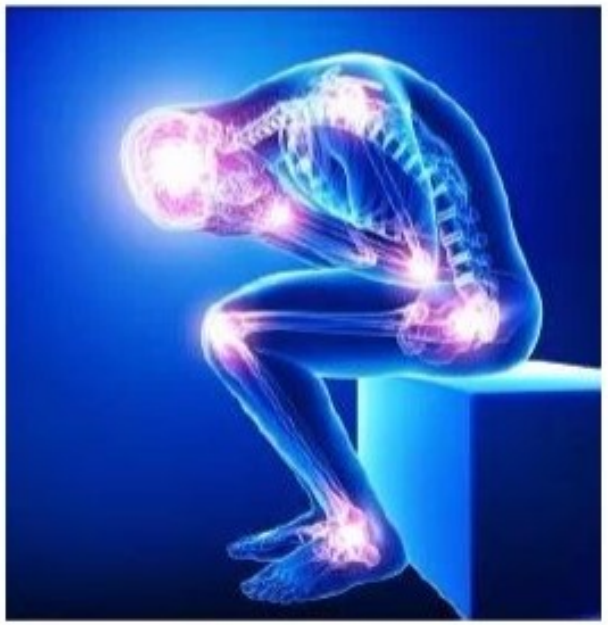
NFB & Chronic Pain Management

Chronic Pain Sources

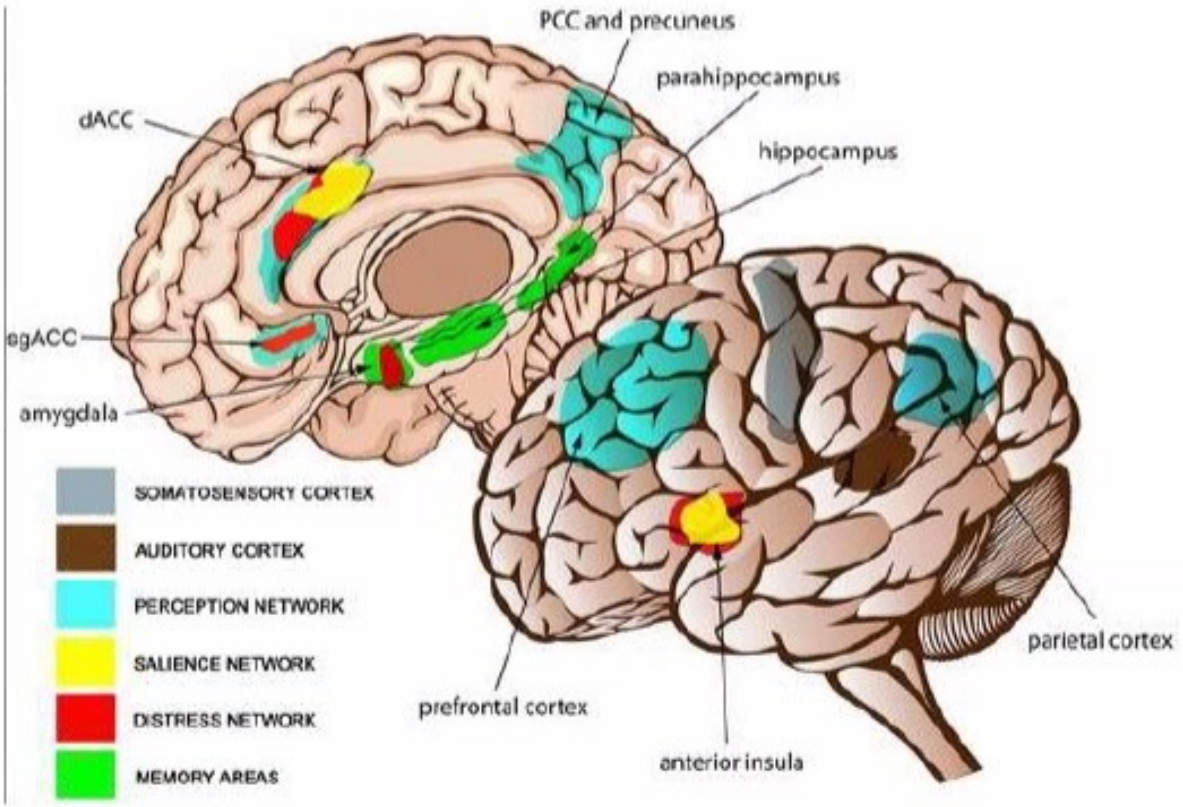
- An injury that has healed (Sprains and Infections)
- A continuous source (Arthritis, Fibromyalgia)
- An unknown source (RSD)

Jensen et al, 2013



Self- Sustaining Pain Networks

- Stimulated pathways become altered.
- They begin firing independently of pain sources.



Repeated Exposure

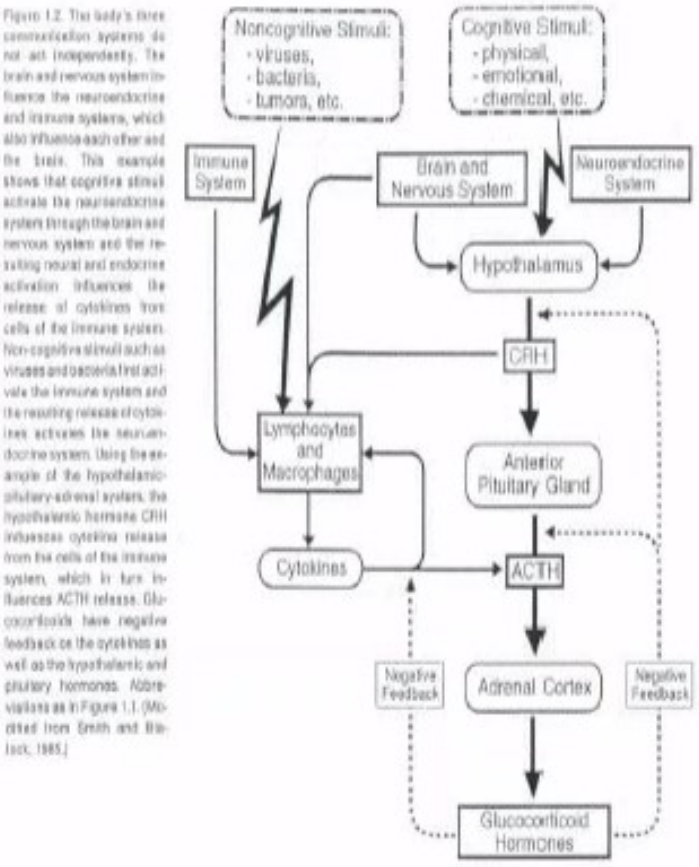
Repeated exposure results in:

- Increased sensitivity
- More Intense response
- Longer lasting experience of pain

Other systems Affected

Endocrine System:

- **Elevated Cortisol**
- **Increased Norepinephrine**
- **Increased R H Beta.**



Depletions Of Key Hormones

Tennant, 2013

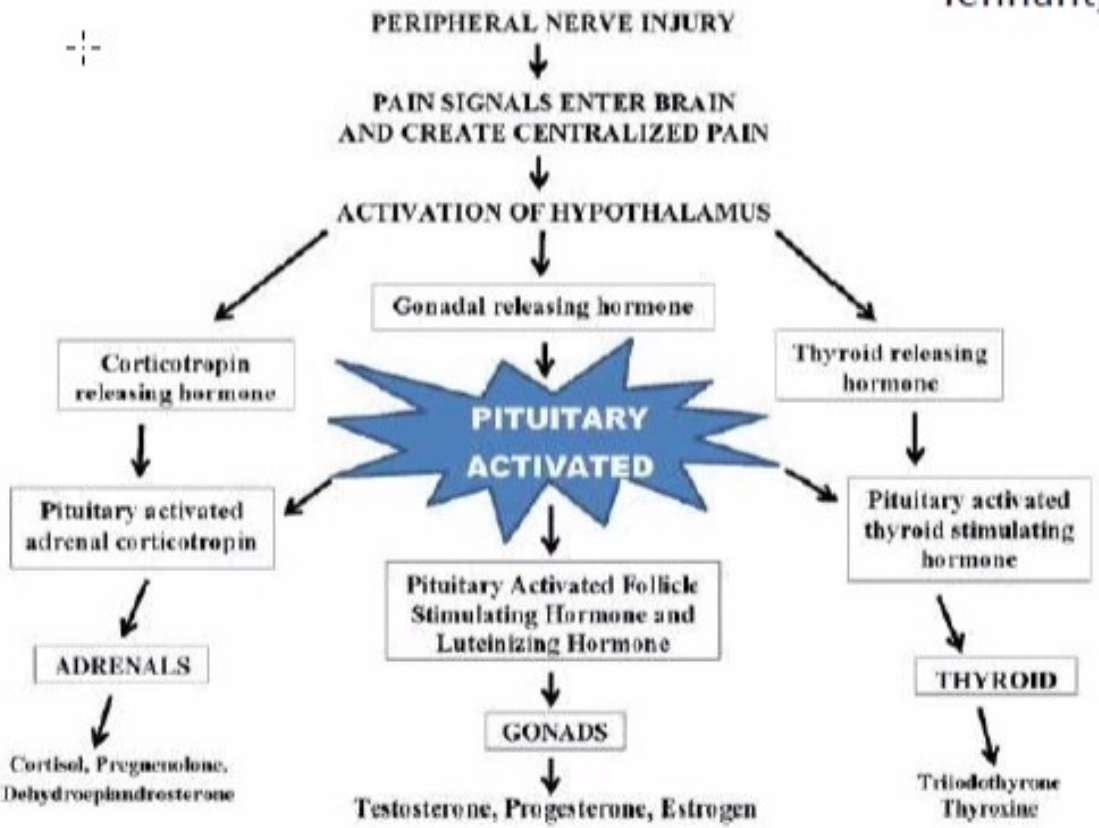


Fig. 1 Pain stimulation of the hormone system causes adrenal, gonad and thyroid hormone levels to elevate in the serum. If pain remains uncontrolled for a considerable time period, hormonal depletion may occur, and serum levels drop below normal

Pain-Control Mechanisms of Hormones

Table 2 Major pain-control mechanisms of hormones

Pain-control mechanism
Anti-inflammatory action
Cellular metabolism
Cellular protection
Glucose control
Immunoreactivity
Tissue regeneration
Central nervous system functions
Receptor binding
Nerve conduction
Maintenance of blood–brain barrier

Tennant, 2013

Critical Hormones For Pain Control

Table 1 Hormones from peripheral glands that are critical for pain control

Hormone
Cortisol
Dehydroepiandrosterone
Estrogen
Pregnenolone
Progesterone
Testosterone
Thyroid

Tennant, 2013

Other Systems Affected

Immune Response:

"Broadly defined, central neuroimmune activation involves the activation of cells that interface with the peripheral nervous system and blood. Activation of these cells, as well as parenchymal microglia and astrocytes by injury, opioids, and other stressors, leads to subsequent production of cytokines, cellular adhesion molecules, chemokines, and the expression of surface antigens *that enhance a CNS immune cascade. This response can lead to the production of numerous pain mediators that can sensitize and lower the threshold of neuronal firing: the pathologic correlate to central sensitization and chronic pain states "* (Deleo et al 2009).

Pathological Neural Response

"Glia have emerged as key contributors to pathological and chronic pain mechanisms. On activation, both astrocytes and microglia respond to and release a number of signaling molecules, which have protective and/or **pathological functions**."

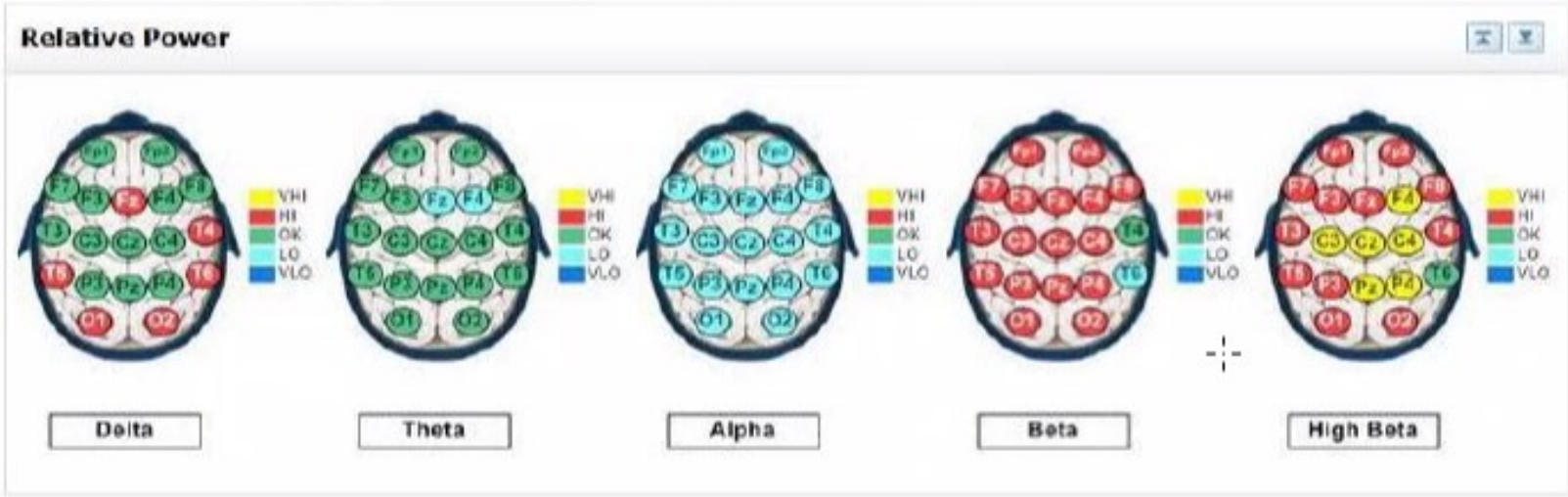
(Milligan & Watkins, 2005)

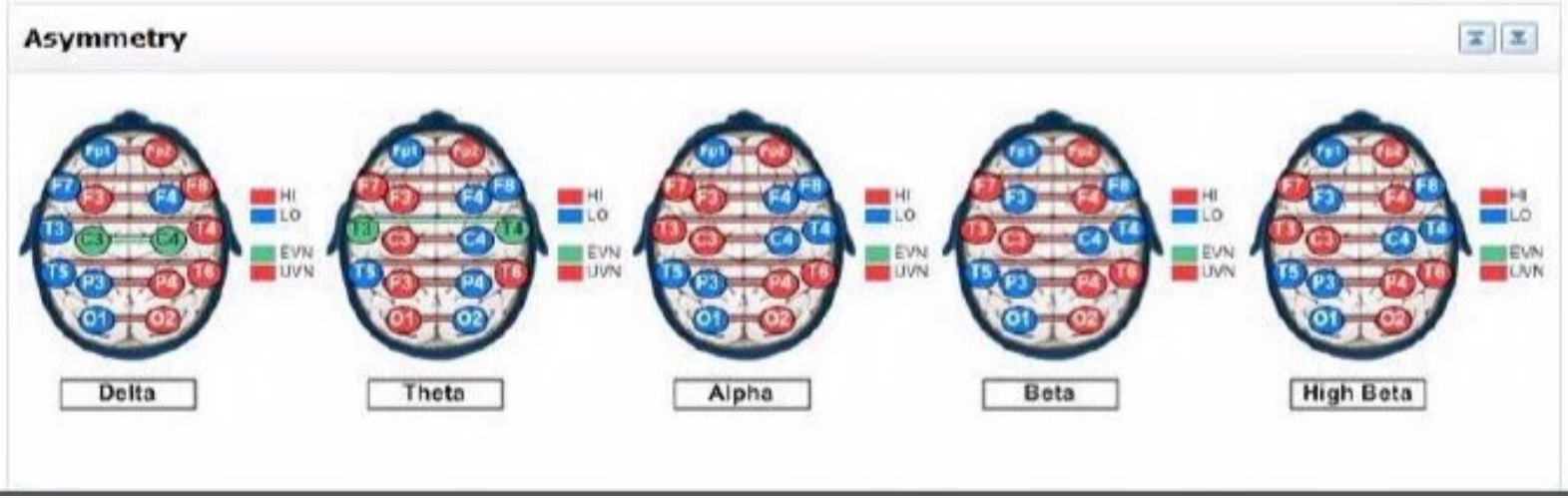
Mood & Pain


Disease Pain
Tense muscles
Stress
Fear / Anger / Frustration
Depression
Fatigue

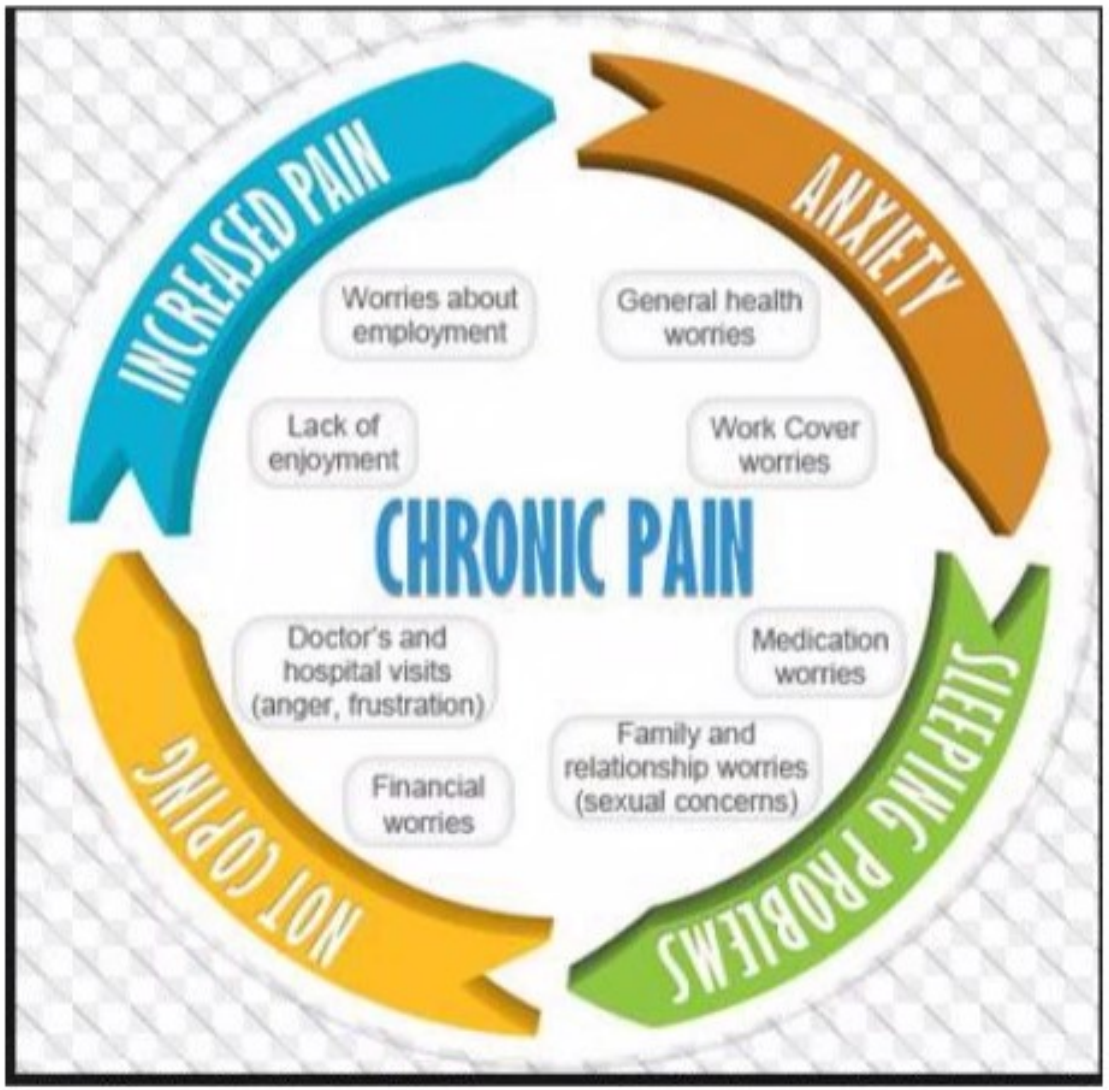
Aggravating Cascade Enhances Pain Experience

