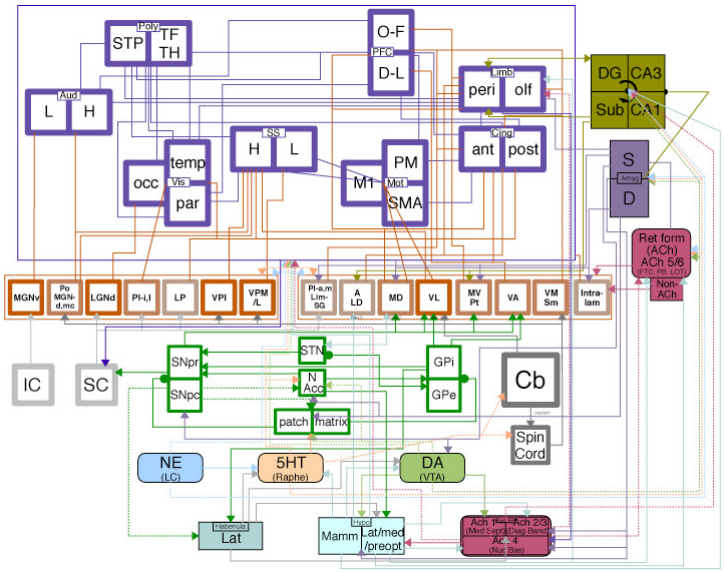
A grasp of brain geography is critical when doing client assessment - being able to ask the right questions based on information in topographical brain maps allows us to relate eeg findings to symptoms the client would not have thought important enough to mention, thereby helping us as clinicians to create more efficacious treatment protocols.

copyright (2011) Stress Therapy Solutions, Inc.



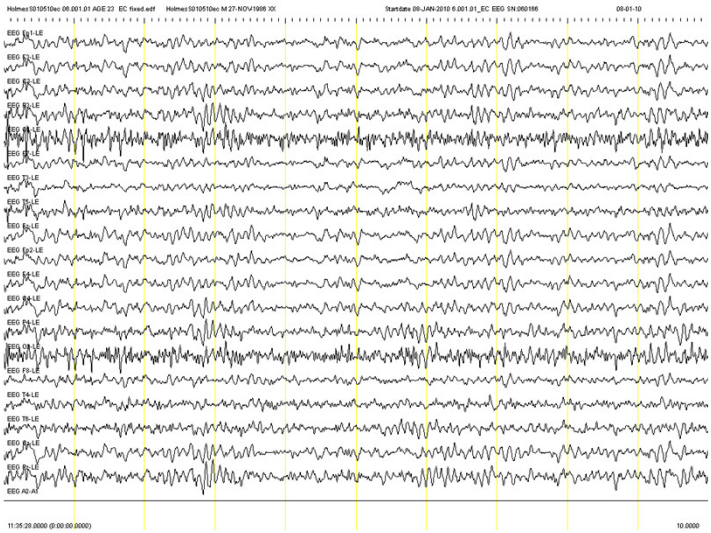
copyright (2011) Stress Therapy Solutions, Inc.

Engineering Diagram of the Brain

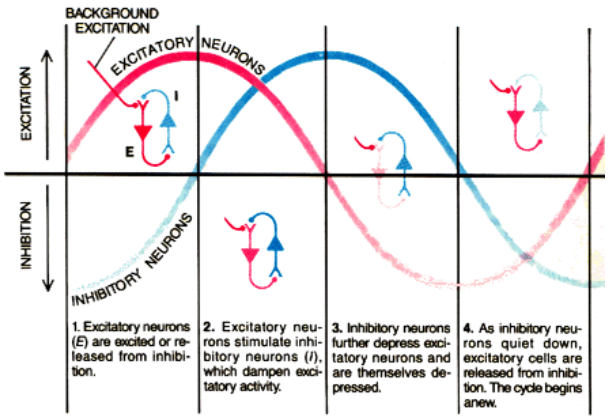


(c) 2007-9 T. F. Collura, Ph.D.
From interstitiality.net

Typical EEG (EC)



Thalamo-Cortical Cycles



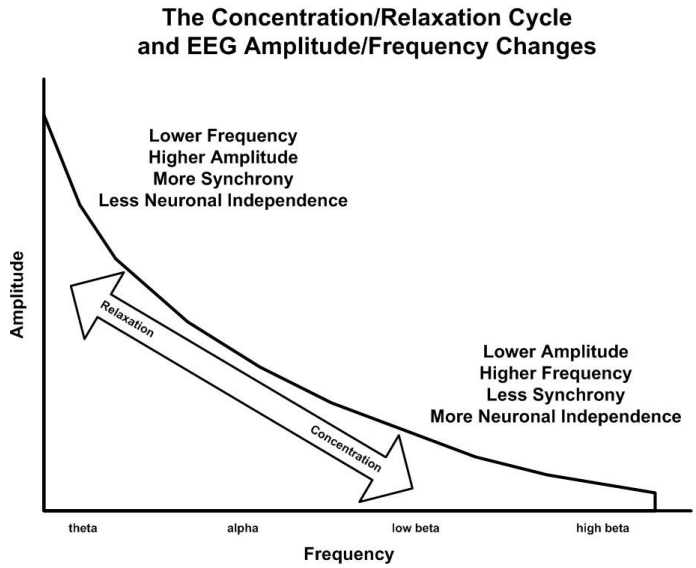
(c) 2007-9 T. F. Collura, Ph.D.

Concentration/Relaxation Cycle

- Discovered by Dr. Barry Sterman in pilots
- “good” pilots preceded each task item with high-frequency, low-amplitude EEG
- Also followed task item with low-frequency, high-amplitude EEG (“PRS”)
- Poorer pilots did not exhibit control of the concentration/relaxation cycle
- Slower reaction time, more fatigue

(c) 2007-11 T. F. Collura, Ph.D.

Concentration/Relaxation Cycle



Frontal Regulation

- Impulse Control
- Anticipate consequences
- Judge quality of experience
- Planning
- Imagining future possibilities
- Sense of responsibility for outcome

Attention Control

- Anterior & Posterior Cingulate
- AC: Orient, acquire objects of attention
- PC: Integration, release objects of attention
- Dysregulation: excessive focus; constant distraction; focus on nothing; too much switching

(c) 2007-11 T. F. Collura, Ph.D.

