

Università degli Studi di Trieste

Corso di Laurea Magistrale in
INGEGNERIA CLINICA

qEEG

**Corso di Complementi di Analisi di Segnali
Biomedici**

Modulo NEUROSEGNALI

Docente Sara Renata Francesca MARCEGLIA



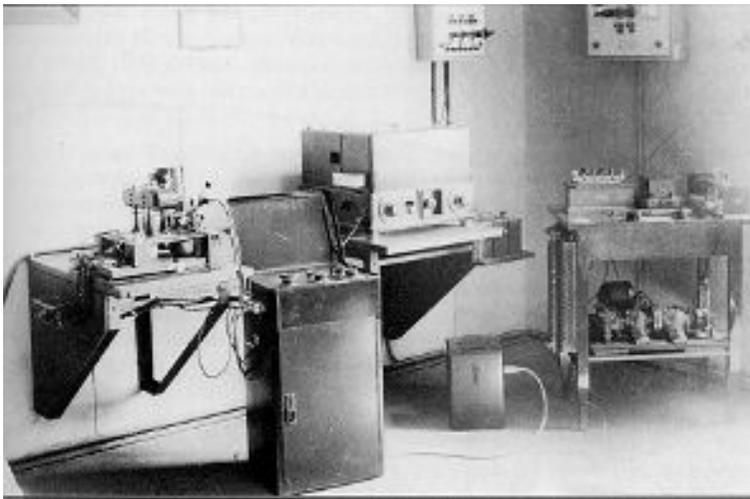
Dipartimento di Ingegneria e Architettura



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EEG - ORIGINE

- 1875: Richard Canton – Primo a registrare l'attività elettrica del cervello. Osserva delle fluttuazioni dell'attività elettrica correlate all'attivazione delle funzioni cerebrali.
- 1920: Hans Berger – Prima registrazione del segnale EEG. Scopre le “onde cerebrali”

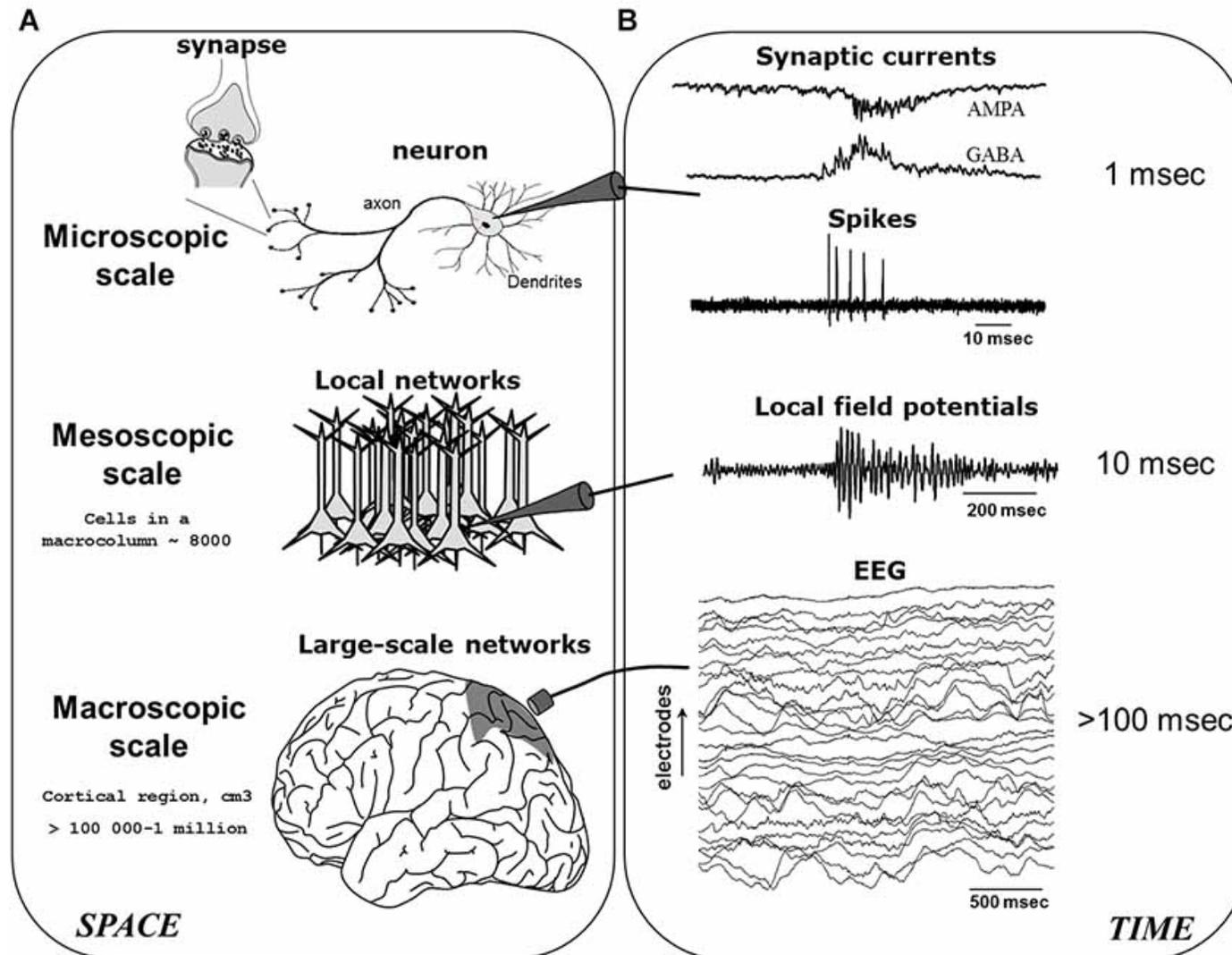


Berger's EEG recording apparatus



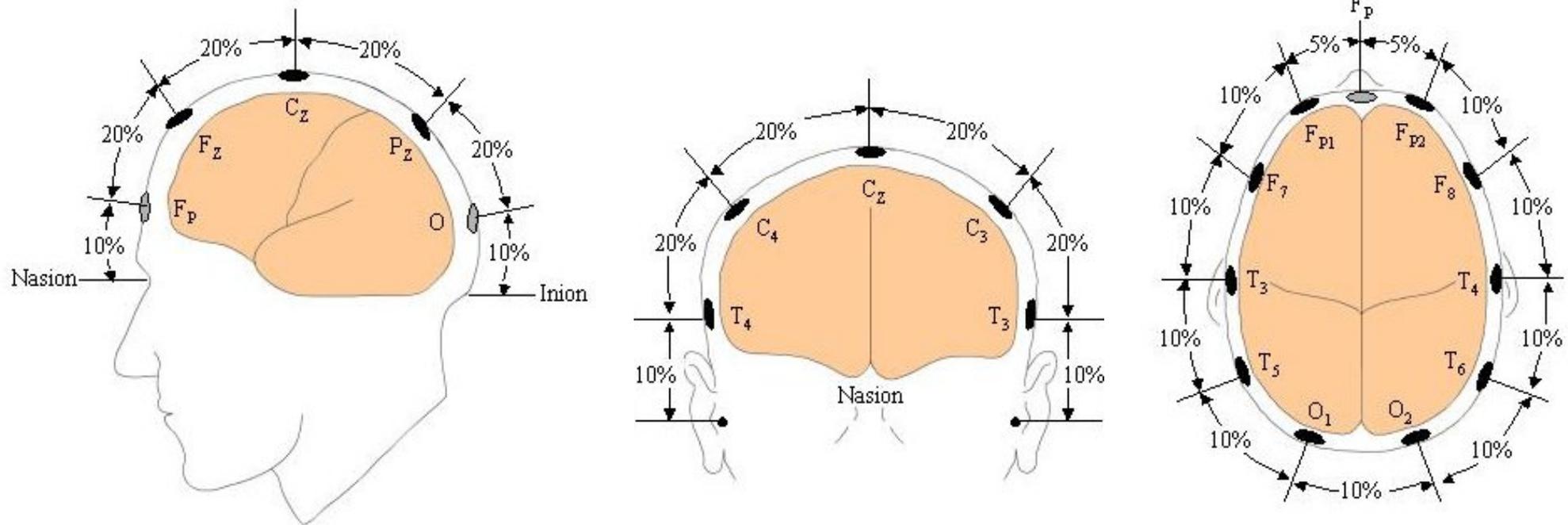
Berger's electrode cap

GENERAZIONE DEL EEG



EEG signals are generated by the integration of neural activity at multiple spatial (A) and temporal (B) scales.

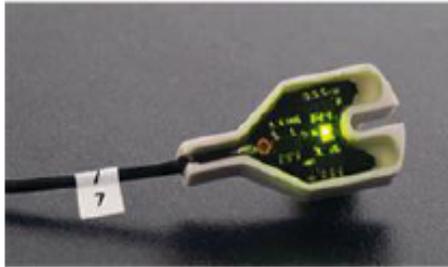
ACQUISIZIONE DEL SEGNALE



Potenziale elettrico relativo alla attività cerebrale registrato sullo scalpo in posizioni standard (sistema 10/20)

Ampiezza: 50 - 100 μ V Banda: 1 - 50 Hz

ESEMPI DI INTERFACCIA



- Minimo 19 elettrodi

SISTEMA DI ACQUISIZIONE



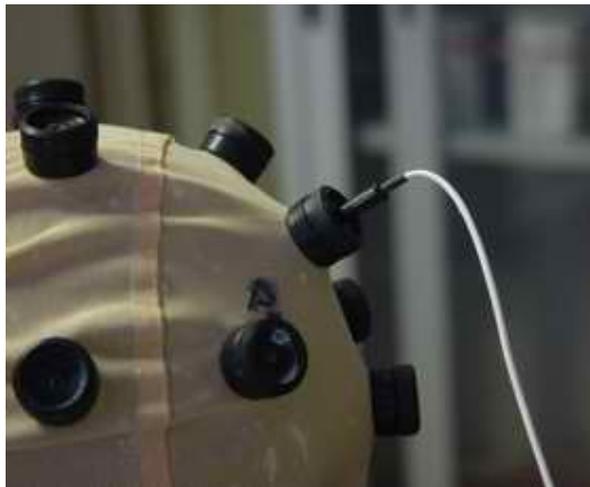
cute sgrassata con alcool, per
diminuire l'impedenza del
circuito



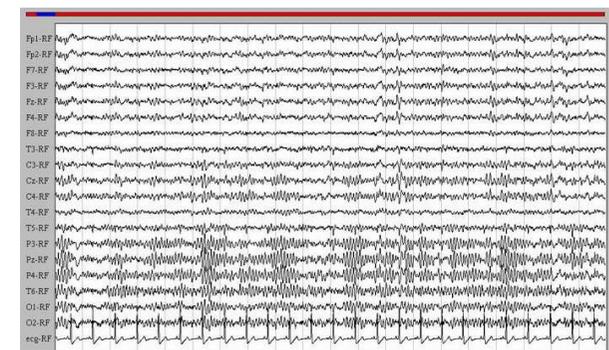
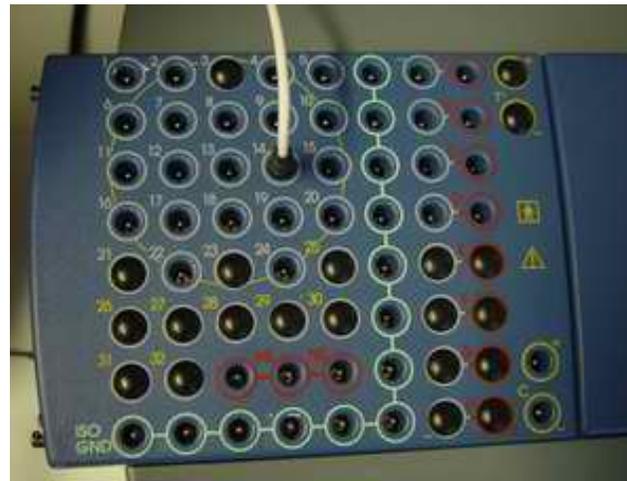
pasta conduttrice applicata
sull'elettrodo



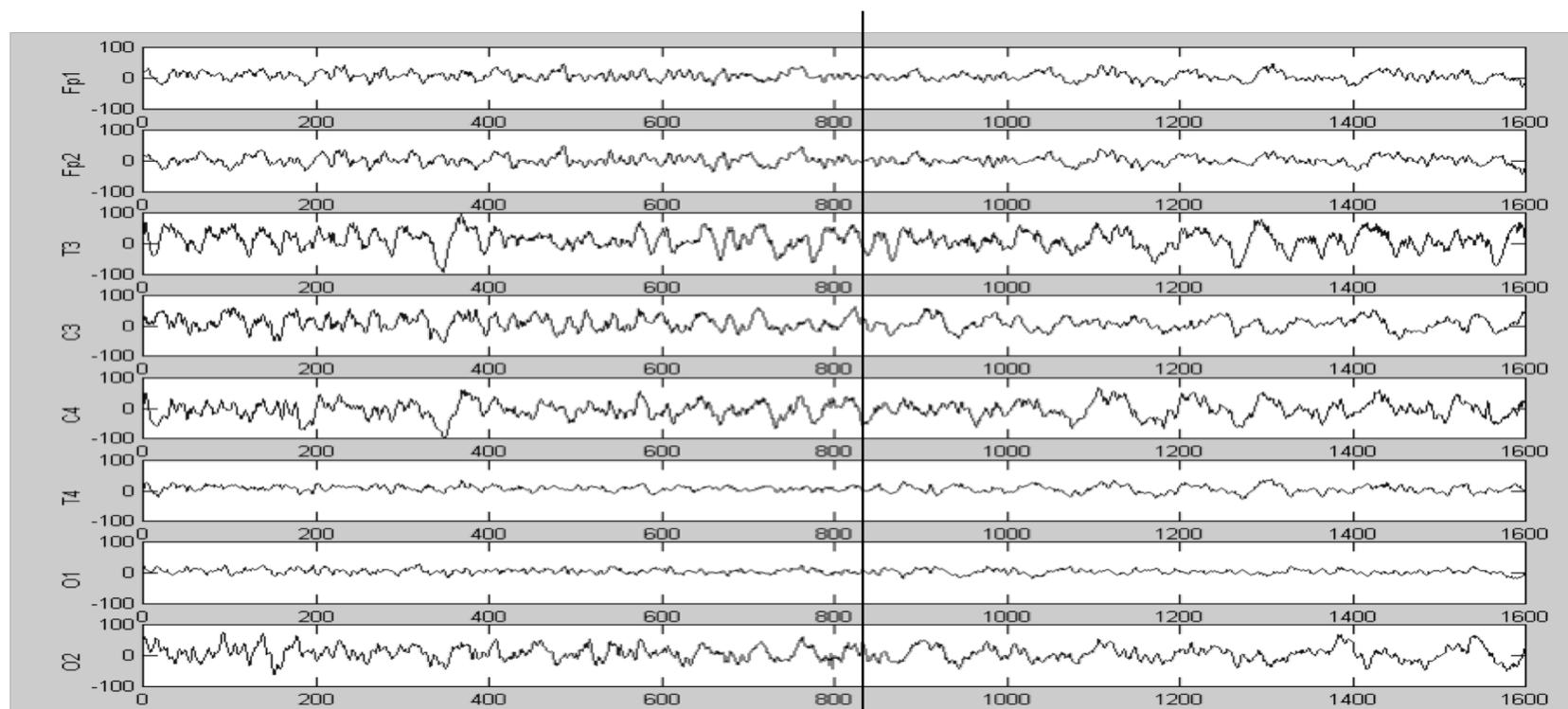
elettrodo viene avvitato in
posizione, sistema 10-20



cavo dell'elettrodo connesso all'elettrodo stesso e alla testina
dell'elettroencefalografo



Sofferenza cerebrale da scarsa ossigenazione



↑
tracciato normale

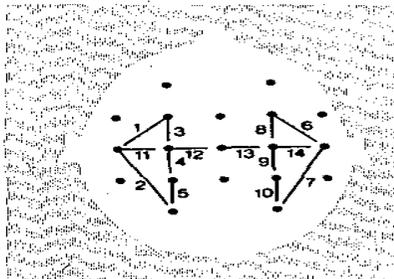
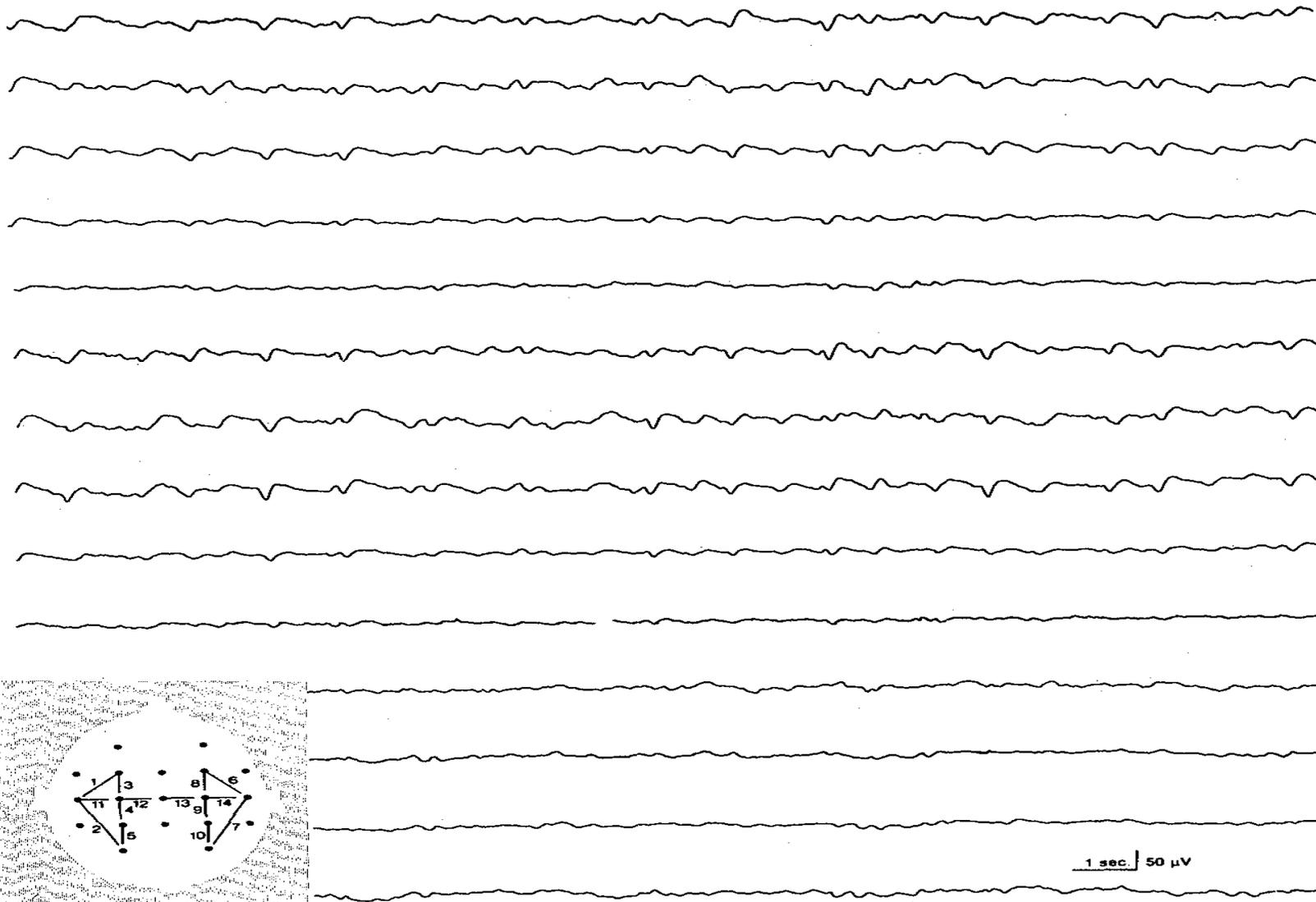
↓
**clampaggio
della
carotide**