Enhanced Anxiety > Insomnia > Mood Disorder





Pain Perception Cycle



Consequences of Insomnia That Enhance Pain Experience

Depression

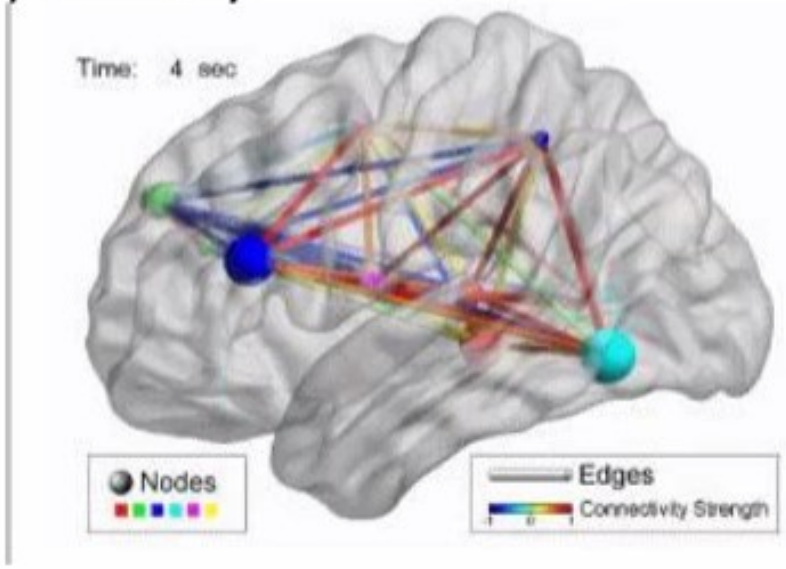
Weakened Immune System

Increased Anxiety

Increased Sensitivity

A Complex Interpretive System Manages Pain Perception

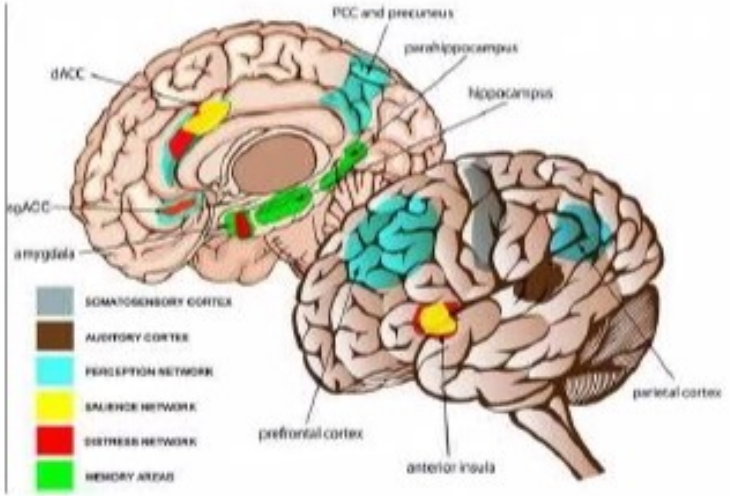
"Pain is now recognized to be the result of a complex interaction of activity in multiple cortical–subcortical neural networks and Processes" (Jensen, 2010)



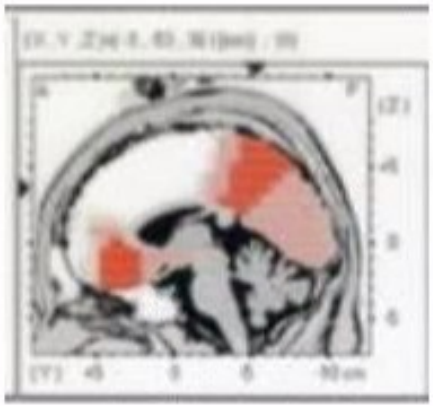
Pain Control Circuit

Cognition Influences Modulatory Pathway

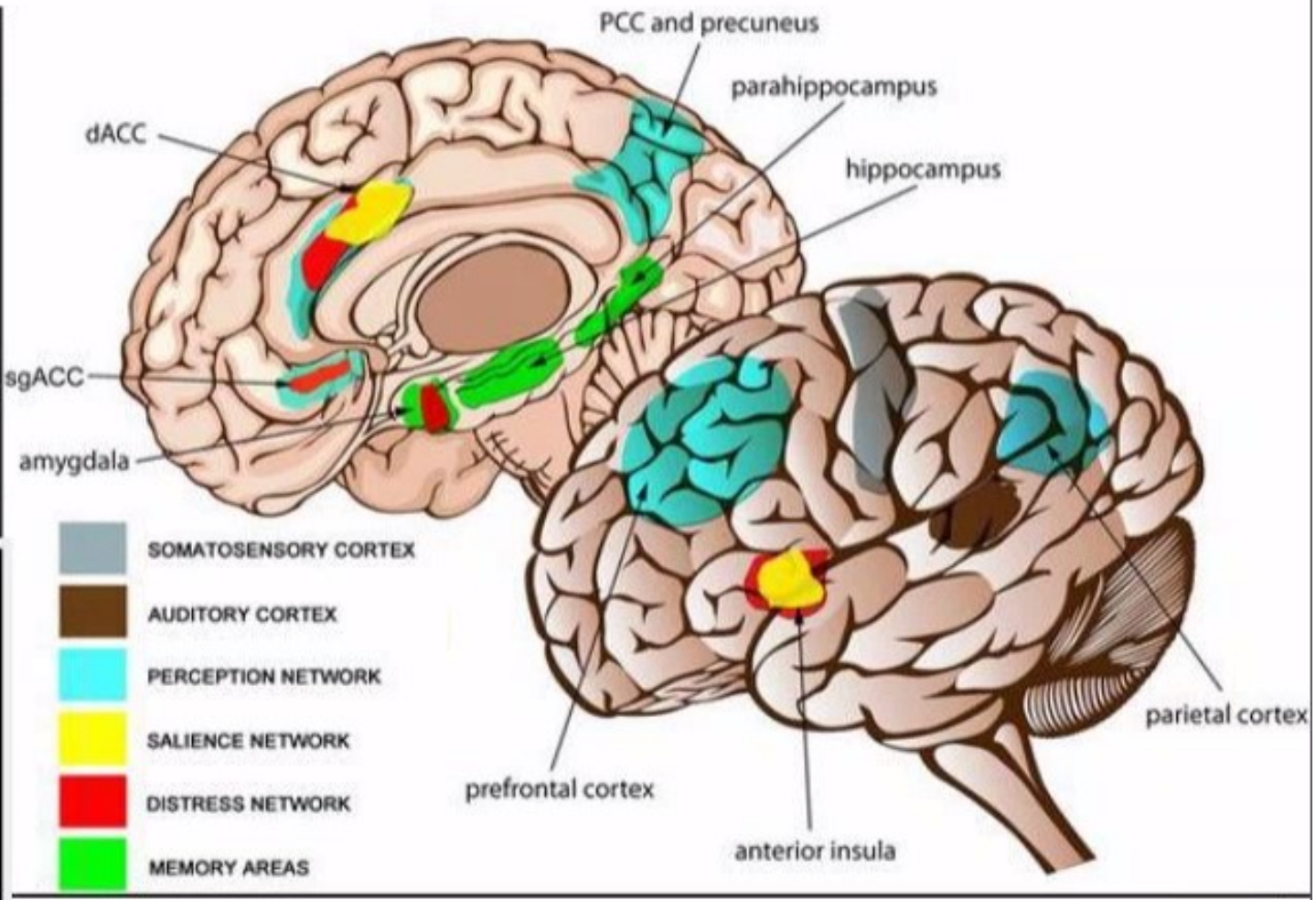
- Frontal Lobes (Anterior Cingulate Right Ventral Prefrontal Cortex)
- Somatasensory Cortex
- Insula
- Thalamic Nuclei
- Periaqueductal gray
- Amygdala
- Spinal cord Nerve fibers from body



Pain Pathways



Fibromyalgia Map



Growing Pain Generating Networks

". . .ongoing activation of pain-related central networks can lead to changes in these networks, consolidating and thus facilitating pain processing even independent of peripheral neural activation." (Gustin et al., 2012)

fMRI Feedback Experiements: (DeCharmes et al, 2005)

Non-Pharmalogical Interventions That Target Cortical & Subcortical Pain Related Activity

- Neurofeedback
- Hypnosis
- Mindfulness Meditation Training
- Current Stimulation (tDCS)

Types of Pain Treated With NFB

- chronic back pain
- peripheral nerve Injury
- pain from cancer
- fibromyalgia,
- trigeminal neuralgia
- migraine headaches
- complex regional
- pain syndrome.
- gastrointestinal pain

Frequencies Associated With Pain

Both acute and chronic pain studies have shown reproducible changes of increased ‘‘fast’’ waves (beta 13–35 Hz).

In some cases also slow alpha (8-10Hz)

As well as theta- which may in fact be related to slow alpha or diminished blood perfusion.

(Bromm and Lorenz, 1998; Chen et al., 1983).

Frequencies of Relief

Generally, efforts to use neurofeedback for pain treatment commonly seek to reduce fast wave and increase normal slower wave activity. (Jensen et al, 2007; Sime, 2004).

Sites Used

Typically sites trained include:

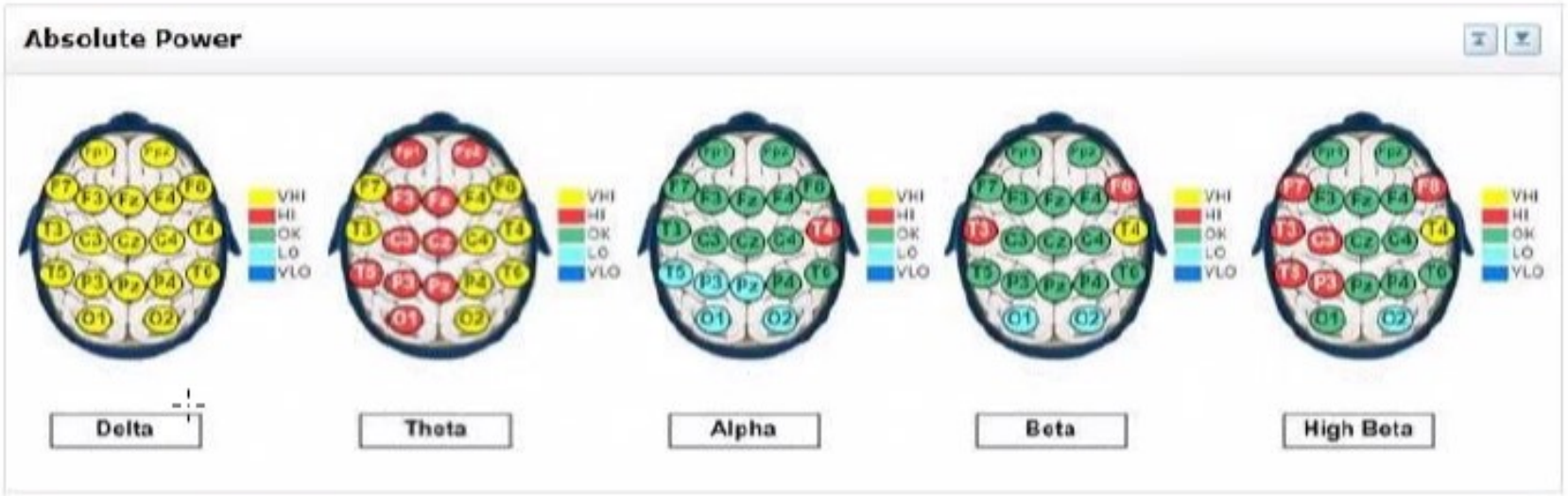
- T3 and T4 (Jensen et al., 2007; Sime, 2004)
- Cz (Caro & Winter, 2011)
- C4 (Kayiran et al., 2010)
- Mixed sites (Jensen et al., 2007; Sime, 2004)

Frequencies Used

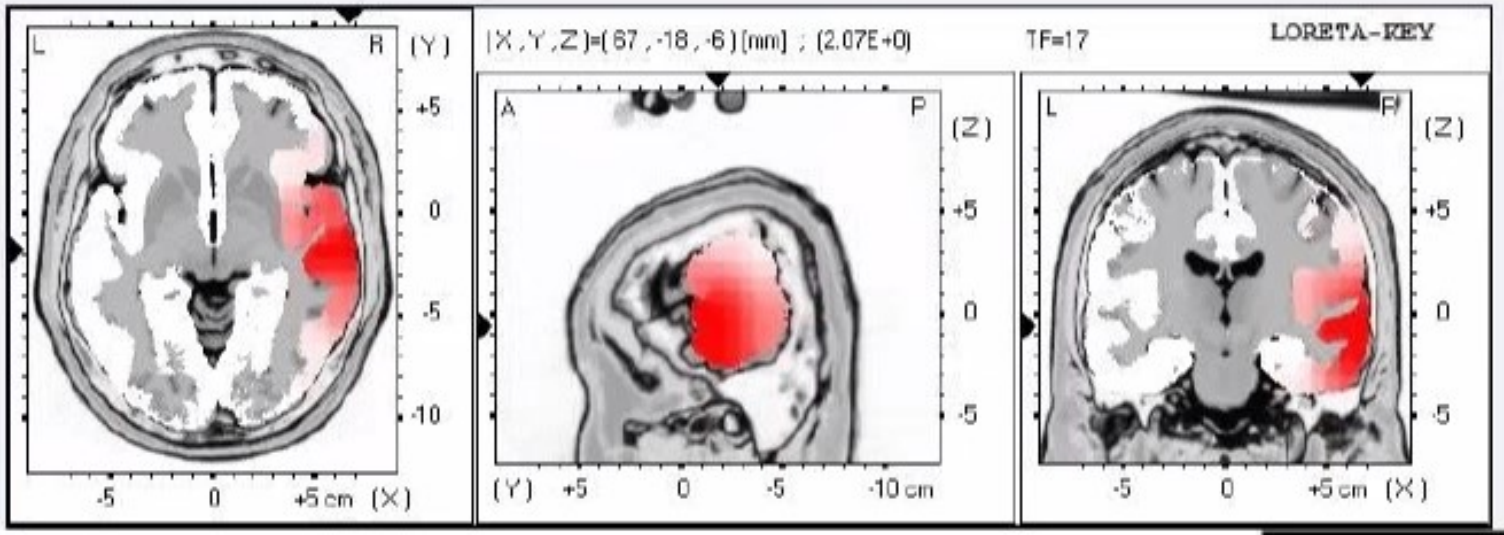
Frequencies reinforced in the neurofeedback protocols have also varied:

- Supression of Beta (Jensen et al , 2007)
- Reinforcement of alpha (9–11 Hz) (Gannon and Sternback, 1971)
- Reinforcement of SMR or 12–15 Hz (Caro and Winter, 2011; Kayiran et al., 2010)
- Some Combination of the above

