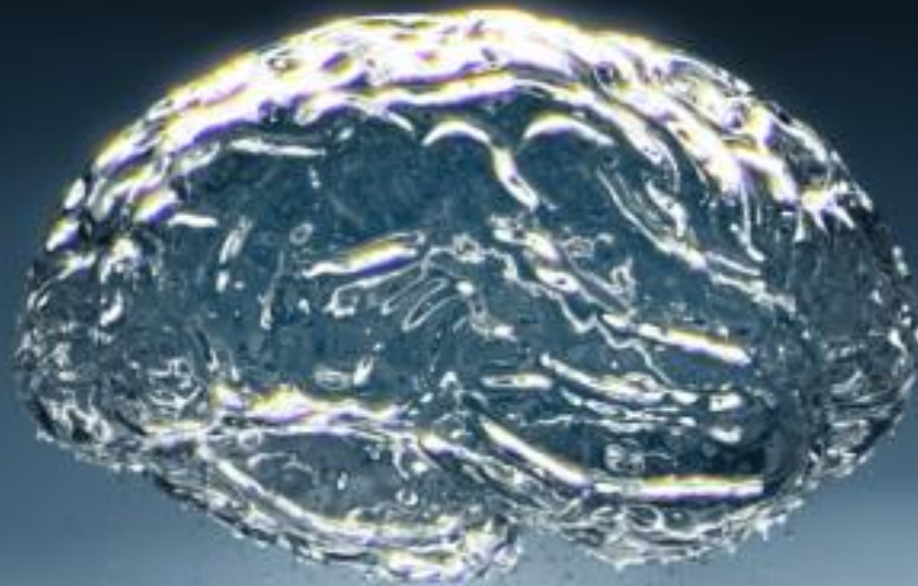


Quantitative Electroencephalography (qEEG) & Neurofeedback in ADHD and Dyslexia

Tony Steffert

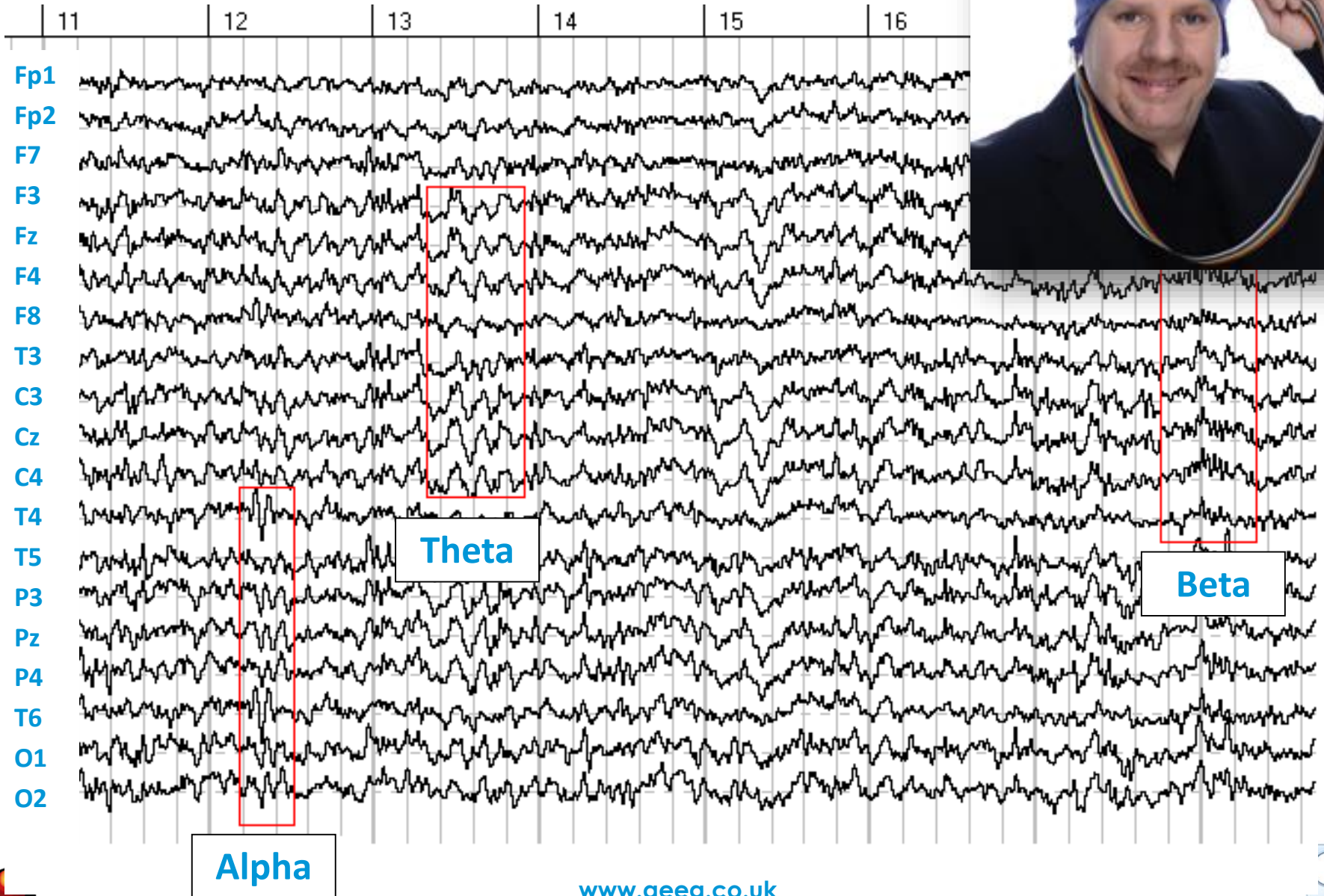
Department of Computing and Communications, MCT
The Open University



www.qeeg.co.uk

Electroencephalography

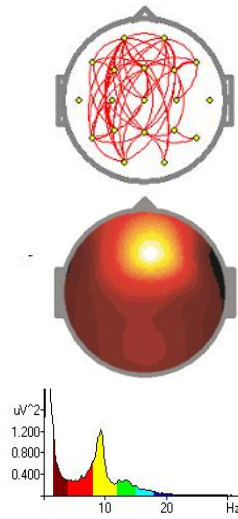
Electrical Activity measured from the Scalp at 19 Points or Channels on the scalp



Neuroimaging

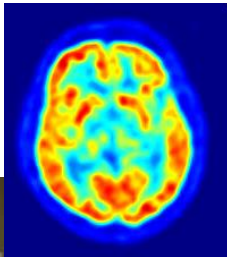
Non-invasive Brain imaging techniques to map anatomy, physiology, perfusion, function and phenotypes of the human brain.

- **PET** Positron emission tomography
- **fMRI** Functional magnetic resonance imaging
- **MEG** Magnetoencephalography
- **CT** Computed tomography
- **SPECT** Single photon emission computed tomography
- **EROS** Event-related optical signal
- **DOI-DOT** Diffuse optical imaging or diffuse optical tomography
- **EEG** Electroencephalography



EEG
£3000 to
£20,000

PET
£200,000

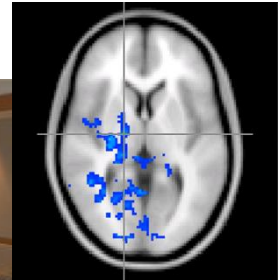


MEG
£2 Million

www.qeeg.co.uk



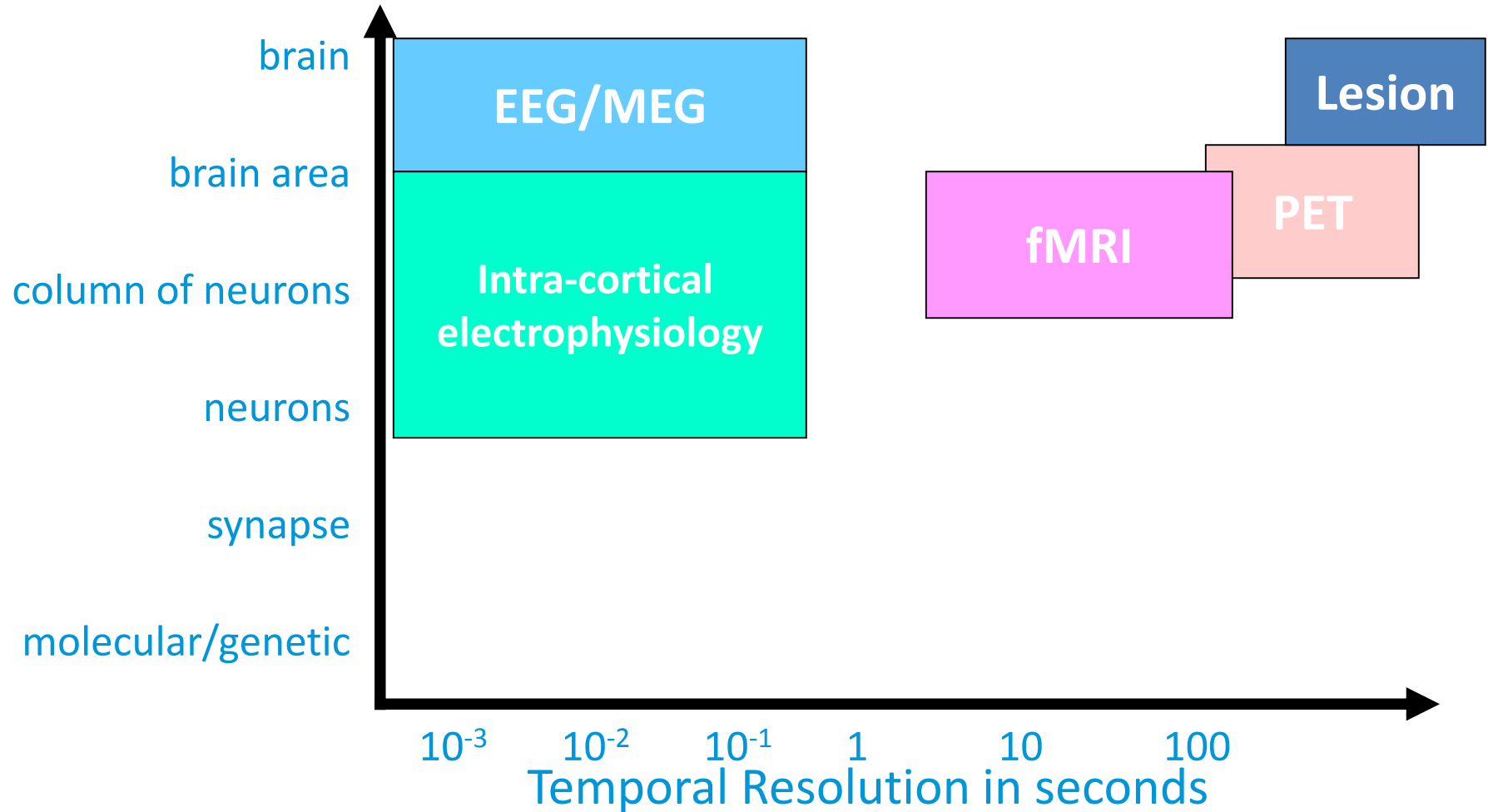
fMRI £2 Million



When and Where:

Temporal Vs. Spatial Resolution

Spatial resolution



From maps to mechanisms through neuroimaging of schizophrenia Andreas Meyer-Lindenberg , Nature, 468, 194–202 (11 November 2010)

Electroencephalography (EEG)



EEG System
£3000 to £20,000



Non-Invasive
Safe - repeated measures
Cheap
Fast
Portable
Can be worn for days
And used "in the wild"

We are coming out of the Lab



Construction Cost =
A Comfortable chair & Quiet room
Don't need a Faraday cage



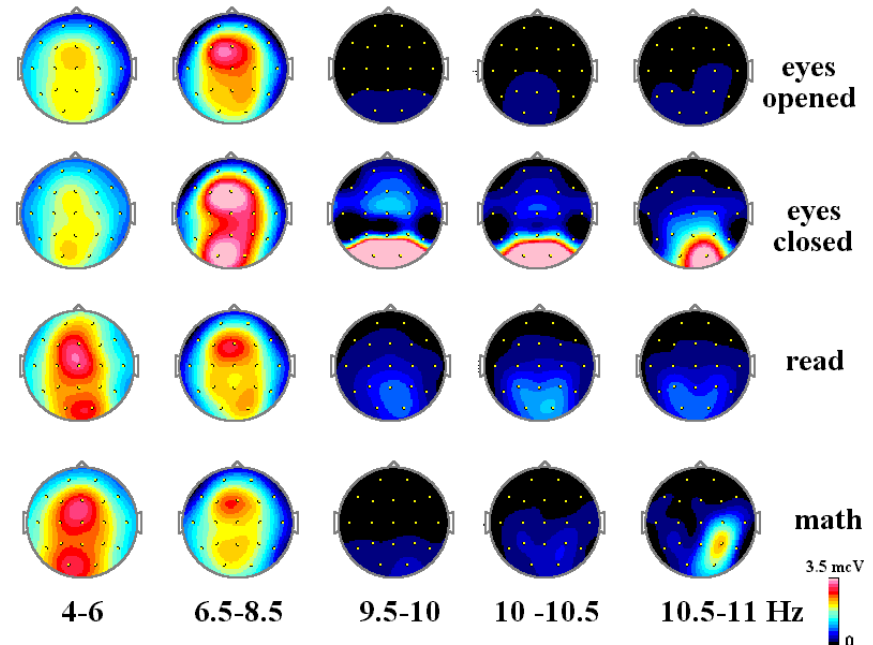
Clinical EEG vs. quantitative EEG

- Clinical EEG usually done by neurologists, or at hospitals
- Neurologists look for seizure activity, and other significant brain disturbances
- Generally reviewed by hand