←
comparsa di onde lente



ALTERAZIONI DELLA MORFOLOGIA

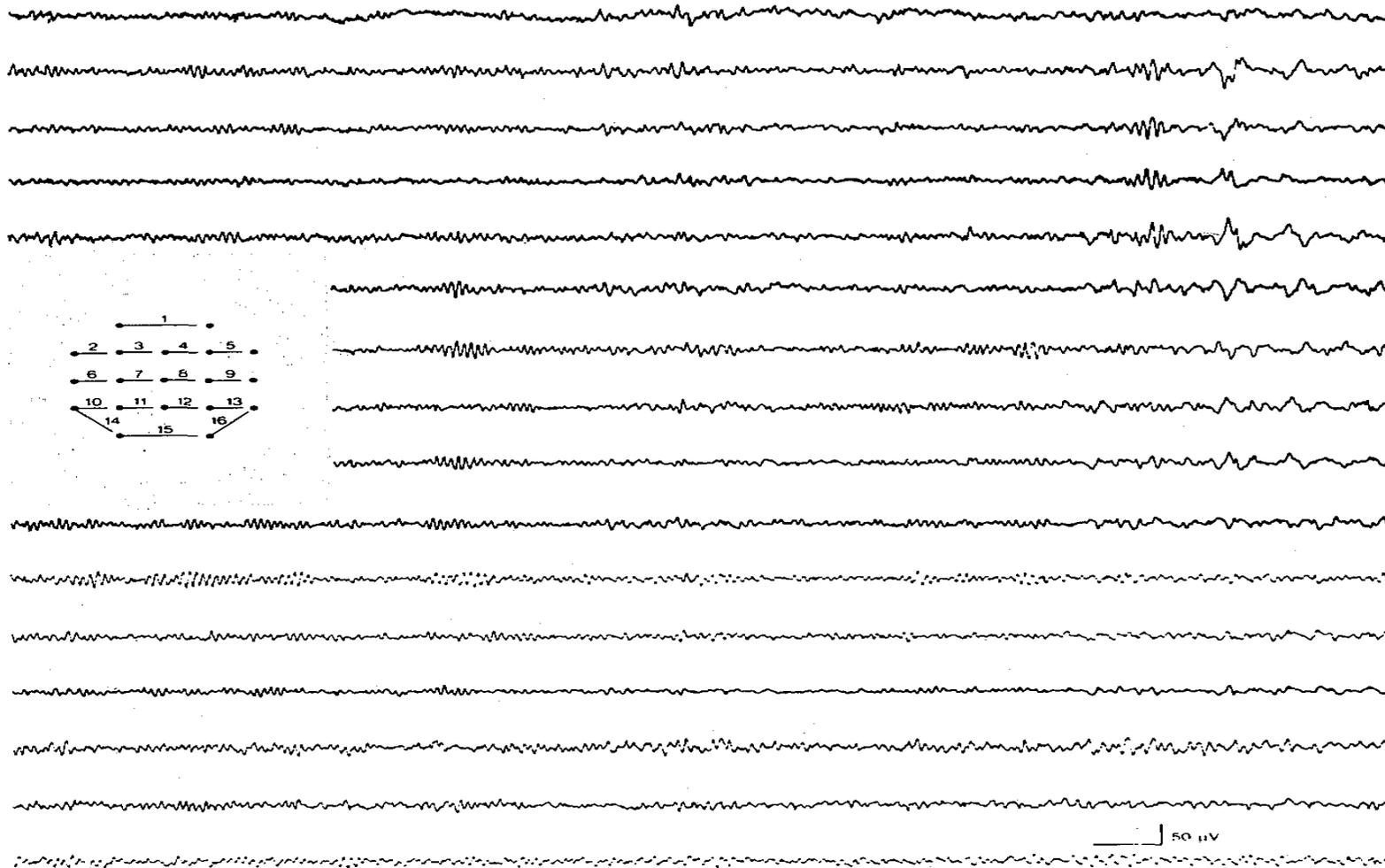
Coma profondo da prolungato arresto cardiaco





EEG E SONNO

Addormentamento fisiologico (soggetto adulto normale)



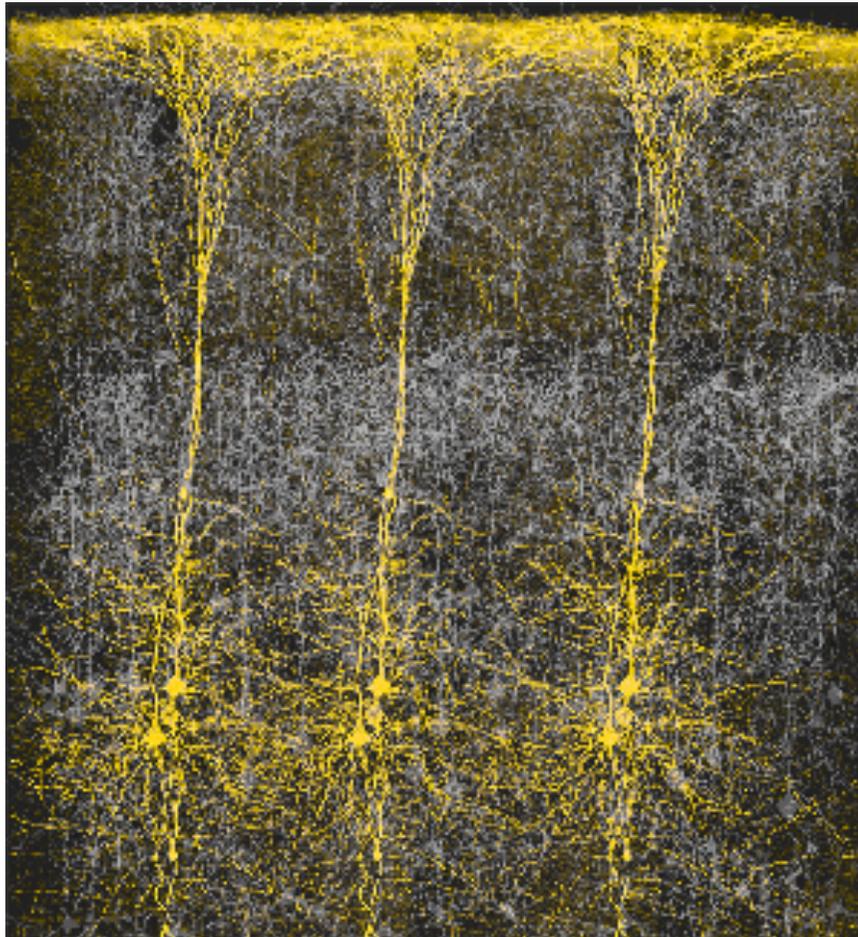
ESEMPIO



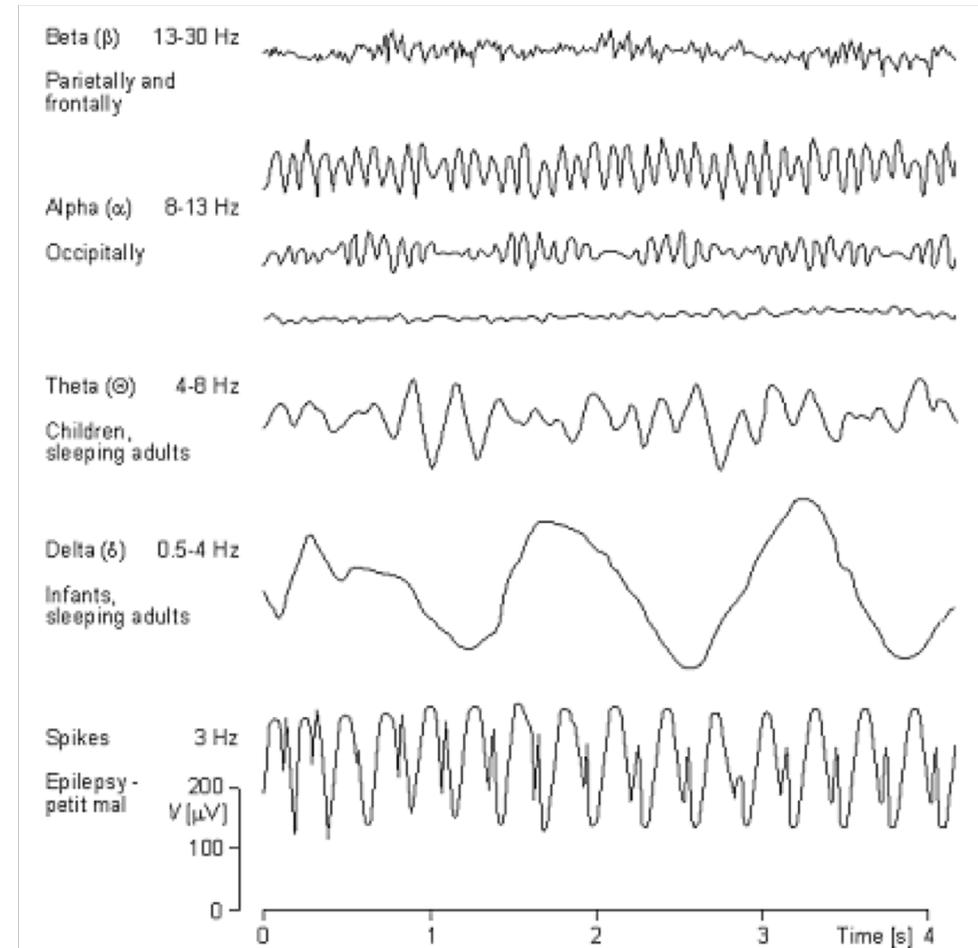
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<https://www.youtube.com/watch?v=XMizSSOejg0>

RITMI EEG

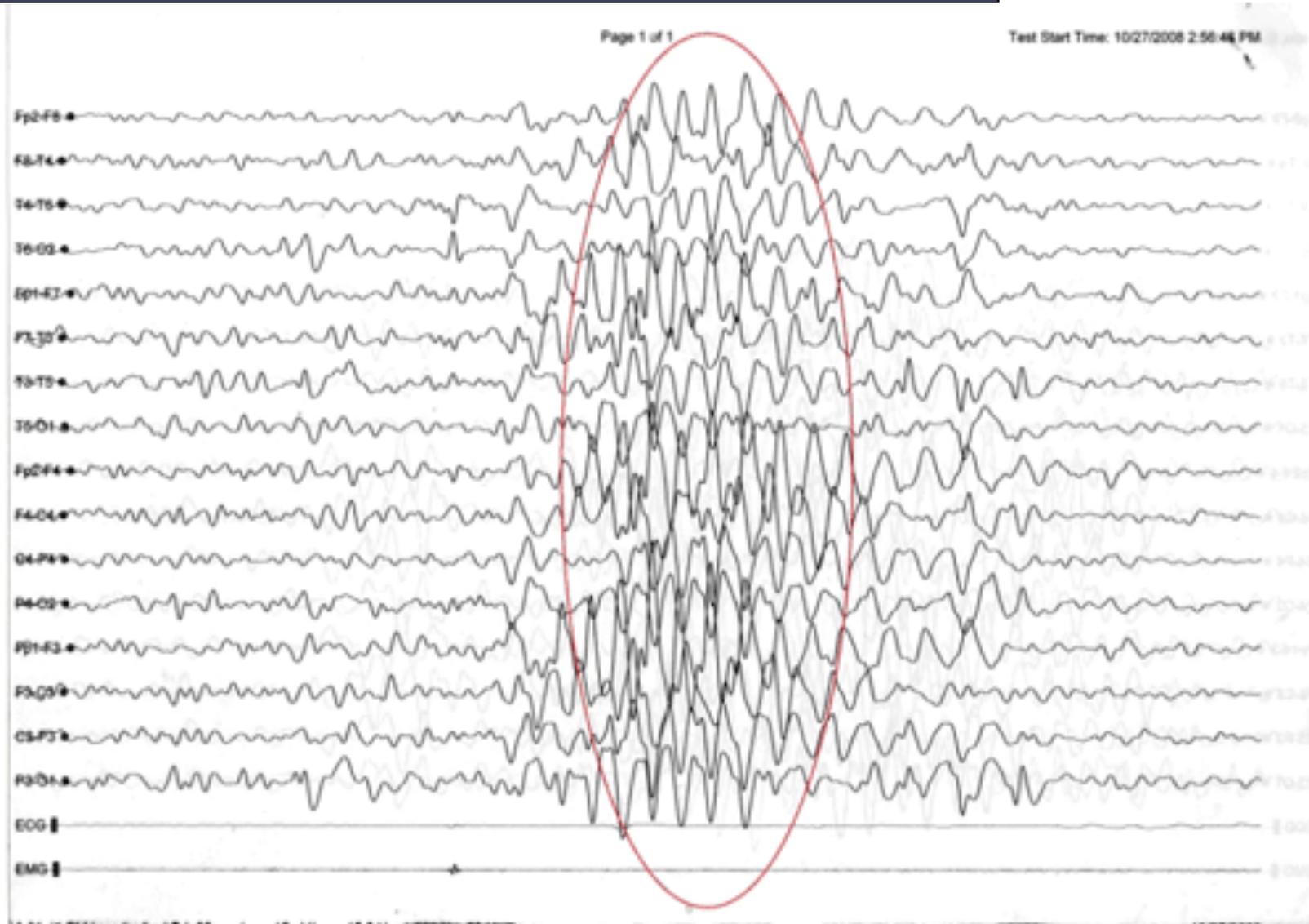


[http://domino.watson.ibm.com/comm/pr.nsf/pages/rscd.neurons_picd.html/\\$FILE/Three%20Golden%20Columns_s.bmp](http://domino.watson.ibm.com/comm/pr.nsf/pages/rscd.neurons_picd.html/$FILE/Three%20Golden%20Columns_s.bmp)



<http://www.biogetic.com/img/eeg2.gif>

ANALISI QUALITATIVA



QUANTITATIVE EEG



- **Electroencephalogram(EEG)**-brain related electrical potentials recorded from the scalp
- **Quantitative EEG(qEEG)**-Mathematical processing of digitally recorded EEG in order to highlight specific waveform components, transform the EEG into a format or domain that elucidates relevant information, or associate numerical results with the EEG data for subsequent review or comparison



Reliability of quantitative EEG features

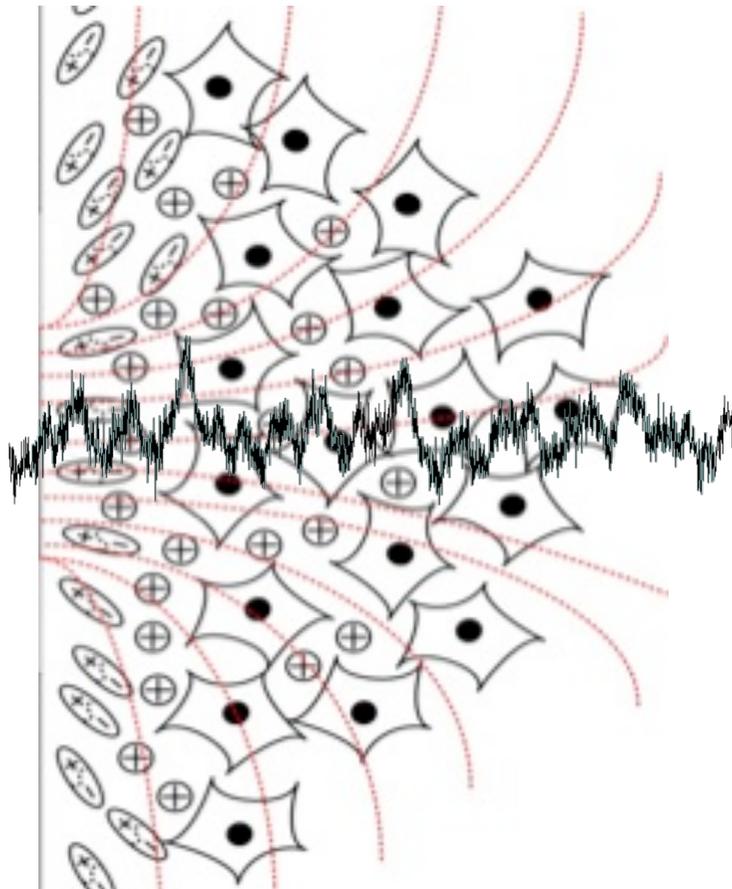
Steinn Gudmundsson ^{a,c}, Thomas Philip Runarsson ^b, Sven Sigurdsson ^a,
Gudrun Eiriksdottir ^c, Kristinn Johnsen ^{c,*}

^a Department of Computer Science, University of Iceland, Reykjavik, Iceland

^b Science Institute, University of Iceland, Reykjavik, Iceland

^c Mentis Cura, Grandagardi 7, 101 Reykjavik, Iceland

ANALISI DEL SEGNALE

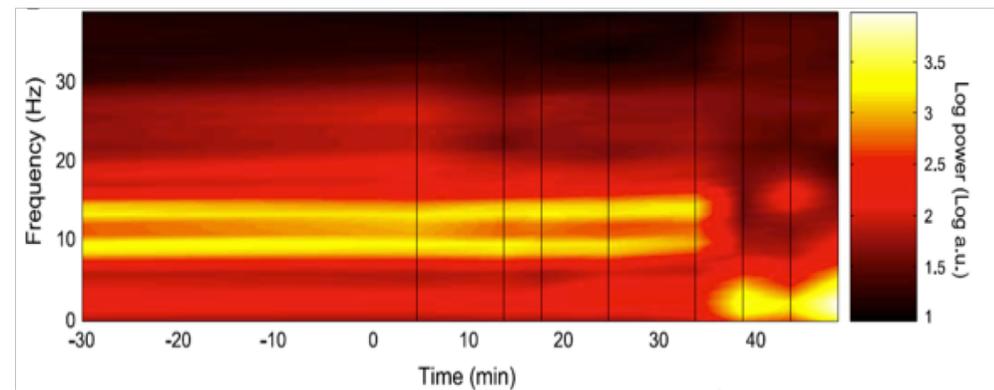
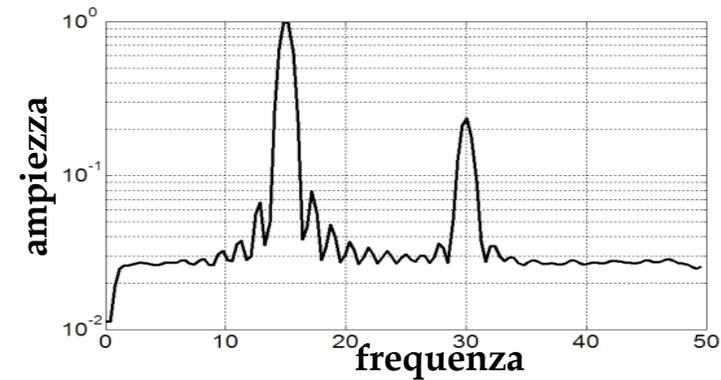
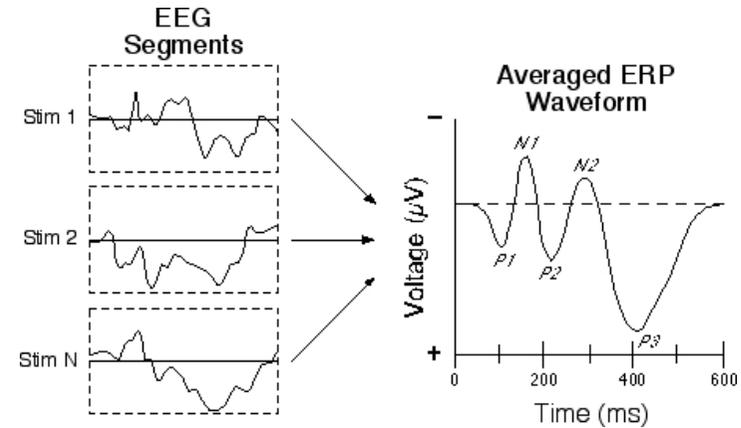