Mood Control

- Left, Right Dorsolateral Frontal Lobes
- Left: Approach, safe
- Right: Withdrawal, unsafe
- Issue: Left is UNDERACTIVATED: failure to process positive experiences
- Treatment: Activate Left Frontal Lobe
- NOT: Activate Right Frontal Lobe

(c) 2007-11 T. F. Collura, Ph.D.

Peripheral Mechanisms

- Muscle – EMG – tension; tmj
- Skin Conductance – relaxation
- Respiration - breathing
- Heart-Rate Variability – resonance
- Sympathetic / Parasympathetic Systems
- Substrate for experience, behavior

(c) 2007-11 T. F. Collura, Ph.D.

Effective Feedback

- Fast – provides timely information to allow temporal binding
- Accurate – so brain has good information to work with, not ambiguous or superfluous
- Aesthetic – so brain will respond well to the content of the feedback without undue effort or confusion

(c) 2007-11 T. F. Collura, Ph.D.

Learning Mechanisms

- Operant Conditioning
- Classical Conditional
- Concurrent Learning
- Self-Efficacy
- Generalization

(c) 2007-9 T. F. Collura, Ph.D.

Instructions to Trainee

- Allow the sounds to come
- Do not “try” to do anything
- Allow yourself to learn what it feels like when you get a point
- Relax and pay attention to the screen
- Let the sounds tell you when you are in the desired state

(c) 2007-9 T. F. Collura, Ph.D.

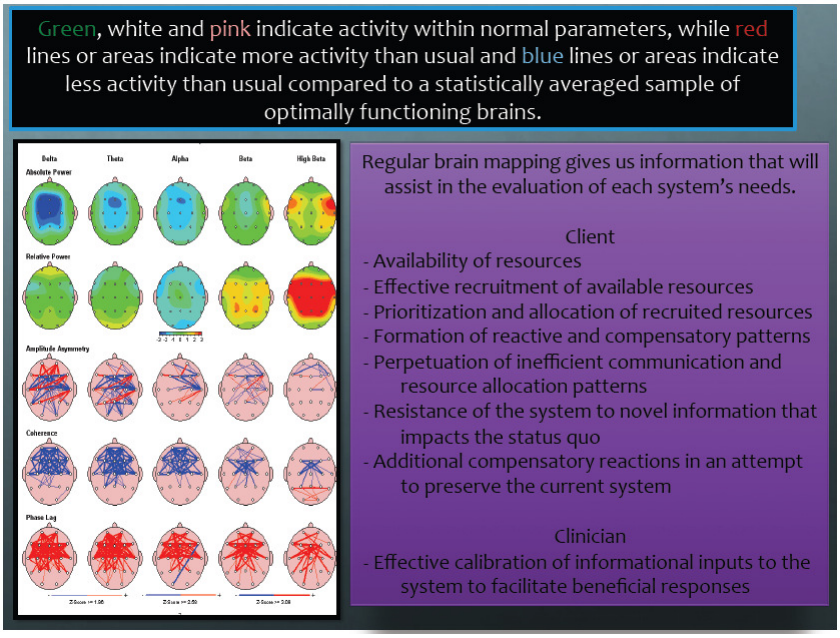
Standard Protocols

- Alert C3 – beta up; theta, hibeta down
- Deep Pz – (Penniston) alpha up, theta up
- Focus C4 – SMR up; theta, hibeta down
- Peak C3-C4 – alpha coherence up
- Peak2 C3-C4 – alert and focus combined
- Relax Oz – alpha up; theta, hibeta down
- Sharp Cz – broadband squash

(c) 2007-9 T. F. Collura, Ph.D.

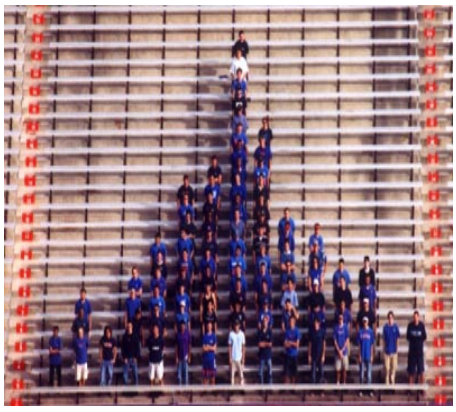
QEEG-based Neurofeedback

- Database-driven
- Compared to normal function
- Identify deviations, dysregulations
- Correlate EEG with behavior, emotion, self-regulation
- Teach new self-regulation skills
- Reduce symptomatology independent of “diagnosis”



Slide courtesy P.J. Rutter © (2011)

Normal Distribution males vs. females



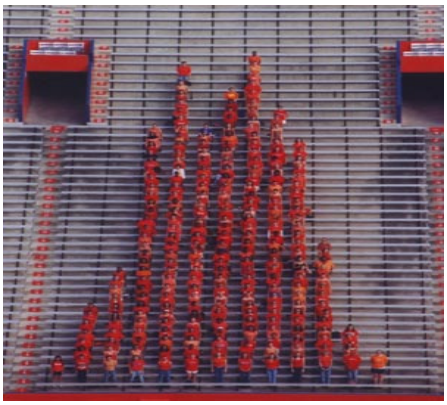


Photo by Gregory S. Pryor, Francis Marion University, Florence, SC.

From: (C. Starr and R. Taggart. 2003. *The Unity and Diversity of Life.* 10th Ed. Page 189.)