- qEEG looks for frequency distribution – that varies from the norm.
- Extensive statistical analysis and Life span normative EEG database

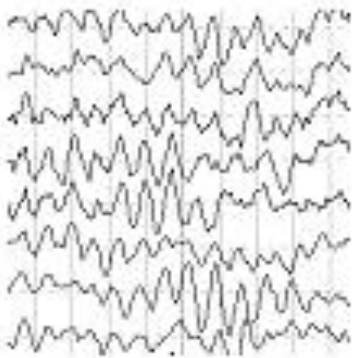
Generalized spike and wave EEG pattern typical for absence seizures.

qEEG spectrums in individual bands

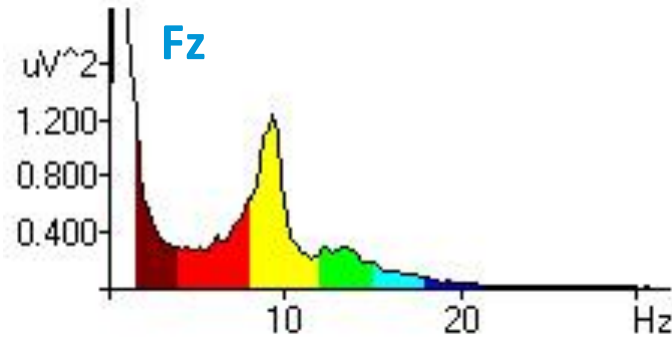


qEEG IMAGING

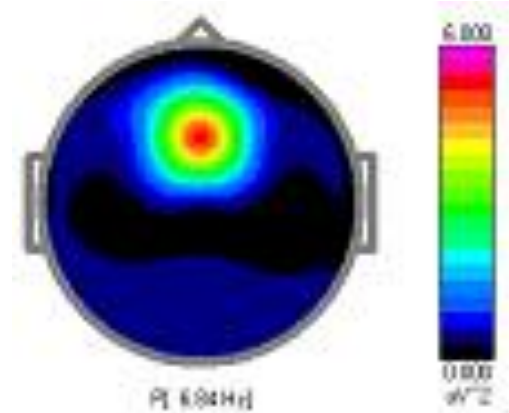
Raw EEG



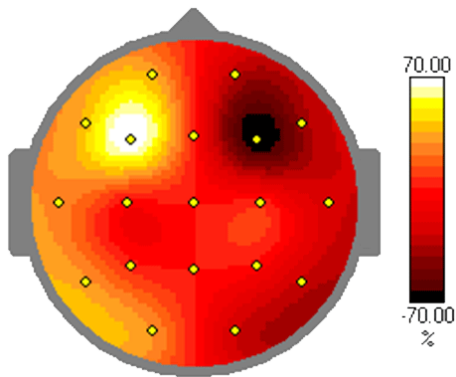
Spectral Band Power



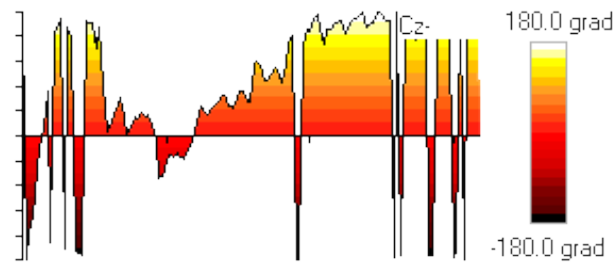
Topographic Band Power



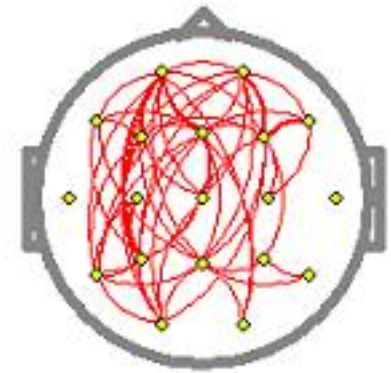
Asymmetry



Phase Lag

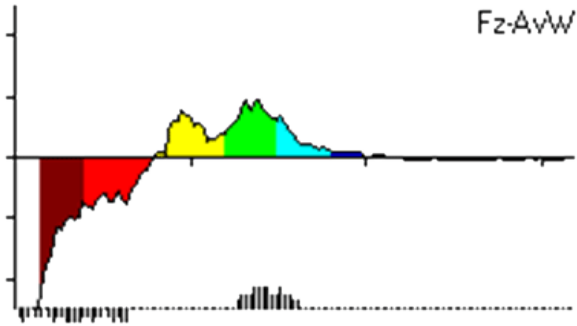


Coherence

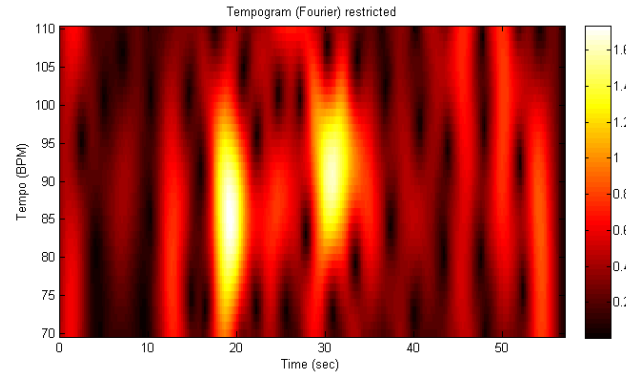


qEEG IMAGING

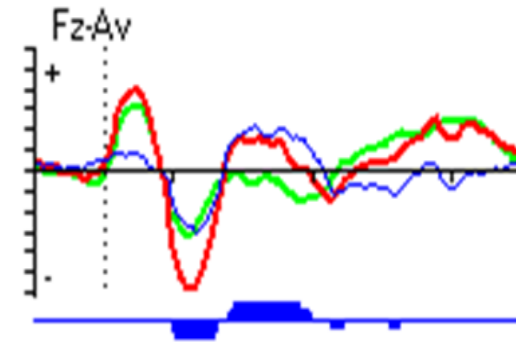
Statistical Difference



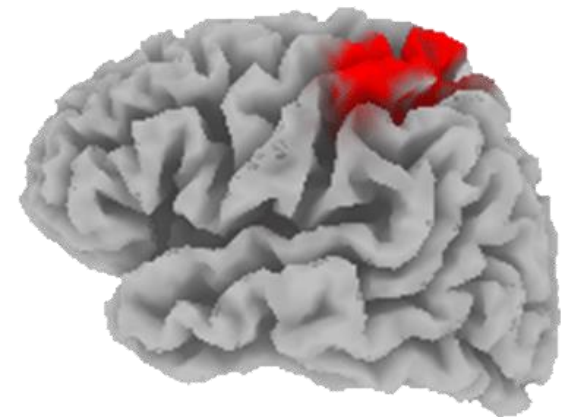
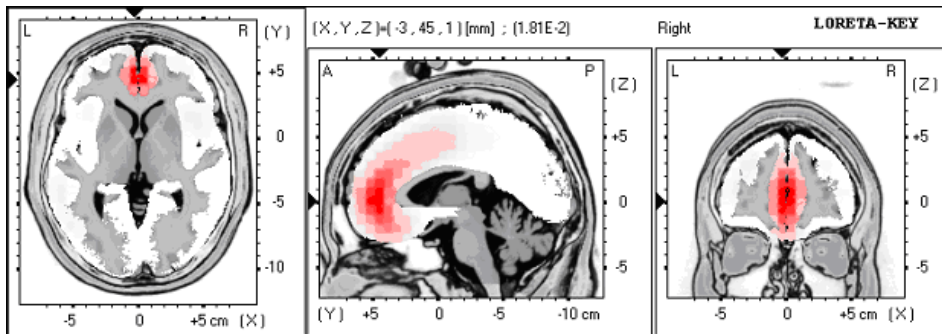
Event Related
Desynchronization



Event Related
Potential



Standardized & Exact low resolution brain electromagnetic tomography
sLORETA & eLORETA



Uses of quantitative EEG

Assessment, Personalized medicine & Tracking Progress:

Biomarkers or **Endophenotype** is a genetic epidemiology term which is used to separate behavioural symptoms into more stable phenotypes with a clear genetic connection.

Phenotypes is a physical trait, Genotype is the alleles of DNA

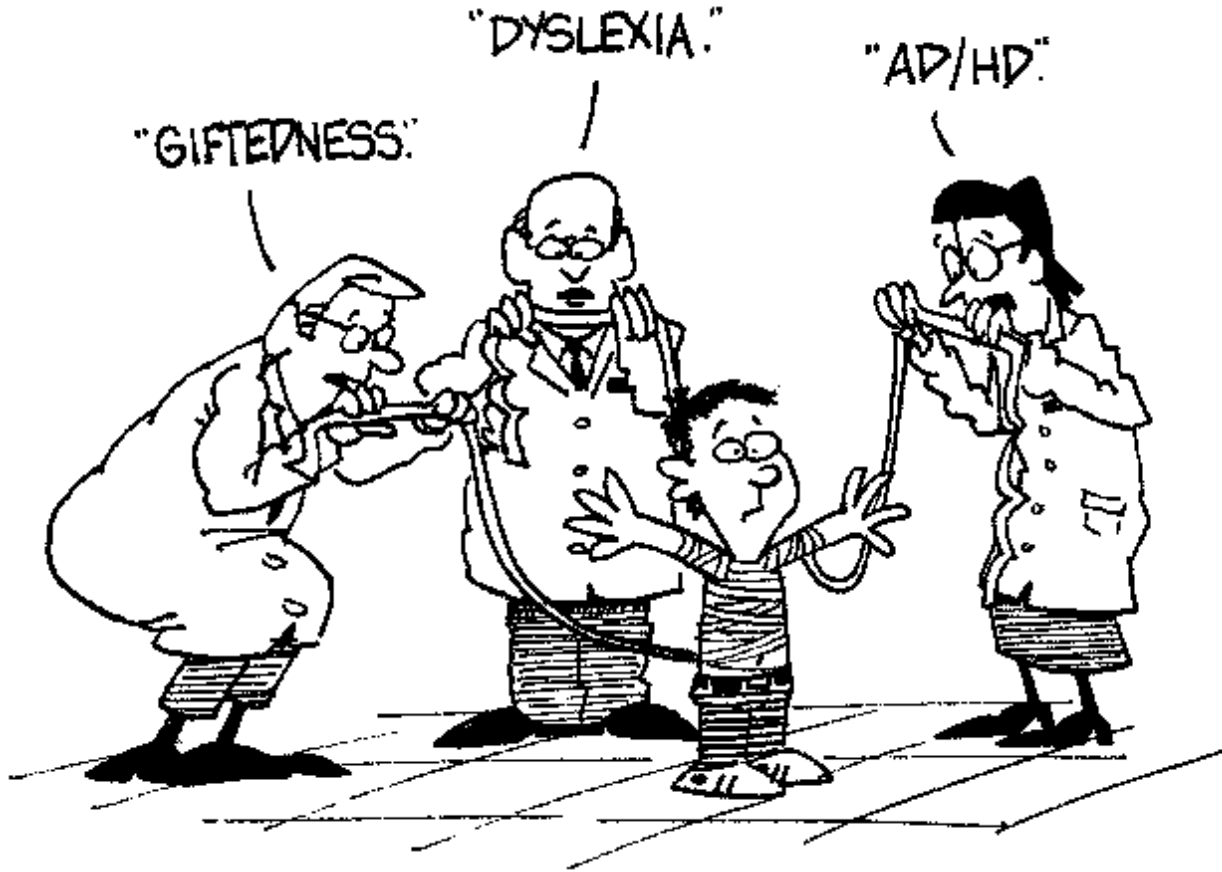
Linking Psychometric and **Neurometric concepts** to identify the **Physiology** underlying a behavioural measure.