Attività sincrona di popolazioni di neuroni → produce oscillazioni

DOMINIO DEL
TEMPO

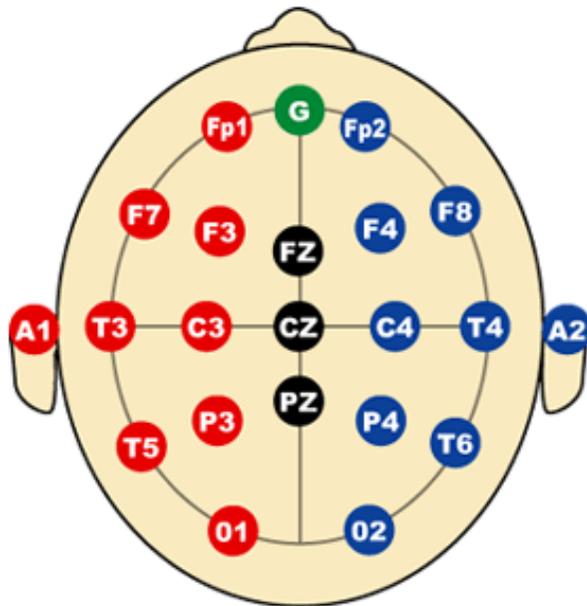
DOMINIO DELLA
FREQUENZA

ANALISI TEMPO-
FREQUENZA



BRAIN MAPPING: LE AREE CEREBRALI

Ogni regione cerebrale può essere associata con una specifica funzione



International 10-20 System of Electrode Placement

BRODMANN AREAS

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

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

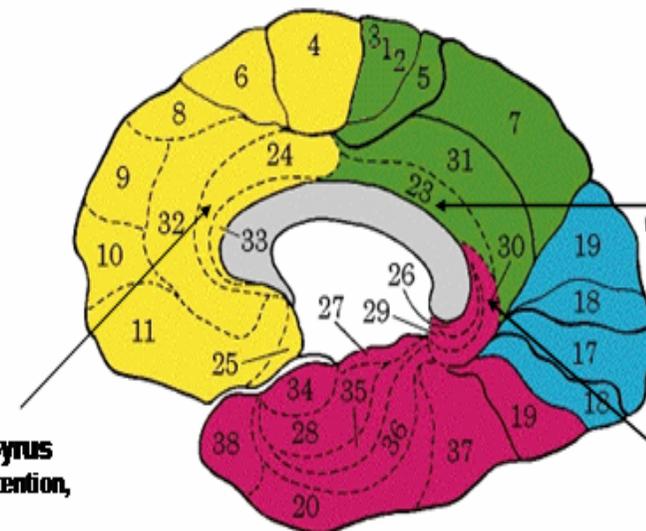
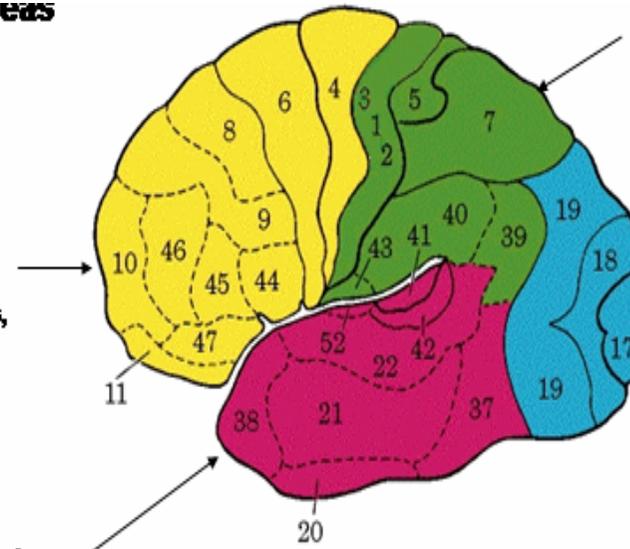
Anterior Cingulate Gyrus
Volitional movement, attention,
long term memory

Parietal Lobe
somatosensory perception integration
of visual & somatospatial information

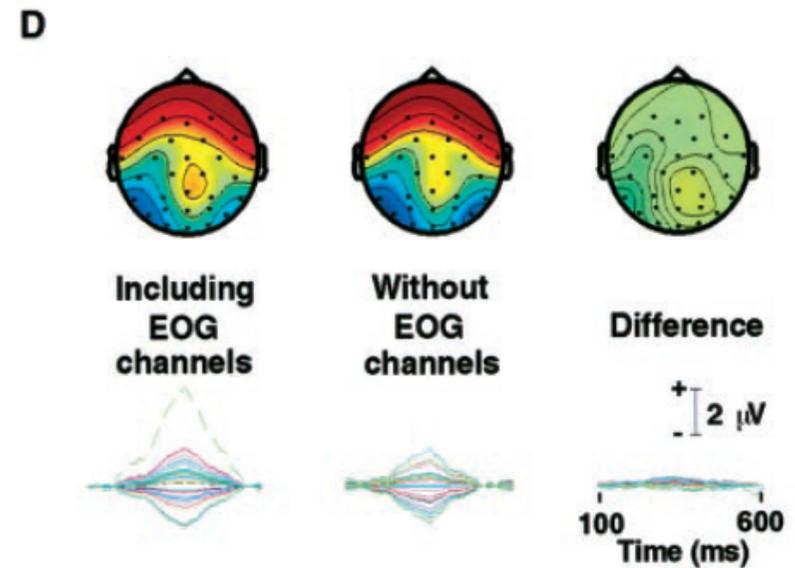
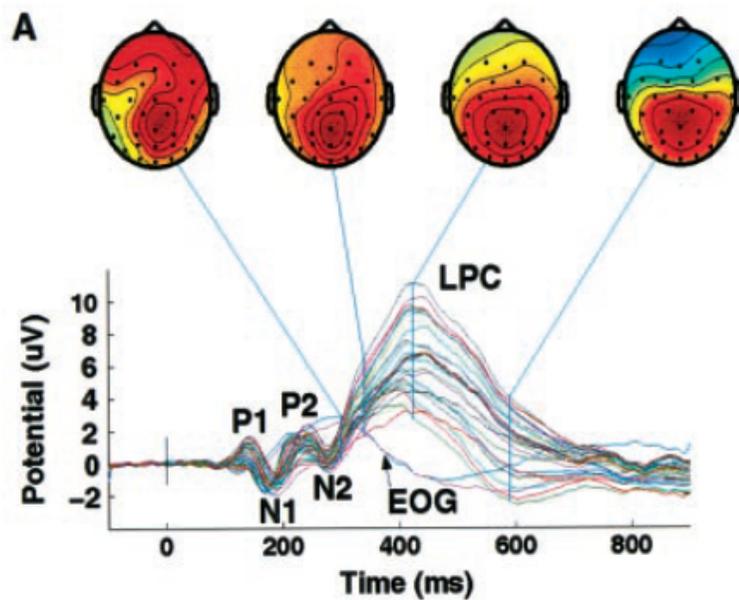
Occipital Lobe
Visual perception &
Spatial processing

Posterior Cingulate
attention, long-term
memory

Parahippocampal Gyrus
Short-term memory, attention



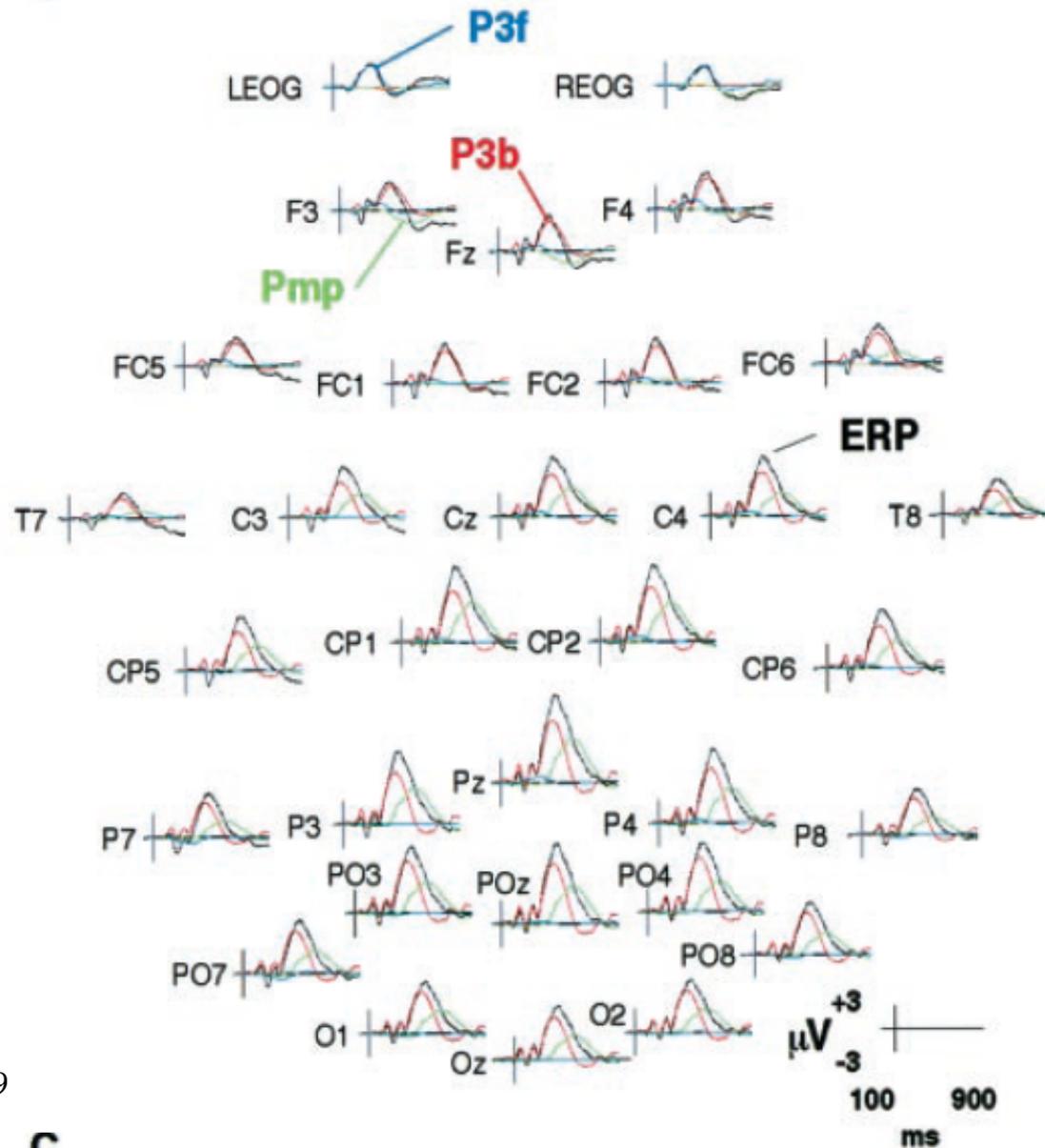
BRAIN MAPPING: IL DOMINIO DEL TEMPO



BRAIN MAPPING: IL DOMINIO DEL TEMPO



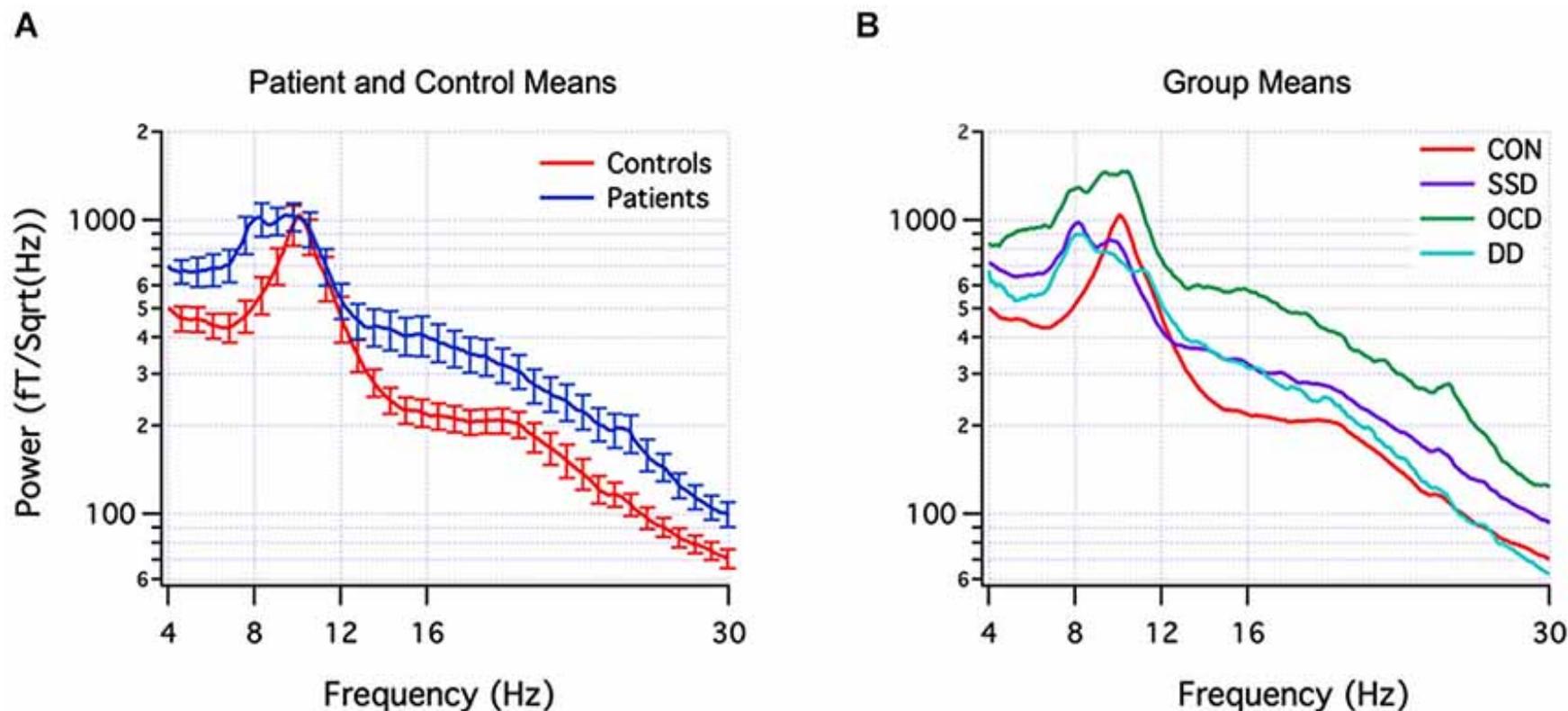
B



Makeig et al, 1999

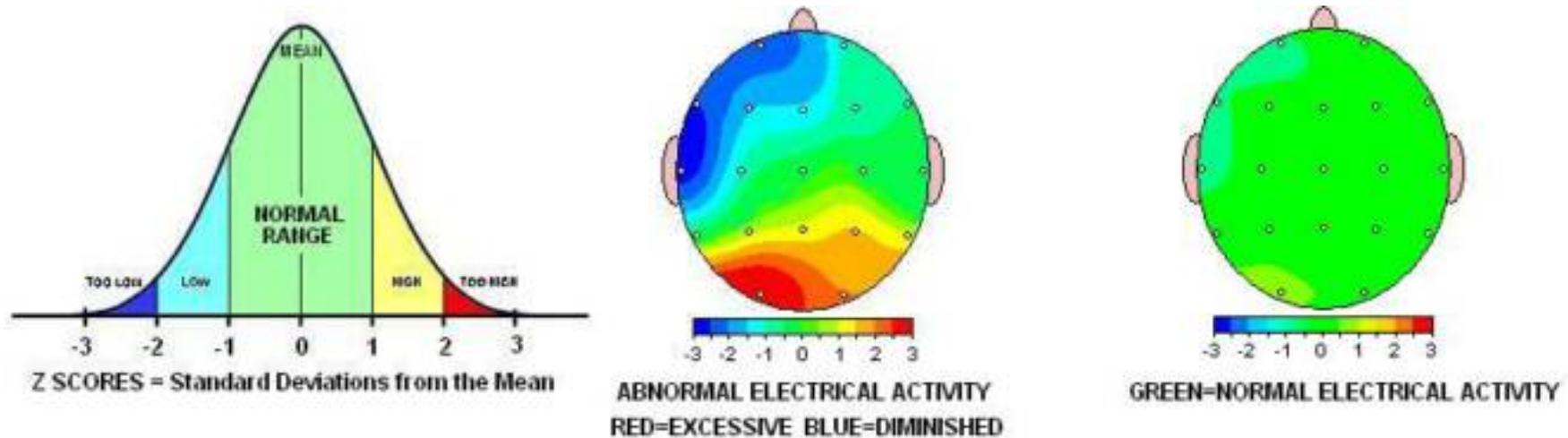
C

BRAIN MAPPING: IL DOMINIO DELLE FREQUENZE



EEG spectral signatures of healthy and psychiatric populations. (Panel A) Mean (\pm SEM) EEG power spectra of healthy control subjects (red) and psychiatric patients (blue). **(Panel B)** Mean subgroup spectra for controls (CON) (red, $n = 18$), schizophrenia spectrum disorder (SSD) (purple, $n = 14$), obsessive-compulsive disorder (OCD) (green, $n = 10$), depression disorder (DD) (light blue, $n = 5$).