Diffuse Pain



Chronic Leg Pain
Tinnitus



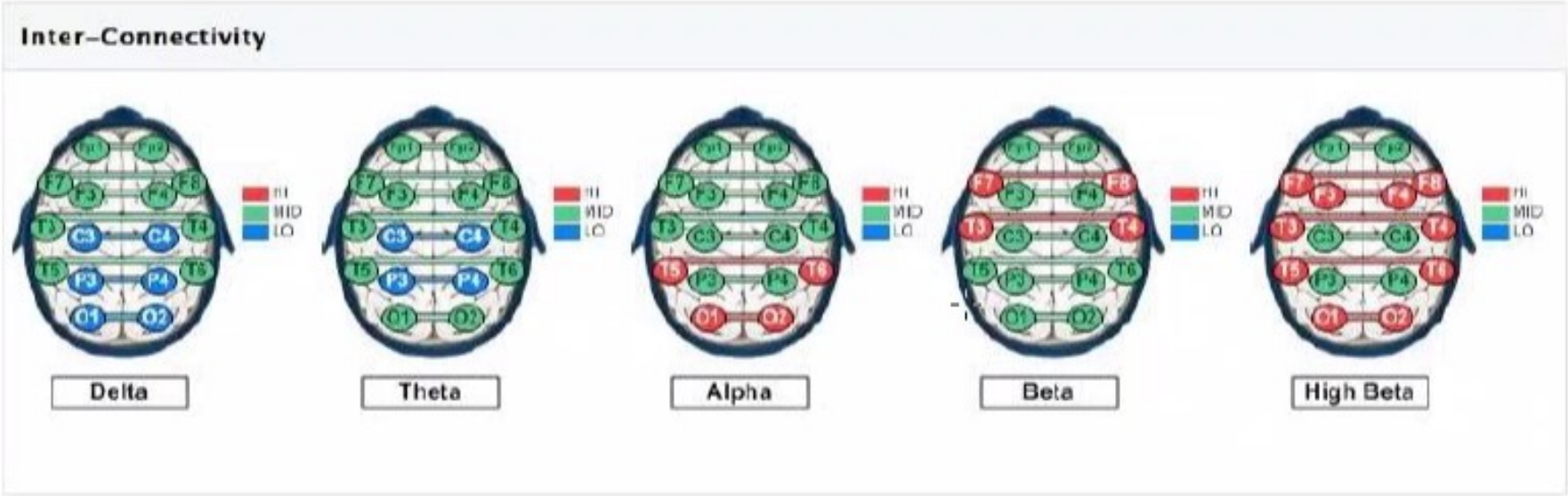
16-18Hz Beta: Pain

1-4Hz Delta: Tinnitus

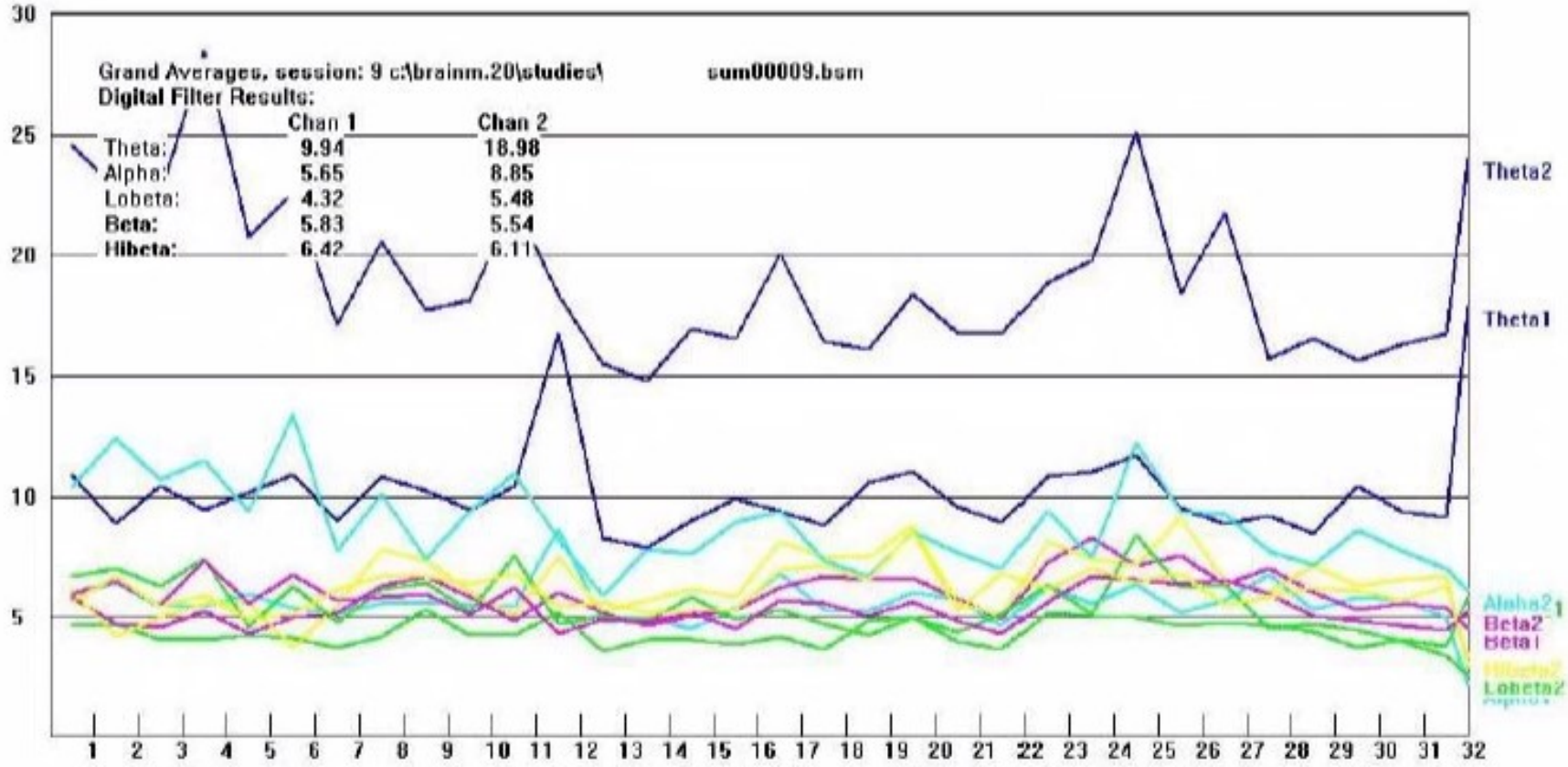
Right Temporal Lobe

Insula

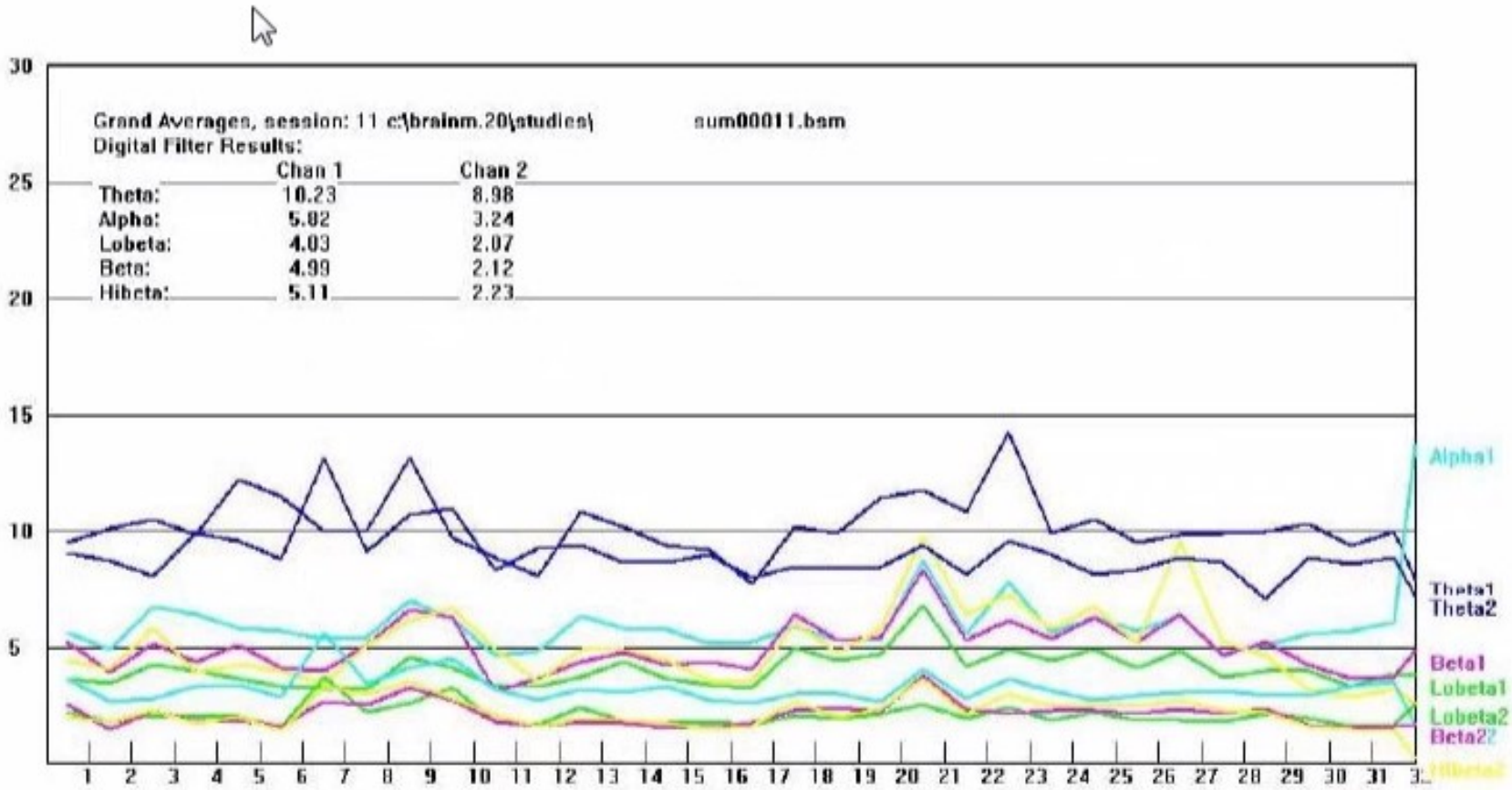
Pain Coherence



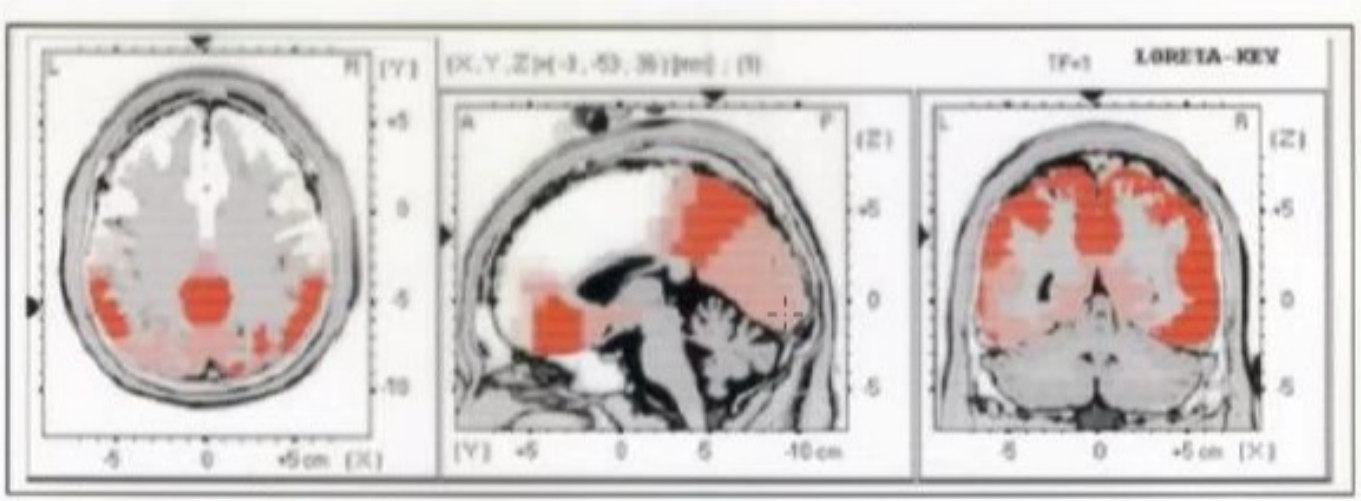
High Pain Day



Pain Low Day


Grand Averages, session: 11 c:\brainm.20\studies\ sum00011.bam
Digital Filter Results:
Chan 1 Chan 2
Theta: 10.23 8.98
Alpha: 5.82 3.24
Lobeta: 4.03 2.07
Beta: 4.99 2.12
Hibeta: 5.11 2.23
30
25
20
15
10
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Alpha1
Theta1
Theta2
Beta1
Lobeta1
Lobeta2
Beta22

Fibro Case 1



Fibromyalgia

Richard Soutar, Ph.D.

Fibromyalgia Definition

- Fibromyalgia is a disorder characterized by widespread musculoskeletal pain accompanied by fatigue, sleep, memory and mood issues. Researchers believe that fibromyalgia amplifies painful sensations by affecting the way your brain processes pain signals.
- Symptoms sometimes begin after a physical trauma, surgery, infection or significant psychological stress. In other cases, symptoms gradually accumulate over time with no single triggering event.
- Women are much more likely to develop fibromyalgia than are men. -Mayo Clinic

Symptoms

- **Pain symptoms of fibromyalgia**
- Deep muscle pain and soreness
- Morning stiffness
- Flu-like aching
- Radiating pain
- Sensitivity to touch
- **Other symptoms of fibromyalgia**
- Problems sleeping
- Fatigue
- Difficulty thinking clearly, also known as "fibro fog"
- Difficulty performing everyday tasks
- Stress and anxiety
- Depression
- Migraine headaches

Top Ten Symptoms

- Top Ten Fibromyalgia Symptoms
- Pain all over
- Fatigue
- Sleep difficulties
- Brain fog
- Morning stiffness
- Muscle knots, cramping, weakness
- Digestive disorders
- Headaches/migraines
- Balance problems
- Itchy/burning skin

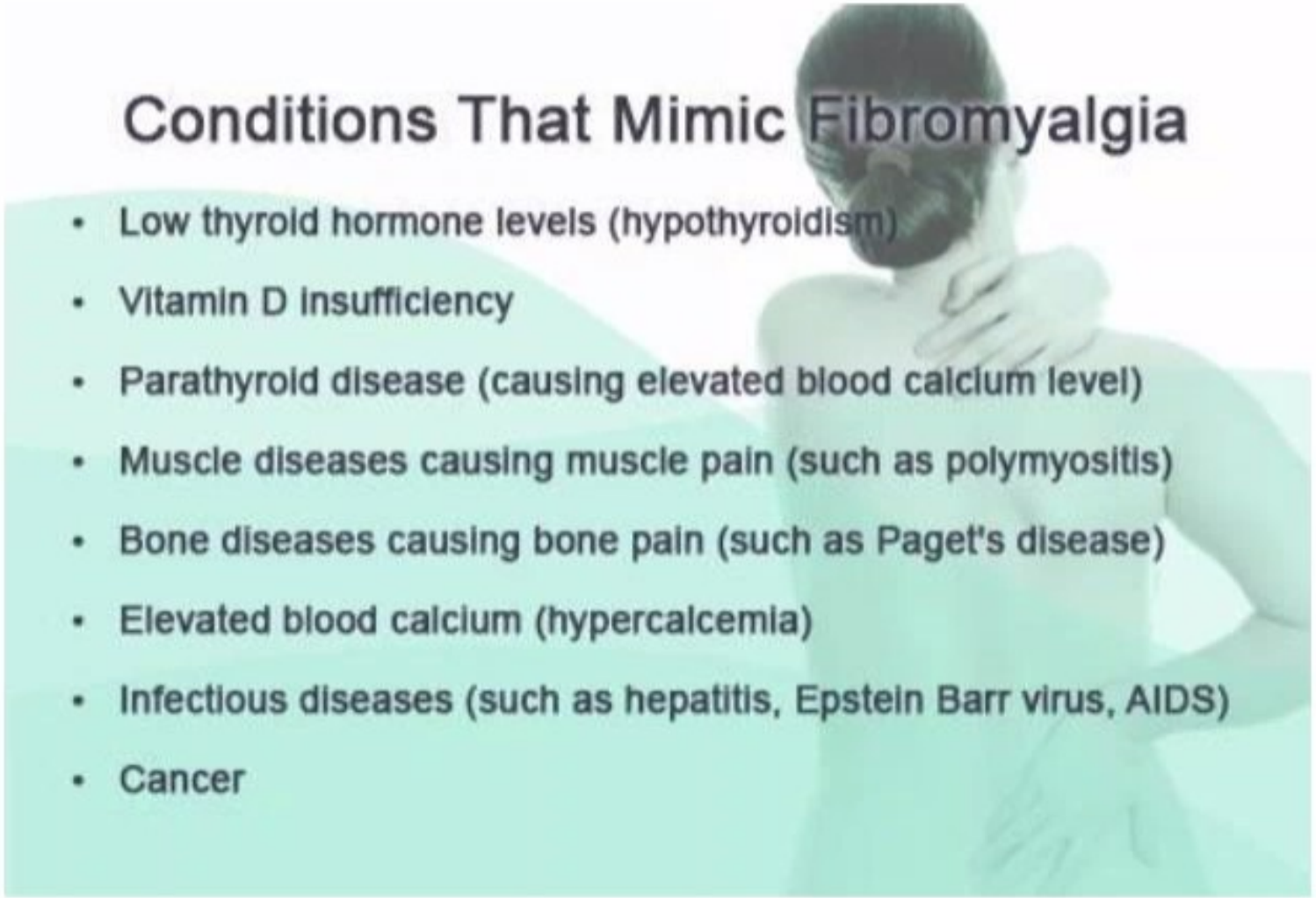
Additional Symptoms

- chest pain unrelated to the heart
- shortness of breath
- dizziness
- nasal congestion
- painful periods
- palpitations
- irritable bladder/interstitial cystitis
- profuse sweating
- tingling/numbness sensations
- chemical sensitivities
- vulvodynia (vulvar pain)
- difficulty focusing eyes
- the feeling of swollen extremities
- dry/burning eyes and mouth

Aggrevating Factors

- Weather (especially cold climates and changes in barometric pressure), cold or drafty environments, hormonal fluctuations (premenstrual and menopausal states), poor quality sleep, stress, depression, anxiety, and over-exertion can all contribute to fibromyalgia symptom flare-ups.

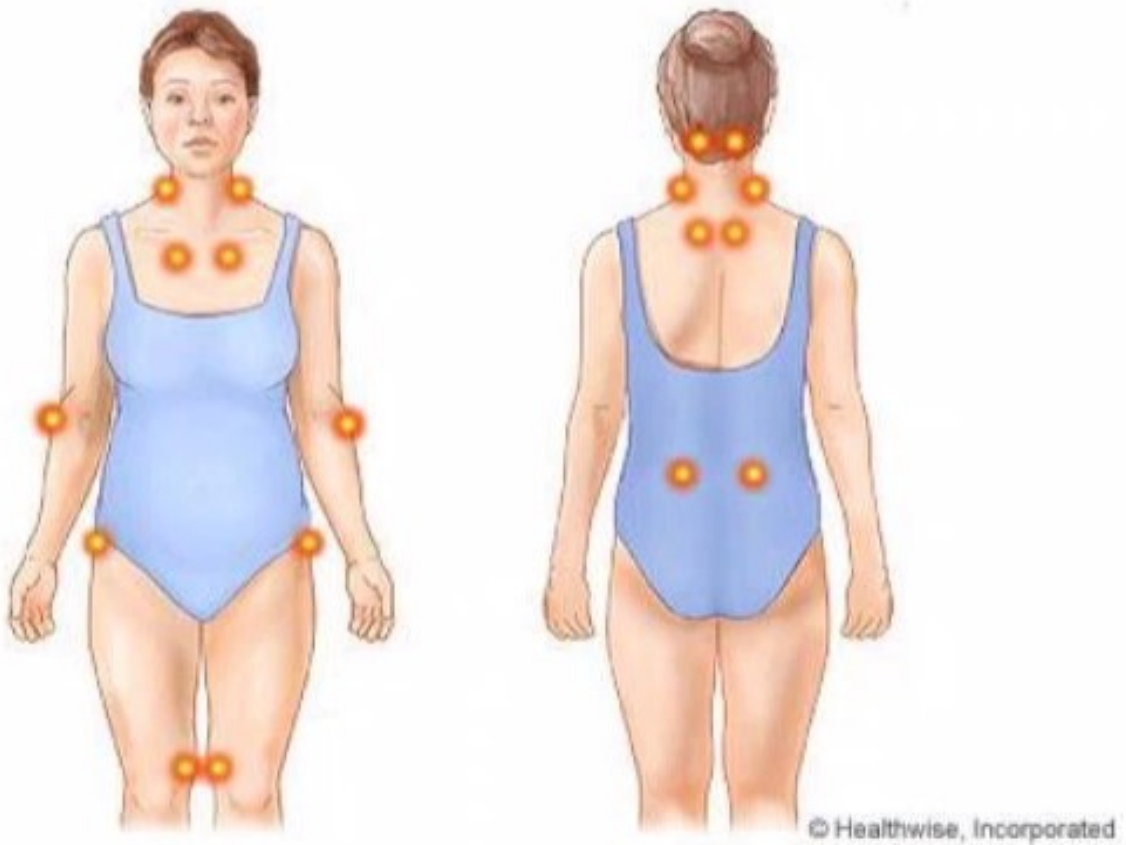
Differential Diagnosis



Conditions That Mimic Fibromyalgia

- Low thyroid hormone levels (hypothyroidism)
- Vitamin D insufficiency
- Parathyroid disease (causing elevated blood calcium level)
- Muscle diseases causing muscle pain (such as polymyositis)
- Bone diseases causing bone pain (such as Paget's disease)
- Elevated blood calcium (hypercalcemia)
- Infectious diseases (such as hepatitis, Epstein Barr virus, AIDS)
- Cancer

11 Out of 18 Tender Points



Still A Mystery

- Cause is unknown
- No known Cure

Treatments

- SSRIs
- SNRIs
- Savella
- Massage
- Infrared Sauna
- Physical Therapy
- Acupuncture
- Yoga
- Medical Marijuana

Supplements

- SAMe
- 5-HTP
- Magnesium
- Melatonin
- St John's Wort

qEEG Research

Biofeedback
Volume 34, Issue 3, pp. 114-120

Association for Applied Psychophysiology & Biofeedback
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SPECIAL ISSUE

The Assessment of Brain Wave Activity in Fibromyalgia Using Quantitative Electroencephalography Techniques

Mary Donaldson, MEd, and Stuart Donaldson, PhD

Myosymmetries, Calgary, Alberta

Keywords: fibromyalgia, QEEG, brain wave activity, central nervous system, chronic pain

Recent research into fibromyalgia has suggested dysfunction in the central nervous system (CNS) as a possible contributor to this chronic pain condition. If changes in the CNS are involved in fibromyalgia, then dysfunctional brain activity should be present. This article specifically focuses on the brain wave activity in a group of fibromyalgia sufferers. In this study, 40 fibromyalgia sufferers underwent quantitative electroencephalography (QEEG), and these data were analyzed for significant deviations as compared to nonfibromyalgia individuals. The results suggest that more research is needed to investigate the somewhat increased beta activity and decreased alpha activity in the eyes open condition.