- **Subtype:** e.g. ADHD more usefully than DSM
- **Protocols:** Neurofeedback or Transcranial DC Stimulation (tDCS)
- **Prognosis:** Help predict treatment outcomes, including medication
- **Tracking:** Pre vs. Post change measures

(e.g. 50% of psychiatric patients have attention problems)

www.qeeg.co.uk

Subtypes of ADHD



There are at least 5 sub-types of ADHD based on the qEEG/ERPs and some people can have more the one type

ADHD Subtypes in qEEG/ERP - Overview

Type 1: Increased theta in frontal-central cortex (app. 30%)

Type 2: Increased theta-beta-ratio in frontal-central cortex (app. 30%)

Type 3: Increased frontal – midline theta (app. 4%)

Type 4: Overactivated frontal, central or parietal cortex (18-26 Hz) (app. 4%)

Type 5: alpha-excess, slow-alpha-excess (app. 30%)
(Mu-rhythm)
over whole cortex
in posterior temporal and/or temporal/parietal areas

Also: Undiagnosed Epilepsy

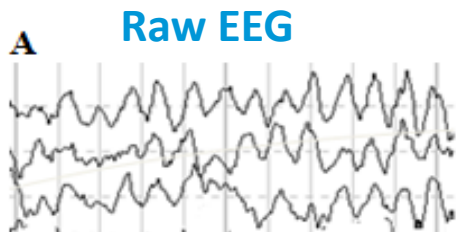
Some people can have more the one Subtype

ADHD - Sub-types

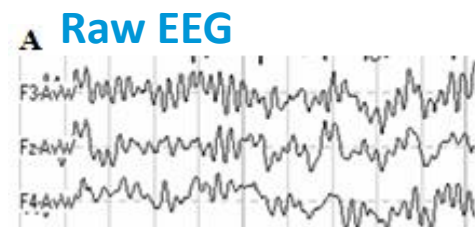
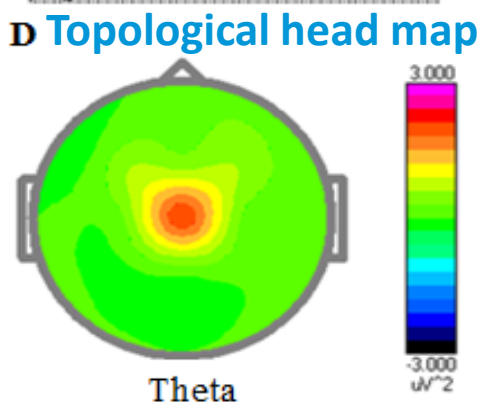
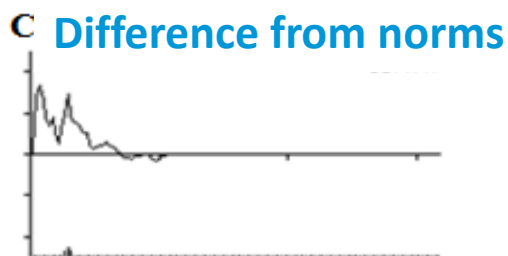
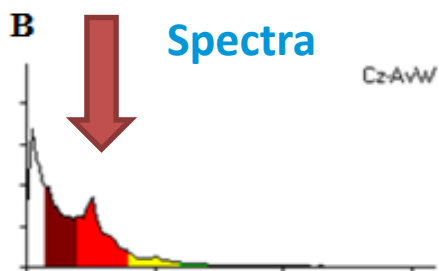
Hypoarousal

There are at least 5 qEEG/ERPs sub-types

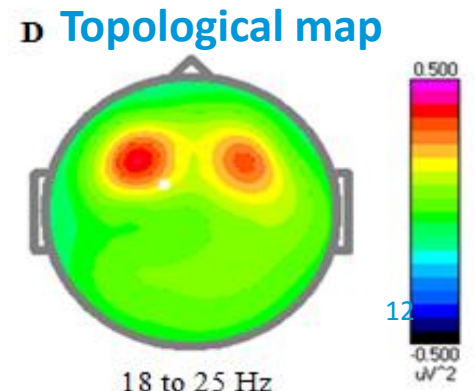
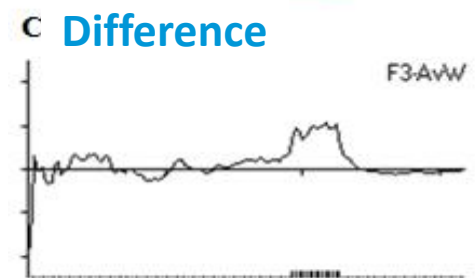
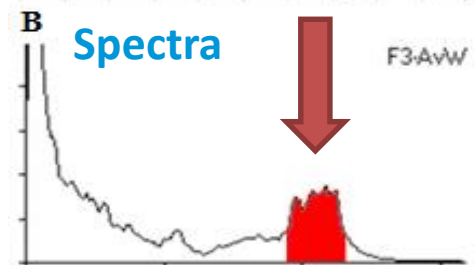
Hyperarousal



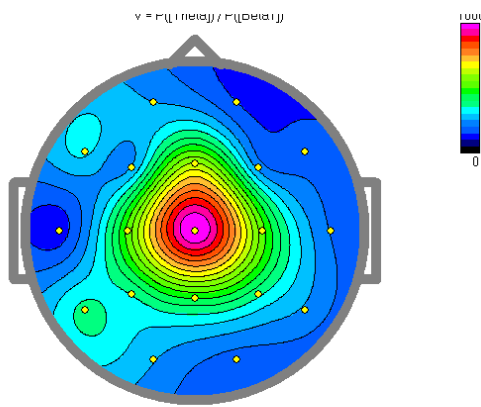
Excessive low frequency activity in the frontal and central lobes
- around 60% of the ADHD population



Excessive beta activity in the frontal lobes
- around 5 to 7%



Theta/Beta ratio attention index



www.qeeg.co.uk

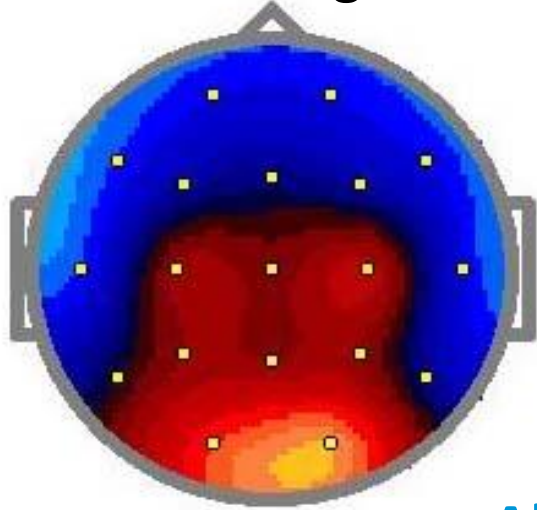
Dyslexia

Left (linear) vs. right (connected)

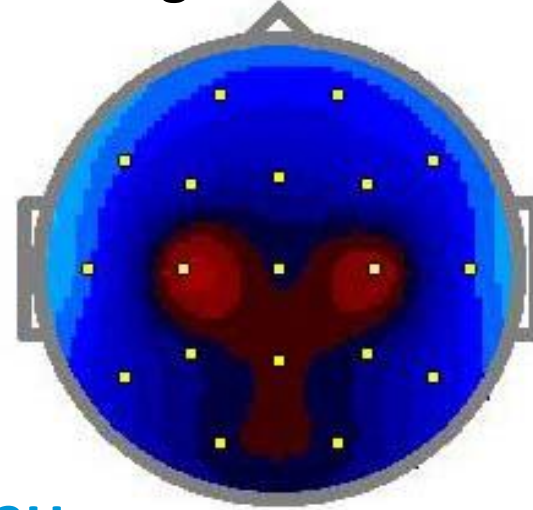


Sub-Types of Dyslexia - Visual

Reading



Reading with coloured Glasses



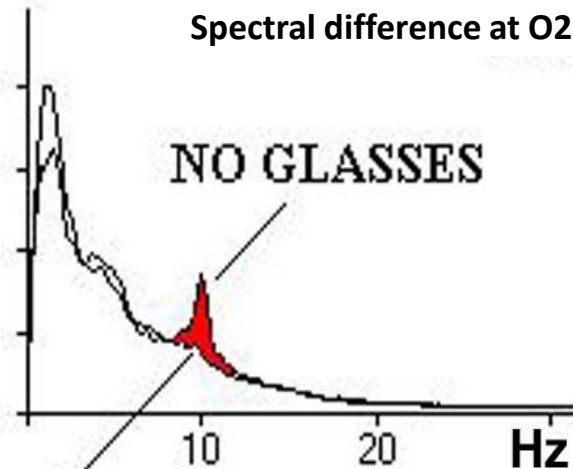
6.000

0.000

μV^2

Alpha 8-12Hz

48 Visual Dyslexics

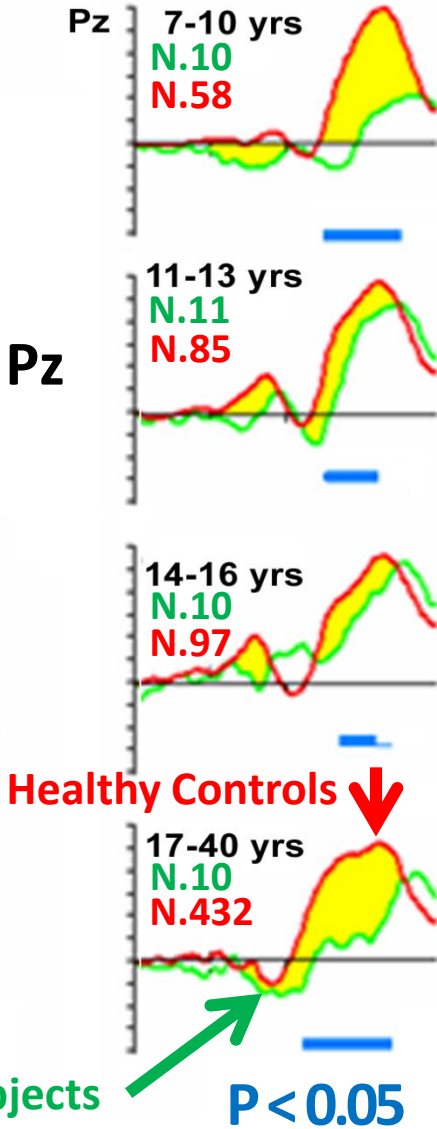
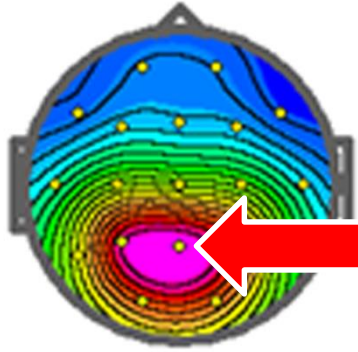


Visual dyslexics have excess occipital alpha when reading i.e. Hypoactivation

www.qeeg.co.uk

Deficits of the Dorsal Independent component of the P3b ERP

GO trial



sLORETA

41 Dyslexics

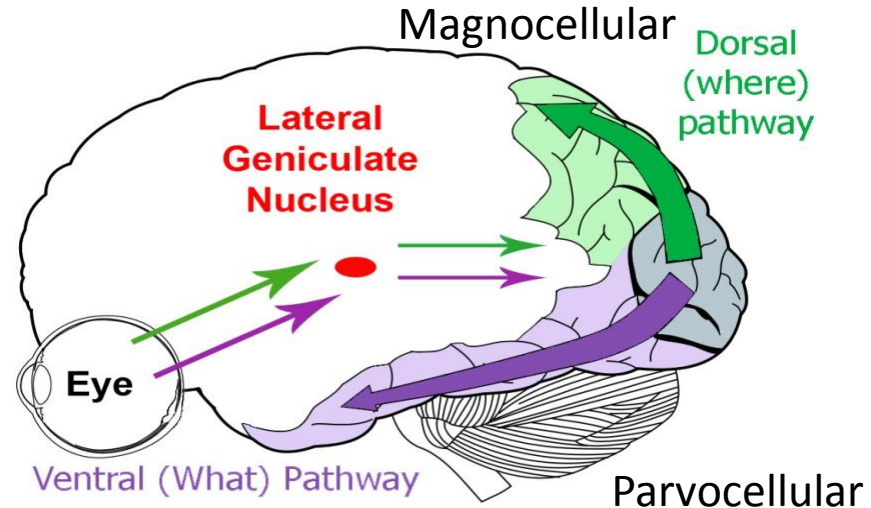
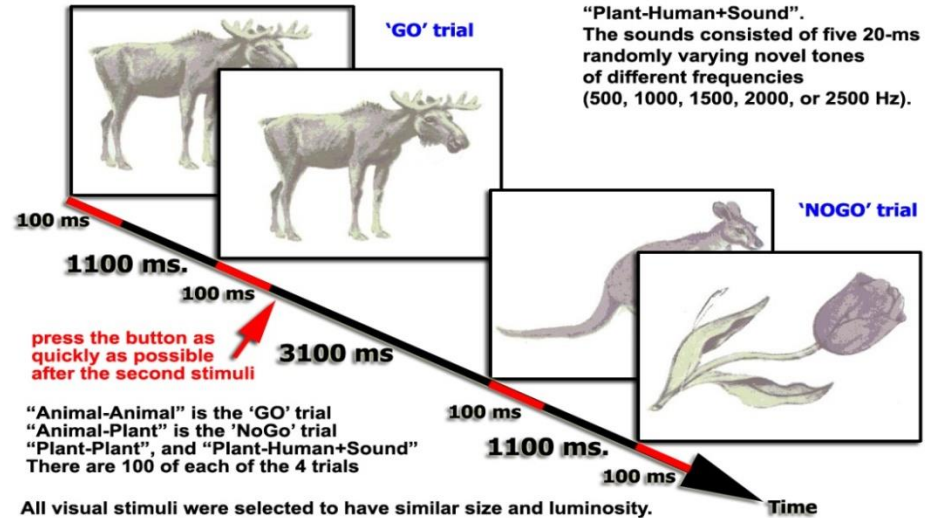
Dyslexic Subjects

P < 0.05

Controls from The Human Brain Index (HBI) EEG and ERP reference database.