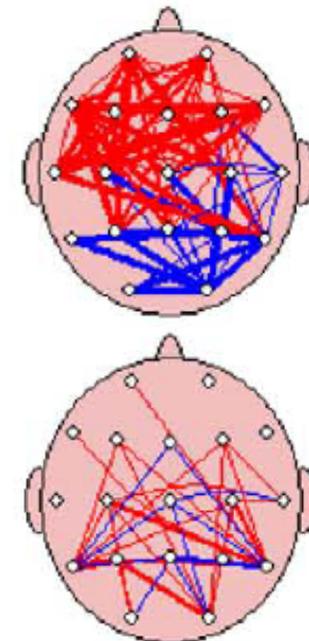
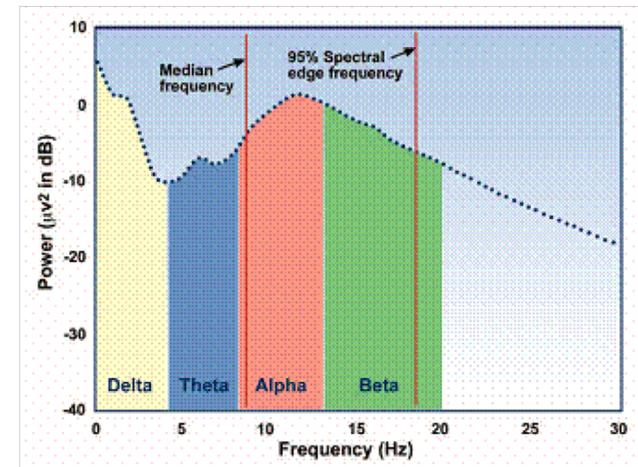
Z-SCORES: DISTINZIONE NORMALE/PATOLOGICO



- È necessario definire dei range di normalità → derivano dalla popolazione dei controlli
- Z-score: rappresenta la distanza normalizzata (in numero di deviazioni standard) di un certo valore rispetto alla media ed è definito nell'intervallo $[-3 ; 3]$
- Le diverse patologie possono essere definite in termini di differenza di attività EEG nelle diverse aree cerebrali alle diverse frequenze

DEFINIZIONI

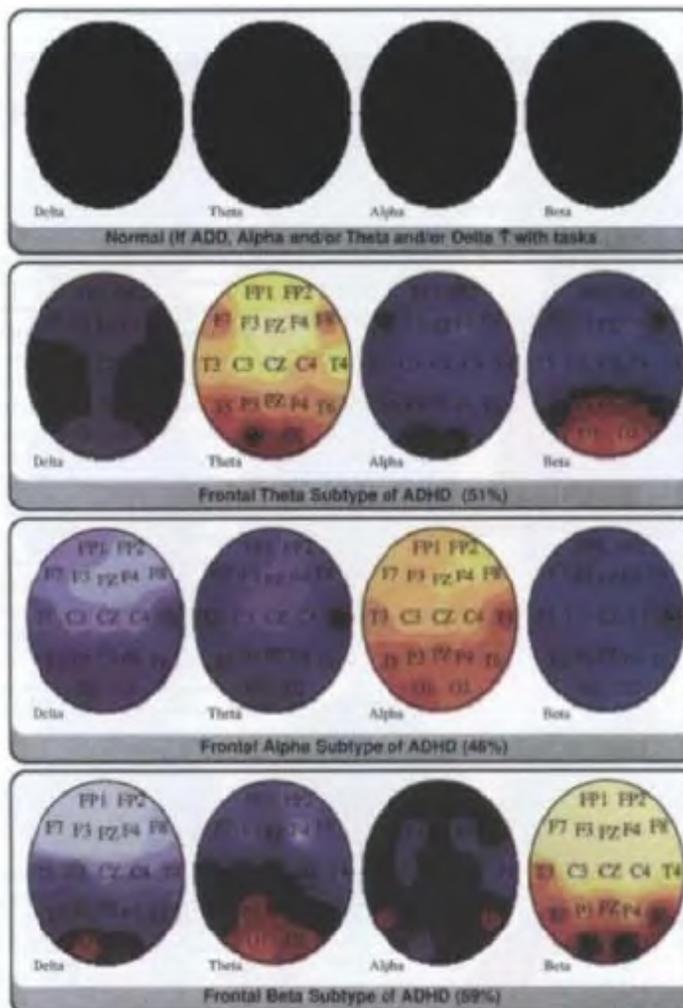
- **Potenza Assoluta (absolute power):** quantità di segnale EEG in una certa banda (integrale della potenza di ciascuna frequenza in una certa banda)
- **Potenza Relativa (relative power):** contributo all'EEG di una certa banda rispetto alla potenza totale (rapporto tra la potenza assoluta in una banda e la potenza totale)
- **Coerenza (coherence):** relazione di fase (sincronizzazione) tra oscillazioni registrate in diversi elettrodi (misura della relazione tra oscillazioni in diverse aree cerebrali)
- **Asimmetria (inter-lead asymmetry):** differenza della potenza in banda tra due siti, normalmente valutata nei due emisferi (destra vs sinistra)



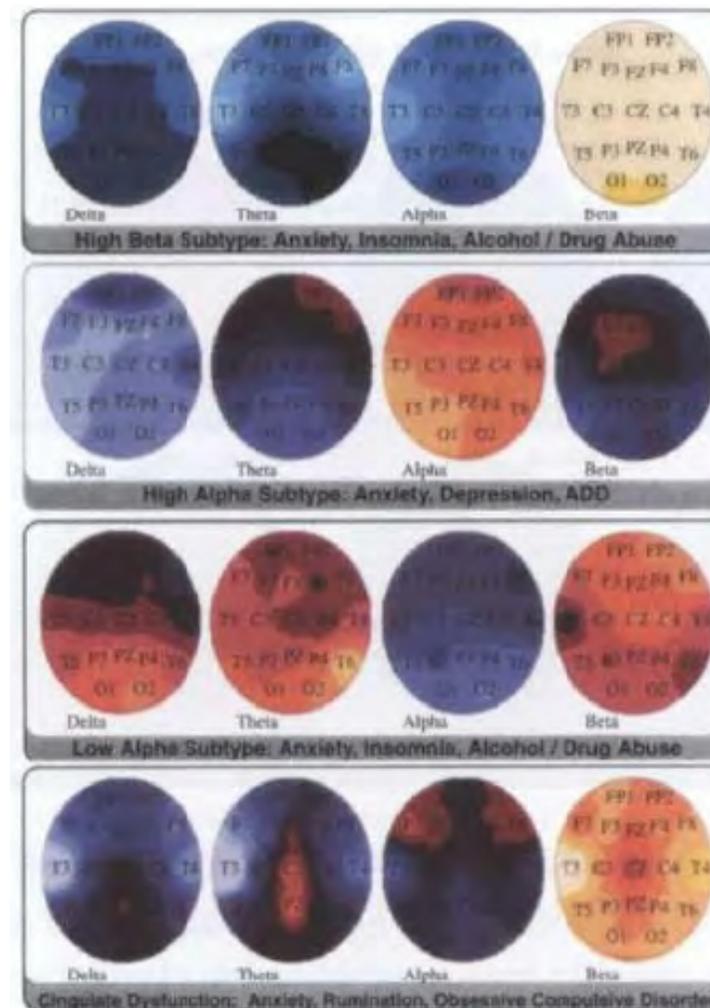
Z-SCORES: ESEMPI



EEG Signatures for ADHD



EEG Signatures for Anxiety Disorders



Article

Clinical Advantages of Quantitative Electroencephalogram (QEEG)–Electrical Neuroimaging Application in General Neurology Practice

J. Lucas Koberda¹, Andrew Moses^{1,2}, Paula Koberda^{1,2}, and Laura Koberda^{1,2}

- 150 qEEGs analizzati per valutare l'utilità clinica (contributo alla diagnosi o al decision-making/trattamento)
- Definiti 5 gruppi principali → epilessia, cefalea, trauma cranico, declino cognitivo, attention deficit disorder (ADD)
- **Il qEEG contribuisce clinicamente nel 95% dei casi**

Clinical EEG and Neuroscience
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DOI: 10.1177/1550059412475291
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EPILESSIA

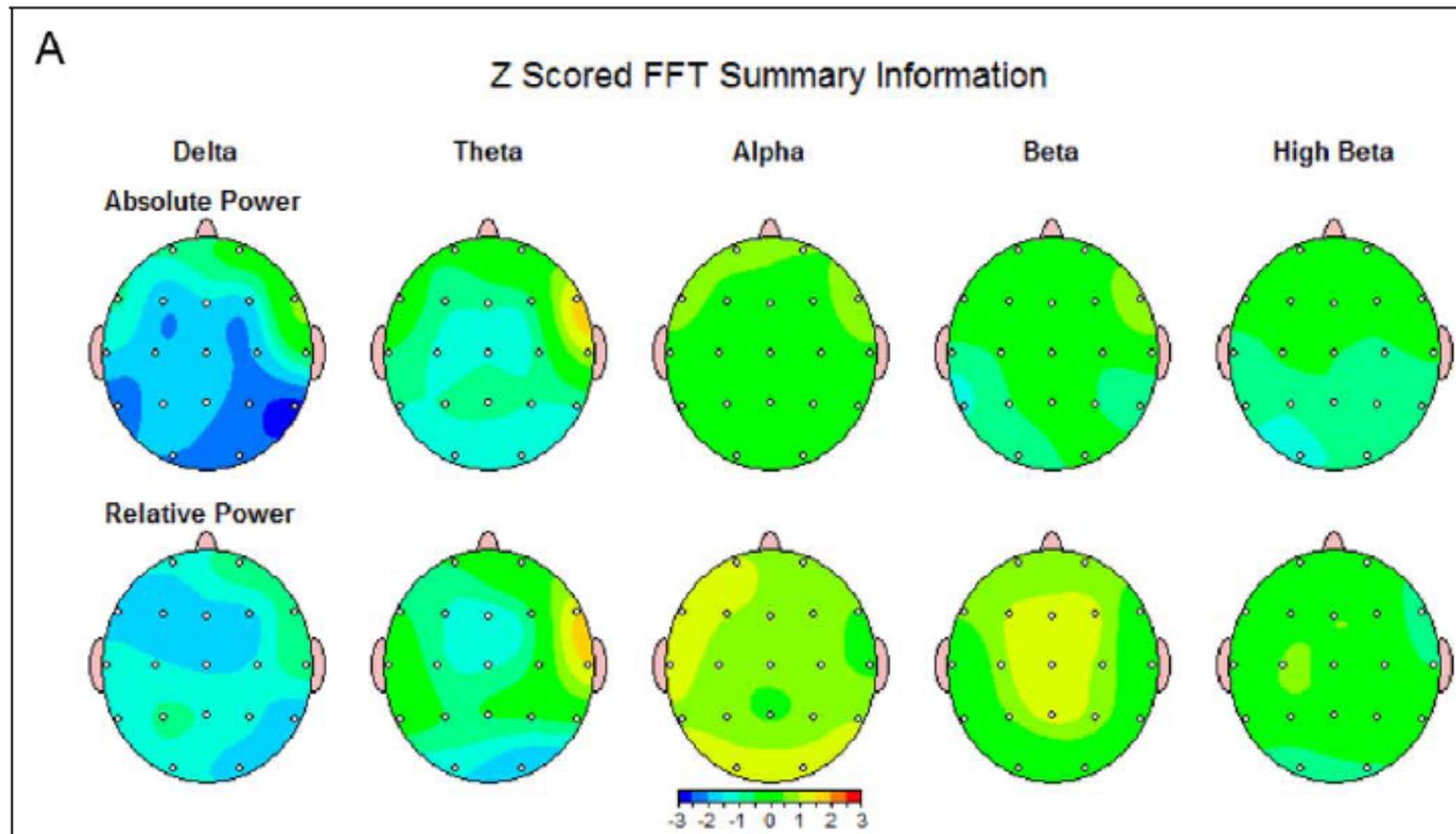
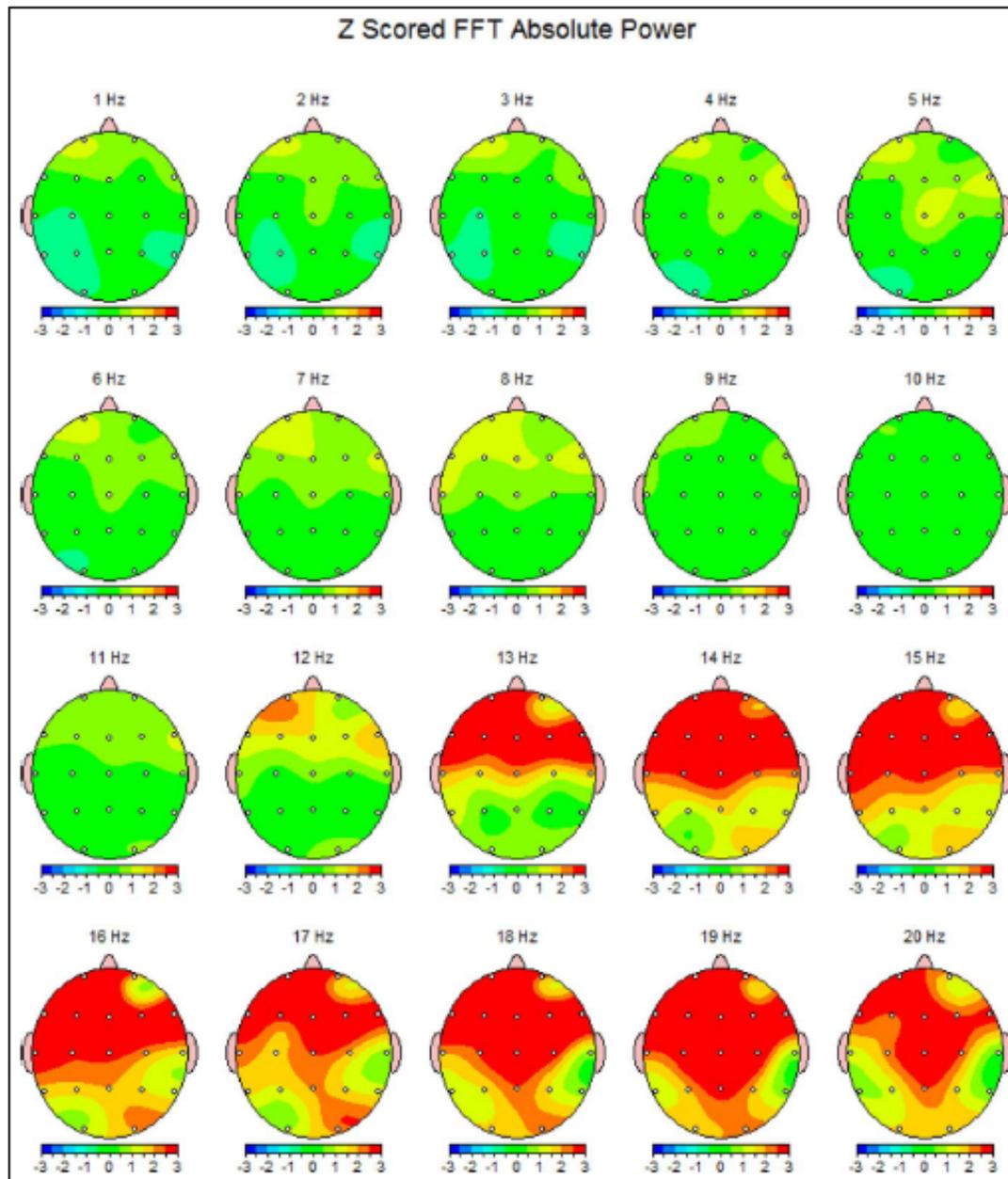


Figure 1. A, Patient with epilepsy had right temporal increase in θ power; second picture from the upper left shows increase in the right temporal θ power, yellow color indicates that this area is between 1 and 2 standard deviations (SDs) from the norm. **B,** Low-resolution electro-

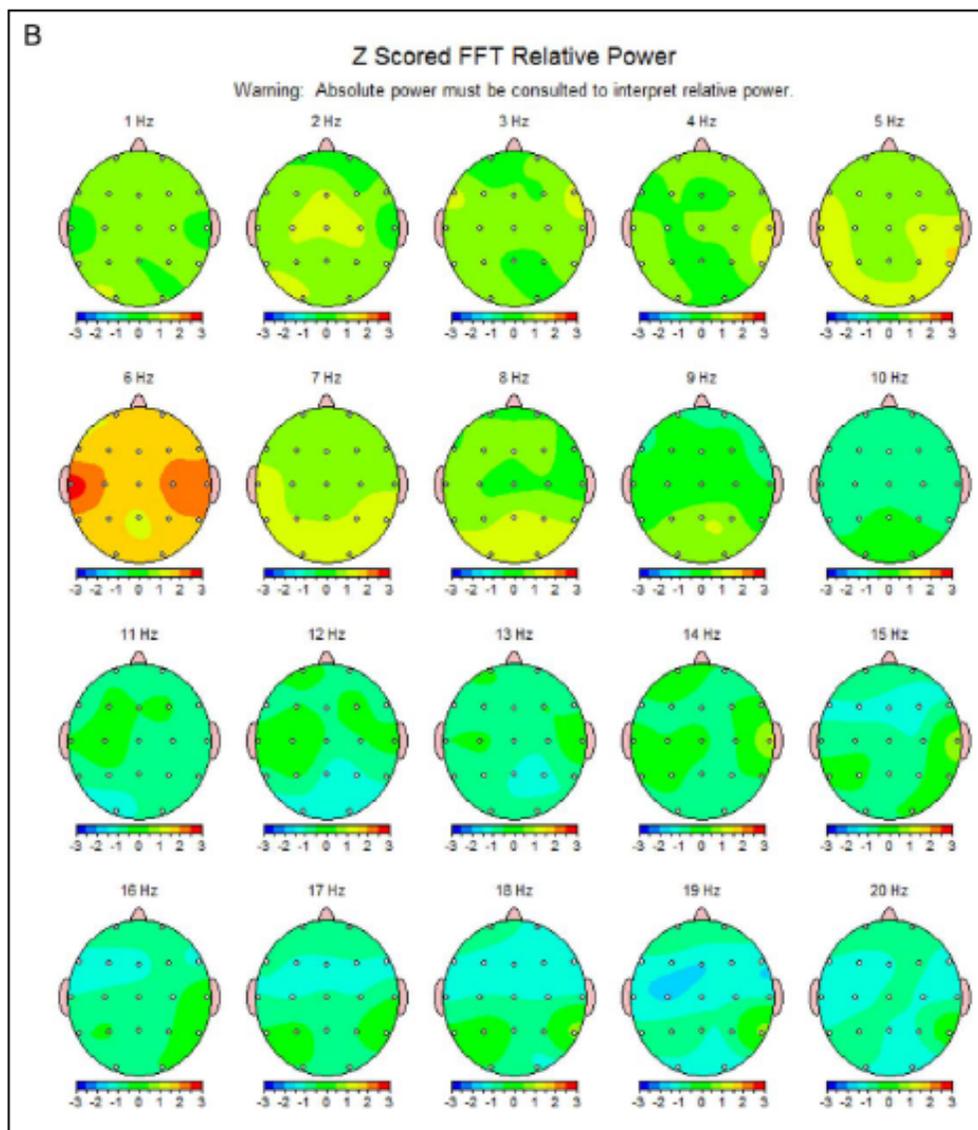
CEFALEA



**Increased absolute
FRONTAL BETA
power** in patient with
chronic headache
(HA); frontal red area
(between 2 and 3
standard deviation
[SD])

in pictures shows 13 to
20 Hz frequency (green
color shows areas
between 0 and 1 SD;
yellow between 1 and 2
SD).