Hudson & Pope, 1989; Yunus, Ahles, Aldag, Masi, 1991), psychosocial factors (A. S. Russell, 1995), and sleep disturbance (alpha intrusion; Moldofsky, 1993, 1995; Moldofsky & Lue, 1992; Modofsky, Scarisbrick, England, & Smythe, 1975).

More recently, attention has focused on dysfunctional activity in the central nervous system (CNS) as a possible source or cause for this dysfunction. Mense, Simons, and Russell (2001) suggested a neuroplasticity model as a probable source of the pain, implicating changes in the central pain pathways as causing the dysfunction. P. Flor-Henry (personal communication, March 31, 2006) has indicated that there is a significant change in brain wave activity that differentiates

Higher frontal than posterior alpha

Table 3. Eyes closed by frequency				
Site	Alpha Mean	Beta Mean	Delta Mean	Theta Mean
F1	.3372	.07475	−.5865	.08125
F2	.2842	.1228	−.4695	.02100
F7	.08125	.4708	−.5400	.04475
F8	.1785	.3107	−.4985	−.0270
F3	.1265	.1922	−.5275	.2133
FZ	.1957	−.1365	−.4776	.3275
F4	.1838	.05550	−.4803	.1710
T3	.05650	.2748	−.4738	−.0355
T4	.2172	.4013	−.6258	−.1533
C3	−.0608	.4452	−.4250	.1793
CZ	−.0667	.1375	−.3440	.3737
C4	.01375	.3572	−.4573	.1655
T5	−.1014	.4645	−.2853	.01175
T6	−.2240	.6373	−.2220	.1498
P3	−.1443	.5781	−.2740	.1405
PZ	−.1295	.3867	−.1995	.1483
P4	−.0600	.4748	−.2427	.00175
O1	−.3147	.6965	−.1112	.2207
O2	−.3717	.5612	−.0370	.3110

Elevated Midline Posterior Beta

Photic Study

J Clin Psychol. 2001 Jul;57(7):933-52.

Treatment of fibromyalgia incorporating EEG-Driven stimulation: a clinical outcomes study.

Mueller HH[1], Donaldson CC, Nelson DV, Layman M.
Author information

Abstract

Thirty patients from a private clinical practice who met the 1990 American College of Rheumatology criteria for fibromyalgia syndrome (FS) were followed prospectively through a brainwave-based intervention known as electroencephalograph (EEG)-driven stimulation or EDS. Patients were initially treated with EDS until they reported noticeable improvements in mental clarity, mood, and sleep. Self-reported pain, then, having changed from vaguely diffuse to more specifically localized, was treated with very modest amounts of physically oriented therapies. Pre- to posttreatment and extended follow-up comparisons of psychological and physical functioning indices, specific FS symptom ratings, and EEG activity revealed statistically significant improvements. EDS appeared to be the prime initiator of therapeutic efficacy. Future research is justified for controlled clinical trials and to better understand disease mechanisms.

Study Design

- N = 36
- SL 90
- Modified Fibromyalgia Impact Questionnaire
- Visual Analogue Scales
- One hour Sessions
- 3-5 Sessions Weekly

Protocol Used

EEG active treatment sites vary from patient to patient as do the number and length of sessions at each site. Generally, treatment sites are selected on the basis of where each patient demonstrates the highest amplitudes and *SDs* of evoked EEG in the low frequency bands (i.e., delta, theta, and alpha) on the initial mapping. The goals of therapy are to reduce the overall amplitude of evoked EEG in the delta, theta, and alpha wave bands to approximately the same level as the beta activity and to increase the variability of the dominant frequency from all sites where initial mapping shows excess slow wave activity (e.g., slow:fast ratios S:3:l). Treatment sessions are generally one hour in length and scheduled at least twice weekly, although more frequent sessions (4-5 per week) are encouraged early in treatment.

To reduce delta and theta slow wave activity

Kayram et al

Appl Psychophysiol Biofeedback
DOI 10.1007/s10484-010-9135-9

Neurofeedback Intervention in Fibromyalgia Syndrome; a Randomized, Controlled, Rater Blind Clinical Trial

Sadi Kayıran · Erbil Dursun · Nigar Dursun · Numan Ermutlu · Sacit Karamürsel

Abstract We designed a randomized, rater blind study to assess the efficacy of EEG Biofeedback (Neurofeedback-NFB) in patients with fibromyalgia syndrome (FMS). Eighteen patients received twenty sessions of NFB-sensory motor rhythm (SMR) treatment (NFB group) during 4 weeks, and eighteen patients were given 10 mg per day escitalopram treatment (control group) for 8 weeks. Visual of EEG rhythms ($p > 0.05$ for all). However, theta/SMR ratio showed a significant decrease at 4th week compared to baseline in the NFB group ($p < 0.05$). These data support the efficacy of NFB as a treatment for pain, psychological symptoms and impaired quality of life associated with fibromyalgia.

Study Design

- Random Assignment
- 18 received NFB 20 sessions SMR- C4
- 18 received Escitalopram
- Visual Analogue Scales for pain
- Hamilton & Beck Inventories
- Fibromyalgia Impact Questionnaire
- Short Formd 36

Outcome

- Both groups showed improvement
- NFB group showed greatest improvement on all measures
- Efficacy felt during 2nd week and reached maximum at 4th week out of 24 weeks total.

Theta/SMR Ratios

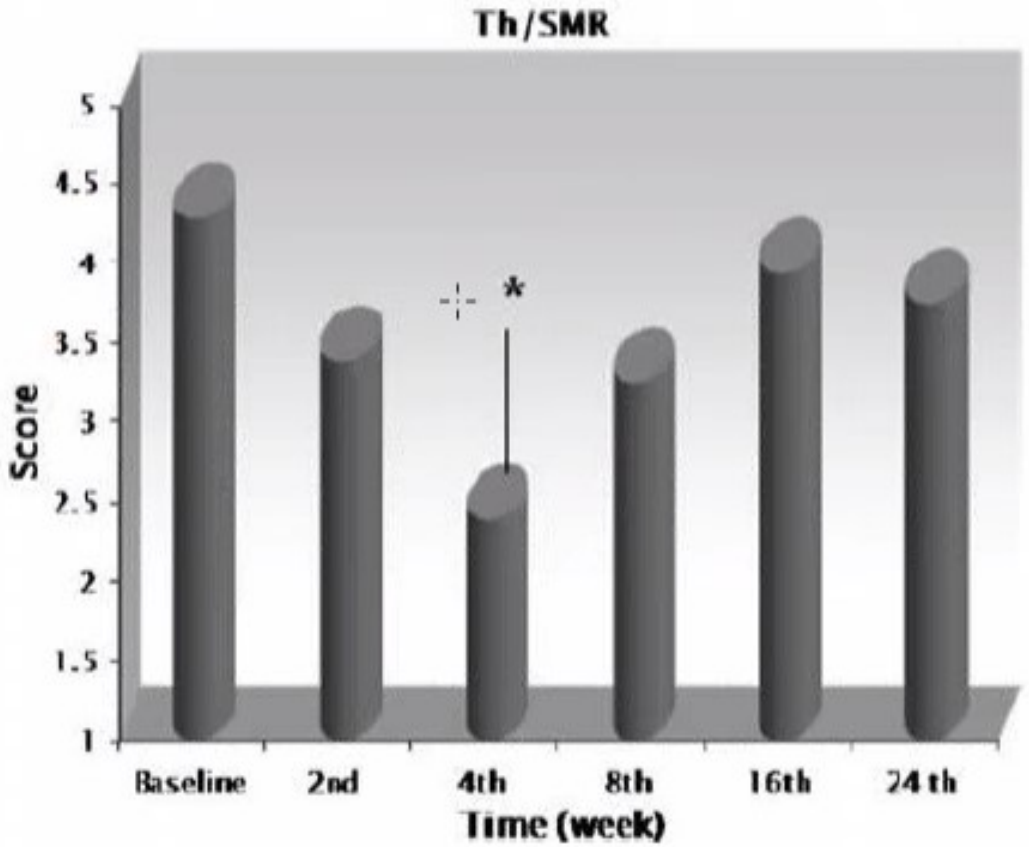


Fig. 3 Theta/SMR ratios in the NFB group (* Wilcoxon sign test: baseline-4th week: $p < 0.05$)

Significantly Reduced Anxiety & Depression

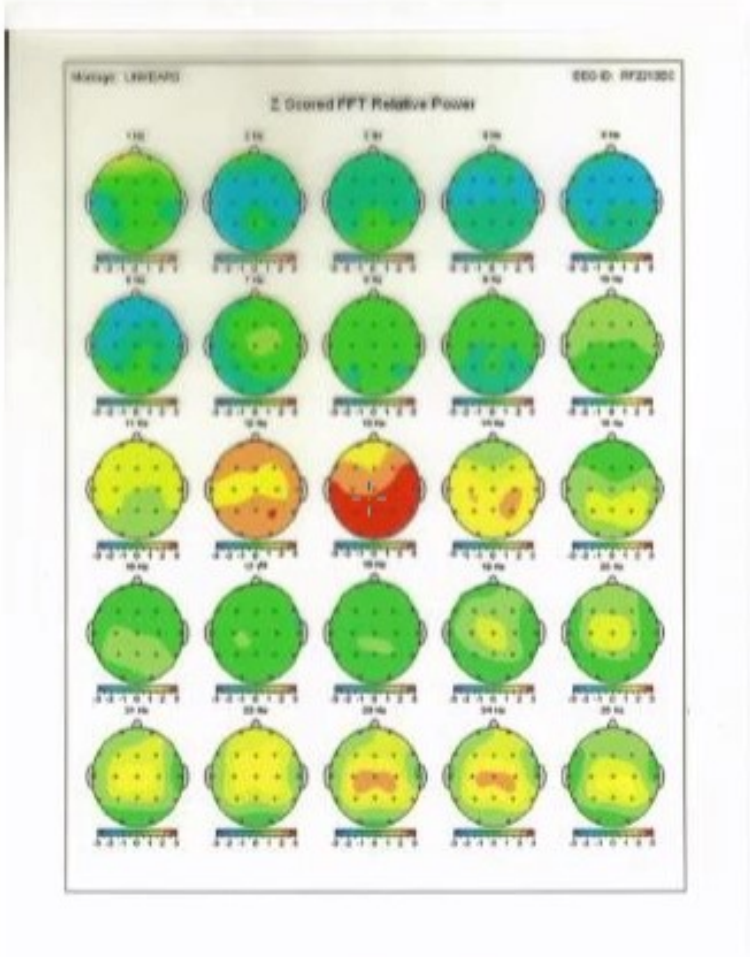
Table 2 HDS and BDS scores in the NFB and control groups

Depression	HDS					BDS				
	NFB		Control		Mann–Whitney U	NFB		Control		Mann–Whitney U
	Mean	SE	Mean	SE	p	Mean	SE	Mean	SE	p
Baseline	16.94	1.349	20.83	0.733	0.003	21.50	2.639	26.00	2.154	0.152
2nd week	9.89	1.022	15.89	0.953	***0.000***	7.11	1.143	17.50	2.150	***0.000***
4th week	4.78	0.827	11.94	0.923	***0.000***	3.22	0.698	9.78	0.899	***0.000***
8th week	4.83	0.628	8.22	0.765	***0.004***	3.28	0.565	6.33	0.464	***0.000***
16th week	5.39	0.578	11.78	0.835	***0.000***	4.17	0.781	10.56	0.584	***0.000***
24th week	6.33	0.583	13.39	0.776	***0.000***	4.72	0.881	12.33	0.498	***0.000***
Friedman	$p < 0.001$		$p < 0.001$			$p < 0.001$		$p < 0.001$		

Case Study Profile

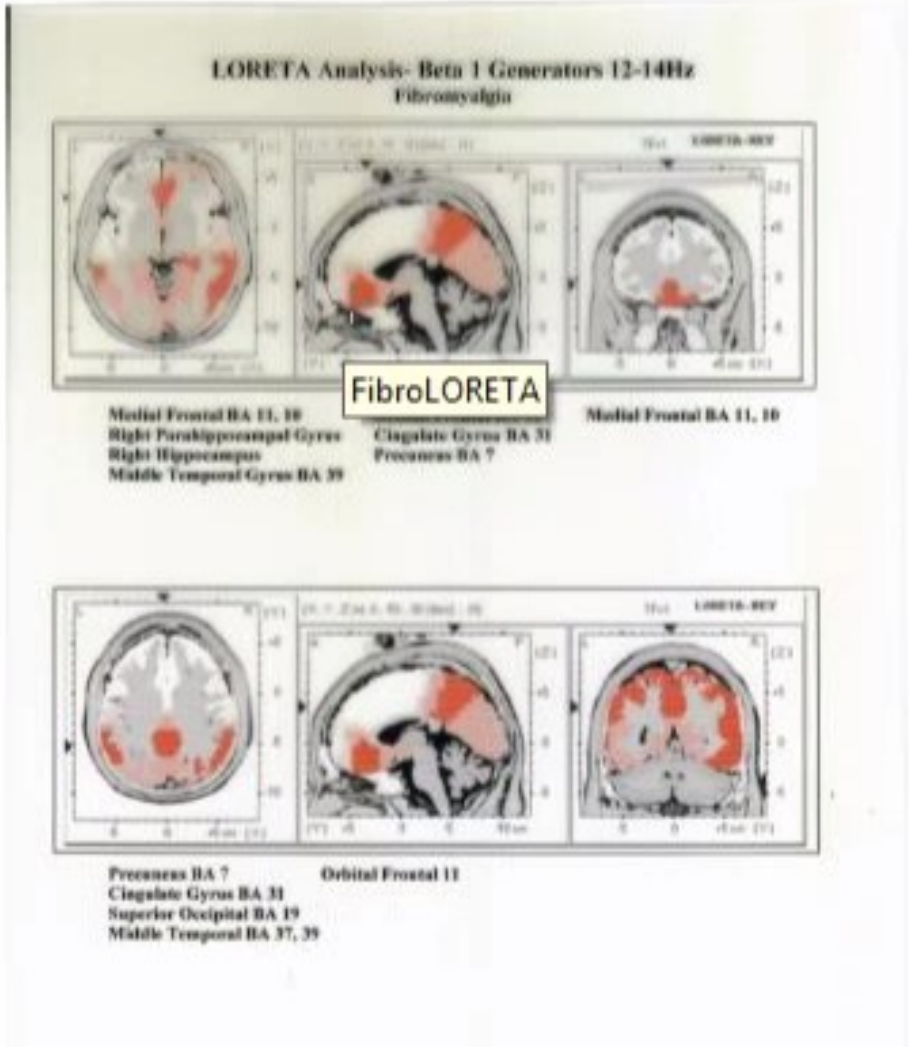
- Mid 30s
- Gulf War Vet
- Symptomatic Since War
- Opiod Patch
- Zoloft

Typical qEEG Profile



Elevated Posterior
Low Beta
Elevated Posterior
Beta 20-30Hz

Symptom Changes
LORETA Locations

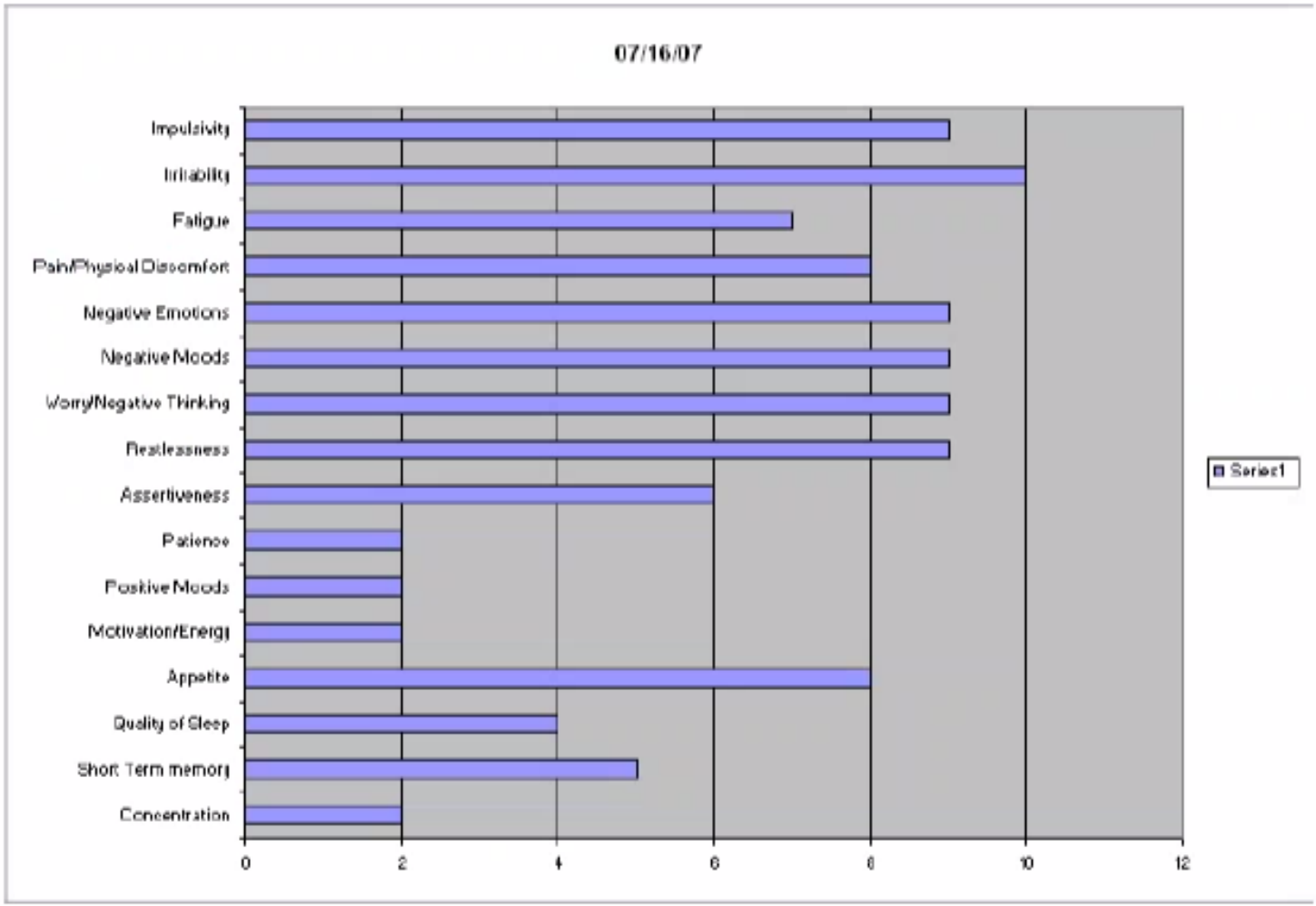


Protocol

- Enhance Alpha 9-11Hz
- Inhibit Beta 15-30 Hz
- Photic Stim 10Hz
- Eyes Closed
- Pz Location