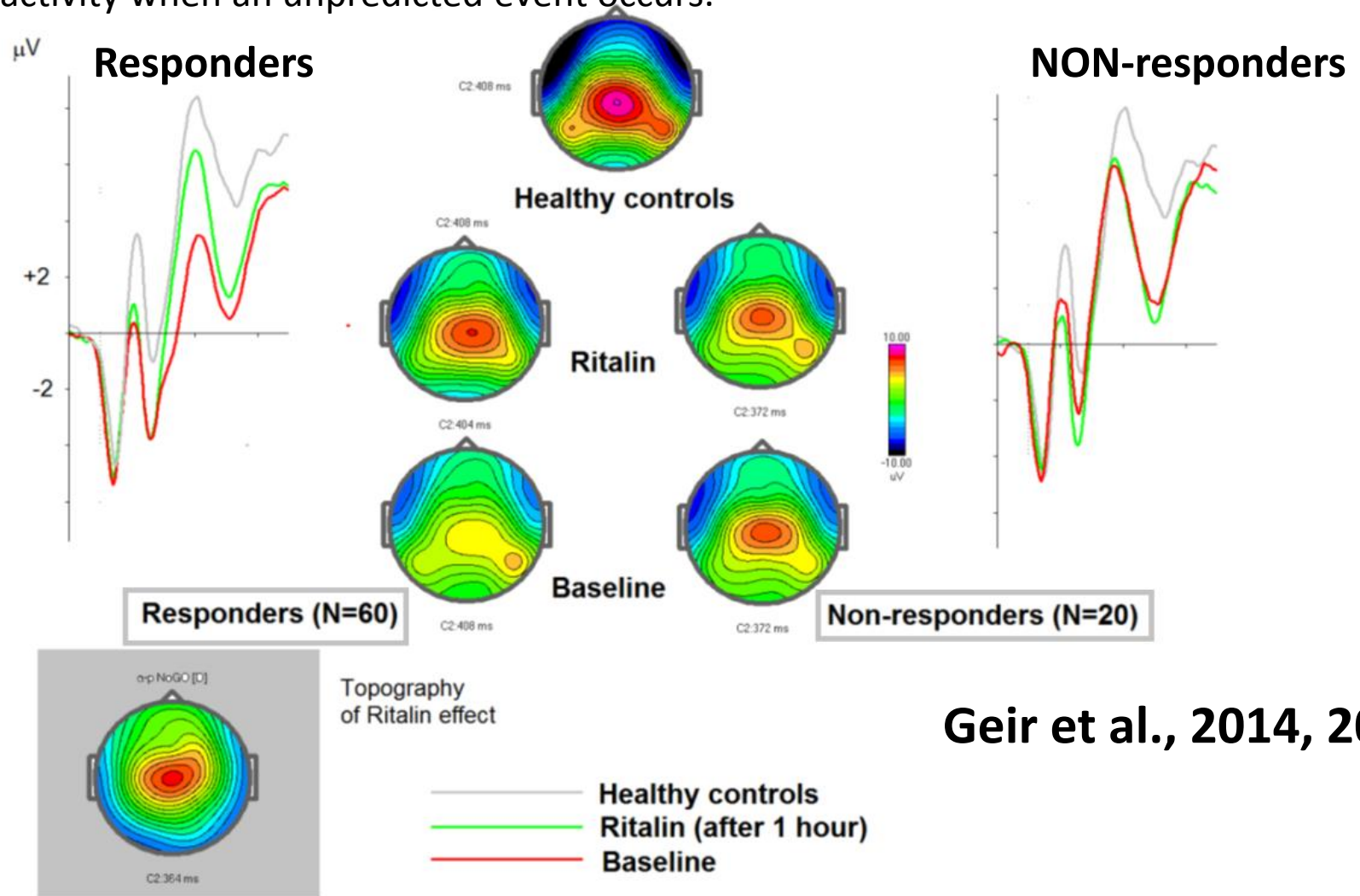
www.qeeg.com

The Event-Related Potential is a GO/NOGO, Visual Continuous Performance Task. It's an Executive dysfunction task used to sub-type AD/HD & predict medication response.



Ritalin Responders vs. Non-Responders

The **P3 NOGO** reflects operation of action inhibition when there is a need to suppress the ongoing activity when an unpredicted event occurs.



Geir et al., 2014, 2015

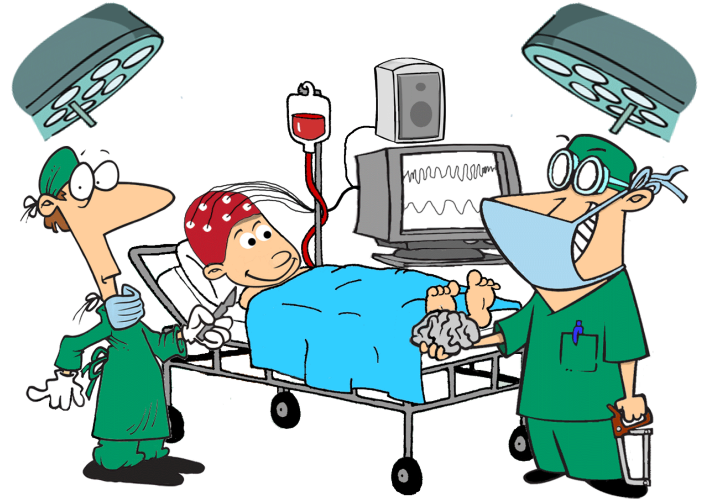
The results of **one dose Ritalin** intake in the groups of Responders and NON-responders.

Real-Time EEG

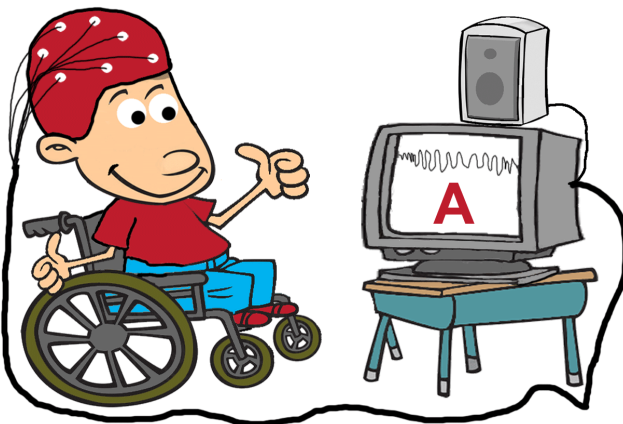
Art & Brain-Computer Musical Instrument (BCMI)



Surgical Monitoring



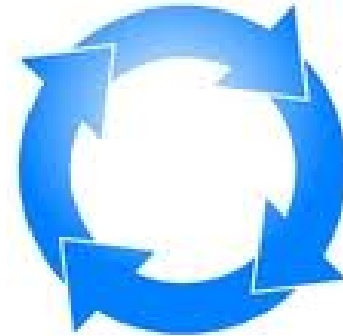
Brain Computer Interface (BCI)



Neurofeedback



Neurofeedback



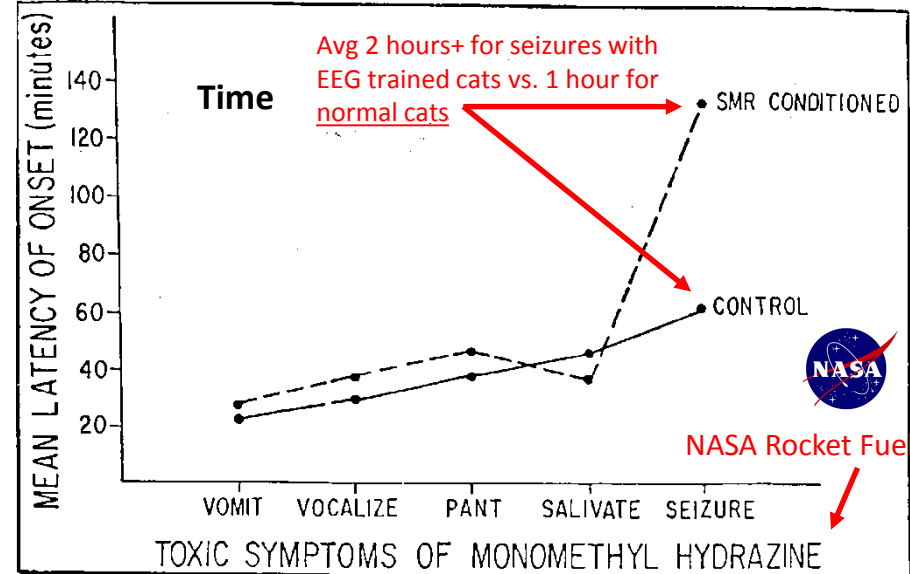
Real-Time EEG Neurofeedback

Neurofeedback: From Cats to Epilepsy to ADHD

Prof. Joe Kamiya – 1950 Alpha Training

Prof. Barry Sterman

- 1965: Cats and chicken soup
- 1971: Margaret Fairbanks sufferer from epilepsy and was denied a driver's license.
- Intractable epileptics achieved a 60% reduction in seizure rate.
- Meta Study of EEG Neurofeedback for Epilepsy - 82% demonstrated significant (>30%) seizure reduction
- Average reduction exceeded 50%

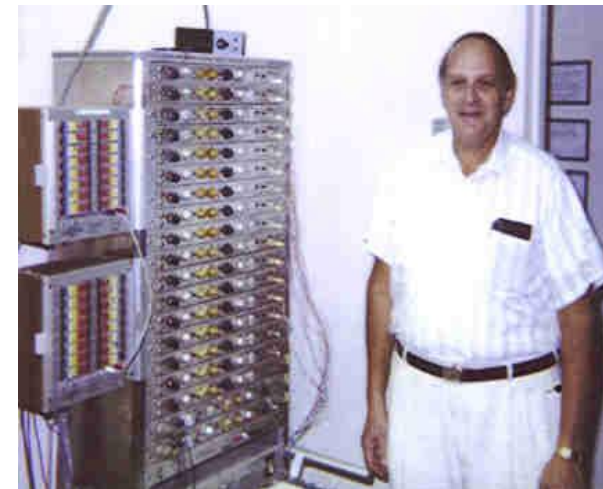


Sterman, M.B.; Friar, L. 1972. **Suppression of seizures in an epileptic following sensorimotor EEG feedback training.** *Electroencephalography and Clinical Neurophysiology*, Volume 33, Issue 1, July 1972 , Pages 89-95

Prof. Joel Lubar

- ABA design with ADHD

Lubar J F & Shouse M N (1976) EEG and behavioural changes in a hyperactive child concurrent training of the sensorimotor rhythm (SMR). A preliminary report. *Biofeedback & Self-Regulation*, 1 (3) 293-306



Neurofeedback: The Feedback Loop & Operant conditioning

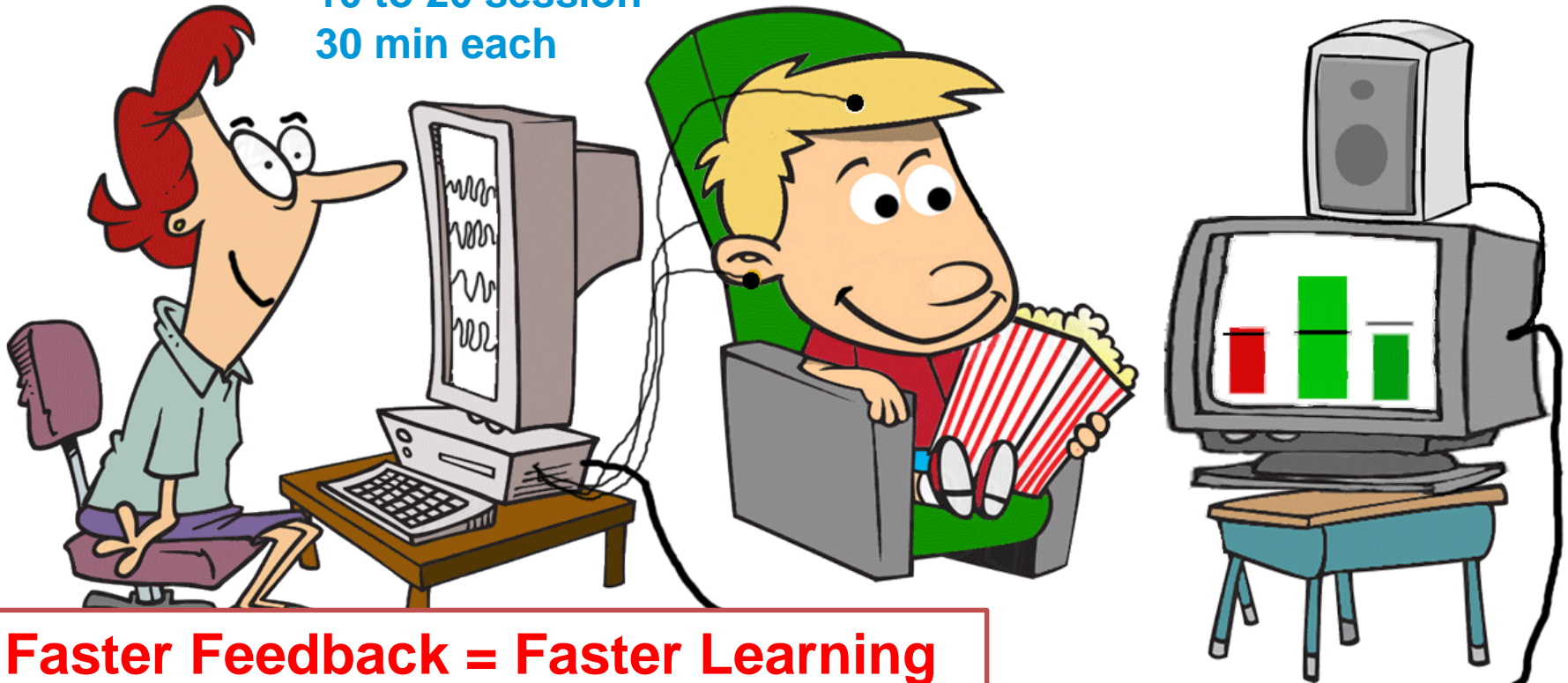
Immediacy - the quicker the feedback the shorter the learning time

Contingency - how accurately or fully the signal represents the activity

Saliency - how rewarding or noticeable the signal is

10 to 20 session
30 min each

Mostly visual feedback
Basic sound reward



Neurofeedback with marmoset monkeys

SMR, spectral peak around 12-14Hz) for 15 marshmallows, daily 30-minute training sessions.