TRAUMA CRANICO



Patient with PCS had **increased bilateral TEMPORAL (6 Hz) THETA power** (at 6 Hz frequency bilateral temporal power is in red indicating it is within 2 to 3 standard deviation [SD] from the norm

DECLINO COGNITIVO

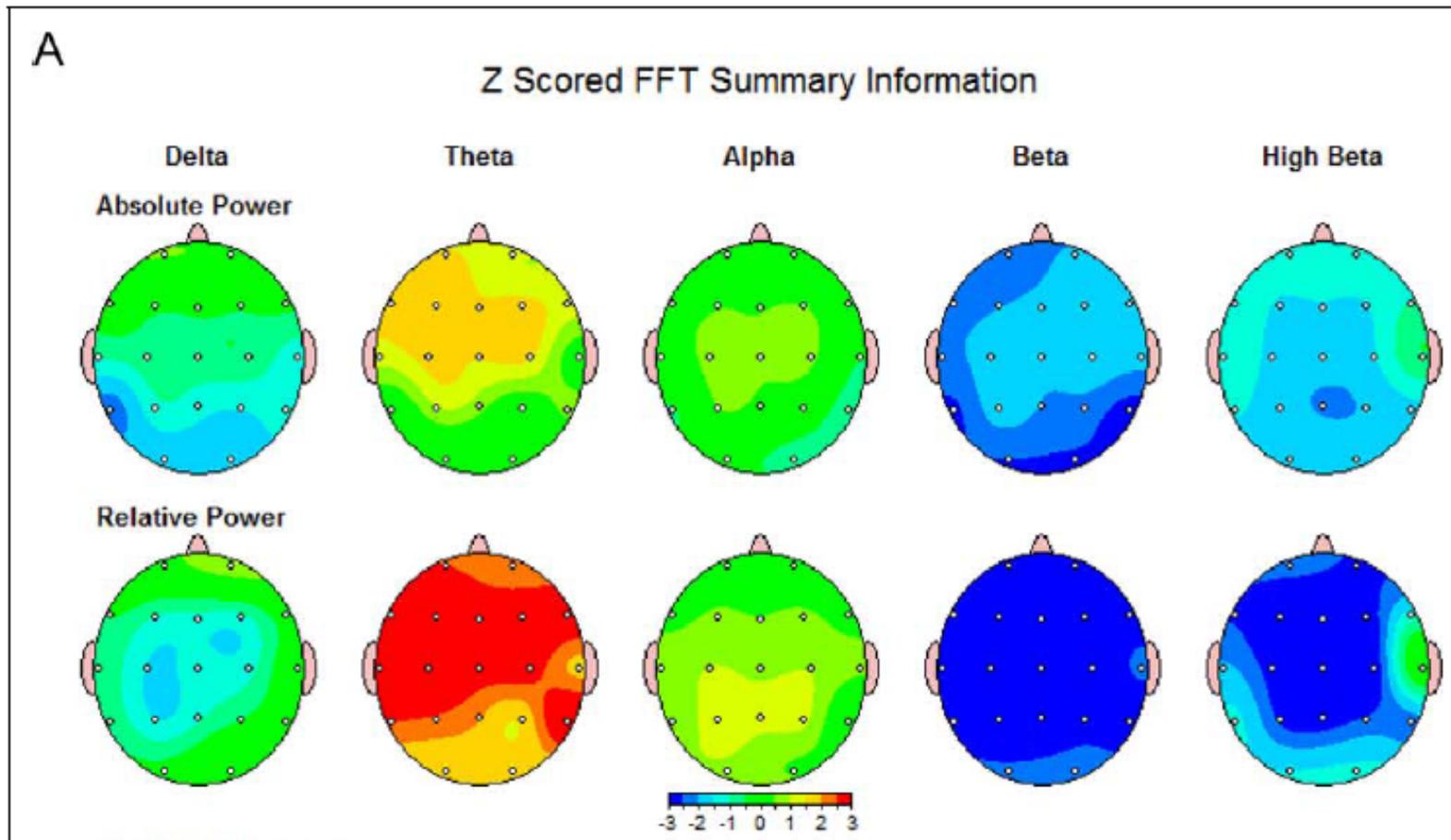


Figure 4. A, Patient with progressive cognitive problems had increased frontotemporal θ power (yellow color is between 1 and 2 standard deviation [SD] in absolute power and red color between 2 and 3 SD in relative power). B, Low-resolution electromagnetic tomography analysis

ATTENTION-DEFICIT DISORDERS

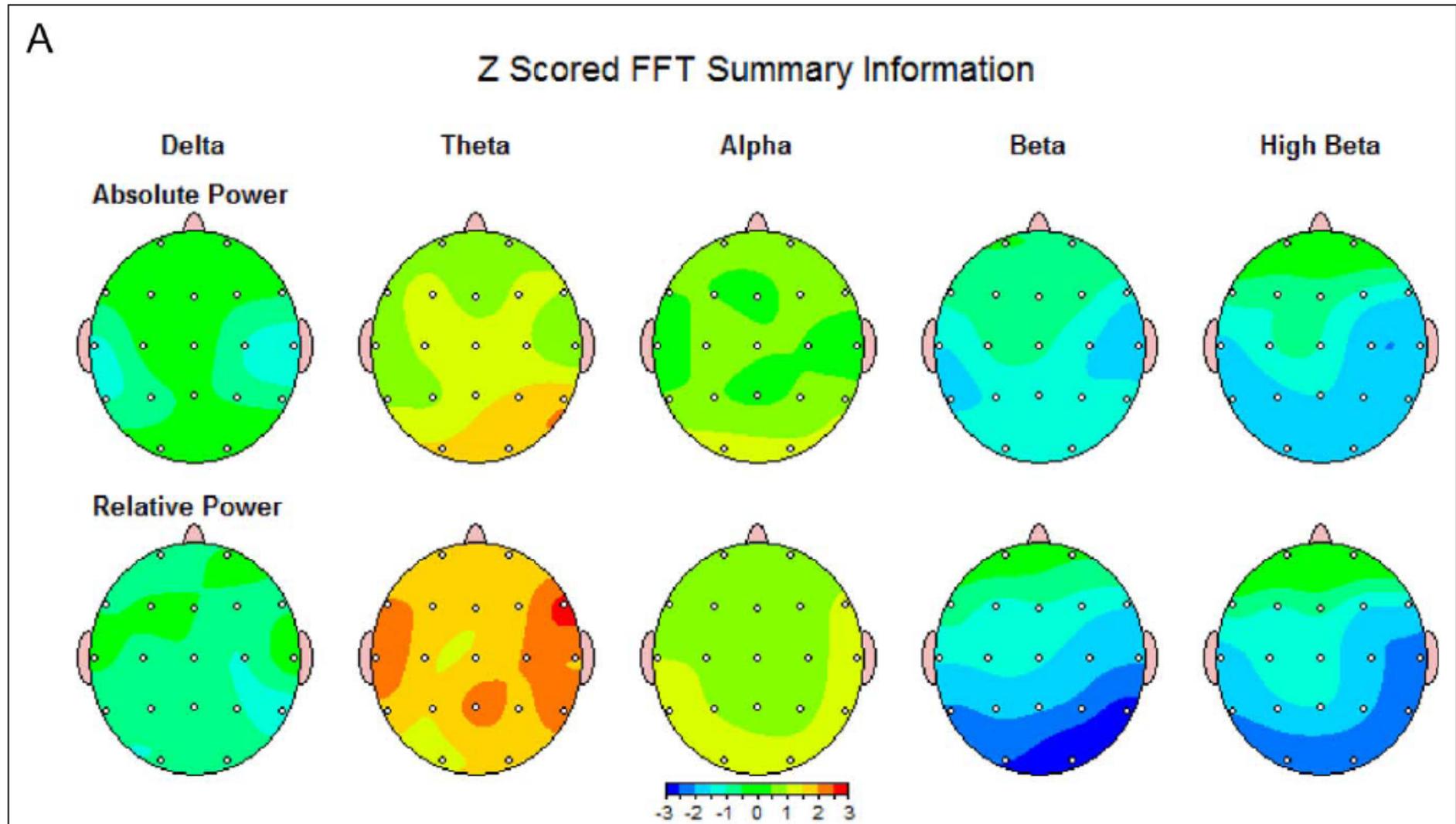


Figure 5. A, Patient with attention deficit disorder (ADD)/Asperger syndrome (AS) showed increased frontotemporal θ power (yellow areas 1-2 standard deviation [SD]; red 2-3 SD). B, Patient with diagnosis of ADD/AS showed increased θ/β ratio (yellow areas 1-2 SD; red areas 2-3

NEUROFEEDBACK



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NEUROFEEDBACK

- “Normalizzazione” dell’attività oscillatoria tramite giochi/esercizi/compiti che variano in base all’ampiezza delle oscillazioni nelle diverse bande
- Il soggetto esegue il compito e ha come feedback un parametro qEEG (tipicamente la potenza assoluta o relativa della banda che risulta non normale)
- Il soggetto impara la strategia mentale per mantenere il valore della banda nel range di normalità

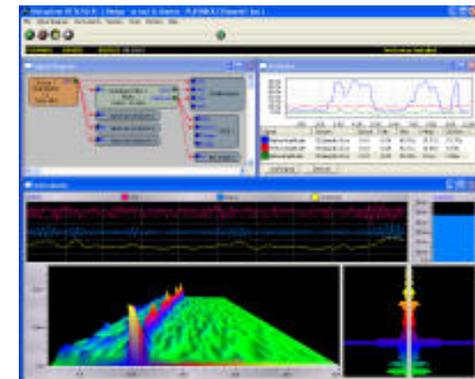
STRUMENTAZIONE PER NEUROFEEDBACK



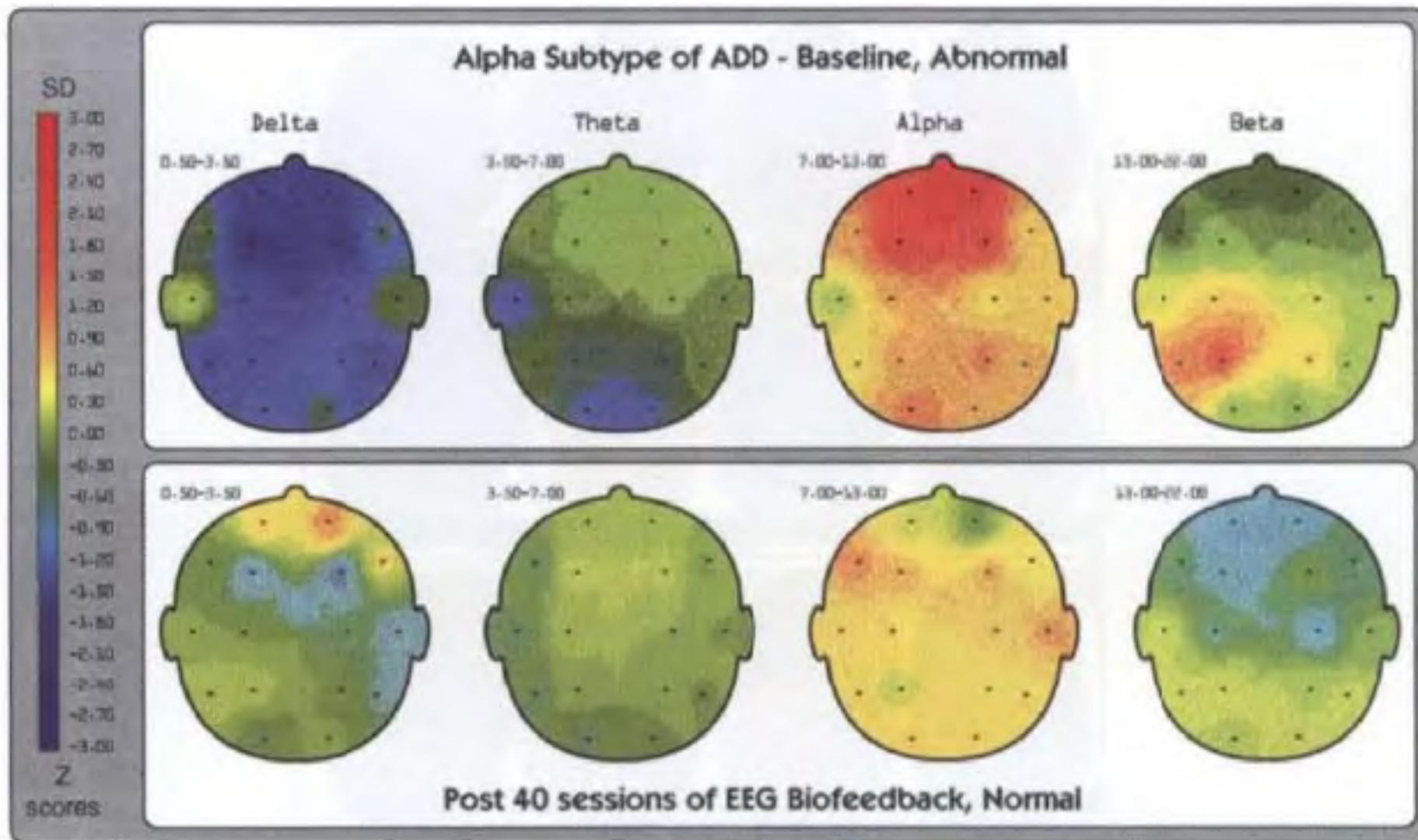
- Hardware
 - Testina EEG
 - Elettrodi/cuffia



- Software
 - Programmi per l'acquisizione, analisi e visualizzazione del segnale EEG
 - Video games, movie player,



OBIETTIVO



UNA STORIA...



https://www.youtube.com/watch?v=hNR_DitnSe4

Chris Kaman's Story

- NBA basketball player for the Clippers
- Diagnosticato di ADHD a 3 anni
- Ha forti problemi di concentrazione
- L'analisi EEG mostra in realtà un aumentato ritmo beta
- Il neurofeedback gli permette di comprendere come tenere il ritmo beta sotto controllo e migliorare anche le performance sportive

NEUROFEEDBACK IN CLINICA: PEDIATRIA



Table 1

Evidence for NF for pediatric ADHD, LD, autism, and epilepsy, based on criteria by the USPSTF level of certainty of research evidence and recommendation grade

Disorder	Quality of Evidence for Children or Adolescents/Clinical Recommendation	Basis of Recommendation
ADHD	Fair to good/recommend (with reservation)	12 published RCTs (4 are sham-controlled with nonsignificant effects that did not use optimal protocols)
Autism	Fair/recommend (with reservation)	4 small RCTs (2 sham-controlled with significant effects, 1 wait-list control with several improvements, reportedly maintained over a period of 6 mo, and 1 compared with a biofeedback condition and a wait list)
Learning disorders	Poor to fair/insufficient evidence to make a recommendation	2 studies using operationalized definitions and assessments of LD, and 1 small RCT
Epilepsy	Poor/insufficient evidence to make a recommendation	There are no clinical trials specific to pediatric epilepsy, although children and adolescents have been included in trials of NF for epilepsy; 2 meta-analyses of NF reported 82% of subjects experienced >50% seizure reductions ⁶⁴ & 79% statistically significant reduction in frequency of seizures ⁶⁵

NEUROFEEDBACK IN CLINICA: ADOLESCENTI

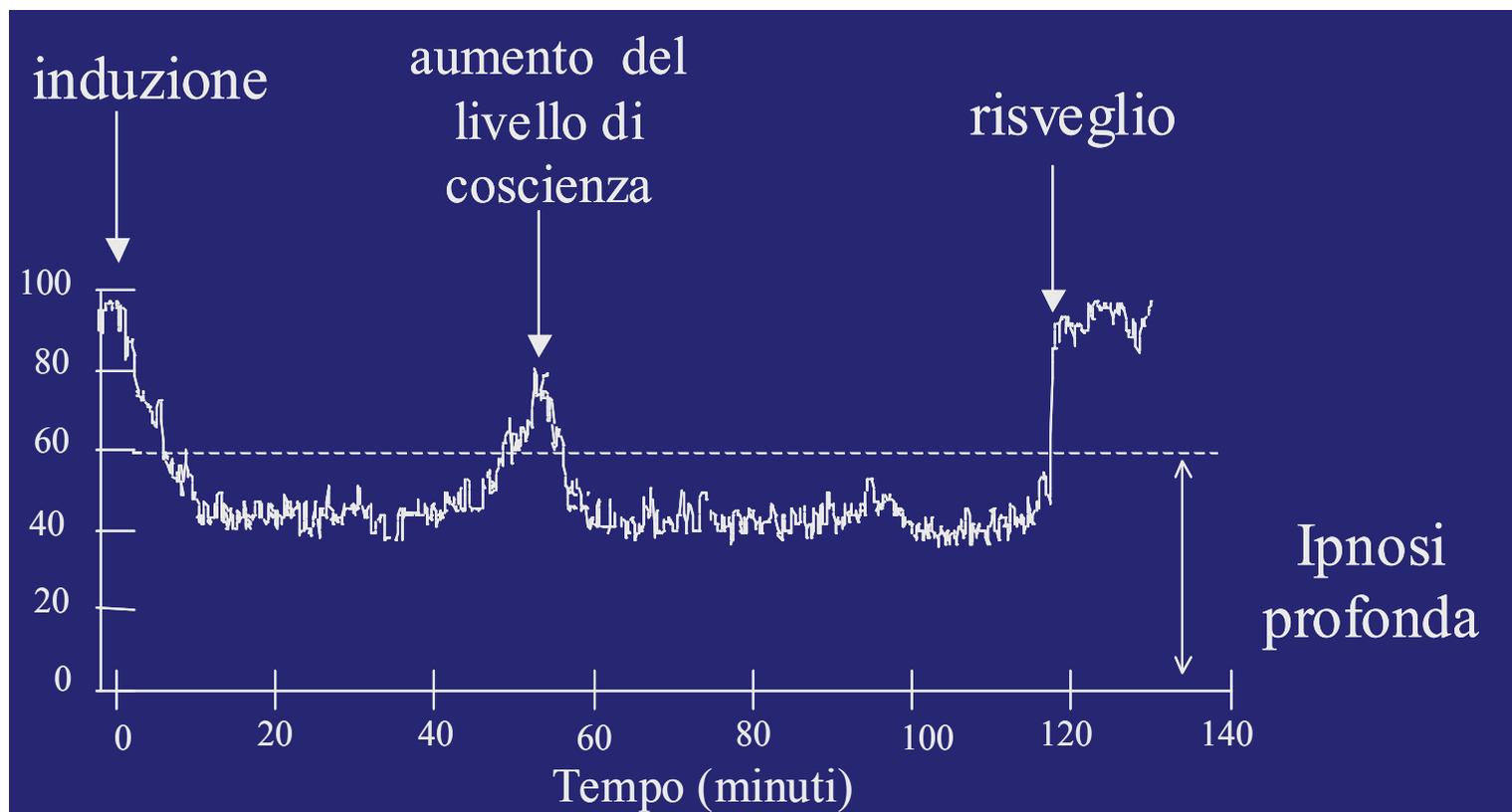


Table 2
Evaluation of surface NF in youth: the evidence base

Indications	NF Method	Quality of Research	Strength of Recommendation	Evidence Base
Depression	Alpha asymmetry	Fair	Recommend	1 case study ⁶⁶
Anxiety	Increase alpha/theta ratio or SMR/theta ratio	Fair	Recommend	1 RCT ⁷²
Performance anxiety	Alpha/theta training	Good	Recommend	1 RCT and 1 open trial ^{97,115}
Mental retardation	NF based on individual qEEG	Good	Recommend	2 clinical trials
TBI	Decrease theta/increase beta	Fair	Recommend	1 RCT comparing physical therapy with NF
PTSD	Decrease delta/theta activity	Fair	Recommend	Non-randomized controlled study
Alcohol abuse	Alpha/theta training	ND	ND	ND
Substance abuse	Alpha/theta training	ND	ND	ND