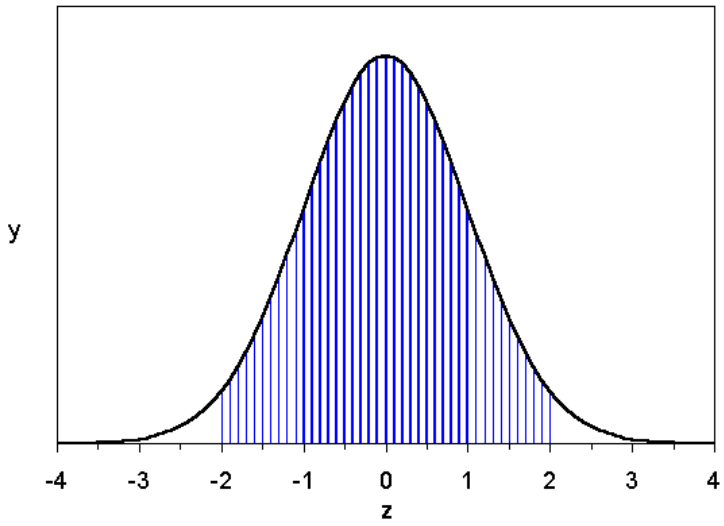
(c) 2007-9 T. F. Collura, Ph.D.

Purpose of z scores

- Method to understand a population
- Method to understand an individual
- Uses statistics to evaluate quantities
- Standard method applicable to any measurement
- Important for connectivity, phase, asymmetry measures

(c) 2007-9 T. F. Collura, Ph.D.

Bell Curve using z scores



(c) 2007-9 T. F. Collura, Ph.D.

Z score training approach

- Compute ongoing z scores
- Apply as training variables
- Establish targets and criteria
- Provide feedback
- Uses unique predefined bands, not adjustable in z DLL software
- Bands are independent of those used in the main EEG software

(c) 2007-9 T. F. Collura, Ph.D.

Z scores used for EEG

- Absolute power
- Relative power
- Power ratios
- Asymmetry
- Coherence
- Phase

(c) 2007-9 T. F. Collura, Ph.D.

Live Z-Score Training Policy

- EEG deviation(s) should be consistent with clinical presentation(s)
- EEG normalization should be reasonable
- Consider coping, compensatory traits
- Consider “peak performance” traits
- Consider phenotypes & recommendations
- Monitor subjective and clinical changes

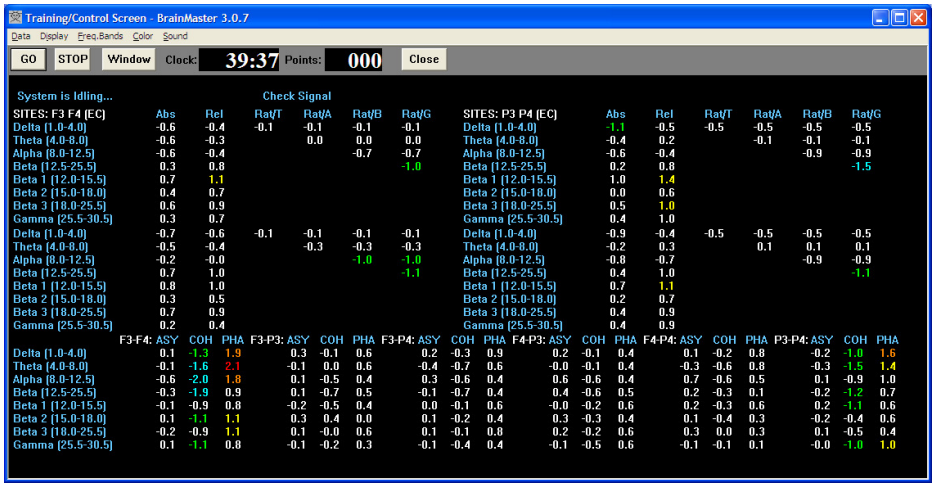
(c) 2008 Thomas F. Collura, Ph.D.

Phenotypes and Live Z-Scores

- Most Phenotypes “map” to live z-scores
  - Diffuse Slow
  - Focal Abnormalities, not epileptiform
  - Mixed Fast & Slow
  - Frontal Lobe Disturbances – excess slow
  - Frontal Asymmetries
  - Excess Temporal Lobe Alpha
  - Spindling Excessive Beta
  - Generally Low Magnitudes
  - Persistent Alpha
  - + Diffuse Alpha deficit
- Exceptions:
  - “Epileptiform” (requires visual inspection of EEG waveforms)
  - Faster Alpha Variants, not Low Voltage (requires live z-score for peak frequency)
- Many phenotypes can be addressed via. LZT Training
  - Inhibits, rewards referenced to normal population or biased for enhance/inhibit
- Phenotypes do not (currently) consider connectivity deviations
  - Hypocoherent Intrahemispheric (L or R)
  - Hypercoherent Interhemispheric (e.g. frontal)
  - Diffuse Coherence / Phase Abnormalities

(c) 2008 Thomas F. Collura, Ph.D.

Live Z Scores – 4 channels (248 targets)



SITES: F3 F4 [EC]	Abs	Rel	Rat/T	Rat/A	Rat/B	Rat/G
Delta (1.0-4.0)	-0.6	-0.4	-0.1	-0.1	-0.1	-0.1
Theta (4.0-8.0)	-0.6	-0.3		0.0	0.0	0.0
Alpha (8.0-12.5)	-0.6	-0.4			-0.7	-0.7
Beta (12.5-25.5)	0.3	0.8				-1.0
Beta 1 (12.0-15.5)	0.7	1.1				
Beta 2 (15.0-18.0)	0.4	0.7				
Beta 3 (18.0-25.5)	0.6	0.9				
Gamma (25.5-30.5)	0.3	0.7				
Delta (1.0-4.0)	-0.7	-0.6	-0.1	-0.1	-0.1	-0.1
Theta (4.0-8.0)	-0.5	-0.4		-0.3	-0.3	-0.3
Alpha (8.0-12.5)	-0.2	-0.0			-1.0	-1.0
Beta (12.5-25.5)	0.7	1.0				-1.1
Beta 1 (12.0-15.5)	0.8	1.0				
Beta 2 (15.0-18.0)	0.3	0.5				
Beta 3 (18.0-25.5)	0.7	0.9				
Gamma (25.5-30.5)	0.2	0.4				