Ingrid Philippens Ph.D

Department of Immunobiology, Biomedical Primate Research Centre, Rijswijk, The Netherlands.

www.qeeg.co.uk

This time the reword is turned off



“Where is my marshmallows”

www.qeeg.co.uk

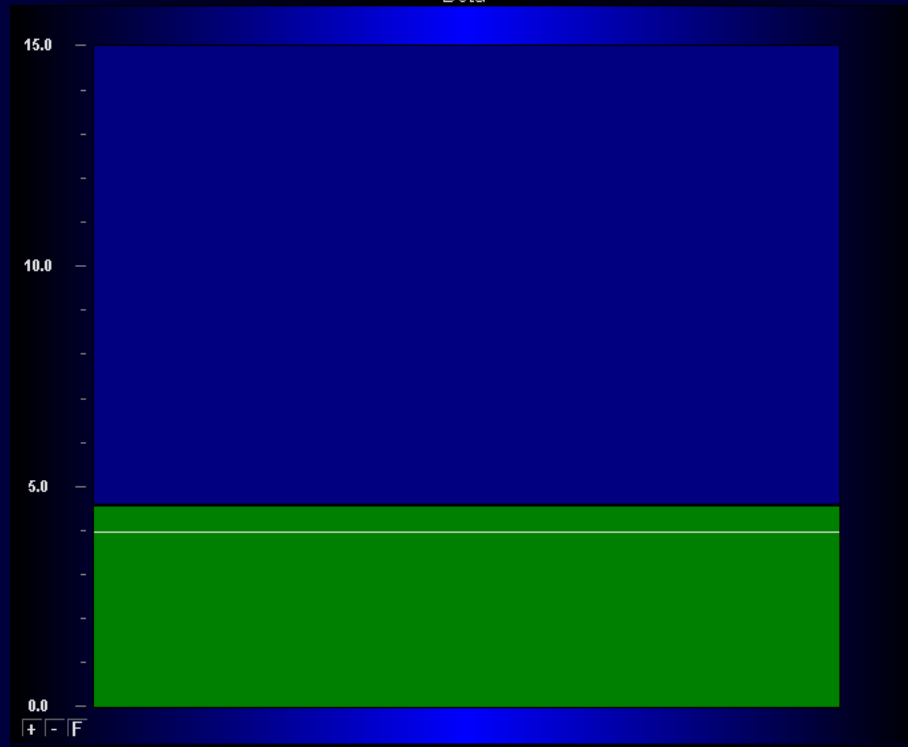
Typical Neurofeedback Screen (Nexus – From MindMedia)

BioTrace+ Software for NeXus-4 Screen: <Bars.screen> Client: <M02,M02.>

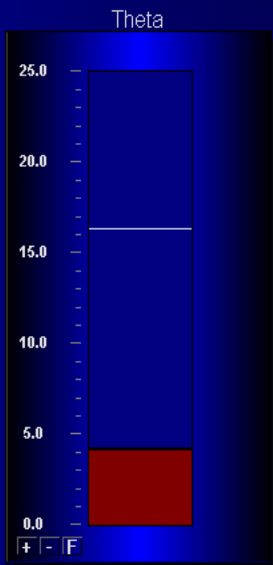
File Screen Configuration Help



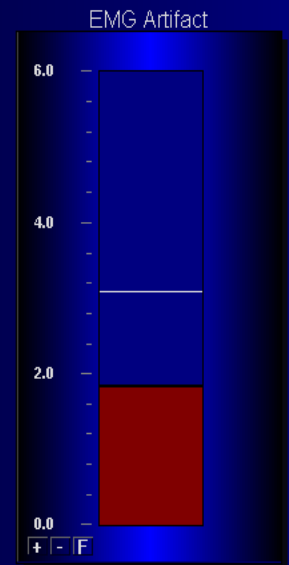
Beta



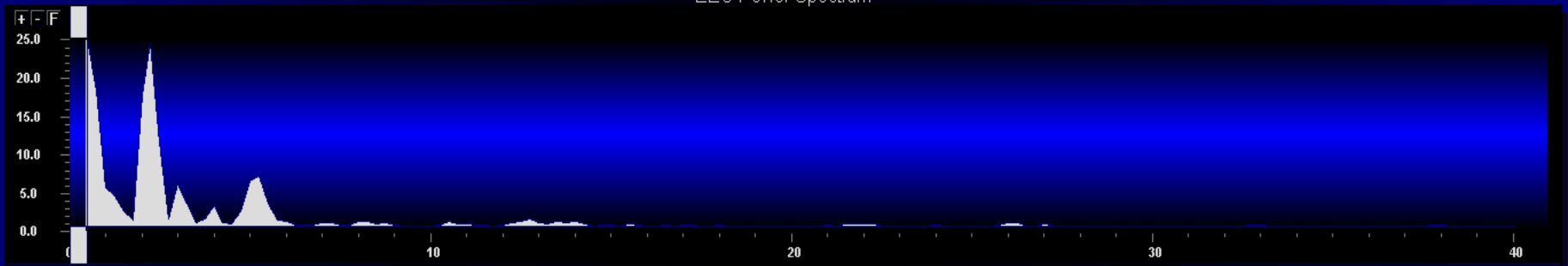
4 to 8 Hz



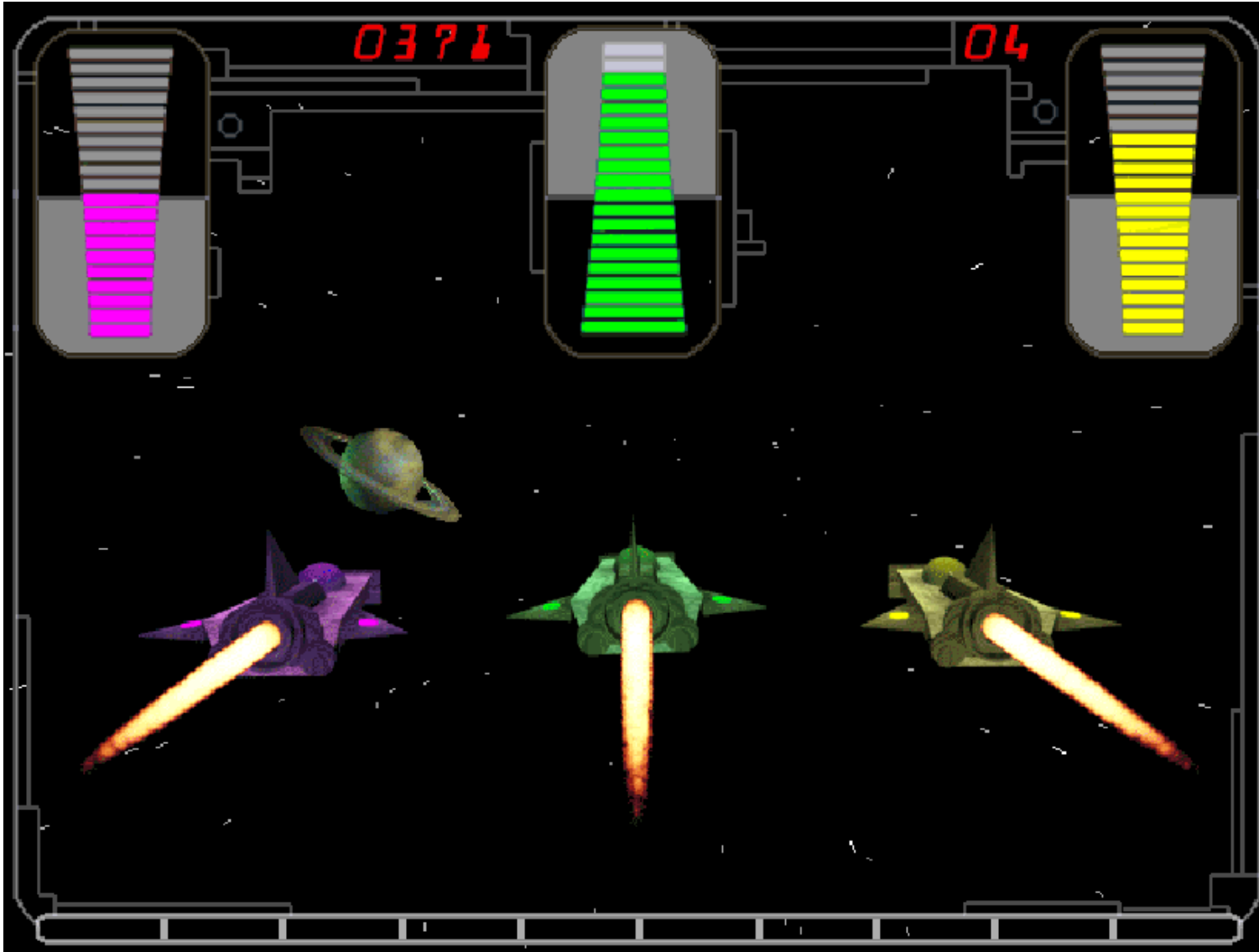
20 to 30 Hz



EEG Power Spectrum



Neurofeedback Game (Space Race from EEGer)



The subject wants their green rocket ship to get in front of the others.

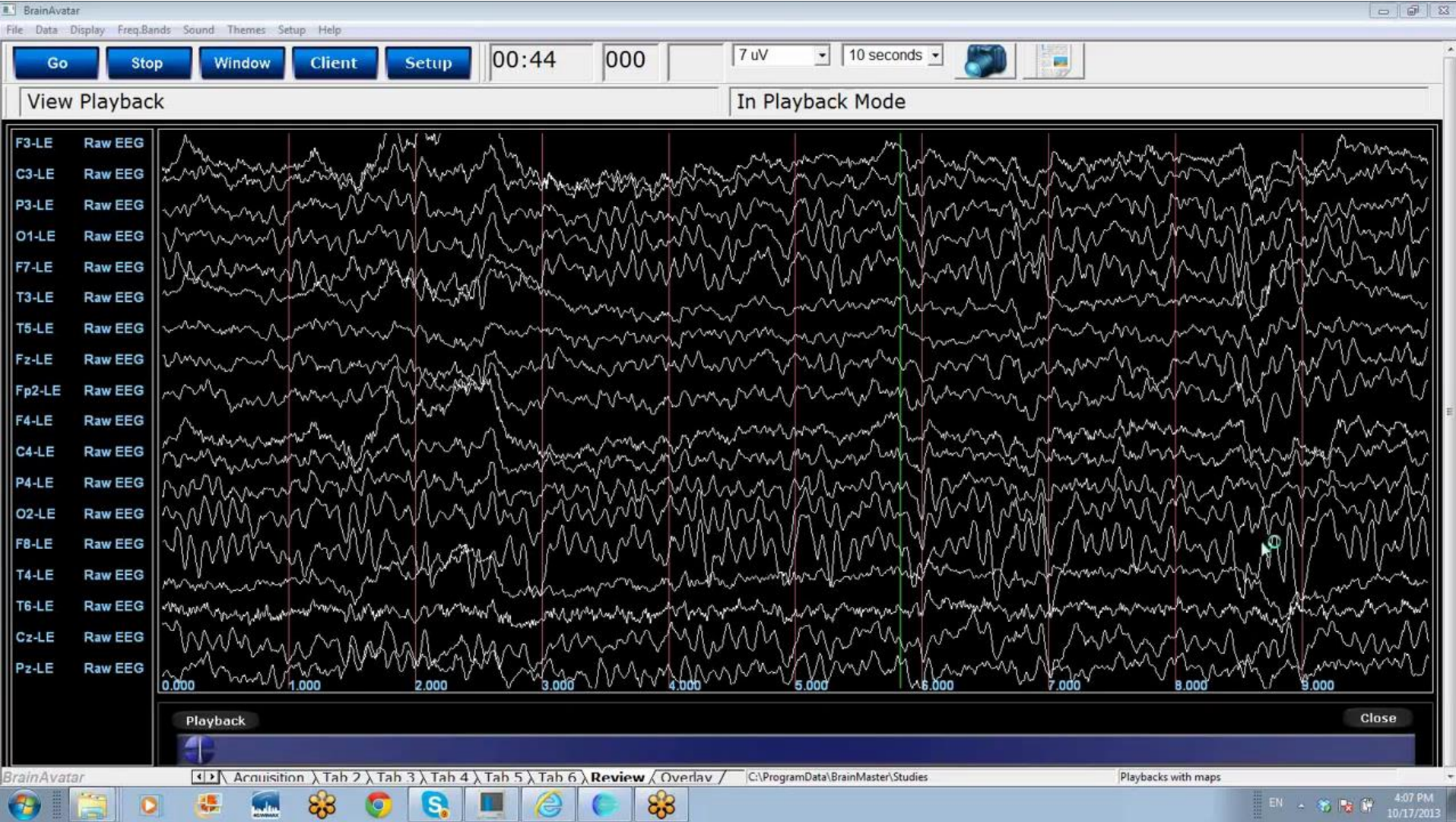
When the “Theta” and “High beta” are below the threshold and the green “Task beta” is above the threshold the subject will get the Reward.