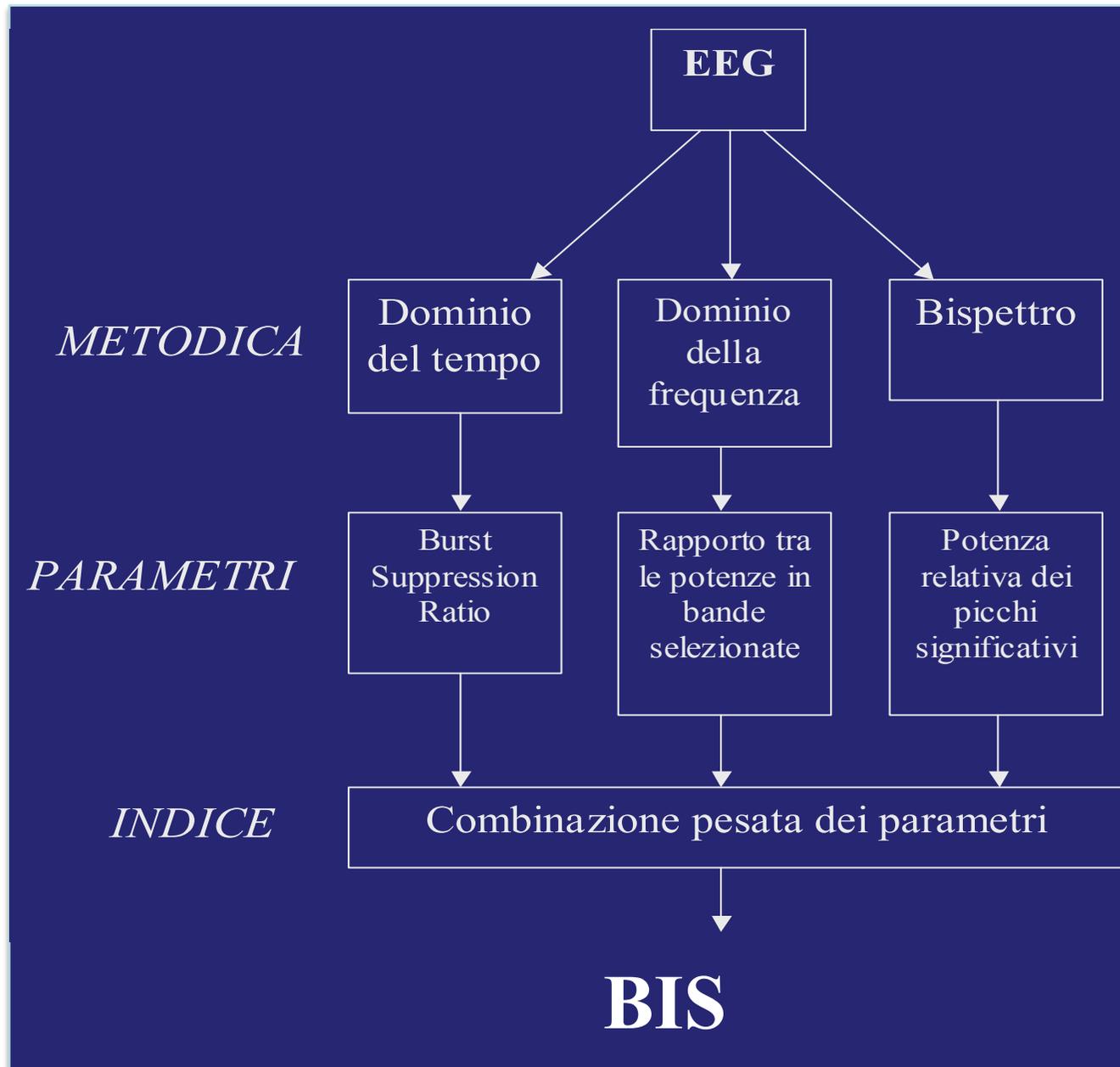
qEEG IN PRATICA: L'INDICE BIS

Il BIS rappresenta un **indice in uso nelle sale operatorie** da qualche anno, e ha dato origine ad una vasta letteratura. Il BIS fornisce in tempo reale un **numero fra 0 e 100** proporzionale al grado di ipnosi: **100 corrisponde al paziente sveglio, 0 all'assenza di attività elettrica cerebrale**.



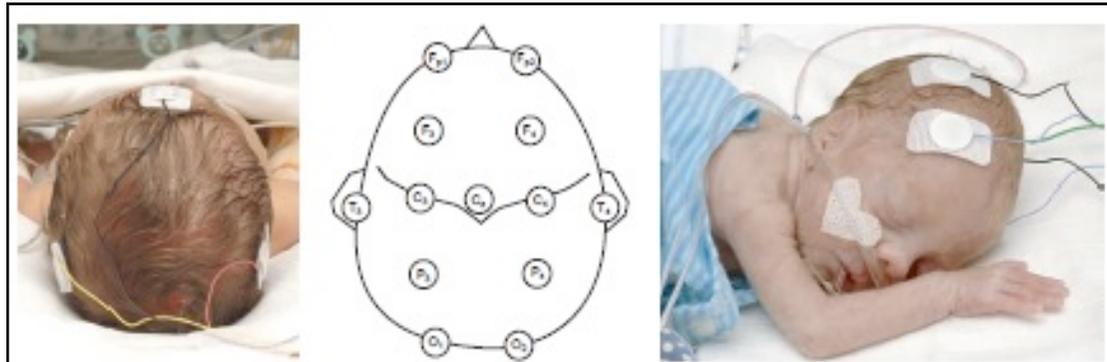


IL CALCOLO DEL BIS



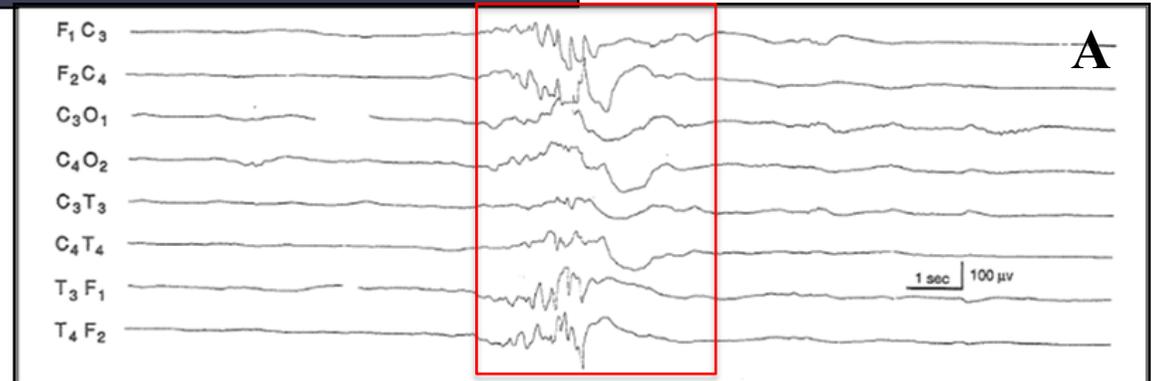
qEEG IN NEONATOLOGIA

In neonatologia l'**EEG** è determinante per definire lo stato di salute e di sviluppo in relazione all'**età concezionale EC** (numero di settimane che comprende il periodo di gestazione più l'intervallo di tempo intercorso dalla nascita) del neonato.

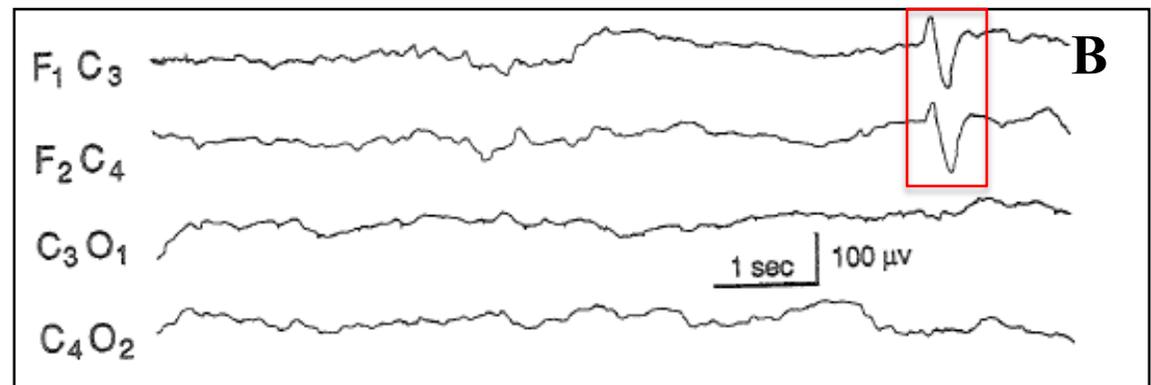


ANALISI QUALITATIVA

- Neonato prematuro (EC 27-28 settimane)
- Burst bisincroni preceduti e seguiti da periodi di quiescenza dell'attività elettrica.



- Neonato sano (EC 36 settimane)
- Sharp Waves frontali, bisincrone



Distinzione
EEG-Artefatti

Individuazione
pattern significativi

Correlazione con
EC e quadro clinico

Diagnosi e Prognosi

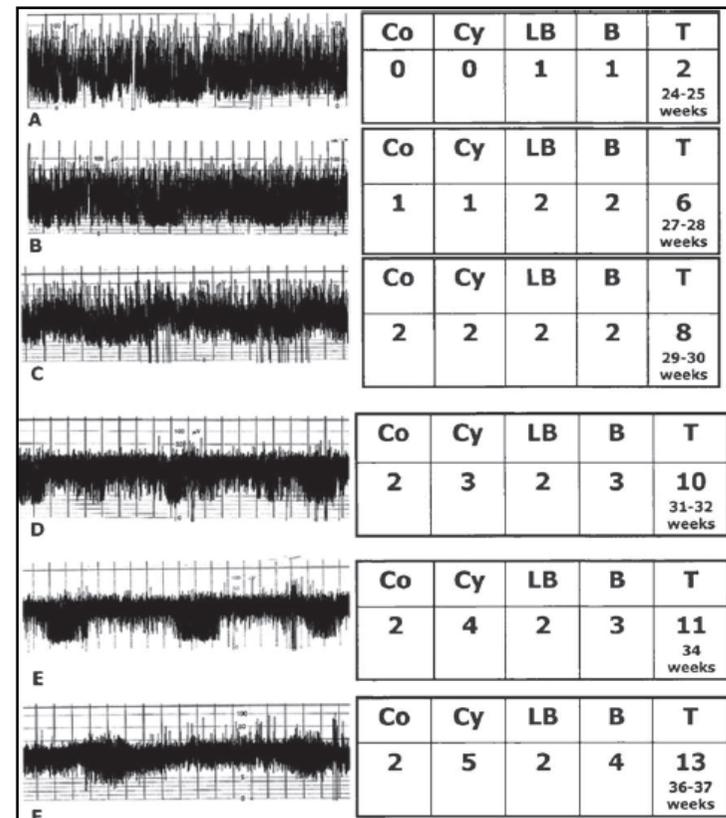
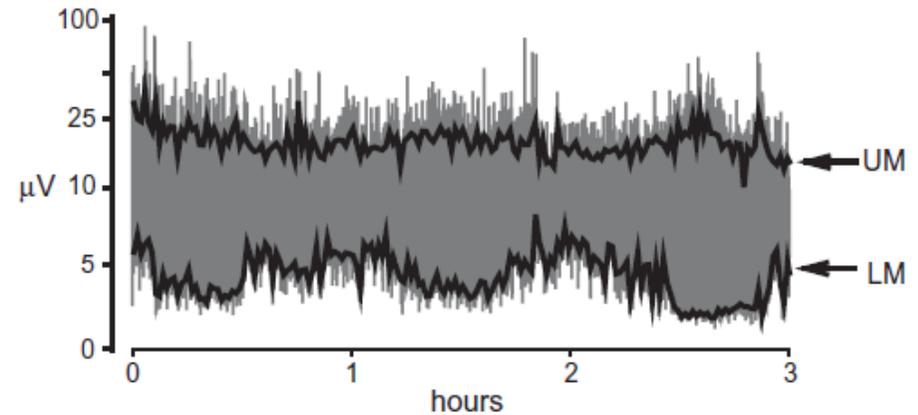
ANALISI SEMI-QUANTITATIVA

aEEG →

**rappresentazione dell'ampiezza
picco-picco(ppA) del EEG**

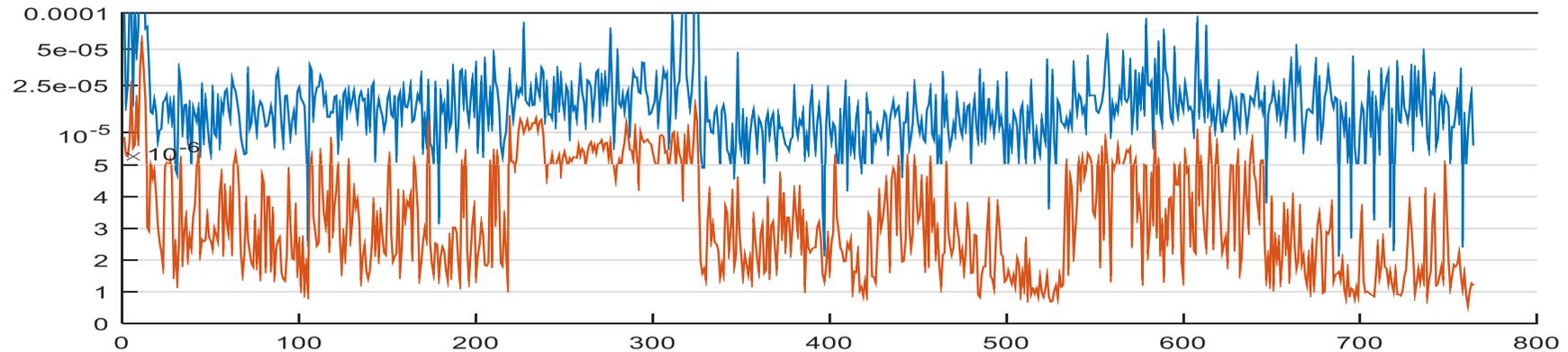
Principali indici aEEG:

- LM (lower margin), UM (upper margin) 5° e 95° percentile correlato ai valori d'ampiezza EEG nell'intervallo di tempo considerato.
- $\text{Bandwidth} = | \text{UM} - \text{LM} |$
- Metodo di Burdjalov → assegna un punteggio a alternanza dei cicli sonno-veglia, andamento del LM e dell'ampiezza delle registrazioni, da cui si ottiene un punteggio totale compreso tra 0 e 13 che viene poi correlato all'EG del neonato.

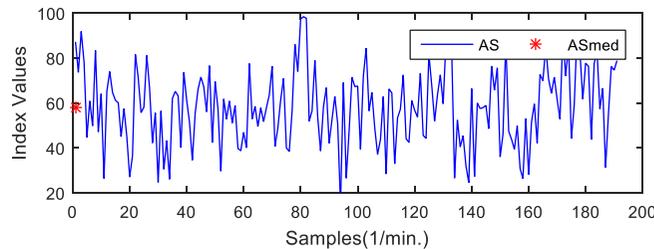


ANALISI QUANTITATIVA

1. Calcolo del aEEG

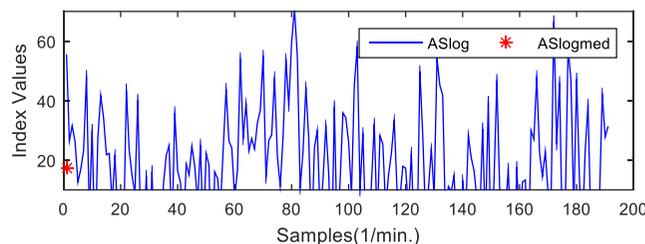


2. Estrazione automatica di indici che, sulla base della letteratura, correlano con l'EC



• **Asymmetry Transformed Index=37.1006**

• **EC Stimata= 27.4745**



• **Log Asymmetry Transformed Index=5.4478**

• **EC Stimata= 34.038**



ANALISI QUANTITATIVA

3. Vengono estratti gli indici che meglio performano in una popolazione di 30 registrazioni EEG
4. Viene calcolata la combinazione lineare di questi indici a creare un nuovo indice

	Prova 1	Prova 2	Prova 3	Prova 4	Prova 5	Prova 6	Prova 7	Prova 8	Prova 9	Prova 10	All	Risultati	
Indice 1(AS)												0%	
Indice 2(ASlog)	X	X	X	X	X	X	X	X	X	X	X	100%	
Indice 3(LM)	X	X	X	X	X	X	X	X	X	X	X	100%	
Indice 4(LMlog)												0%	
Indice 5(BWlog)	X	X	X	X	X	X	X	X	X	X	X	100%	
Accuratezza	Per difetto	1/6	2/6	2/6	1/6	0/6	2/6	2/6	2/6	0/6	2/6	8/30	23,64%
	Per eccesso	4/6	3/6	1/6	3/6	3/6	4/6	2/6	2/6	3/6	2/6	12/30	44,55%
	>0.5 per eccesso altrimenti per difetto	2/6	3/6	1/6	3/6	1/6	6/6	2/6	2/6	1/6	3/6	11/30	39,7%
Errore medio	-0.0798	-0,2592	0,12	0,248	0,705	-0,05	-0,17	0,11	0,33	0,22	0,29	0,114	
Età media TRAINING SET	32,792	32,75	33,08	32,86	32,75	32,79	33	32,71	32,79	32,83	32,93	32,84	
Età media TESTING SET	33,5	33,67	32,33	33,16	33,67	33,5	32,67	33,83	33,5	33,33	32,93	33,28	

→ Metodo automatico che comporta un errore medio di 0.11 settimane rispetto alla EC

VALUTAZIONE DEGLI EFFETTI DELLA tDCS NEL ALZHEIMER



UNIVERSITÀ
DEGLI STUDI DI TRIESTE

R. Ferrucci, PsyD*
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Transcranial direct current stimulation improves recognition memory in Alzheimer disease



BRAIN STIMULATION

Basic, Translational, and Clinical Research in Neuromodulation

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[July 2012](#) Volume 5, Issue 3, Pages 223–230

Next Article >

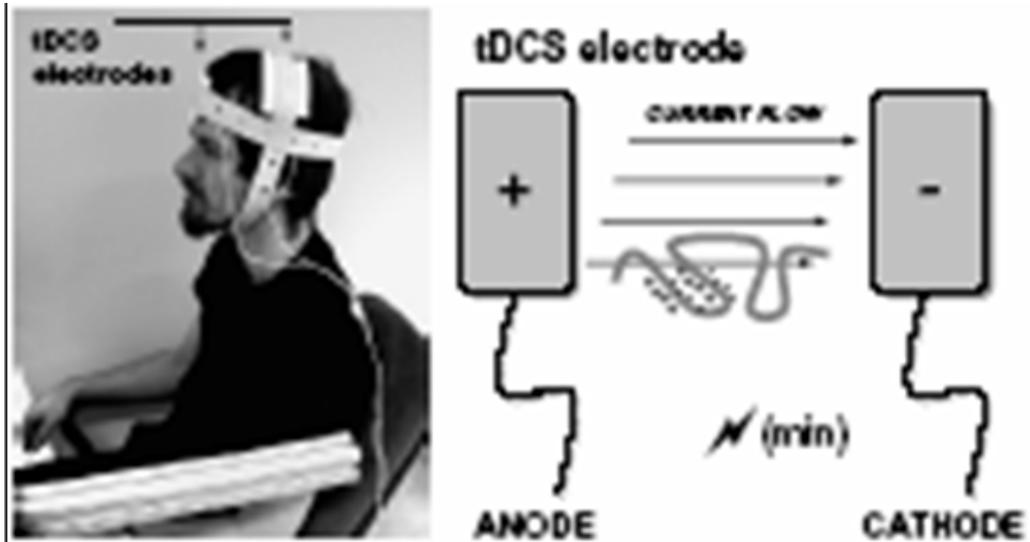
To read this article in full, please review your options for gaining access at the bottom of the page.