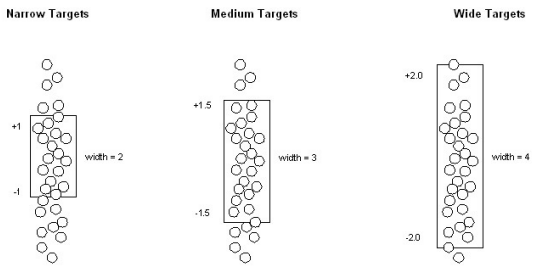
SITES: P3 P4 [EC]	Abs	Rel	Rat/T	Rat/A	Rat/B	Rat/G
Delta (1.0-4.0)	-1.1	-0.5	-0.5	-0.5	-0.5	-0.5
Theta (4.0-8.0)	-0.4	0.2		-0.1	-0.1	-0.1
Alpha (8.0-12.5)	-0.6	-0.4			-0.9	-0.9
Beta (12.5-25.5)	0.2	0.8				-1.5
Beta 1 (12.0-15.5)	1.0	1.4				
Beta 2 (15.0-18.0)	0.0	0.6				
Beta 3 (18.0-25.5)	0.5	1.0				
Gamma (25.5-30.5)	0.4	1.0				
Delta (1.0-4.0)	-0.9	-0.4	-0.5	-0.5	-0.5	-0.5
Theta (4.0-8.0)	-0.2	0.3		0.1	0.1	0.1
Alpha (8.0-12.5)	-0.8	-0.7			-0.9	-0.9
Beta (12.5-25.5)	0.4	1.0				-1.1
Beta 1 (12.0-15.5)	0.7	1.1				
Beta 2 (15.0-18.0)	0.2	0.7				
Beta 3 (18.0-25.5)	0.4	0.9				
Gamma (25.5-30.5)	0.4	0.9				

F3-F4:	ASY	COH	PHA	F3-P3:	ASY	COH	PHA	F3-P4:	ASY	COH	PHA	F4-P3:	ASY	COH	PHA	F4-P4:	ASY	COH	PHA	P3-P4:	ASY	COH	PHA
Delta (1.0-4.0)	0.1	-1.3	1.9		0.3	-0.1	0.6		0.2	-0.3	0.9		0.2	-0.1	0.4		0.1	-0.2	0.8		-0.2	-1.0	1.6
Theta (4.0-8.0)	-0.1	-1.6	2.1		-0.1	0.0	0.6		-0.4	-0.7	0.6		-0.0	-0.1	0.4		-0.3	-0.6	0.8		-0.3	-1.5	1.4
Alpha (8.0-12.5)	-0.6	-2.0	1.8		0.1	-0.5	0.4		0.3	-0.6	0.4		0.6	-0.6	0.4		0.7	-0.6	0.5		0.1	-0.9	1.0
Beta (12.5-25.5)	-0.3	-1.9	0.9		0.1	-0.7	0.5		-0.1	-0.7	0.4		0.4	-0.6	0.5		0.2	-0.3	0.1		-0.2	-1.2	0.7
Beta 1 (12.0-15.5)	-0.1	-0.9	0.8		-0.2	-0.5	0.4		0.0	-0.1	0.6		-0.0	-0.2	0.6		0.2	-0.3	0.6		0.2	-1.1	0.6
Beta 2 (15.0-18.0)	0.1	-1.1	1.1		0.3	0.4	0.0		0.1	-0.2	0.4		0.3	-0.3	0.4		0.1	-0.4	0.3		-0.2	-0.4	0.6
Beta 3 (18.0-25.5)	-0.2	-0.9	1.1		0.1	-0.0	0.6		0.1	-0.1	0.8		0.2	-0.2	0.6		0.3	0.0	0.3		0.1	-0.5	0.4
Gamma (25.5-30.5)	0.1	-1.1	0.8		-0.1	-0.2	0.3		-0.1	-0.4	0.4		-0.1	-0.5	0.6		-0.1	-0.1	0.1		-0.0	-1.0	1.0

26 x 4 + 24 x 6 = 248 (104 power, 144 connectivity)

(c) 2007-9 T. F. Collura, Ph.D.

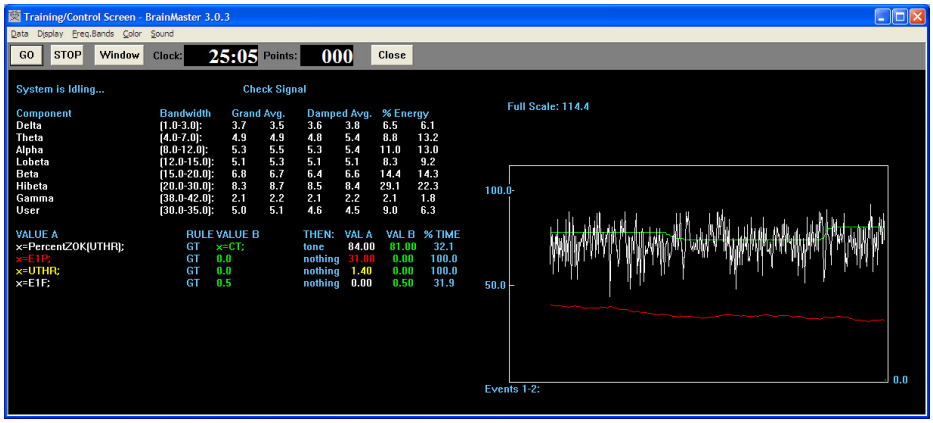
Multivariate Proportional Targeted (MVPT)
Live Z-Score Training (LZT)



Many Z-Scores outside	Some Z-Scores outside	Few Z-Scores outside
Allow Low PercentZOK (50%) to get reward	Allow Medium PercentZOK (80%) to get reward	Require High PercentZOK (95%) to get reward
Ignores Many Outlying Targets	Ignores Some Outlying Targets	Ignores Few Outlying Targets