Negative Symptoms Hi

First Session



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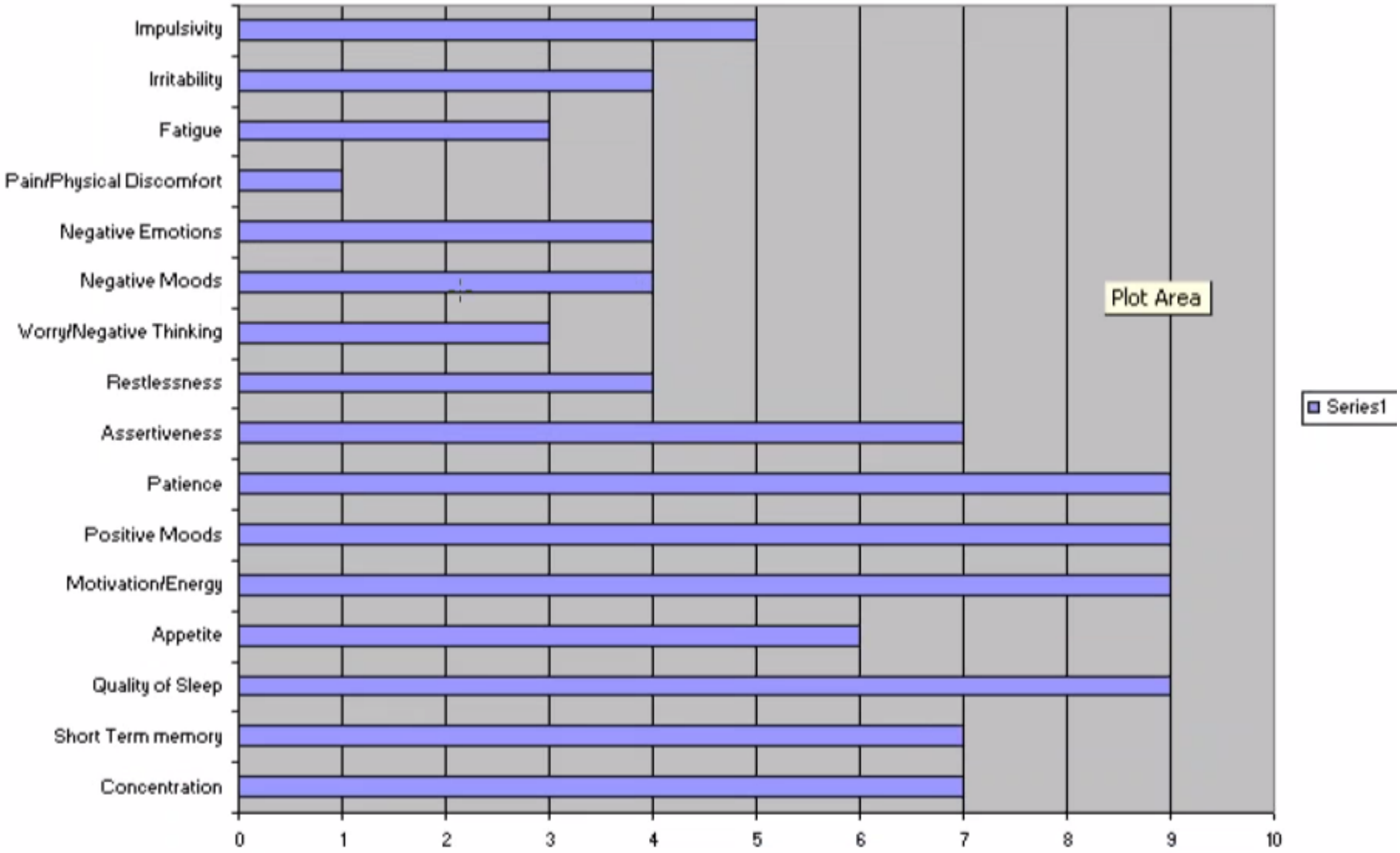
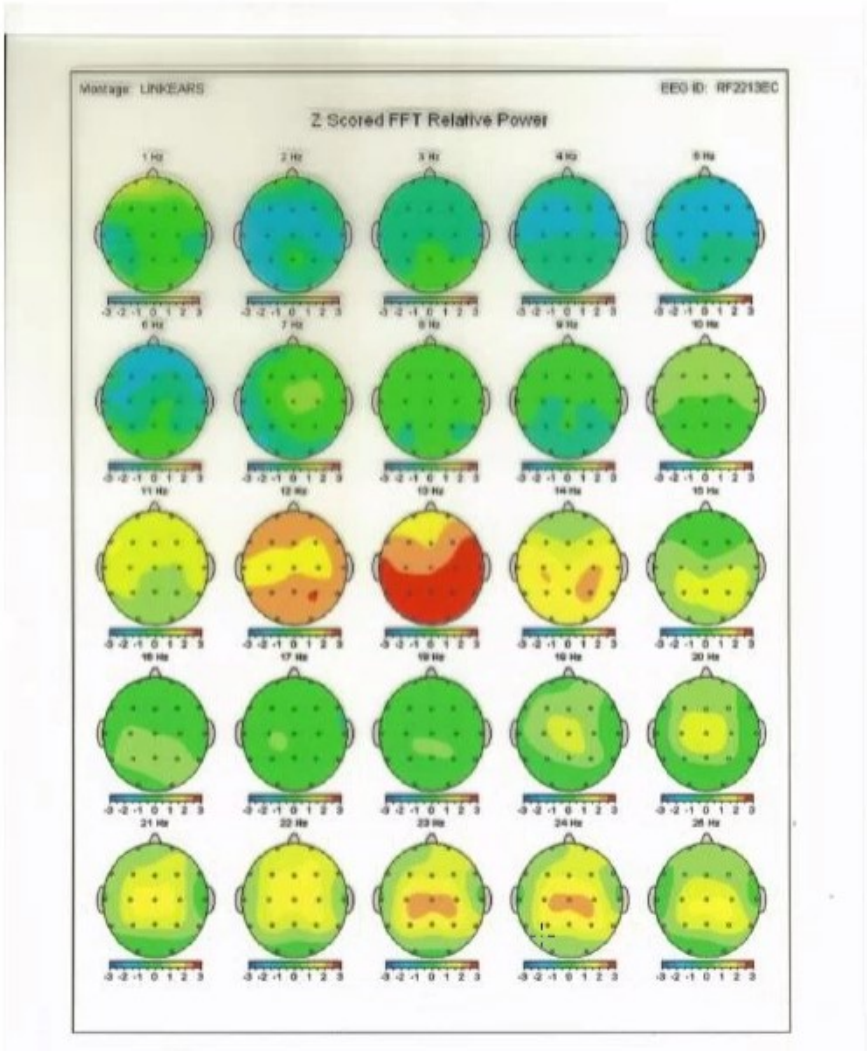

Impulsivity
Irritability
Fatigue
Pain/Physical Discomfort
Negative Emotions
Negative Moods
Worry/Negative Thinking
Restlessness
Assertiveness
Patience
Positive Moods
Motivation/Energy
Appetite
Quality of Sleep
Short Term memory
Concentration
0
1
2
3
4
5
6
7
8
9
10
Plot Area
Series1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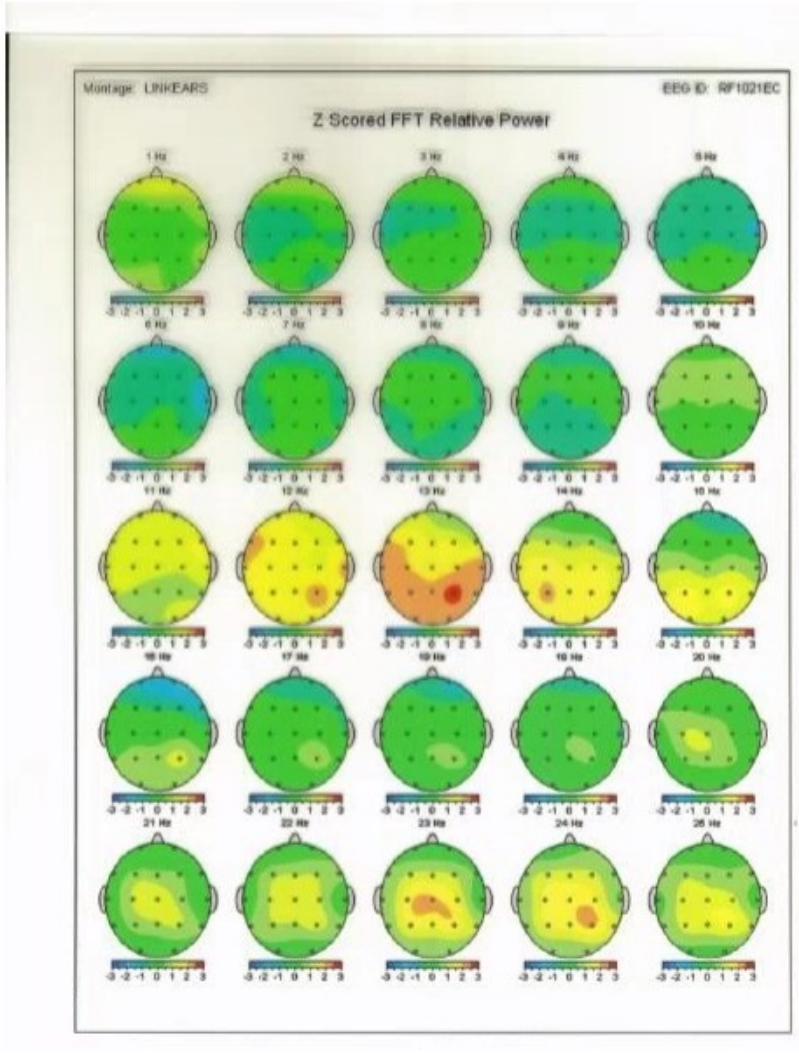
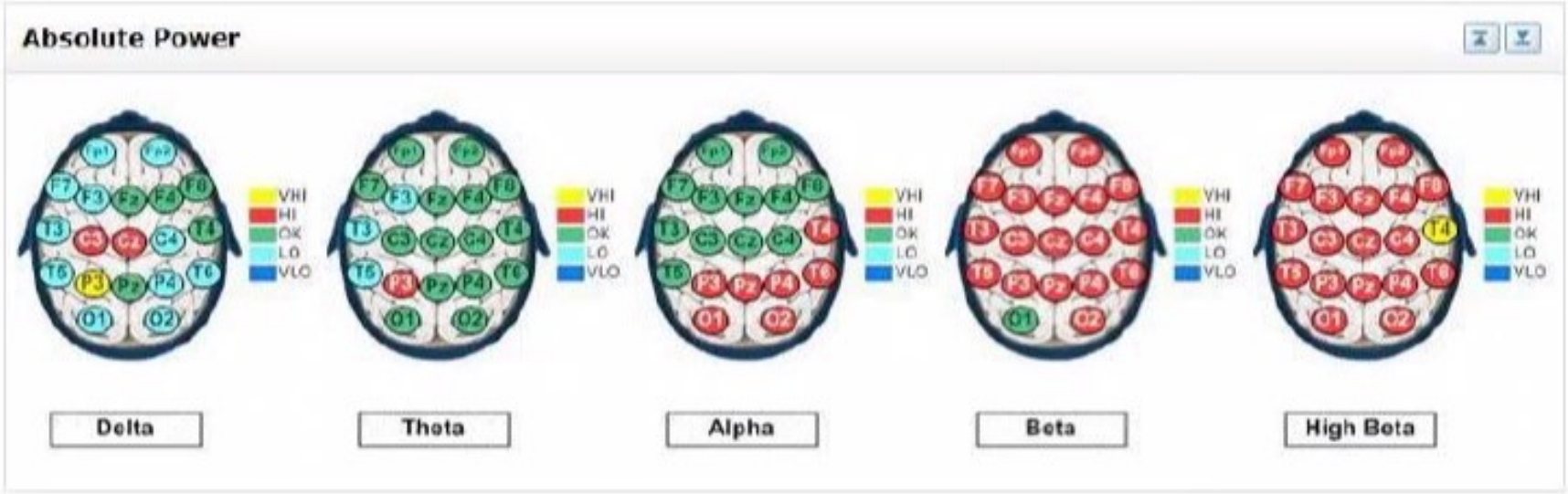
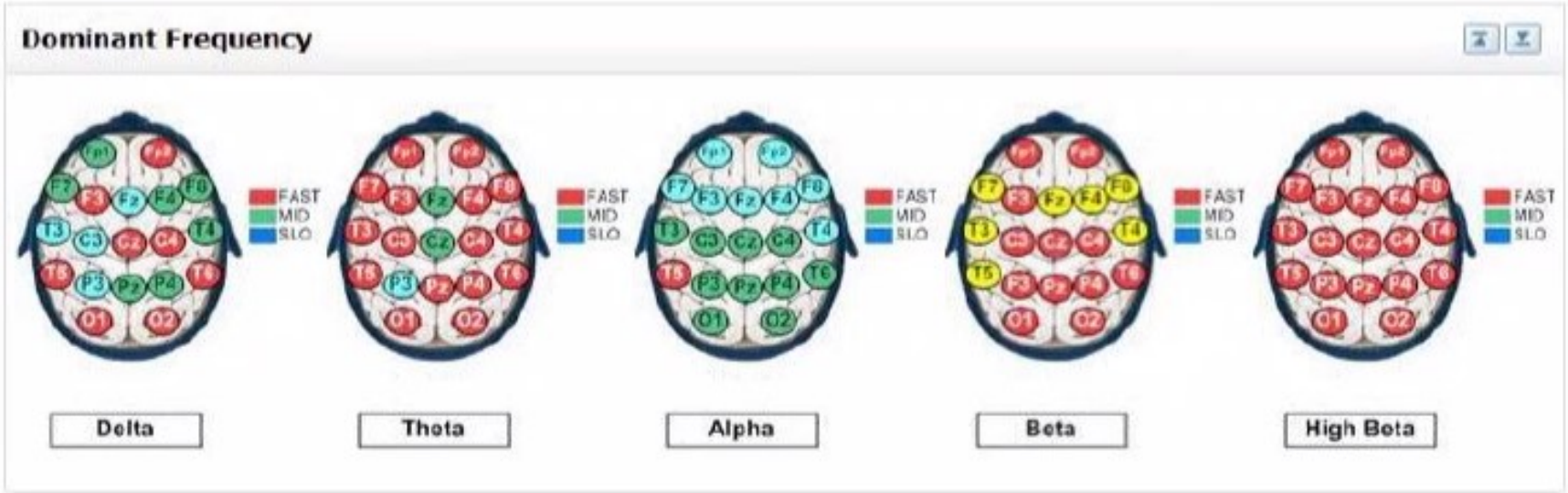
EEG ID: RF2213EC
Z Scored FFT Relative Power