Prolonged visual memory enhancement after direct current stimulation in Alzheimer's disease

[Paulo Sergio Boggio](#), [Roberta Ferrucci](#), [Francesca Mamei](#), [Débora Martins](#), [Oscar Martins](#), [Maurizio Vergari](#), [Laura Tadini](#), [Elio Scarpini](#), [Felipe Fregni](#), [Alberto Priori](#)

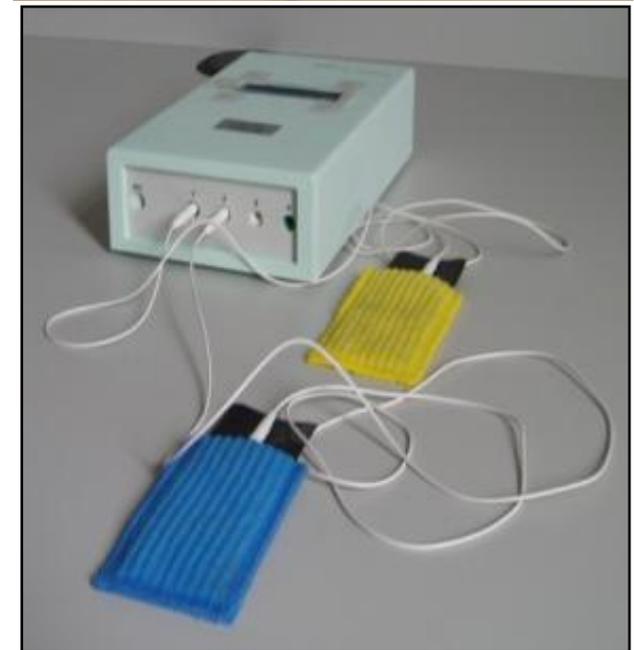
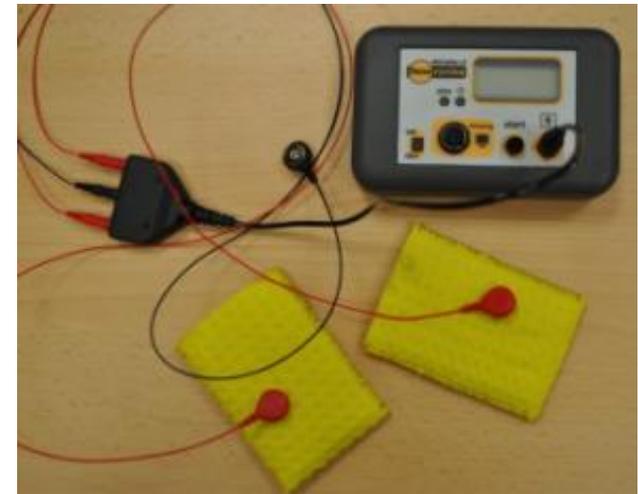
Received: April 14, 2011; Received in revised form: June 15, 2011; Accepted: June 25, 2011; Published Online: July 28, 2011

LA tDCS



Sparing R., Mottaghy FM., Methods 44: 329-337, 2008

Applicazione di **correnti continue** (DC) di intensità **<2 mA**, sullo scalpo in corrispondenza dell'area che si intende modulare per alcuni minuti, anche più volte al giorno.

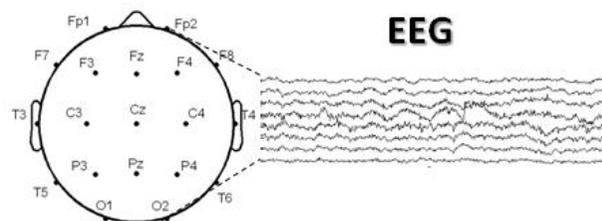
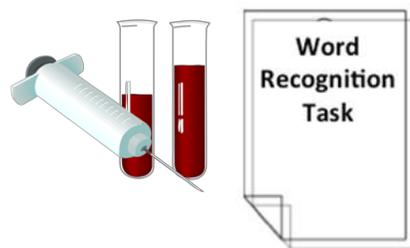


PROTOCOLLO SPERIMENTALE



T0

Baseline Evaluation

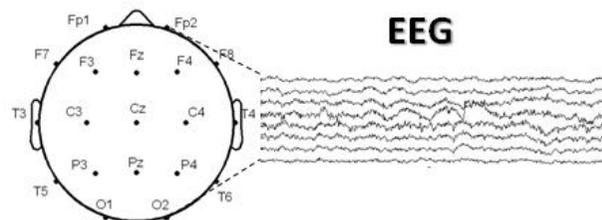
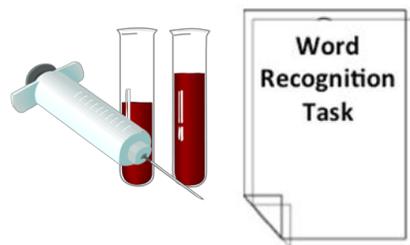
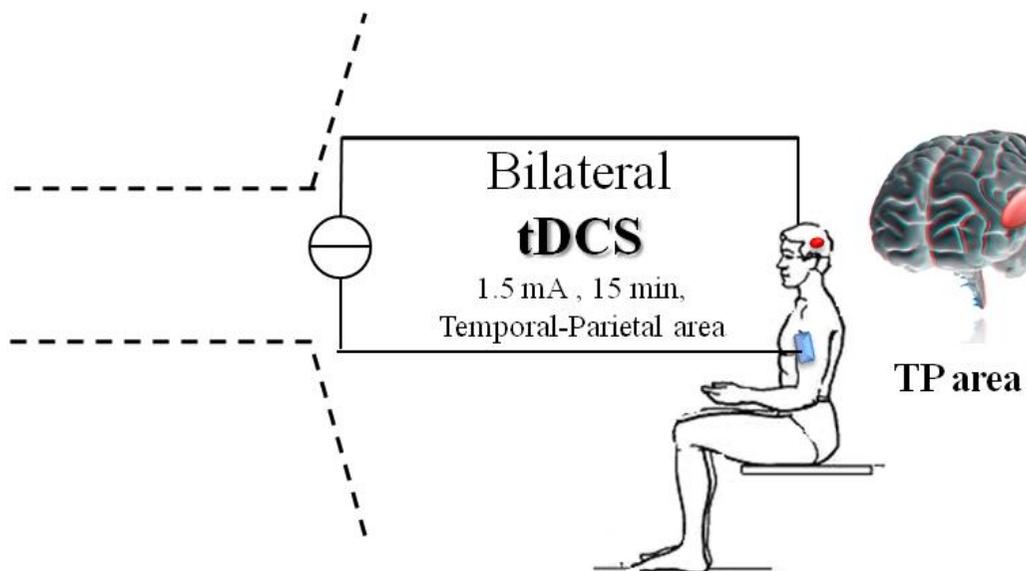


EEG

Stimulation

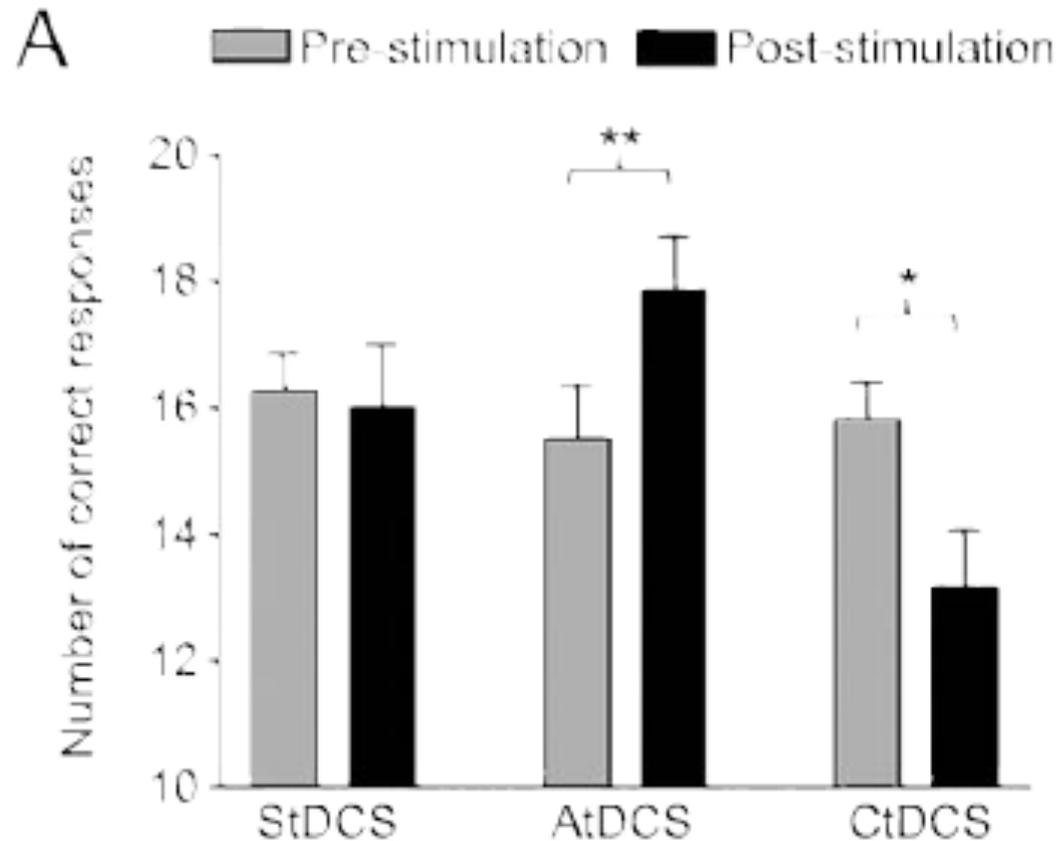
T1

After Evaluation



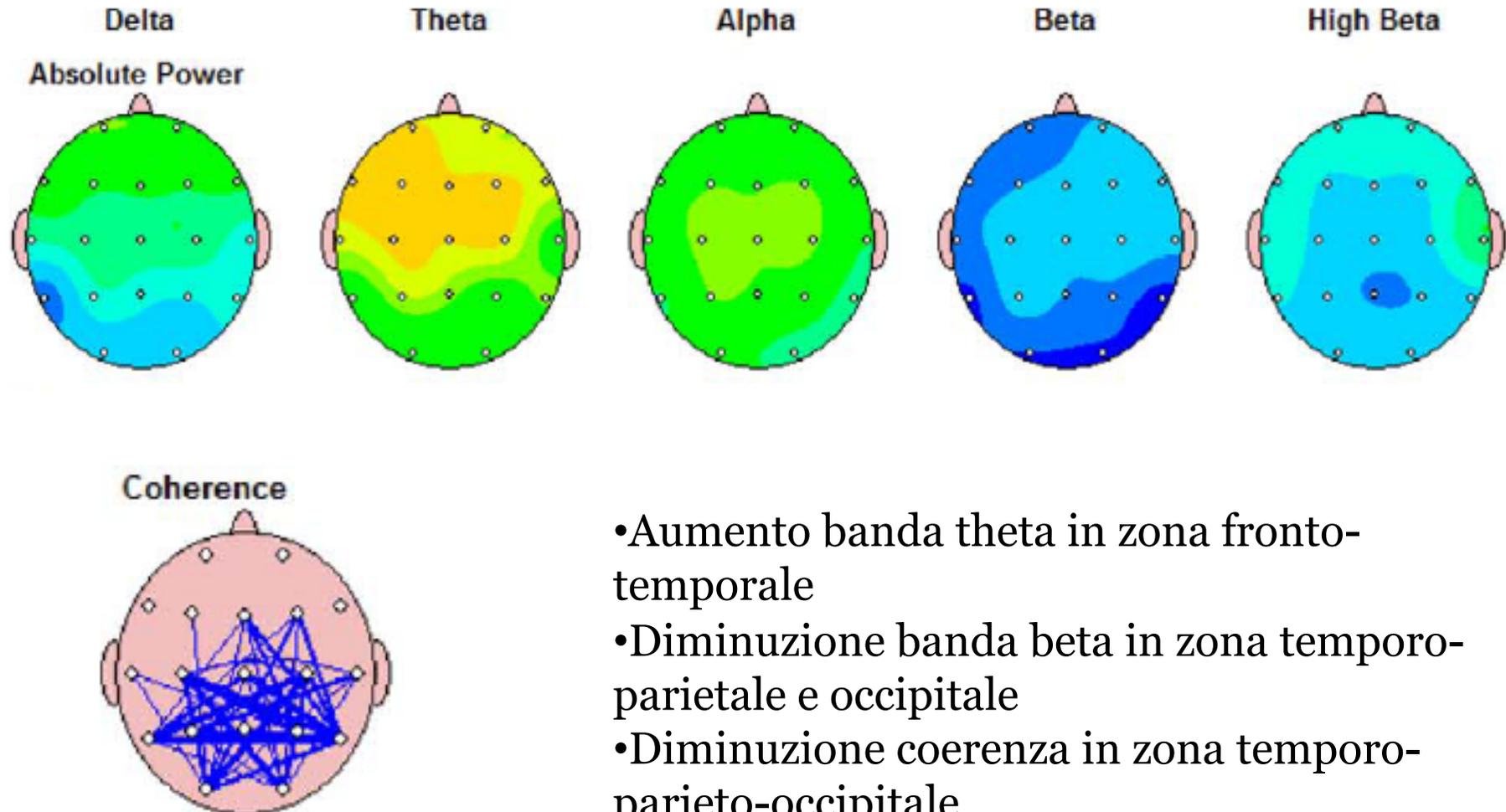
EEG

RISULTATI CLINICI

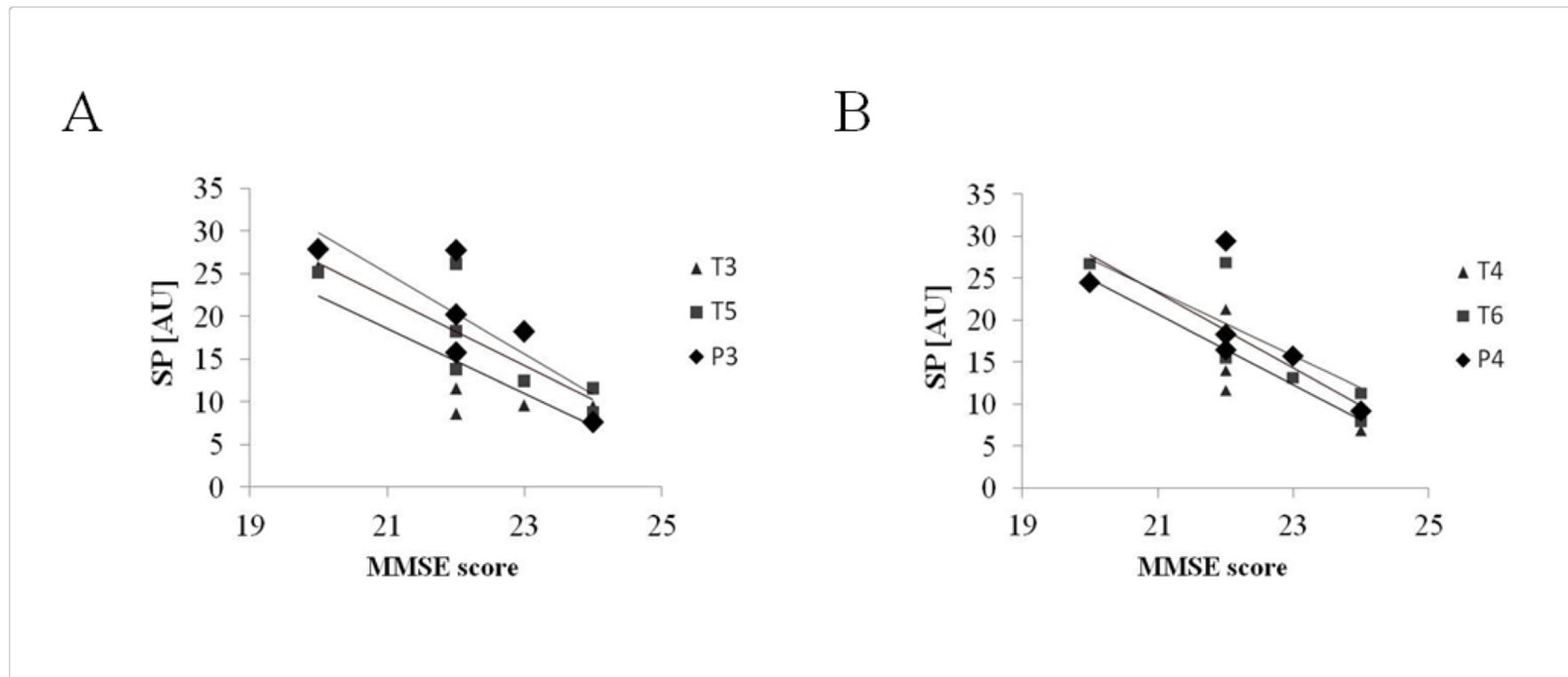


La tDCS anodica migliora la performance al
Word Recognition Task (WRT)