Purple = Theta
(Inhibit)

Green = Task beta
(REWARD) www.qeeg.co.uk

Yellow = High beta
(Inhibit)

Brain Master: Discovery with BrainAvatar



Current Applications

- Academic Cognitive Enhancement
- AD/HD and Learning Disabilities
- Addiction
- Anger
- Anxiety
- Asthma
- Autism
- Autoimmune Disorders
- Brain Injury
- Cerebral Palsy
- Creativity
- Chronic Fatigue Syndrome
- Cognitive Decline
- Coma
- Criminals & Juvenile Offenders
- Depression
- Developmental Disorders
- Dissociative Disorders
- Epilepsy
- Fibromyalgia
- Headache
- Hypertension
- Obsessive Compulsive Disorder
- Optimal Functioning
- Post Traumatic Stress Disorder
- Pain
- Parkinson's Syndrome
- Schizophrenia
- Sleep
- Spasticity
- Stroke
- Tinnitus
- Tourette's Syndrome
- Withdrawal

Clinical, Educational & Peak Performance

www.isnr.org

www.qeeg.co.uk

Meta-Analysis ADHD & Neurofeedback

Arms, de Ridder, Strehl, Breteler, Coenen (2009)

- 15 studies
- 718 subjects
- “Both prospective controlled studies and studies employing a pre- and post-design found **large effect sizes (ES)** for neurofeedback on impulsivity and inattention and a **medium ES for hyperactivity**”
- “clinical effects of neurofeedback in the treatment of ADHD can be regarded as clinically meaningful.”
- **"Efficacious and Specific" (Level 5)**

Arns, Martijn, et al. "Efficacy of neurofeedback treatment in ADHD: the effects on inattention, impulsivity and hyperactivity: a meta-analysis."

Clinical EEG and neuroscience 40.3 (2009): 180-189.

Peak Performance Neurofeedback

- Olympic Gold -India's first solo gold medallist 10 m Air Rifle
- Team sports - AC Milan and Chelsea Football teams
- Winter sports - Canadian Winter Olympics
- Solo sports: Golfing, horse riding
- Glider Pilots
- Dancers
- Theatre Performance

Arns, 2007 Golf performance enhancement by means of real-life neurofeedback training based on personalized event-locked EEG profiles

Abhinav Bindra

four-man bobsled, Turin 2006



LABAN



Subjects: 32 volunteers from the Laban contemporary dance centre in Deptford, London, were randomised to one of 4 groups:

- (1) an alpha-theta neurofeedback group,
- (2) a heart-rate variability group,
- (3) intervention control: a dance movement focus group,
- (4) a non-intervention control group.

The experimental group were given 10 x 20 min sessions of neurofeedback or heart-rate variability training, while the focus group had 10 group sessions.

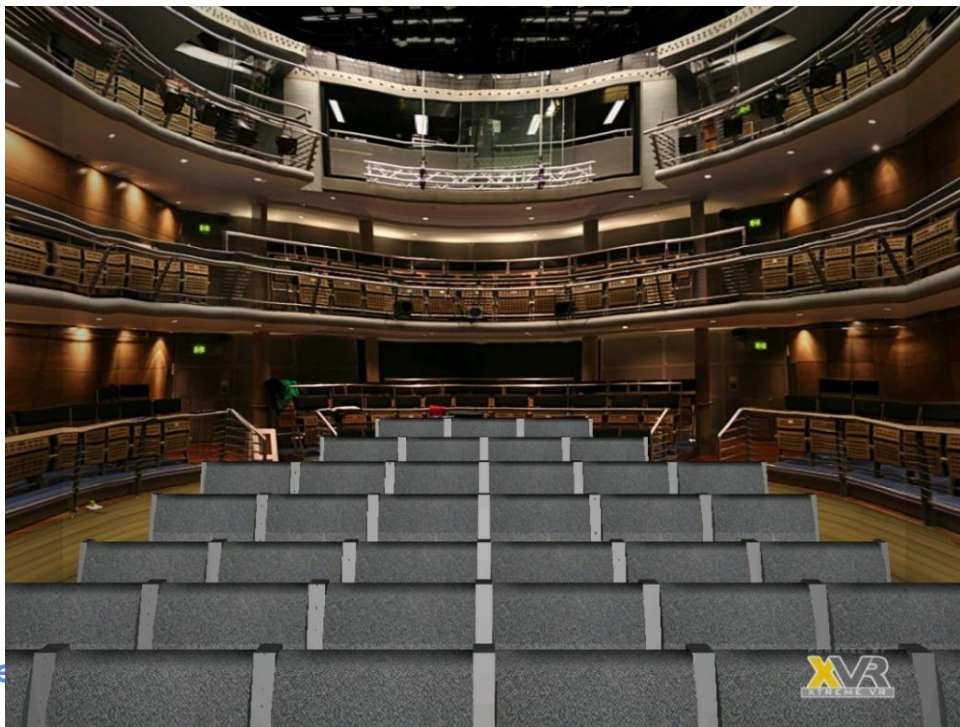
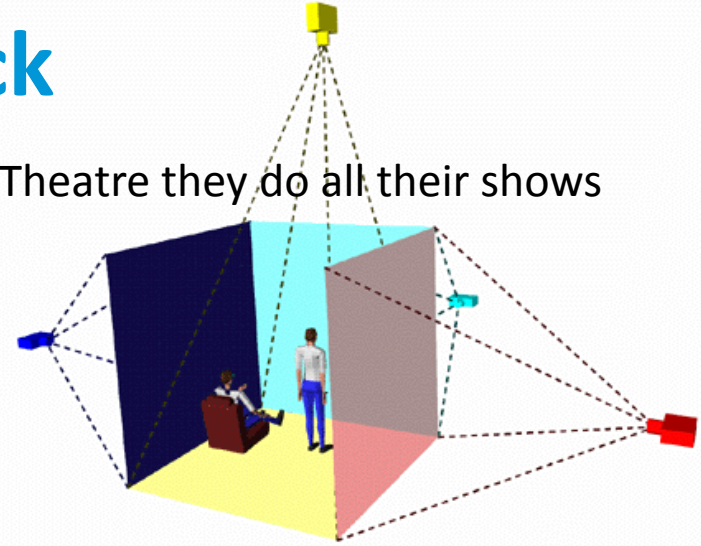


Royal Academy of Dramatic Art RADA

Virtual Reality Neurofeedback

- VR – RADA Vanbrugh Theatre -This is the Theatre they do all their shows
- Parameters driven by EEG:
 - Animate Lighting levels - Reward
 - Audience Distracting noises – Inhibit

Ecologically Valid Virtual Environment





Goldsmiths
UNIVERSITY OF LONDON

Neurofeedback in

eXperience Induction Machine

UNIVERSITAT
POMPEU FABRA

Consumer EEG systems



Necomimi \$50

Saline



Emotiv \$300



Versus \$400



NeuroSky \$100



Emotiv Insight £359



BrainLink Lite £130



Hologram \$70

Star Wars Force Trainer \$137

muse™
the brain sensing headband



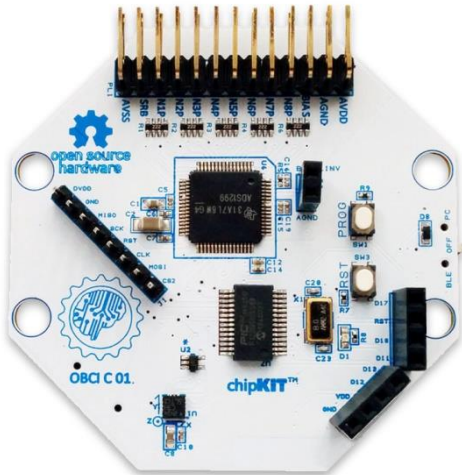
Muse £249

Maker Community - open source EEG

The **maker community** is a contemporary subculture, representing a technology-based extension of DIY culture. The New York Times called makers, 'kitchen table industrialists'

**OpenEEG: Build your own
200 to 400 USD**

<http://openeeg.sourceforge.net/>



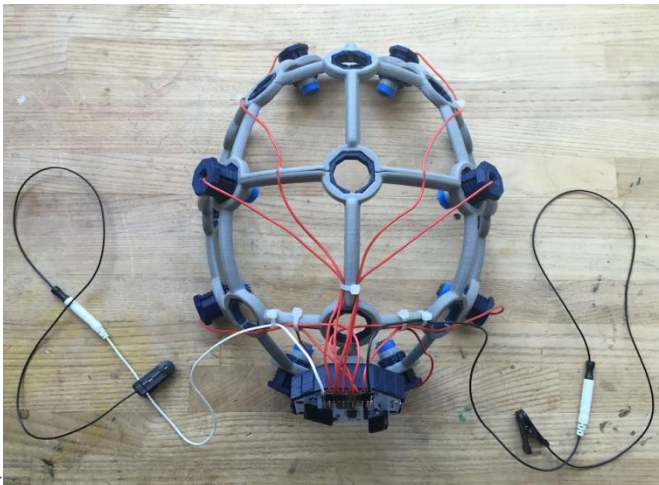
**OpenBCI:
8 channels
\$450**

**Make your
own 3D
printing
Headset**

www.openbci.com



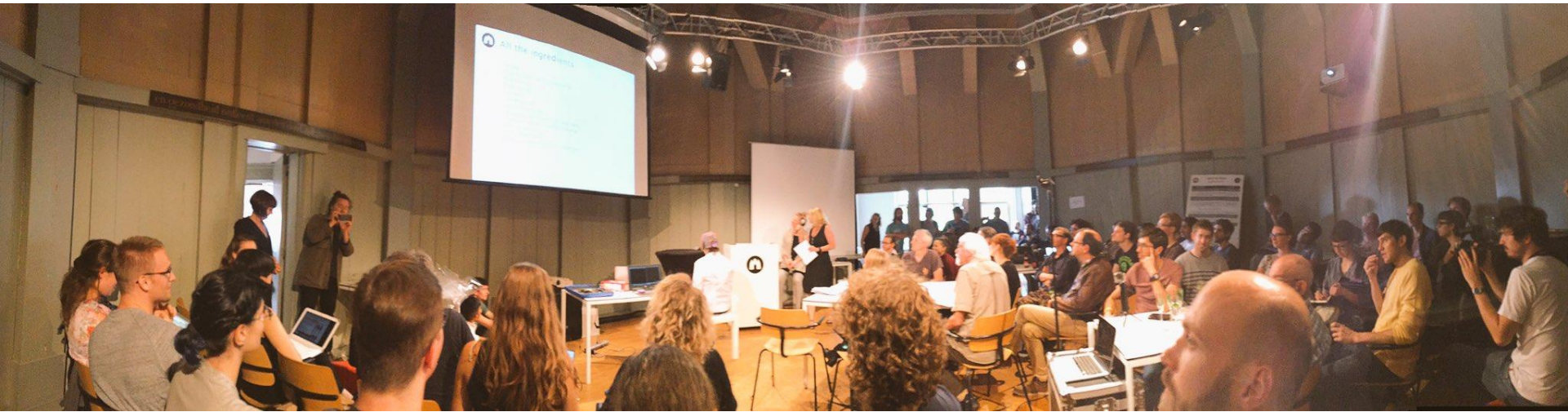
Olimex € 99



www.qeeg.co.uk



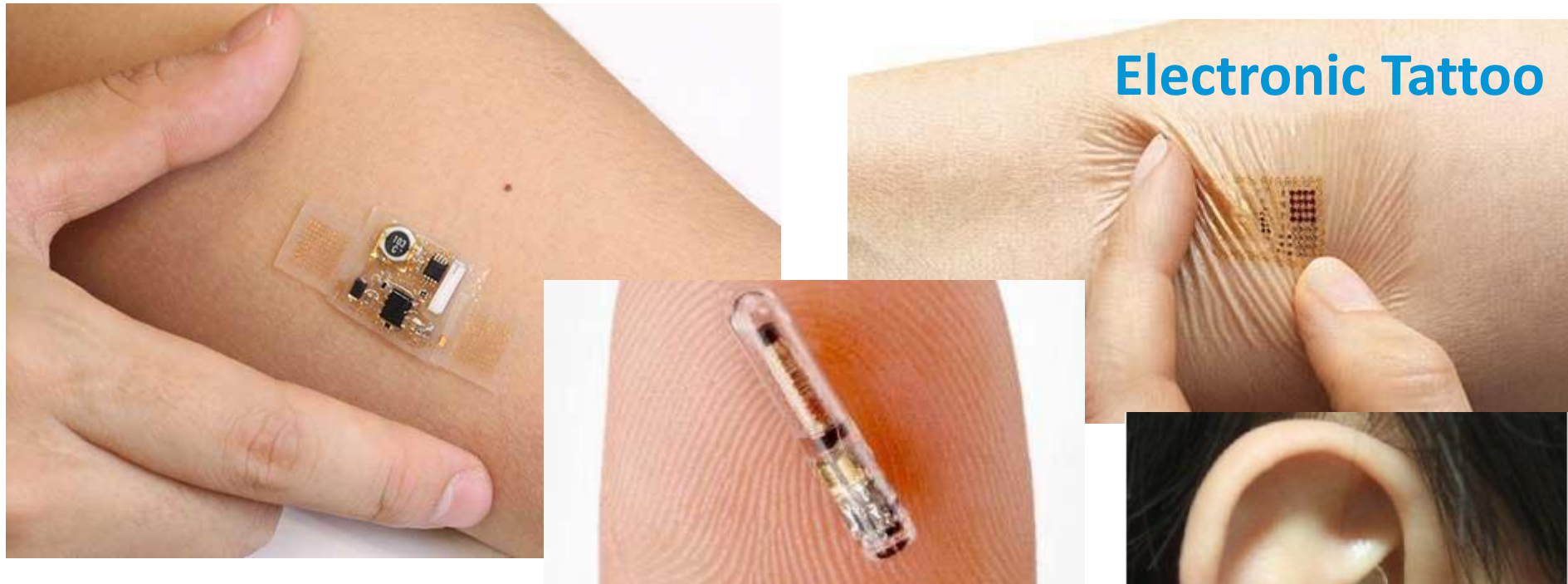
Hack the Brain



Amsterdam:
15 ideas
58 participants (artists, scientists & developers) 8 nationalities
10 teams
2 performances
8 kinds of hardware
<http://hackthebrain.nl/>



Stick-on electronic patches for health monitoring



Electronic Tattoo

Researchers at John A. Rogers' lab at the University of Illinois, Urbana-Champaign have incorporated off-the-shelf chips into flexible electronic patches to allow for high quality ECG and EEG monitoring.