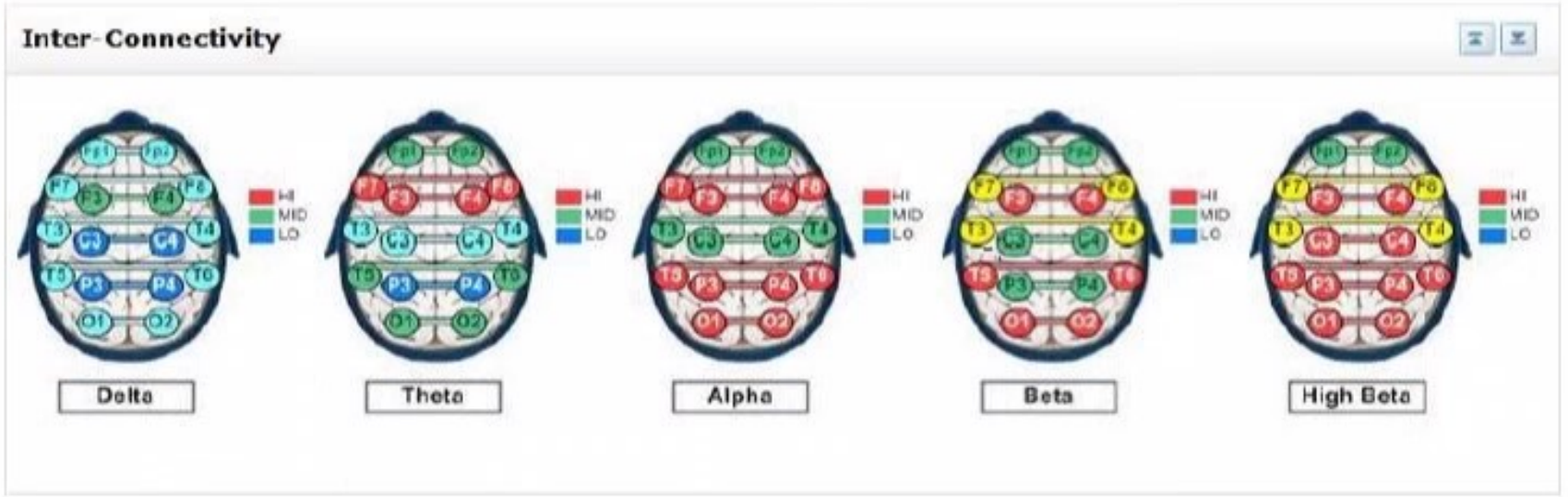

Montage: LINKEARS
EEG ID: RF1021EC
Z Scored FFT Relative Power

Fibromyalgia Pain

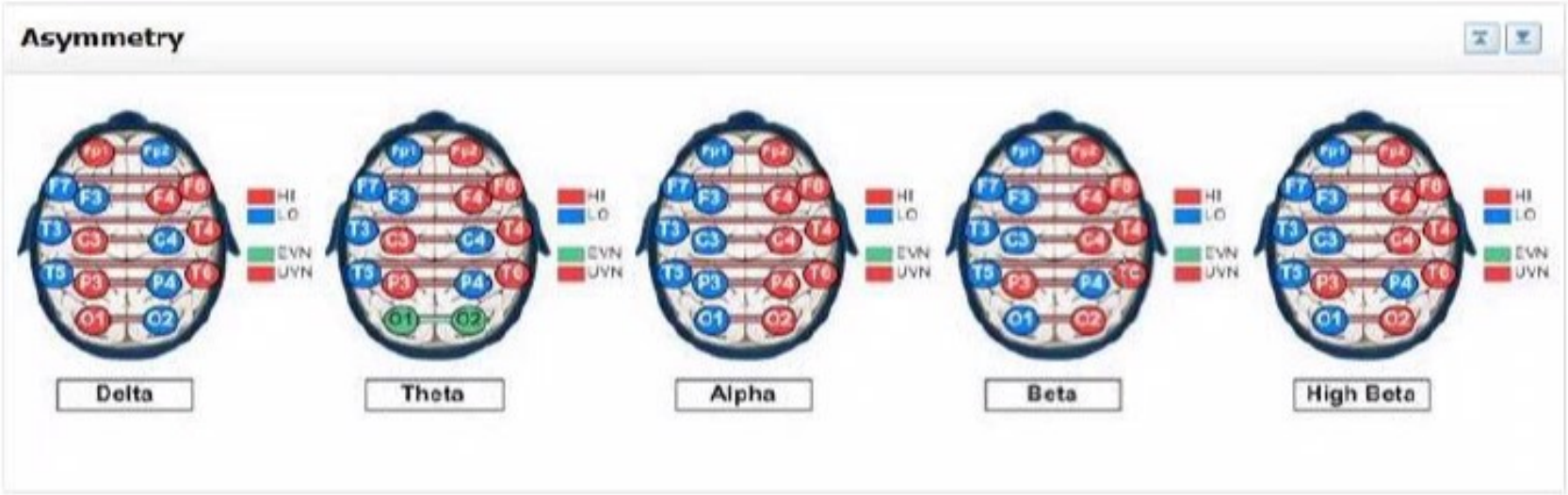




Coherence


Inter-Connectivity
HI
MID
LO
Delta
Theta
Alpha
Beta
High Beta

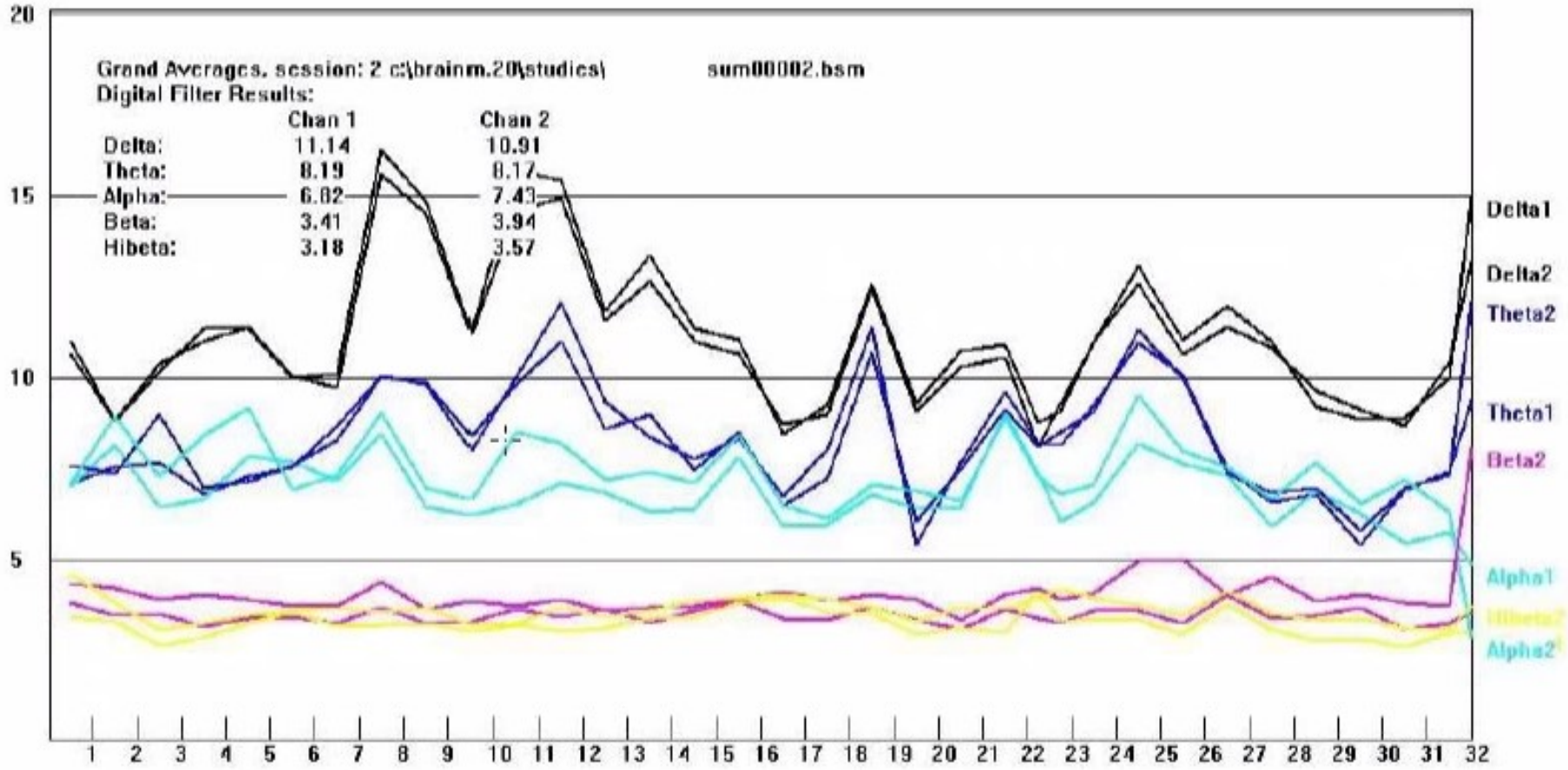
Beta Asymmetry



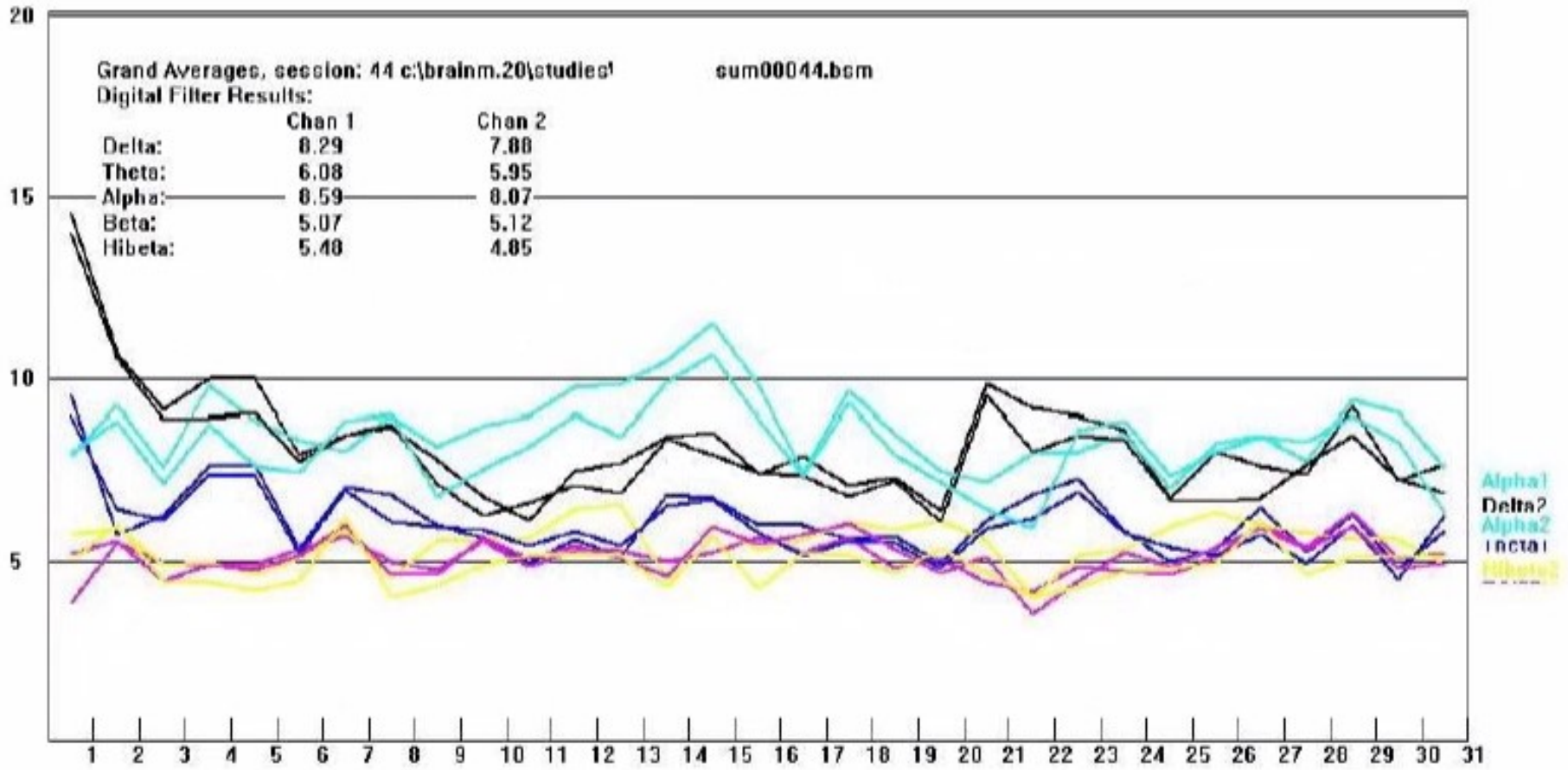
Protocol Recommended

Protocol #	Left Protocol	Right Protocol	Sites	Entrainment Frequency	Entrainment Color
20	9-11d 15-20u	15-30d 9-11u	C3/C4	14hz	Blue
20	9-11d 15-20u	15-30d 9-11u	Fp1/FP2	14hz	Blue

Early Training Sessions



Later Training Sessions



Tinnitus & NFB

Richard Soutar, Ph.D. BCN

Incidence of 15% In Population

- The neurophysiological mechanisms underlying tinnitus perception are not well understood.
- Few group studies have been conducted comparing neuronal activity between individuals with and without tinnitus.

Features of Tinnitus

- A Tone
- A Hissing Noise
- A Roaring Noise
- Combinations of the above
- Continuous In Nature
- Associated With Measurable Hearing Loss
- Most pronounced in the auditory network contralateral to the affected ear.

Mechanical Problems

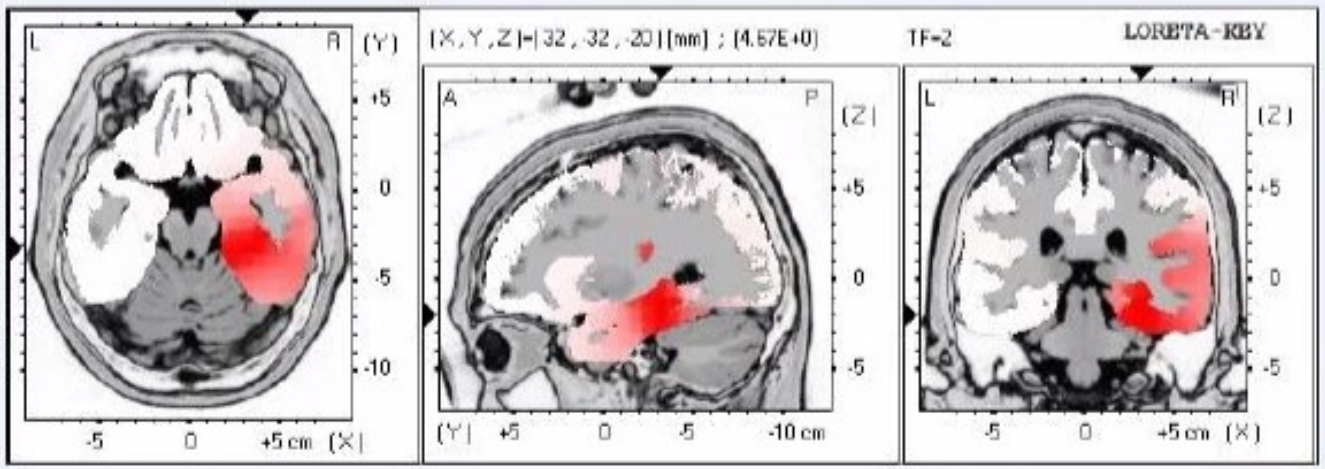
The generation of tinnitus, in most cases, can be linked to damage to the auditory system.

Usually to receptors of the inner ear.

Even in cases where an impairment cannot be assessed audiometrically , there is likely the presence of a deafferentation in the system since certain areas of the brain are now deprived from their normal input.

Disruptions in Processing

- Neurons in the deprived regions of the auditory cortex change both their receptive field and their spontaneous activity.
- Changes in loudness have been correlated with changes in hippocampal activity.



(X= 32 , Y= -32 , Z= -20)
1st Best Match (d= 3 mm)
Brodmann area 36
Parahippocampal Gyrus
Limbic Lobe

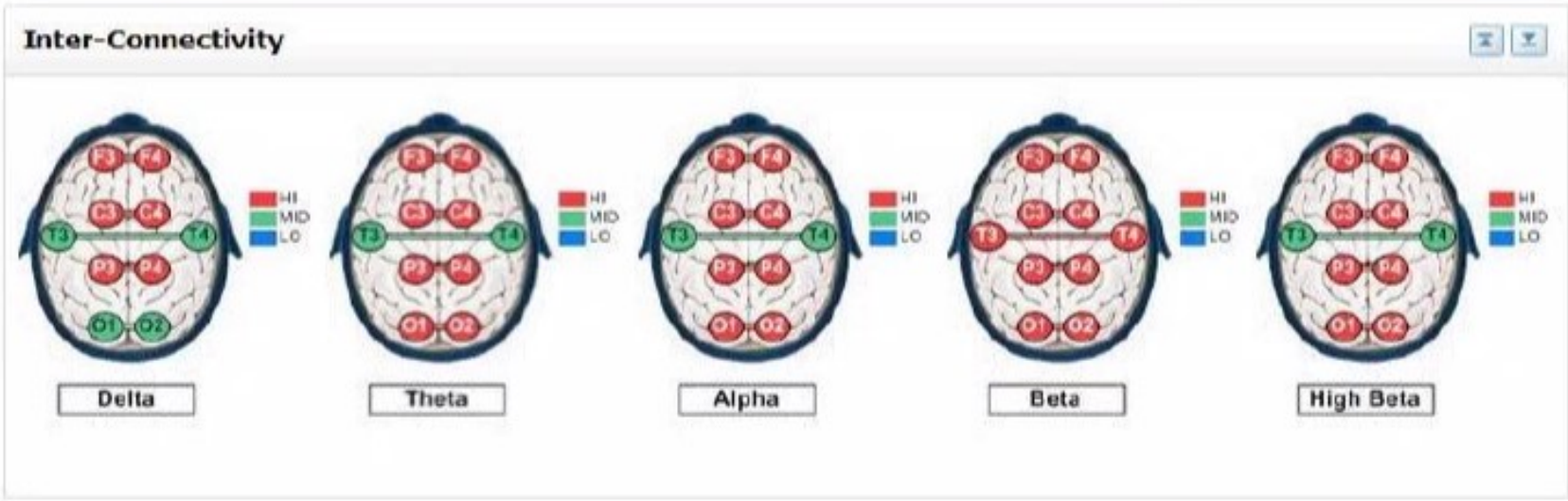
Case 2

Electrophysiological Mechanisms

- Various sources of evidence indicate that deprivation of primary inputs results in the functioning of the system in a manner that is dominated by slow wave activity such as delta and theta.
- This condition likely leads to a hyperpolarisation of thalamocortical cells that activates sodium and potassium currents.
- This activity gradually depolarzes the cell.
- This depolarisation in turn triggers a calcium-mediated low-threshold spike burst.
- The frequency of this hyperpolarisation–spike-burst cycle is approximately in the delta to theta frequency range.

Impact On Other Electrophysiological Dimensions

Coherent slow-wave oscillations have also been reported on a cortical level .



Magnitude Distortions

Increases in delta are often associated with reduced alpha and even beta.

It is difficult to determine is the alpha and beta patterns are a consequence of delta.

EEG Localization Of Dysregulation

Persistant contralateral Gamma increases in frequency related to increases in perceived volume

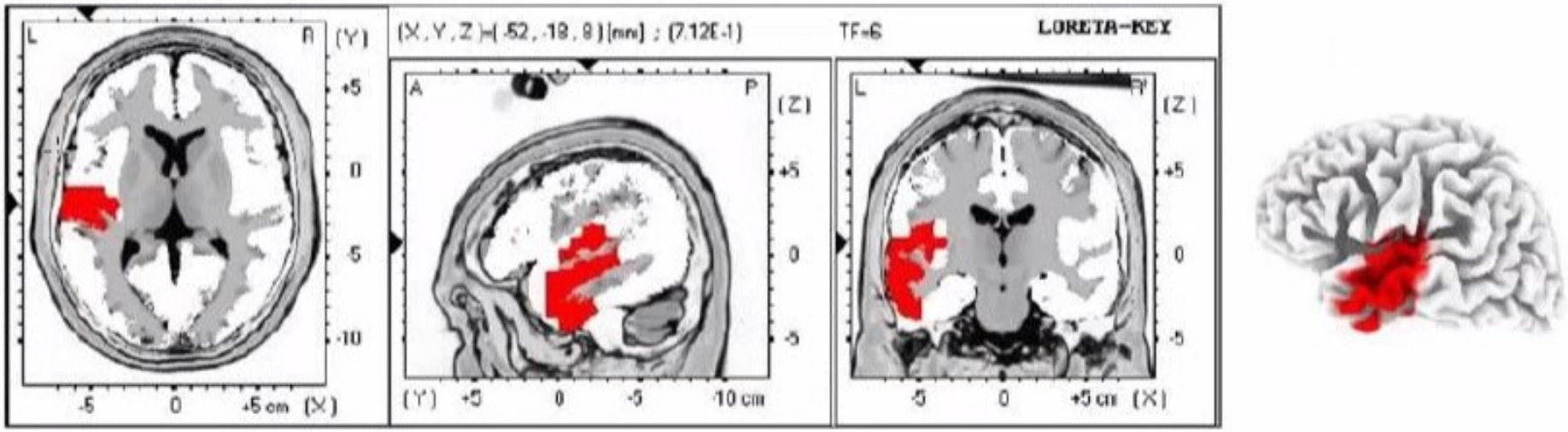


Figure 1. Tinnitus Loudness Dependent Gamma Oscillations in the Contralateral Auditory Cortex. Significant results for current source density (CSD) analysis in the contralateral auditory cortex for gamma band frequencies (30–45 Hz). Relative LORETA current source densities in the gamma band correlate positively with subjective Visual Analogue Scale loudness scores (max $r = 0.73$, $p < 0.05$). All t-statistics displayed in red are positive (the louder the tinnitus is perceived, the higher the gamma CSD). Displayed sections are the axial (left), sagittal (middle), and coronal (right) sections. The image shows significant results only.

doi:10.1371/journal.pone.0007396.g001

Frontal areas may also be involved

Positron emission tomography studies in particular have pointed to additional brain areas involved in attentional and emotional regulation that participate in Tinnitus.