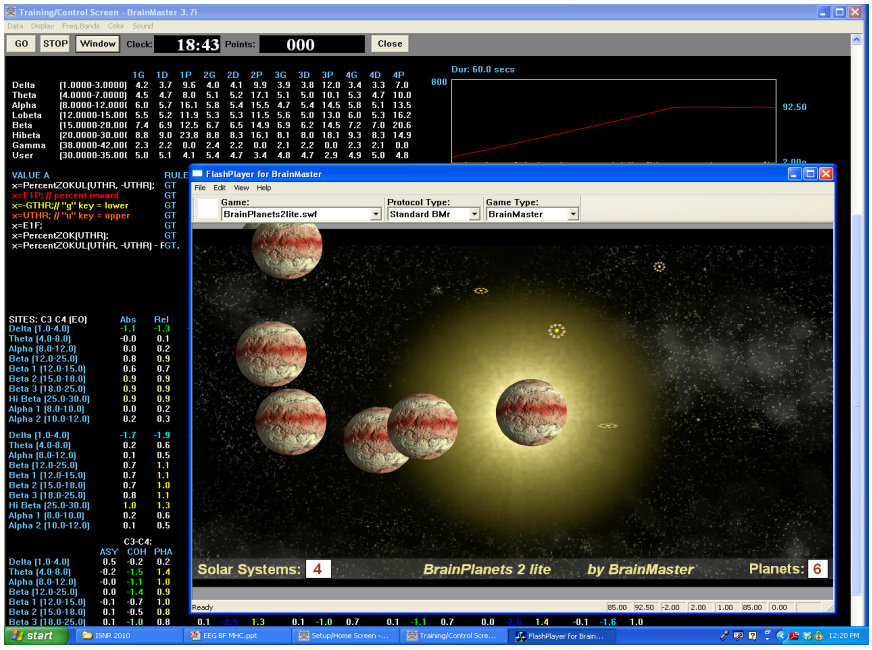
Note: Set rate of feedback reward the same in all cases, between 60% and 80%

Z Score training using Multivariate Proportional (MVP) Feedback

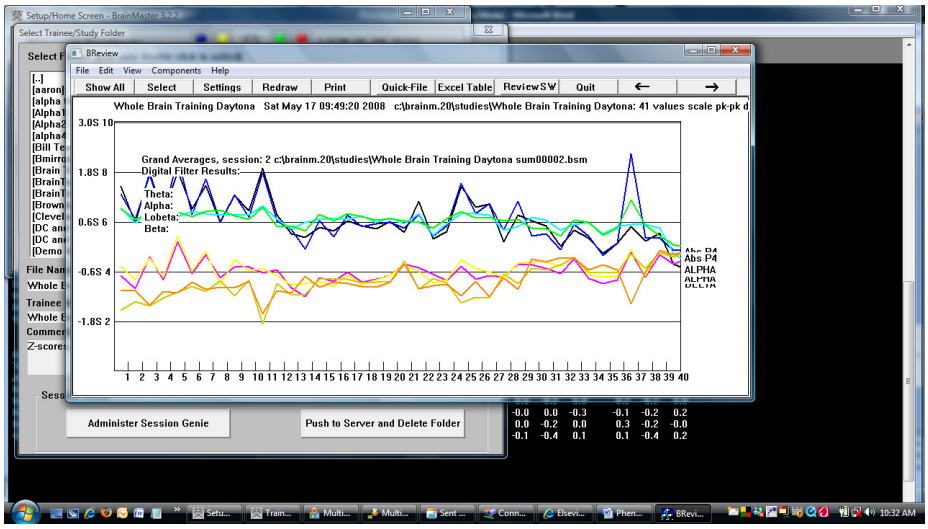


Size of range window (UTHR - currently 1.4 standard deviations)
Threshold % for Reward (CT: between 70% and 80%)
%Z Scores in range (between 50 and 90%)
% Time criterion is met (between 30% and 40%)

(c)(2007 Thomas F. Collura, Ph.D.