<http://www.youtube.com/watch?v=dxhoLxRYsRU>

<https://www.youtube.com/watch?v=4oeFBGFzcrg>

<http://gaggio.blogspot.com/archive/2014/04/06/amazing-brain-animations-3000921.html>

Thank You

Tony Steffert

Researcher in Physiological Sonification
Computing Department, The Open University
qEEG & Neurofeedback & EEG Sonification

www.qEEG.co.uk

tony@qeeg.co.uk





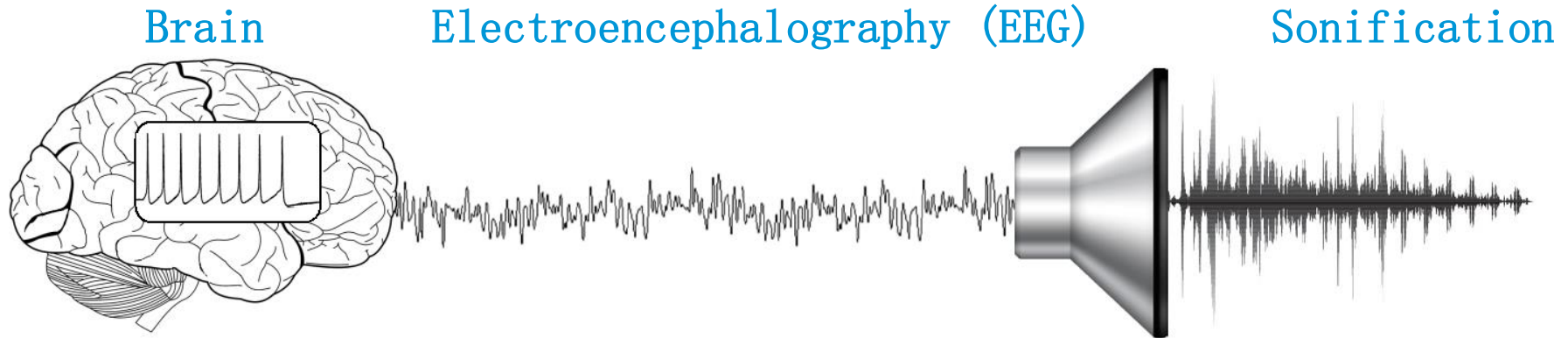
CONFERENCE ON
BIOMEDICAL ENGINEERING AND SCIENCES (IECBES).
04 – 08 December 2016
THE PULLMAN BANGSAR, **KUALA LUMPUR**, MALAYSIA

Dr Bev And Tony Steffert
Workshop:
NEUROFEEDBACK FOR ADHD, AUTISM & DEVELOPMENTAL
COORDINATION DISORDER
8 December 2016

www.iecbes.org

www.qeeg.co.uk

Real-Time Electroencephalography Sonification



Putting the “**Funk**” into
Functional Neuroimaging

www.sonification.qeeg.co.uk



VOCAL SONIFICATION OF PATHOLOGIC EEG FEATURES

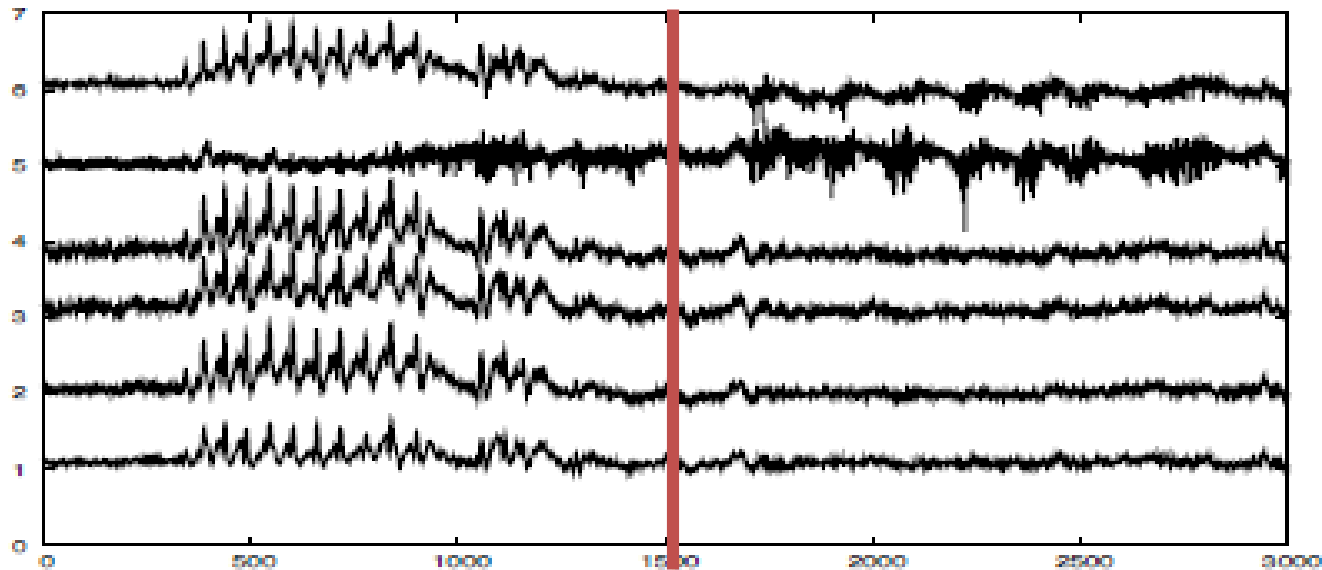
Thomas **Hermann**¹, Gerold **Baier**², Ulrich Stephani³, Helge Ritter¹

¹ Neuroinformatics Group, Bielefeld University, 33615 Bielefeld, Germany
thermann@techfak.uni-bielefeld.de

² Facultad de Ciencias, Universidad Autonoma del Estado de Morelos, 62209 Cuernavaca, México

³ Clinic for Neuropediatrics, University of Kiel, 24105 Kiel, Germany

representative of EEG time series including an epileptic episode.



S1 = 9 sec
Real Time



S2 = 17sec
½ Speed



S3 = 33 sec
4 times slower

Nexus 4, 10, 16, 32

- 2 channels Fast
- Sample Rate: 1024
- Sensors: EEG, EMG, ECG, EOG

- 2 AUX channels
- Sample Rate: 128
- Sensors: RSP, BVP, SC/GSR
- **Temperature.**

- Channels: 4, 10, 16 or 32
- Resolution: 24 bits
- Common mode rejection 110
- Slow Cortical Potential - SCP
- Blue Tooth Wireless

- Dual Monitor
- Filters
- 24 Hour recording

£3500



2 Fast
2 AUX

£5000



4 Fast
6 AUX



24 Fast
8 AUX

SmartBCI from Mitsar

24 EEG Cannels
DC to 70 Hz
300mV Input Range
24 bits ADC Resolution
250 Hz Sampling Rate
Motion

SmartBCI
BCI/EEG/NF/SPORTs



<http://www.mitsar-medical.com/>

G.NAUTILUS - G.Tec's Wireless EEG System With Active Electrodes

maybe around 25k



<http://www.gtec.at/Products/Hardware-and-Accessories/g.Nautilus-Specs-Features>

enobio 8, 20, 32-ch from Starlab

Number of channels: **8 or 20 or 32**

Bandwidth: 0 to 250 Hz.

Sampling rate: 500 SPS

Resolution: 24 bits – 0,05 μ V

Noise: <1 μ V rms from 0 to 250 Hz.

Common mode rejection ratio: -115 dB

Communication: Bluetooth 3.0 and 2.1

Output: EDF+, ASCII data files
or TCP/IP raw data streaming

Operating time:

Enobio 8: 16h,

Enobio 20: 14h,

Enobio 32: 13h

Dimensions: 60 x 85 x 20 mm.

Weight: Enobio 8: 76g, Enobio 20: 77g,

Enobio 32: 86g

Artifact resilience: Yes

DC coupled: Yes, measurement band from 0 to 250 Hz.

Accelerometer Data Recording 3 axis at 100 S/s

MicroSD card interface; Holter mode data storage

ERP experiments with a sub-sample accuracy

Hardware TTL trigger (optional)

Caps available in different sizes or custom sizes

wet or dry electrodes

- 8 channels: € 3995
- 20 channels: € 12495
- 32 channels: € 19995



<http://www.neuroelectrics.com/enobio>

QUASAR

Possible around \$90 k
Dry



Real time classifier for determination of the cognitive workload of a user

B-Alert

www.quasarusa.com



<http://www.bmedical.com.au/shop/neuroscience.htm>

www.qeeg.co.uk

Subset of Biofeedback

which is the feeding back of a biological signal to allow learning

- **Feedback Thermometer - TEMP**

- skin temperature – periphery blood flow



- **Photoplethysmograph - PPGs**

- peripheral blood flow - interbeat interval (IBI), heart rate variability (HRV).

- **Pneumograph – RESP**

- Strain gauge measures abdominal/chest movement – breathing



- **Capnometer**

- Capnograph measures end-tidal CO2 with an infrared detector

- **Hemoencephalography - HEG**

- passive infrared (pIR) measures radiated heat
- near infrared (nIR) oxygenated and unoxygenated blood



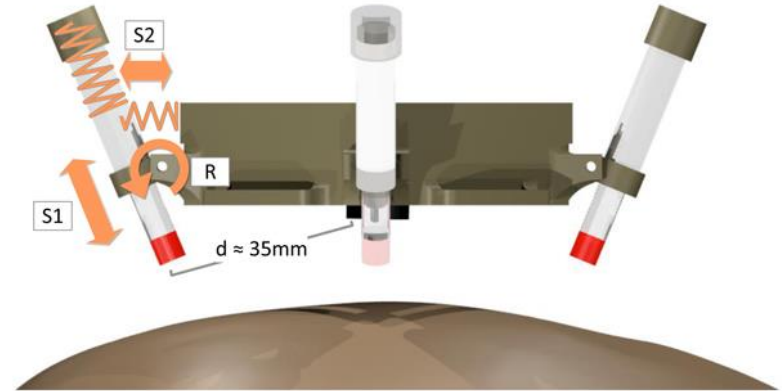
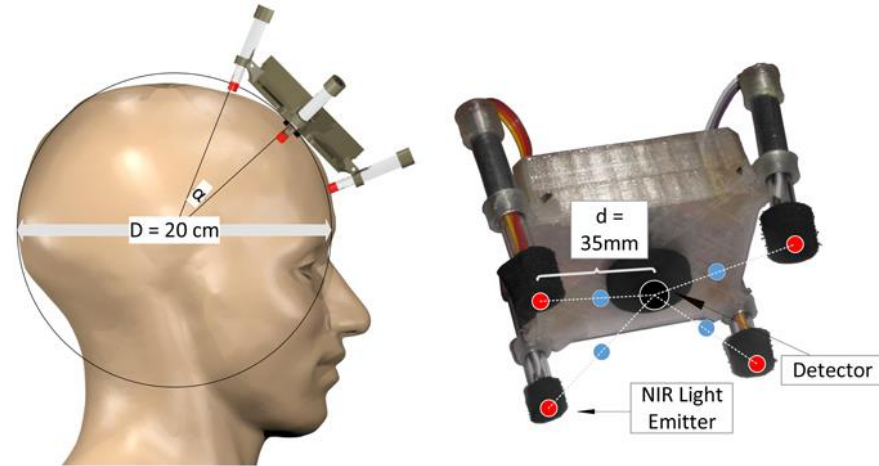
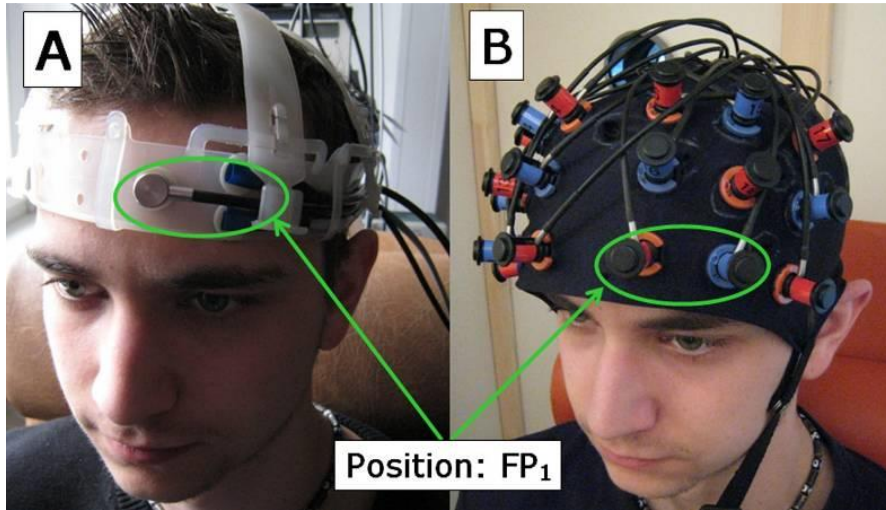
- **Electrodermograph – EDG (Also called GSR, SC and SP)**