Possible Tinnitus Network

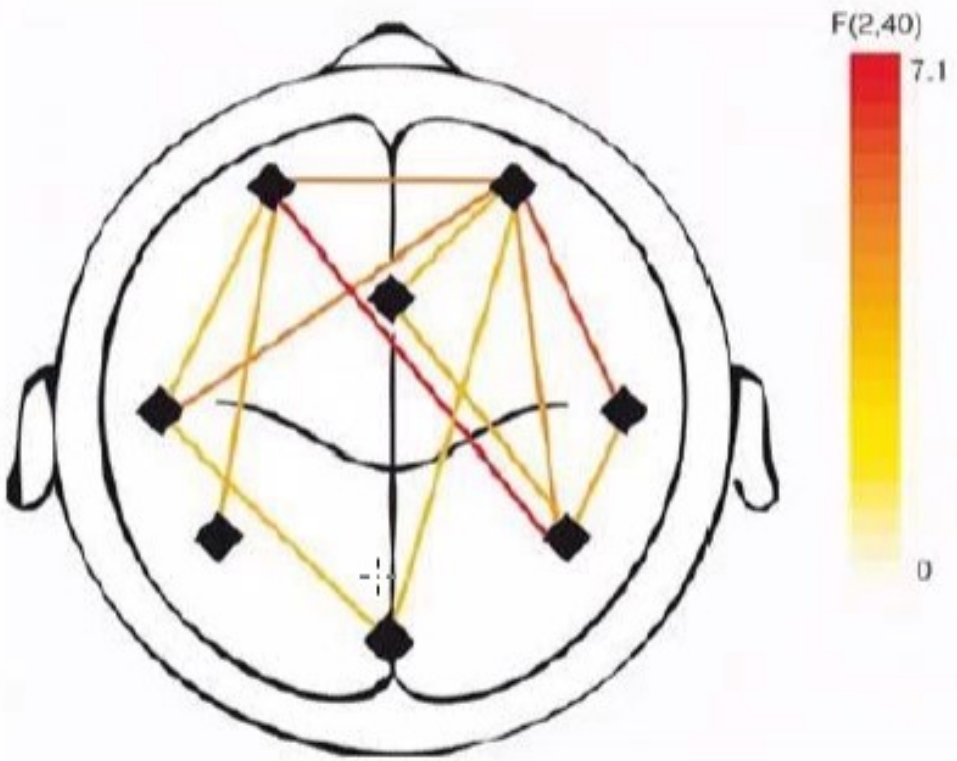


Figure 1. Long-range connectivities with a significant interaction effect *group x condition*. The data are presented in top view showing frontal, temporal and parietal sources in both hemispheres as well as one source at the anterior cingulate cortex and one posterior source. Line colours represent the strength of the interaction.
doi:10.1371/journal.pone.0003720.g001

Elevated delta and low alpha

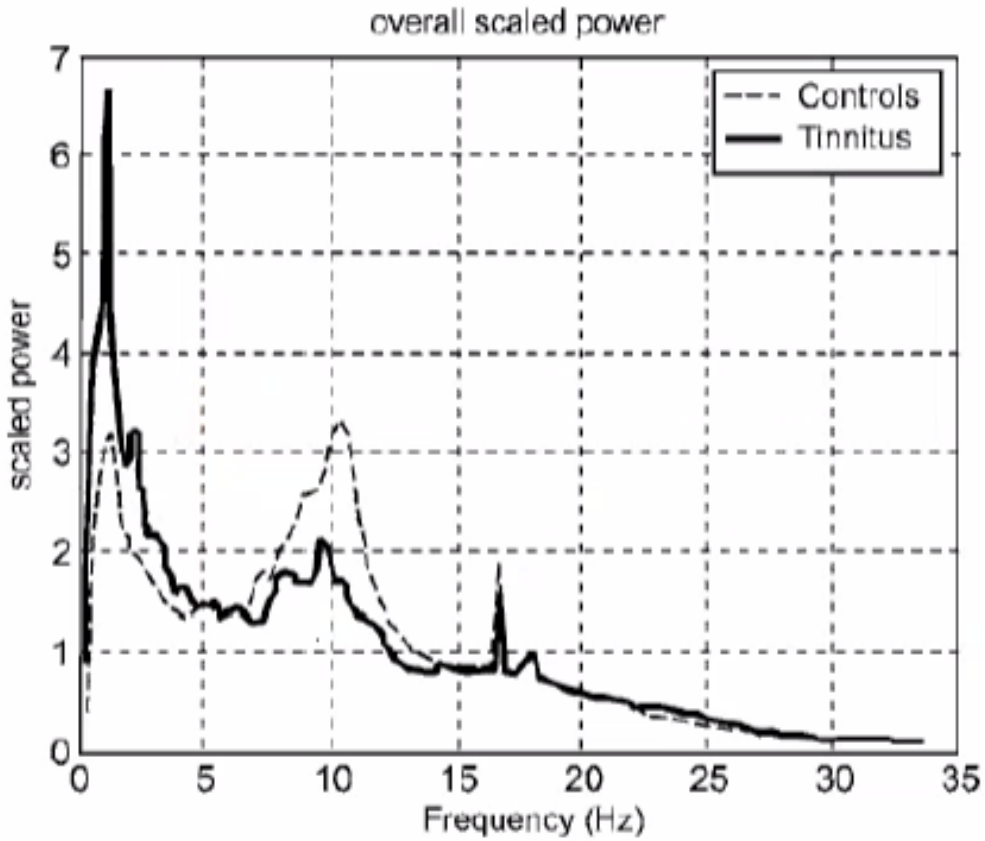


Figure 1. Power Spectra Averaged over All Sensors Show a Reduced Alpha Peak in Participants with Tinnitus and an Enhancement for Delta

The sharp peak centred at 16 2/3 Hz represents technical noise resulting from the 1-km-distant railway system.

DOI: 10.1371/journal.pmed.0020153.g001

Greatest Magnitude Difference is in the alpha band.

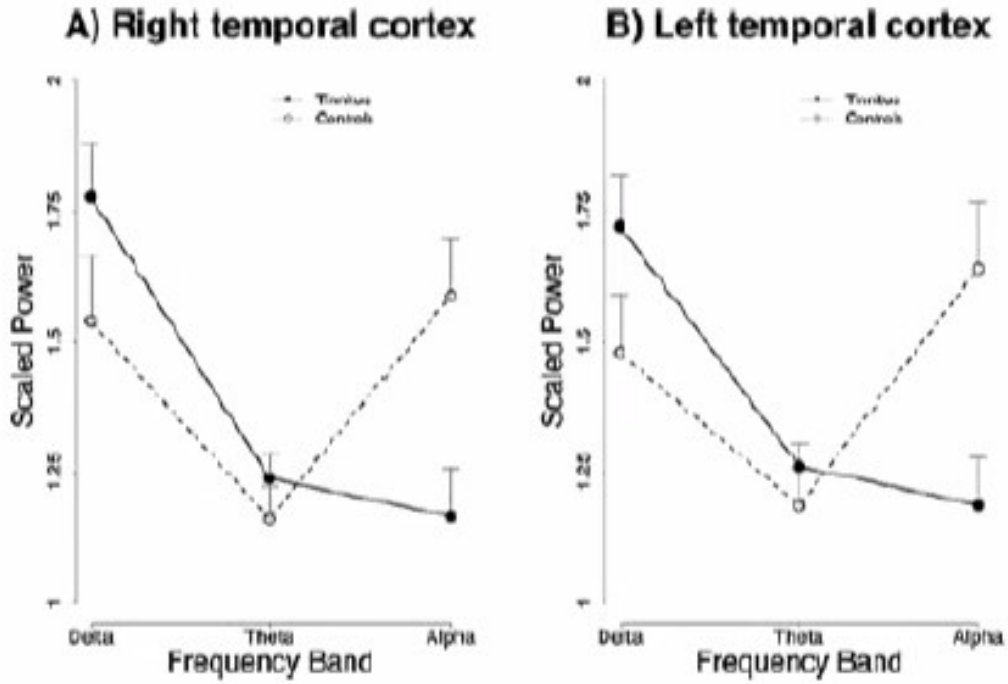


Figure 3. Display of the Group × Frequency Band Interaction Effects Averaged over Temporal Sources

Effects for right (A) and left (B) temporal cortex, where the strongest enhancements of alpha and reductions of were found.

DOI: 10.1371/journal.pmed.0020153.g003

Further Confirmation Of Affected Locations

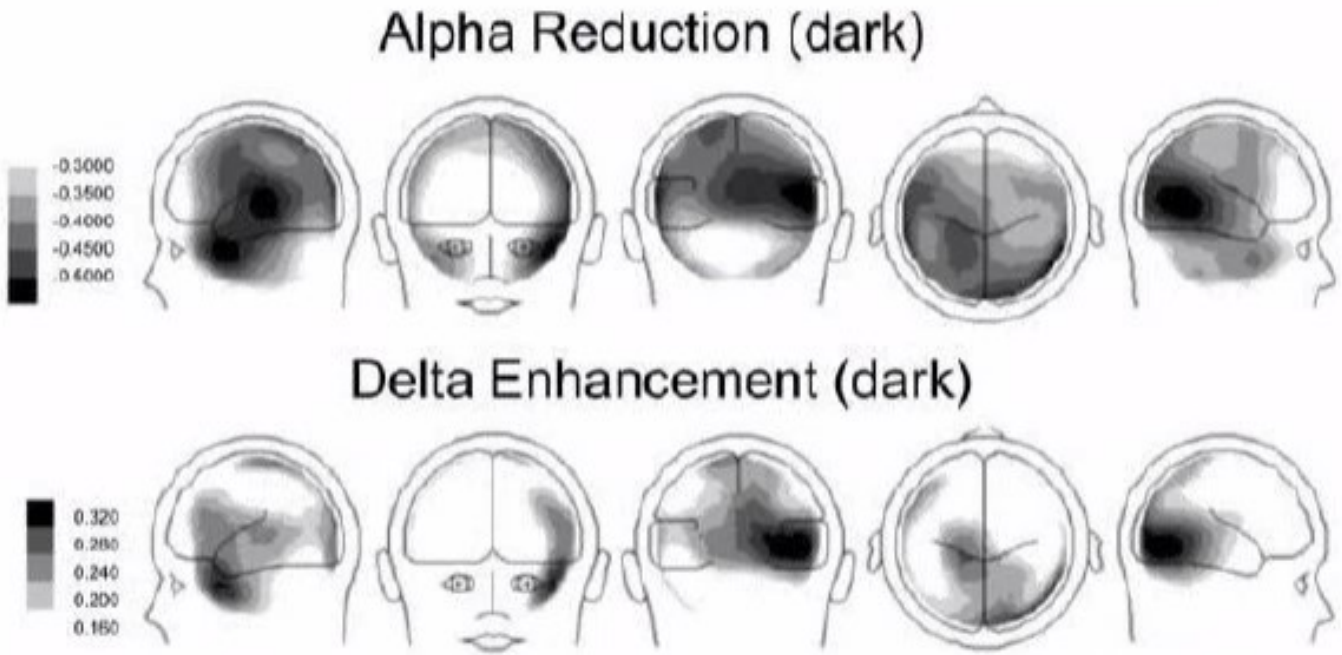
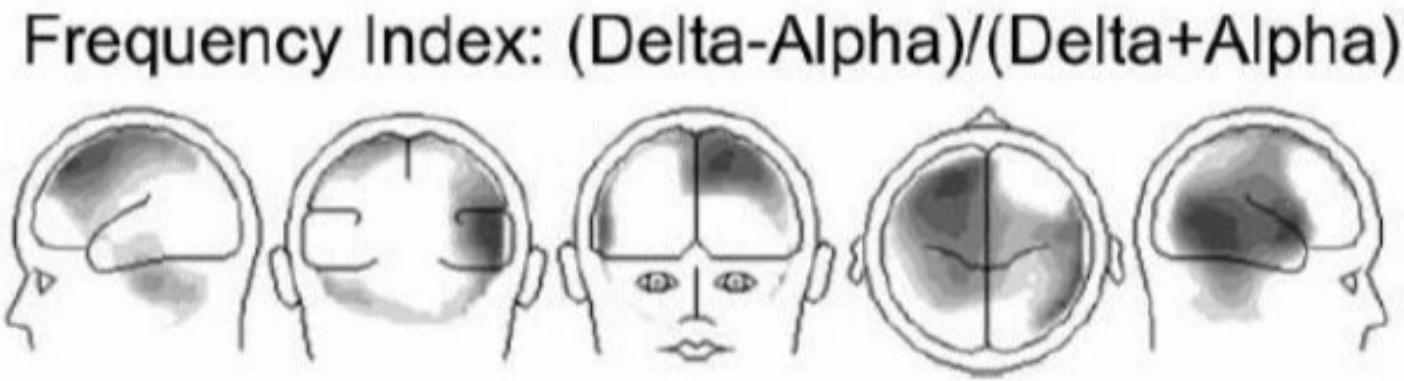


Figure 2. Difference Maps between Participants with Tinnitus and Controls for Alpha and Delta

Correlation With Distress

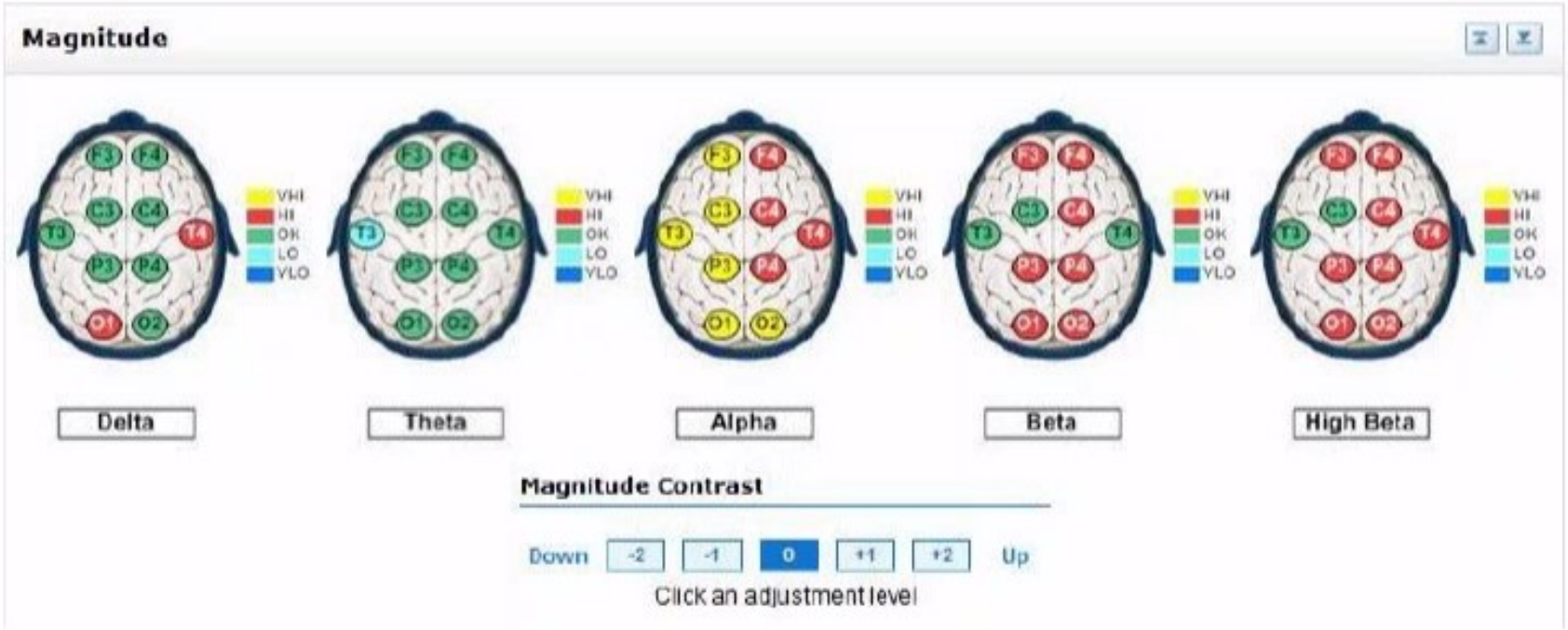


Correlation Map between Alpha, Delta, and Tinnitus-Related Distress

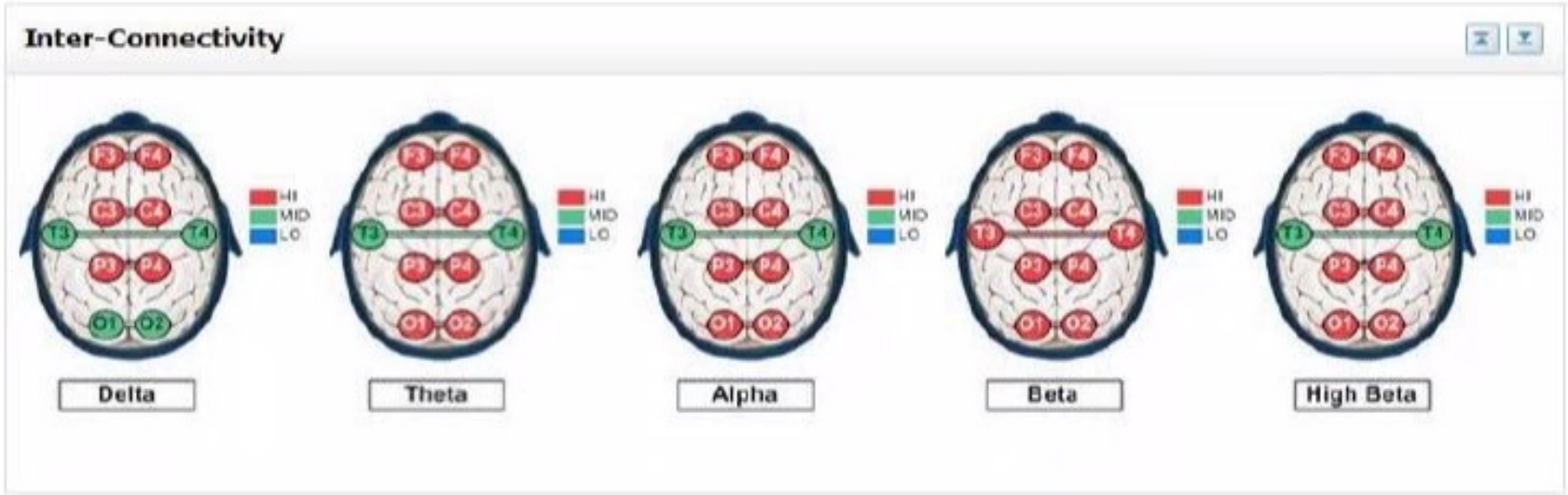
Right Temporal and Left Frontal- integration of sensory and emotional streams.