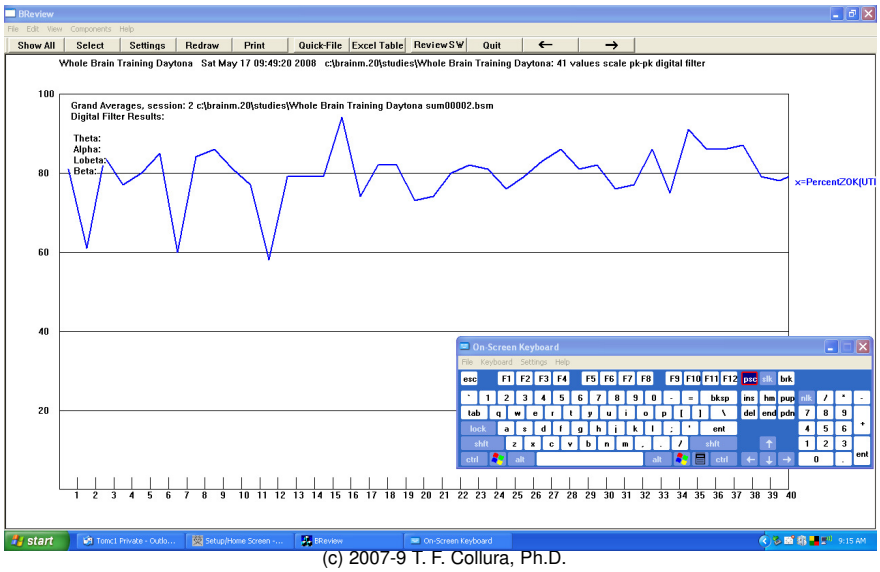


Progress of Live Z-Score Training

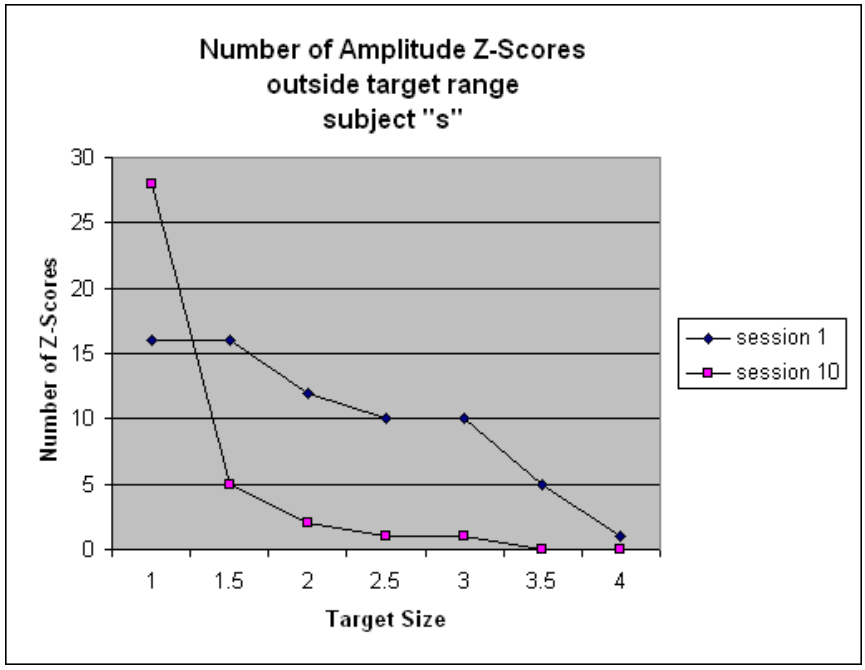


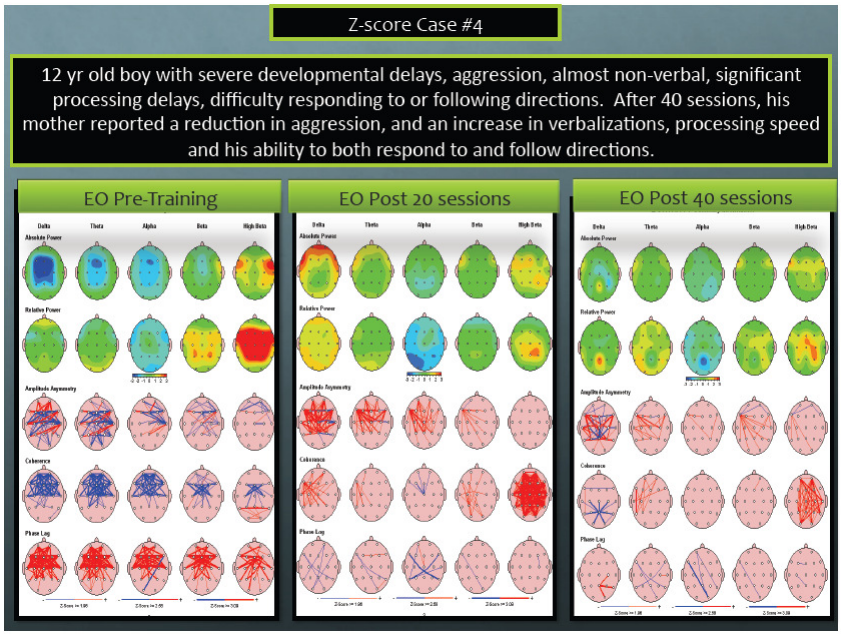
(c) 2007-9 T. F. Collura, Ph.D.

Progress of MVP Variable



(c) 2007-9 T. F. Collura, Ph.D.
(c) 2008 Thomas F. Collura, Ph.D.





Slide courtesy P.J. Rutter © (2011)

Link to Published Studies

- http://www.brainm.com/kb/entry/362/

EEG biofeedback training using live Z-scores and a normative database

Thomas F. Collura, Ph.D.[1], Robert W. Thatcher, Ph.D.[2], Mark Llewellyn Smith L.C.S.W.[3], William A. Lambos, Ph.D., BCIA-EEG[4], and Charles R. Stark, M.D., BCIA-EEG[5]

[1]BrainMaster Technologies, Inc., Oakwood, Ohio, USA
[2]EEG and NeuroImaging Laboratory, Applied Neuroscience, Inc., St. Petersburg, and Professor, Department of Neurology, University of South Florida, Florida, USA
[3]Private Practice, New York, USA
[4]Cognitive Neuro Sciences, Inc. and University of South Florida, Florida, USA
[5]Cognitive Neuro Sciences, Inc., Melbourne, Florida, USA

(2009) in: (Evans, W., Budzynski, T., Budzynski, H., and A. Arbanal, eds) Introduction to QEEG and Neurofeedback : Advanced Theory and Applications, Second Edition. New York: Elsevier.

EEG Biofeedback Case Studies Using Live Z-Score Training (LZT) and a Normative Database

Thomas F. Collura, PhD
Joseph Guan, MM.ED, PhD
Jeffrey Tarrant, PhD
John Bailey, Ph.D.
Fred Starr, MD

(2010) Journal of Neurotherapy 14(2), 22-46.

Contributions also by Doerte Klein, Penijean Rutter, Nancy Wigton, Harry Kerasidis, Charles R. Stark, and Jonathan Walker.

Cases

- Attention – 6
- Anxiety / Mood – 5 (3 comorbid)
- Social / Behavioral – 3
- Autism / ASD – 3
- Behavioral – 2
- Cognitive Efficiency / Memory – 2
- Cerebral Palsy – 1
- PDD – 1
- TBI - 1

Case Study Summary

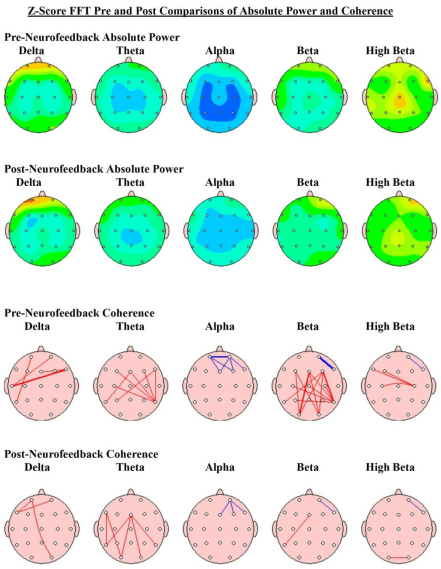
	Number Reported	Visible Improvement
Total Cases Reported	24	
Reporting Presenting Symptoms	22	22
Reporting Clinical/Behavioral Outcome	23	23
Pre- and post-treatment LZT data	10	10
Pre- and post-treatment QEEG Data	12	12
Pre- and post-treatment IVA Data	5	4