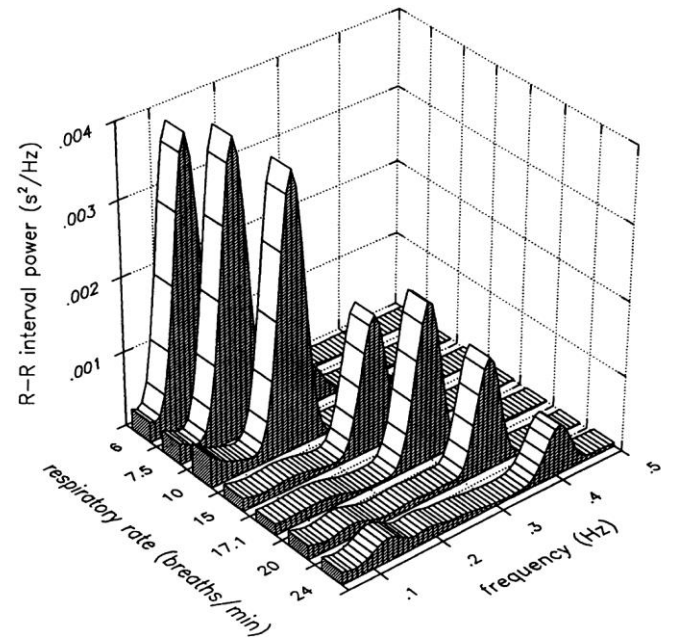
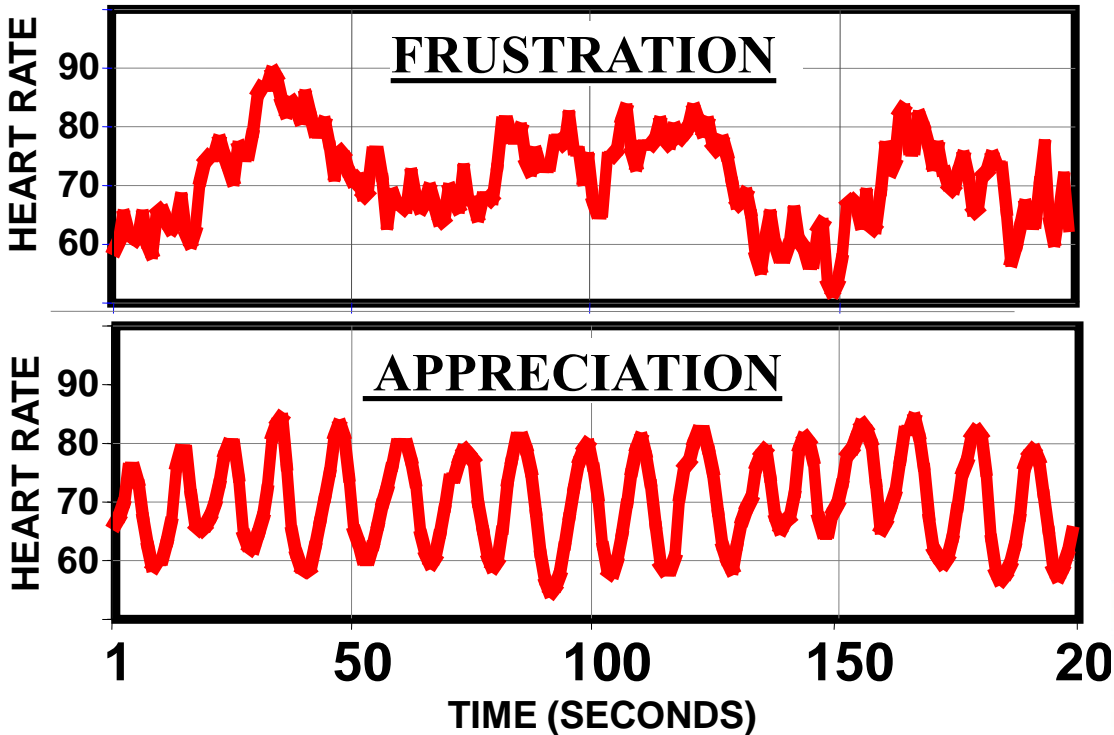
Optical Neurofeedback - Near-infrared spectroscopy (NIRS)

- (A) one channel system LED based, 1 channel
- (B) Commercial multi-channel system (Hitachi ETG-4000) Laser based, 52 channels

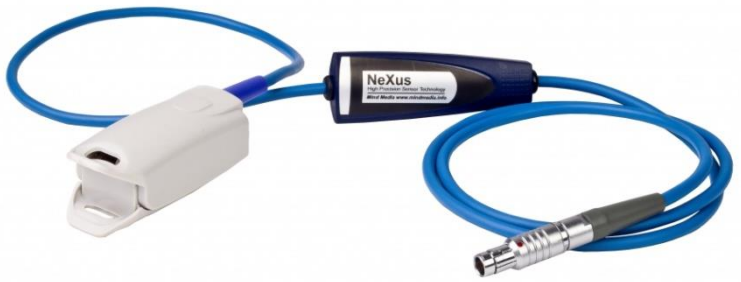
www.opennirs.org



Heart Rate Variability



Blood Volume Pulse (BVP)
Ear or Fingerclip Sensor

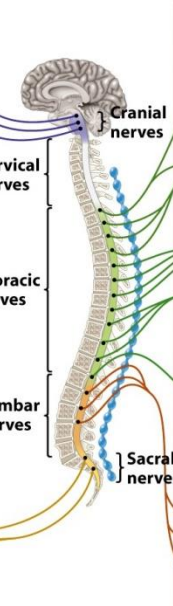


PARASYMPATHETIC NERVES
"Rest and digest"

- Constrict pupils
- Stimulate saliva
- Slow heartbeat
- Constrict airways
- Stimulate activity of stomach
- Inhibit release of glucose; stimulate gallbladder
- Stimulate activity of intestines
- Contract bladder
- Promote erection of genitals

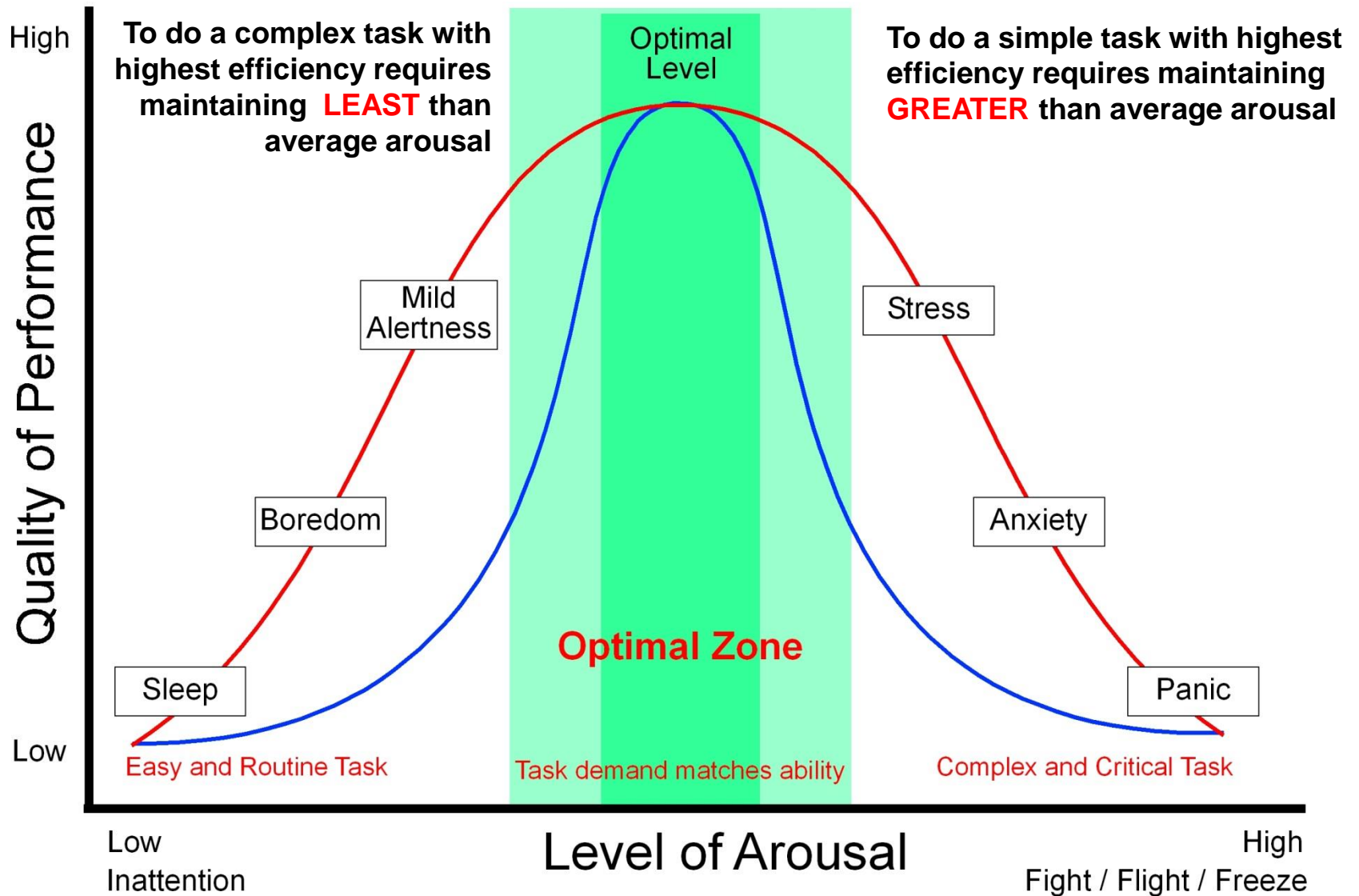
SYMPATHETIC NERVES
"Fight or flight"

- Dilate pupils
- Inhibit salivation
- Increase heartbeat
- Relax airways
- Inhibit activity of stomach
- Stimulate release of glucose; inhibit gallbladder
- Inhibit activity of intestines
- Secrete epinephrine and norepinephrine
- Relax bladder
- Promote ejaculation and vaginal contraction



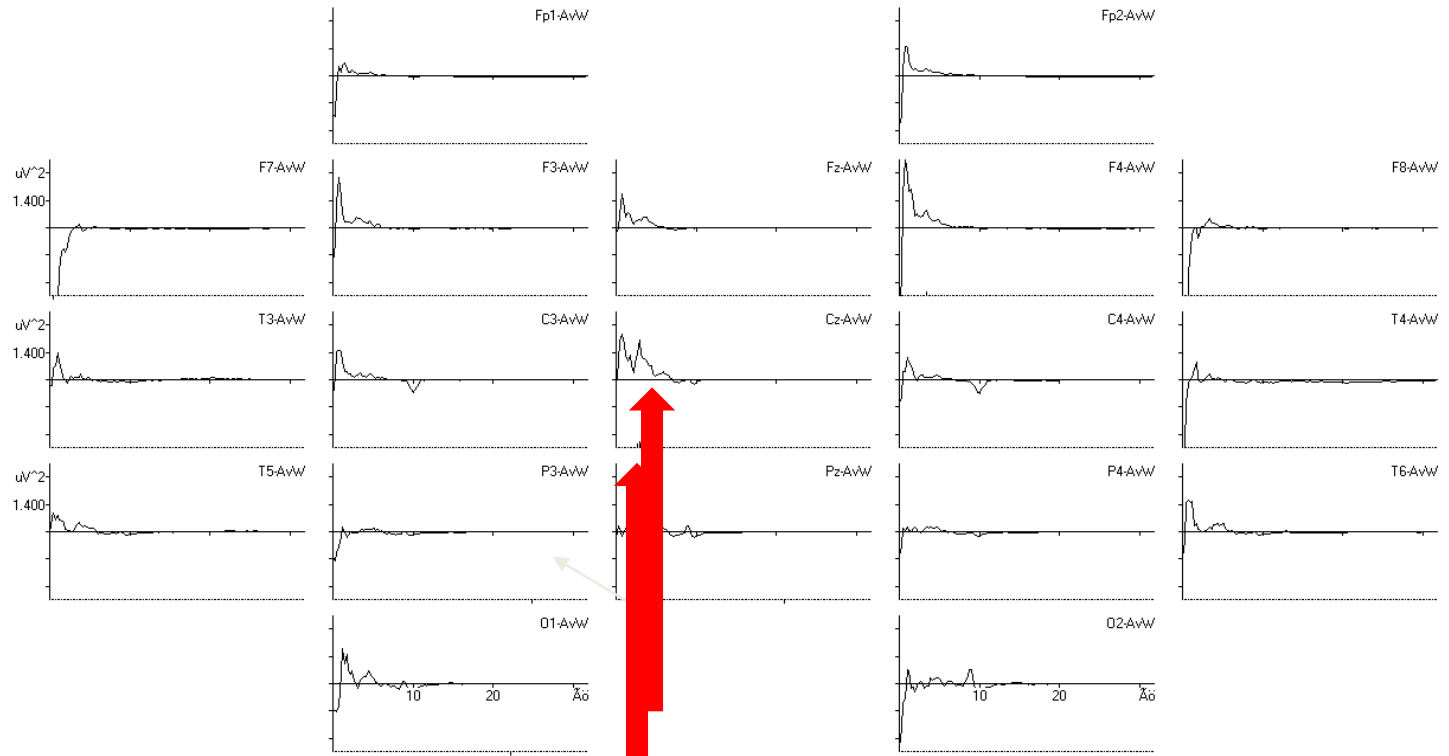
www.qeeg.co.uk

Yerkes-Dodson Law Performance Arousal Curve



Yerkes RM, Dodson JD (1908). "The relation of strength of stimulus to rapidity of habit-formation".
Journal of Comparative Neurology and Psychology 18: 459–482.

Type 1: Increased theta in frontal-central cortex



Sig. $p=0.05$

Comparison with Normative database