Left Side Tinnitus

Case 1

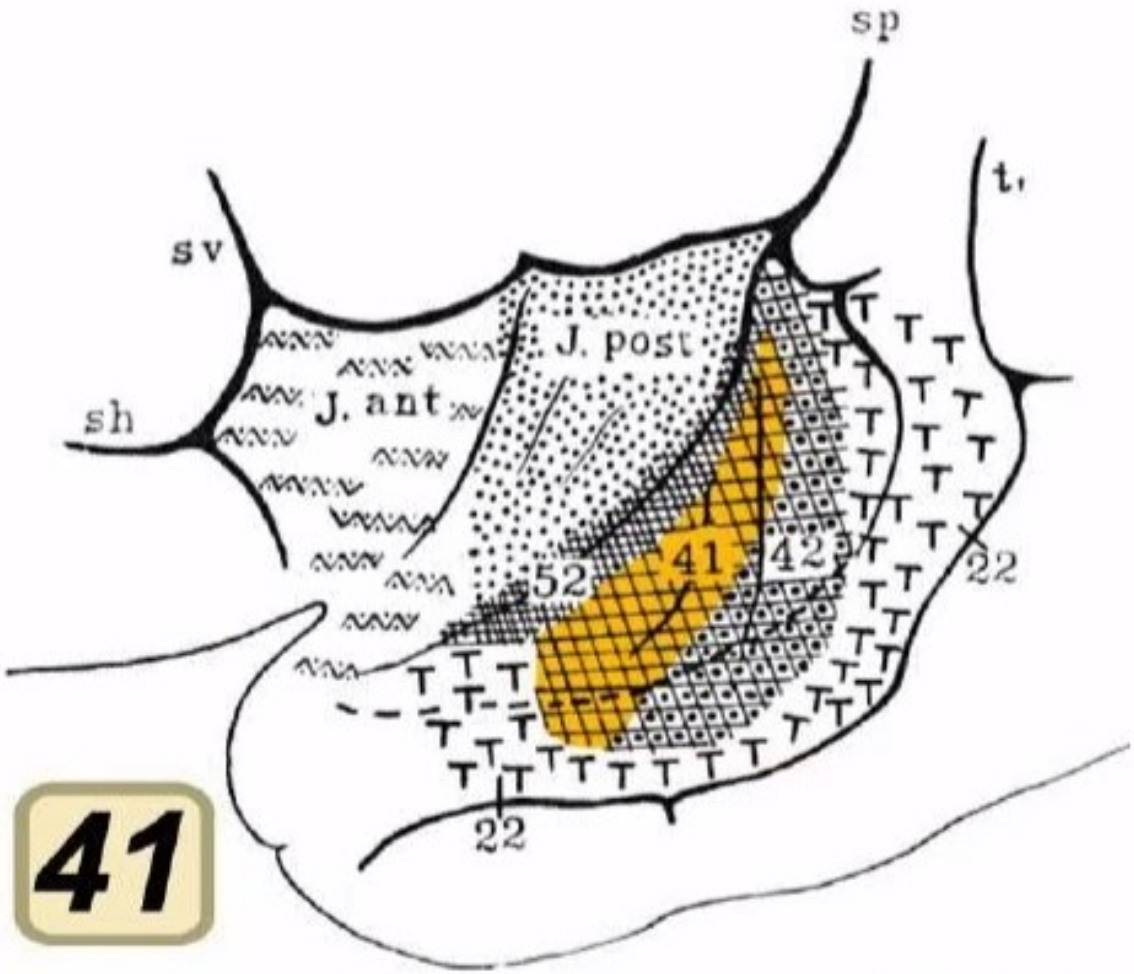


Connectivity



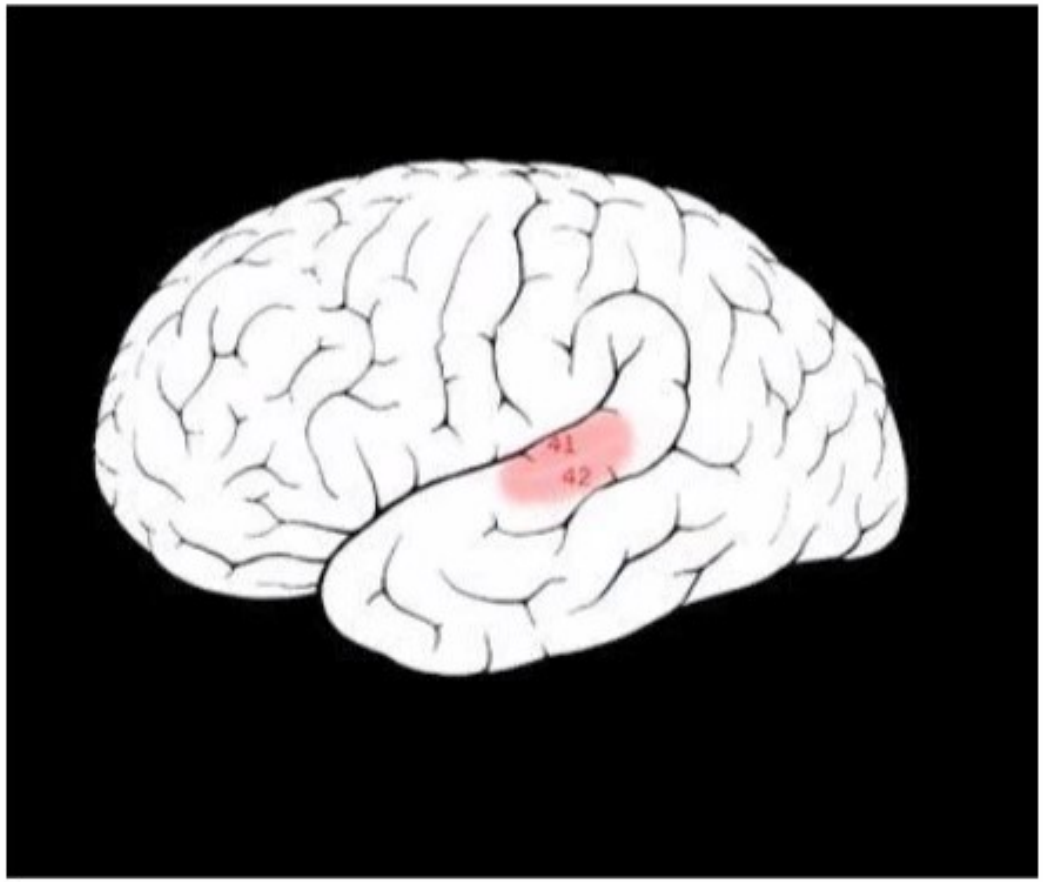
Auditory Cortex

Upper sides of the temporal lobes – in humans on the superior temporal plane, within the lateral fissure and comprising parts of Heschl's gyrus and the superior temporal gyrus, including planum polare and planum temporale (roughly Brodmann areas 41, 42, and partially 22).



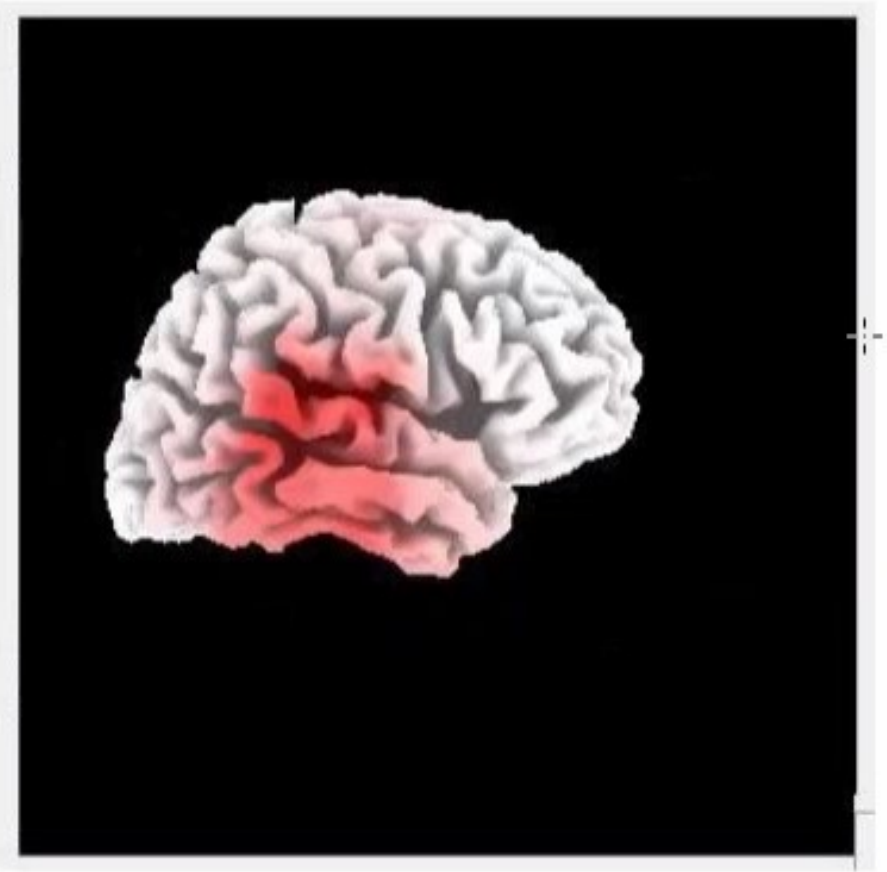
41

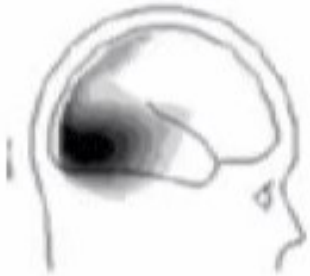
Auditory Cortex
Brodmann Location



Delta BA 41 Surf LORETA

Case 2

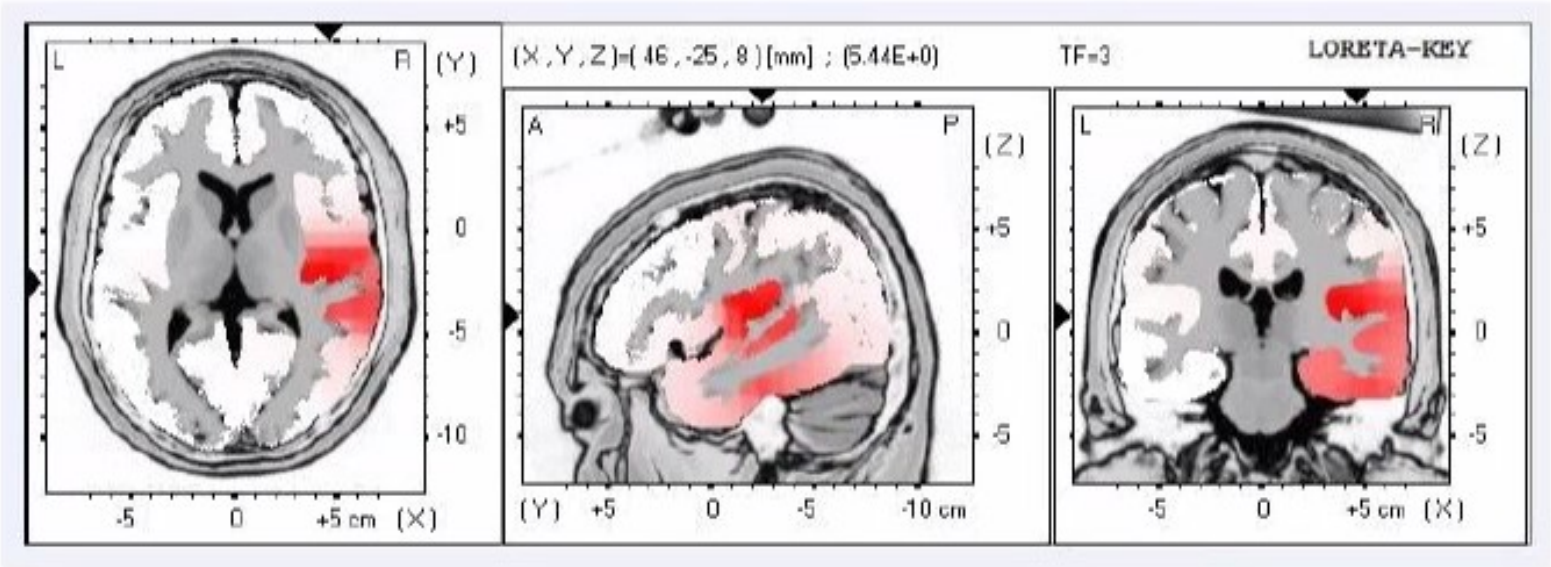




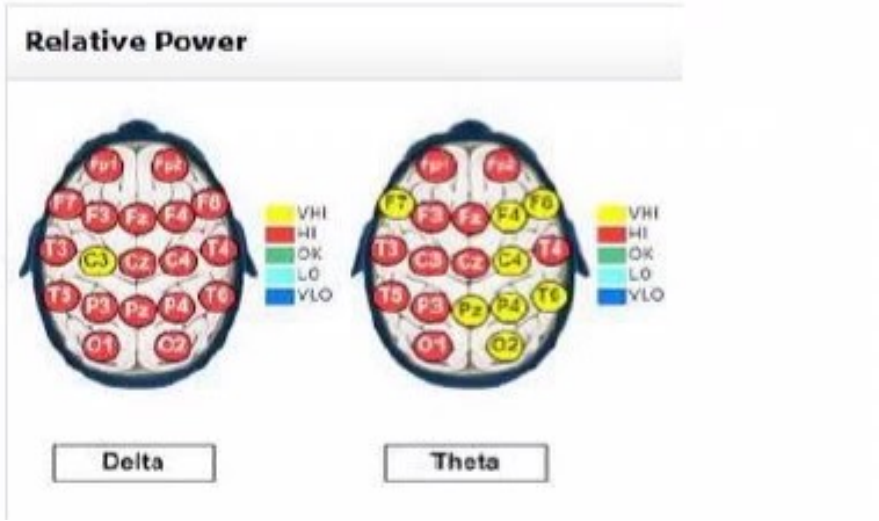
(X= 46 , Y= -25 , Z= 8)
1st Best Match (d= 3 mm)
Brodmann area 41
Superior Temporal Gyrus
Temporal Lobe

LORETA Delta BA 41 3Hz

Case 2 Left Side Tinnitus



Tinnitus Case 2 Map



Statistically Derived Protocol

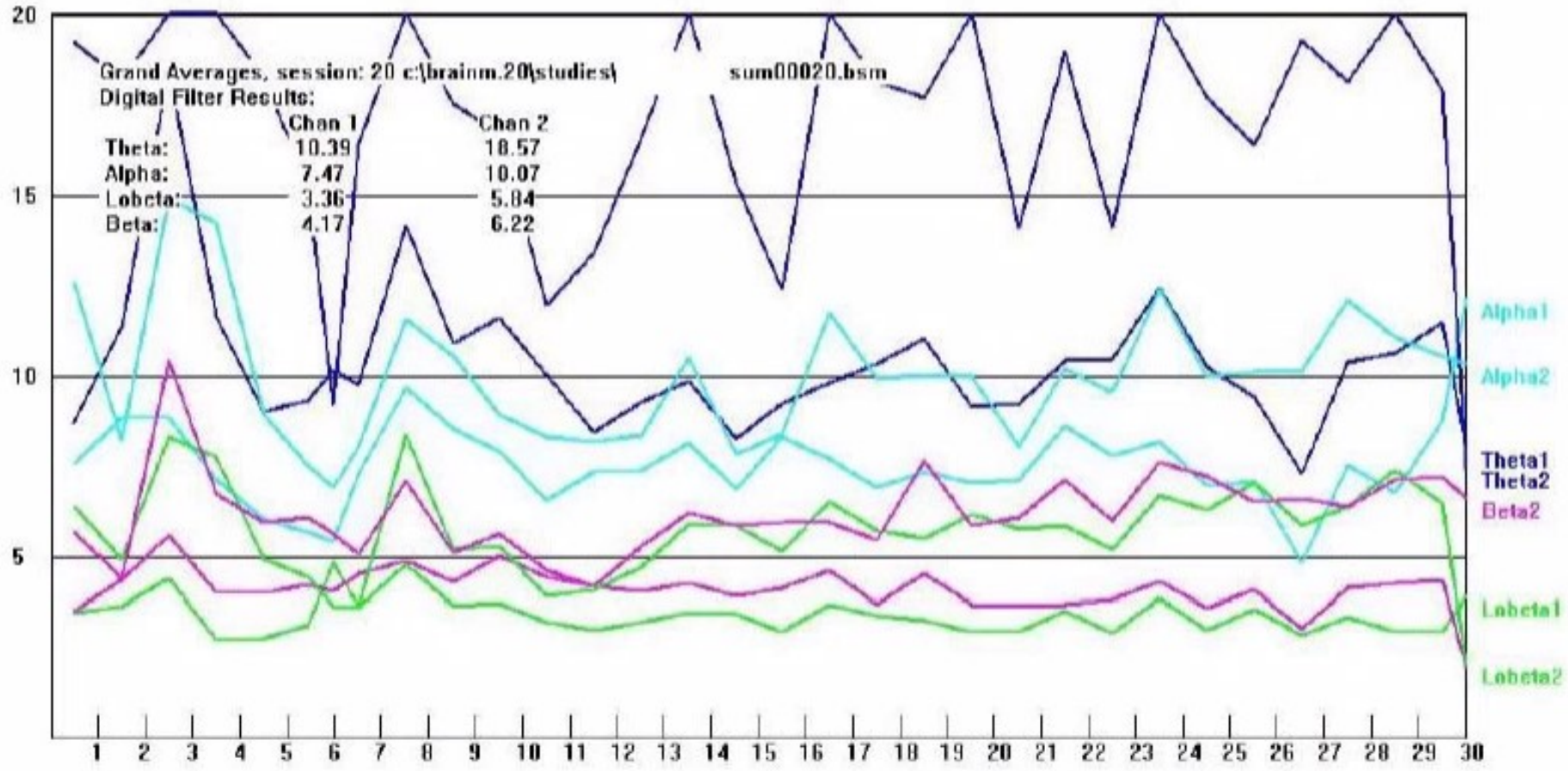
Protocols from Eyes Open Brain Map

Two Channel Protocols - Based on Eyes Open Map

Protocol #	Left Protocol	Right Protocol	Sites	Entrainment Frequency	Entrainment Color
4	2-7d 15-18u	2-7d 13-15u	T3/T4	18Hz	Yellow
3	2-12d 15-20u	2-12d 13-15u	T5/T6	18Hz	Yellow

Note that statistical network analysis locates the key training areas as the same areas in the Brodmann analysis.

High Symptom Session



Low Symptom Session