DQ

- 9 YO male, behavioral problems at school and home, incidents of verbal and physical aggression, inability to control temper, stuttering

DQ NFT

- 39 sessions F3 F4 P3 P4, Fz Pz C3 C4, F3 F4 Cz Pz T3 T4 Fz Cz F3 F4 P3 P4 alpha enhance added with emphasis on parietal via thresholds

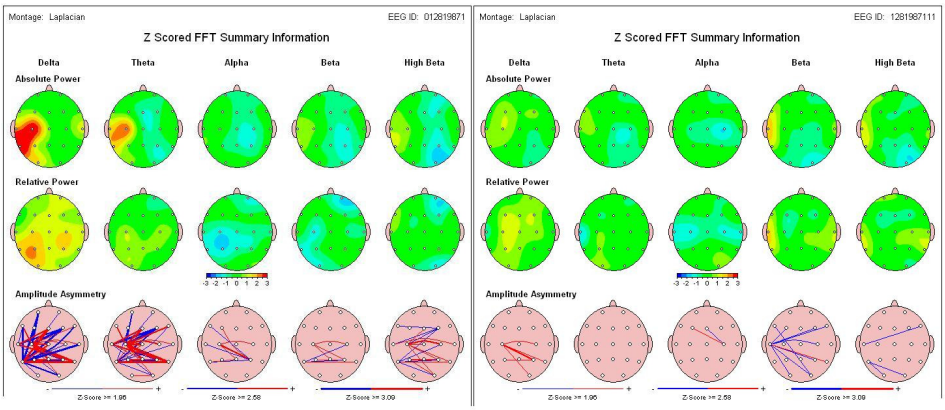


DQ

- speech improved significantly after 15 sessions, much less stuttering at around session 17, less argumentative and stopped temper tantrums after session 22, had stopped taking medications at session 26, seemed happier and friendlier at session 27. improved energy and affect, more cognitive flexibility, able to handle transitions in session and in office, no longer stuttered after 39 sessions. plan to return to full day attendance

NORB

- 21 YO female, currently on academic leave from college "required to get mental health treatment to go back to school" difficulty making friends, socializing, moderate sx of depression. Engrossed in inner "fantasy life"



NORB

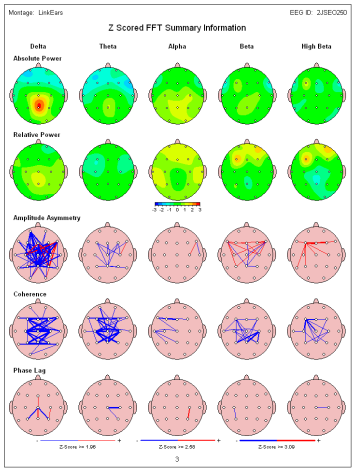
- from mother: I do see improvement in B. Seems to be following through better and completing tasks. Has discussed with me the recommendations about past rigity. Agree that she needs to learn to alter her plans and still accomplish tasks. She has come a long way and I see a great deal of improvement. organization is better and confidence is up.

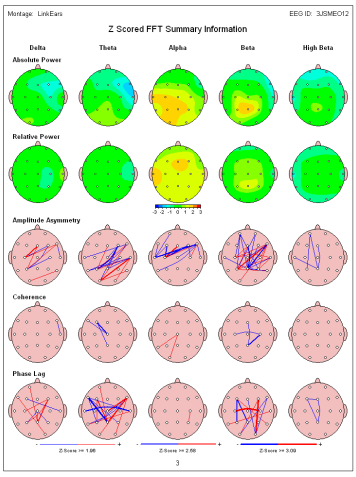
Case of Jack

- 3 YO Male, Mild concussive head injury
- Atonic, absence, myoclonic seizures
- Multi-spike focus, 300-400 uV
- Initially used inhibit & coherence training
- Temporarily improved, then declined
- Then switched to z-score “all coherences normal” training
- Seizures stopped after 3 sessions. Now >5 yr. seizure-free
- Data courtesy of M. L. Smith

(c) 2007-9 T. F. Collura, Ph.D.

Jack QEEG pre and post Z-score training





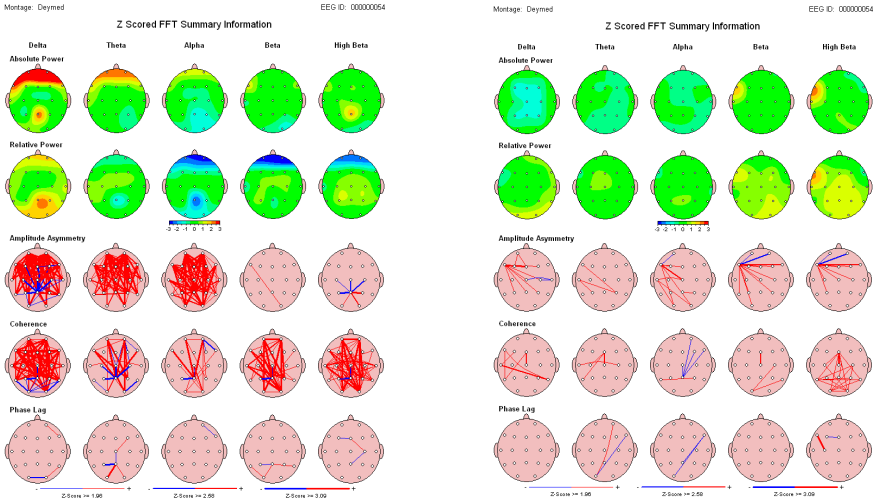
(c) 2007-9 T. F. Collura, Ph.D.

Case of SL

- 7YO Male, discipline problem, AD/HD, easily excited, aggressive
- QEEG Pre and post z-score training
- 21 sessions between QEEG's
- PercentZ training at 85% reward
- Begin F3 F4 P3 P4, later F3 F4 C3 C4
- Begin at +/- 2.0 S.D.
- All scores except 1 within 1.5 S.D. after training
- Significant clinical, school, home improvement
- Clinical: P.J. Rutter
- Data courtesy Drs. C. Stark & W. Lambos

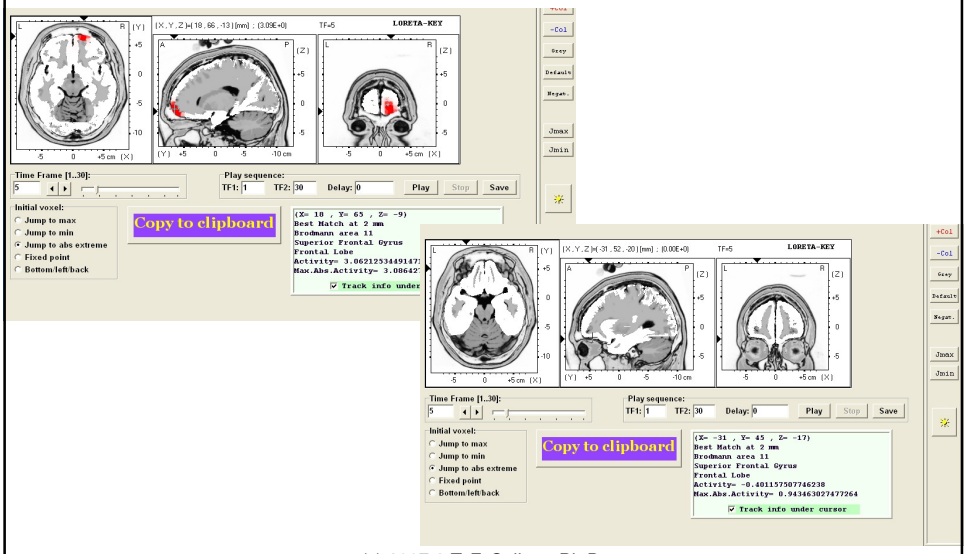
(c) 2007-9 T. F. Collura, Ph.D.

SL - EO Pre and Post



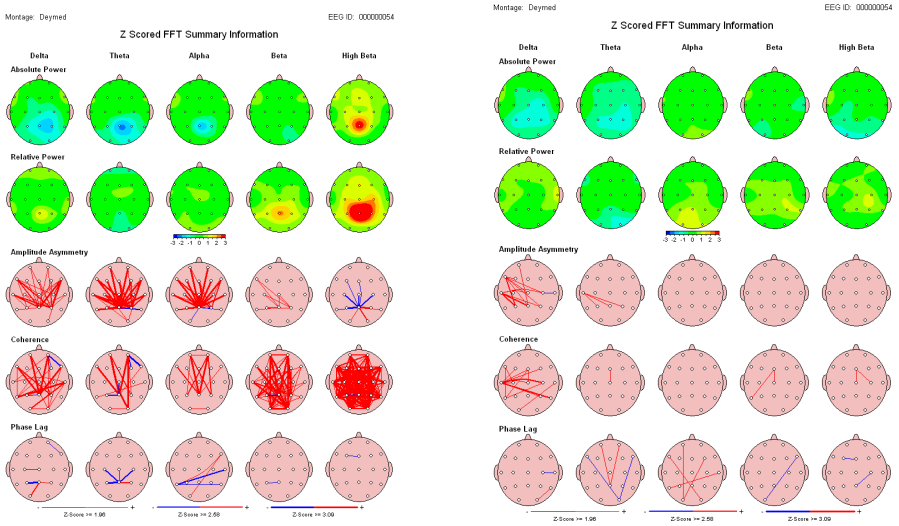
(c) 2007-9 T. F. Collura, Ph.D.

SL - EO Loreta Pre and Post



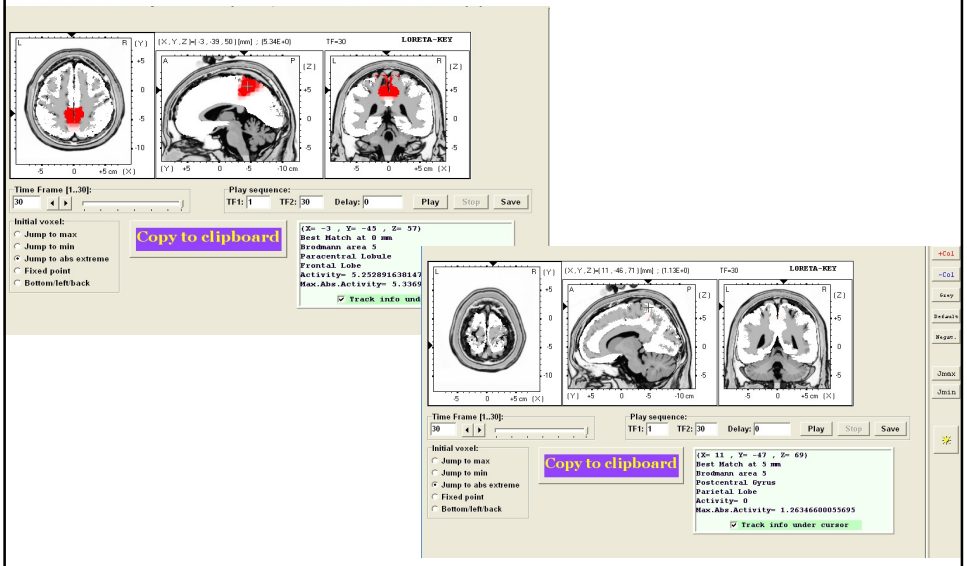
(c) 2007-9 T. F. Collura, Ph.D.
(c) 2008 Thomas F. Collura, Ph.D.
Data from Stark & Lambos

SL - EC Pre and Post



(c) 2007-9 T. F. Collura, Ph.D.

SL - EC Loreta Pre and Post



(c) 2007-9 T. F. Collura, Ph.D.

Summary

- New method using normative data
- Comprehensive whole-head approach
- Normalizes both activation & connectivity
- Multiple targeting & biasing capability
- Consistent with QEEG & Phenotype approaches
- Provides brain with complex information
- Simple training format
- Effective for assessment & training

(c) 2007-9 T. F. Collura, Ph.D.