IL PATTERN EEG NEL ALZHEIMER



IL PATTERN EEG CORRELA CON LO STATO DEL PAZIENTE



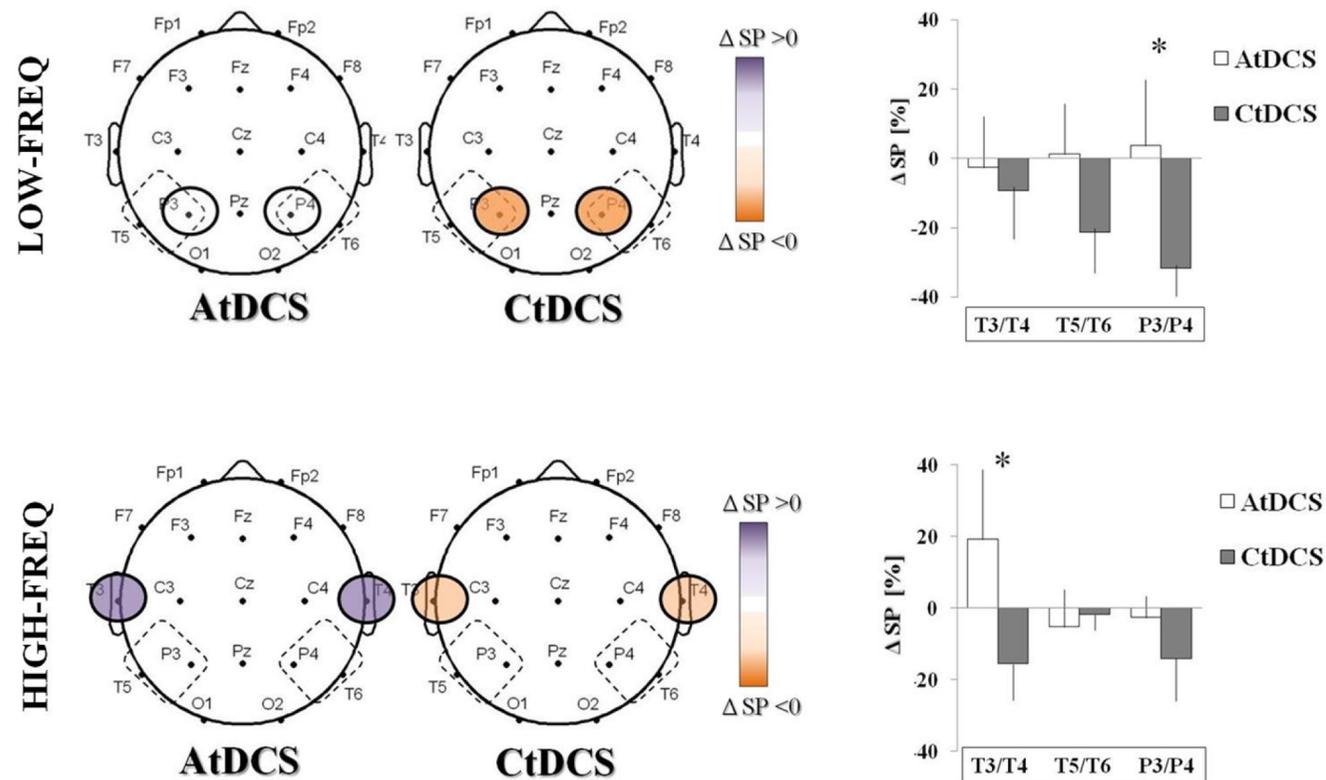
All'aumentare del MMSE score diminuisce l'oscillazione beta

EFFETTO DELLA tDCS SULLA ABSOLUTE POWER



A

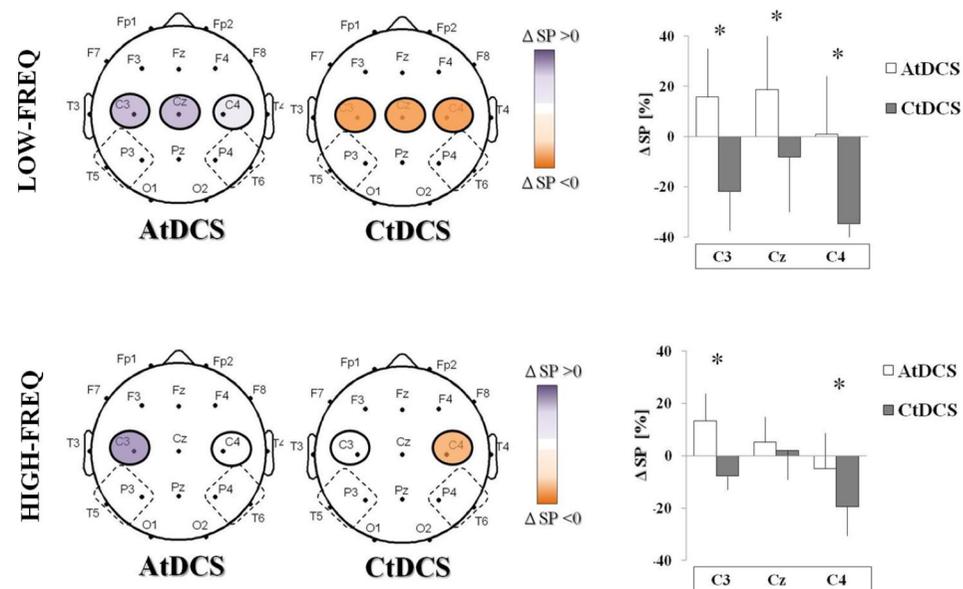
Temporo-Parietal spectral power



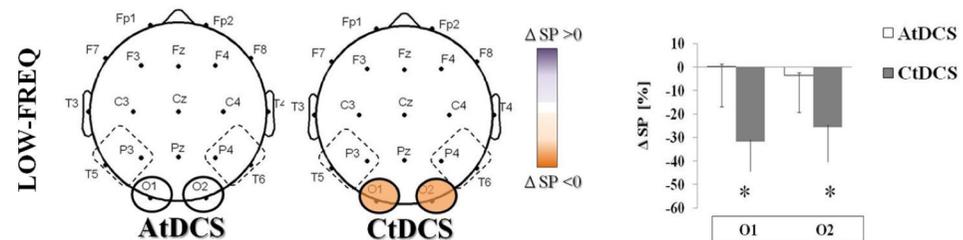
EFFETTO DELLA tDCS SULLA ABSOLUTE POWER



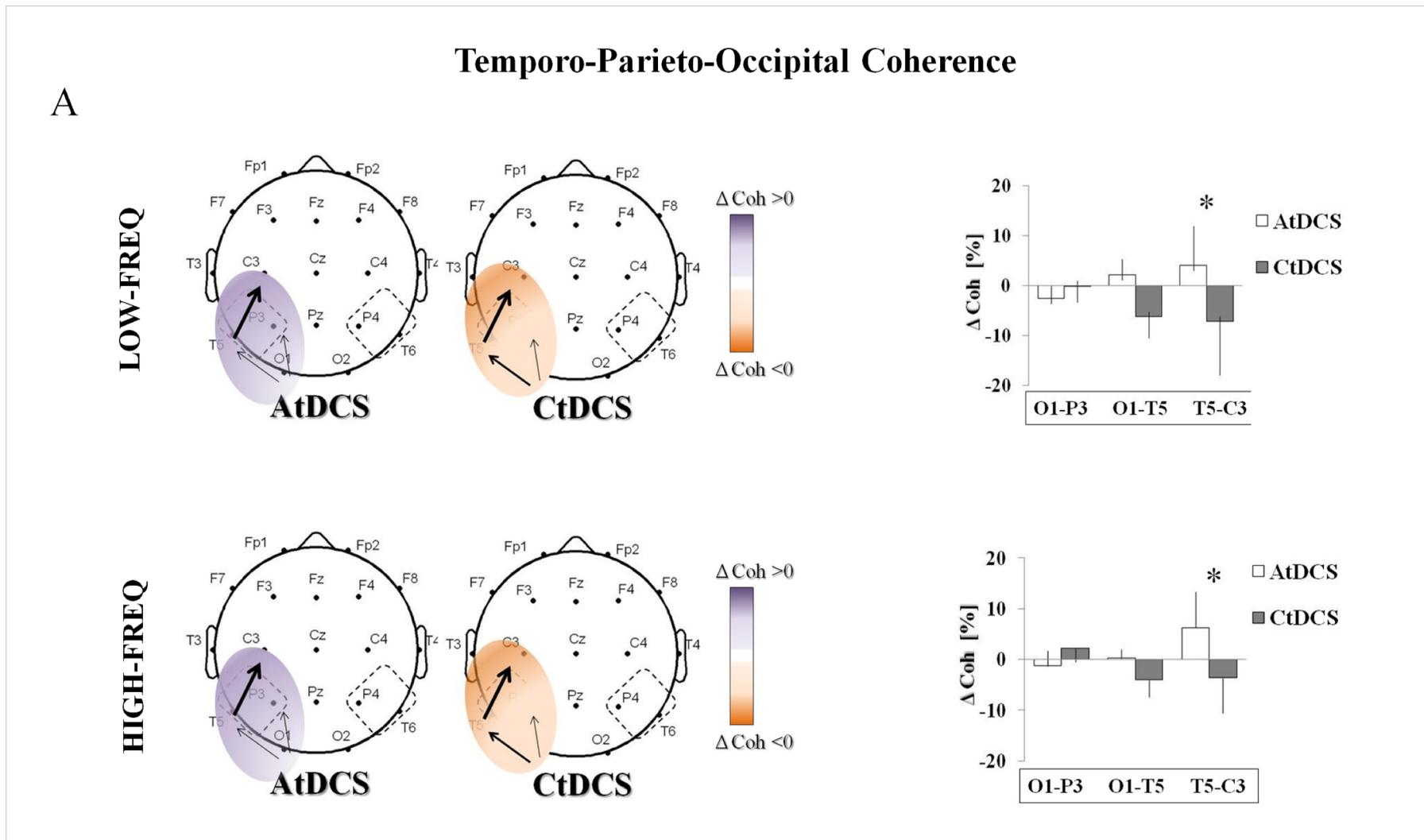
B Central spectral power



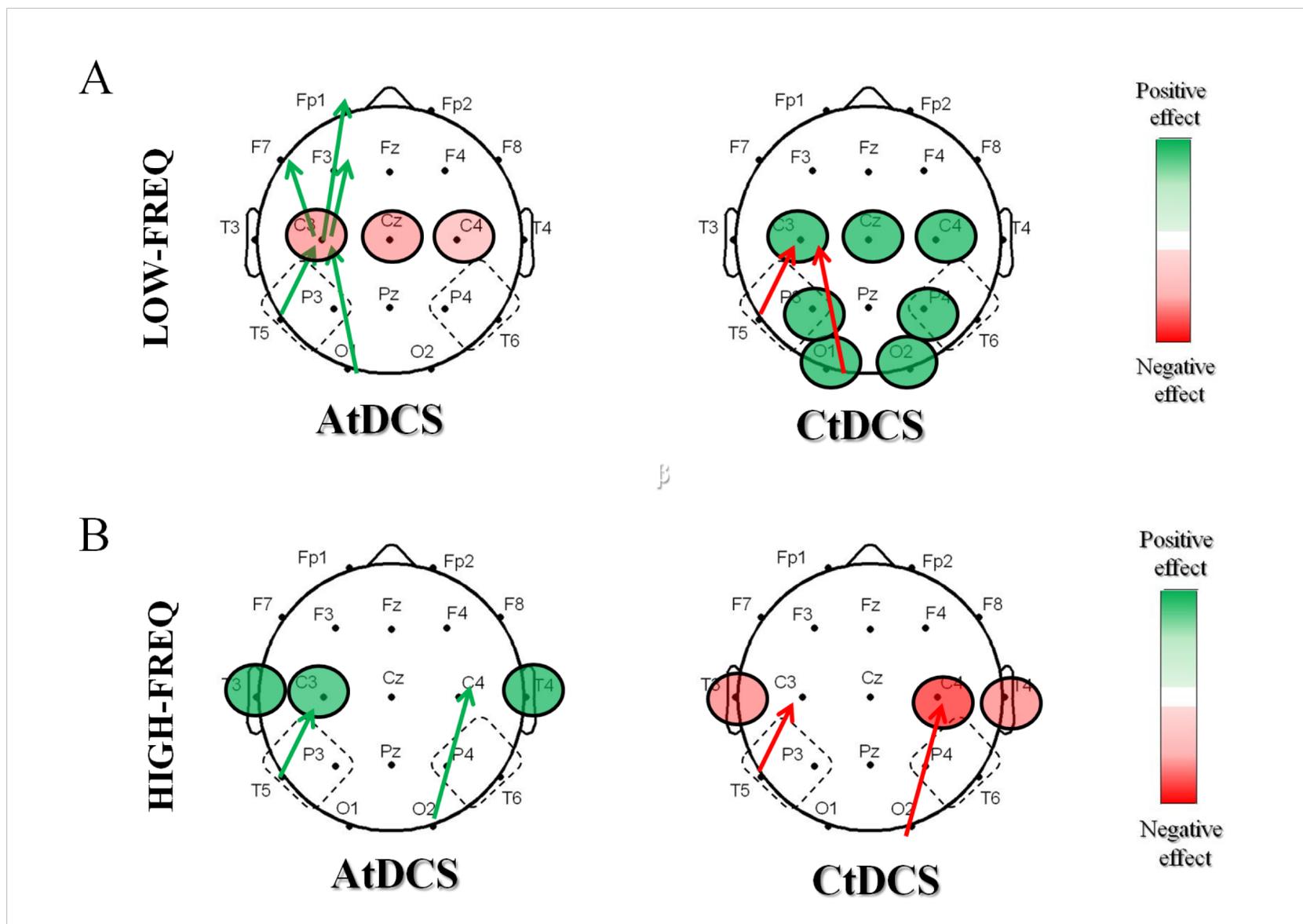
C Occipital spectral power



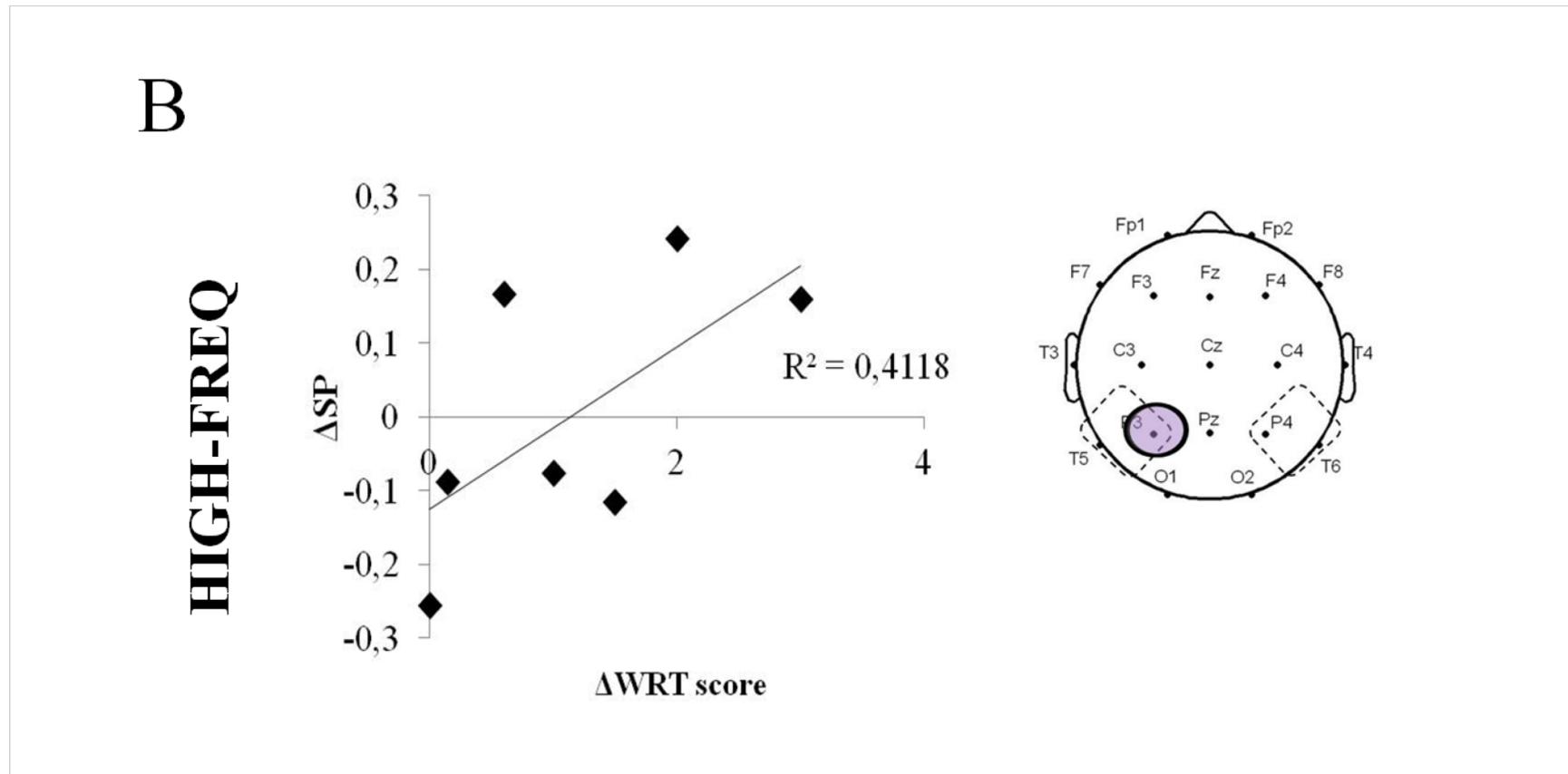
EFFETTO DELLA tDCS SULLA COERENZA



EFFETTO COMPLESSIVO SUL EEG



CORRELAZIONE CON EFFETTO CLINICO



L'aumento dell'oscillazione beta correla con il miglioramento al WRT

qEEG: RIASSUNTO DELLO STATO DELL'ARTE



- Il qEEG consiste nell'estrazione di parametri quantitativi dal segnale elettroencefalografico che derivano principalmente dall'analisi nel dominio del tempo e nel dominio della frequenza
- Mediante le tecniche di qEEG è possibile individuare pattern specifici di alcune patologie
- Il neurofeedback si basa sull'utilizzo del qEEG per "normalizzare" i pattern patologici
- Il qEEG, anche se ancora non è entrato nella pratica clinica, dimostra di essere un supporto affidabile alla diagnosi e al decision-making

IL CASO DI STUDIO



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Functionally Independent Components of the Late Positive Event-Related Potential during Visual Spatial Attention

Scott Makeig,¹ Marissa Westerfield,^{2,5} Tzyy-Ping Jung,³ James Covington,² Jeanne Townsend,^{2,5}
Terrence J. Sejnowski,^{3,4} and Eric Courchesne^{2,5}

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PROTOCOLLO SPERIMENTALE

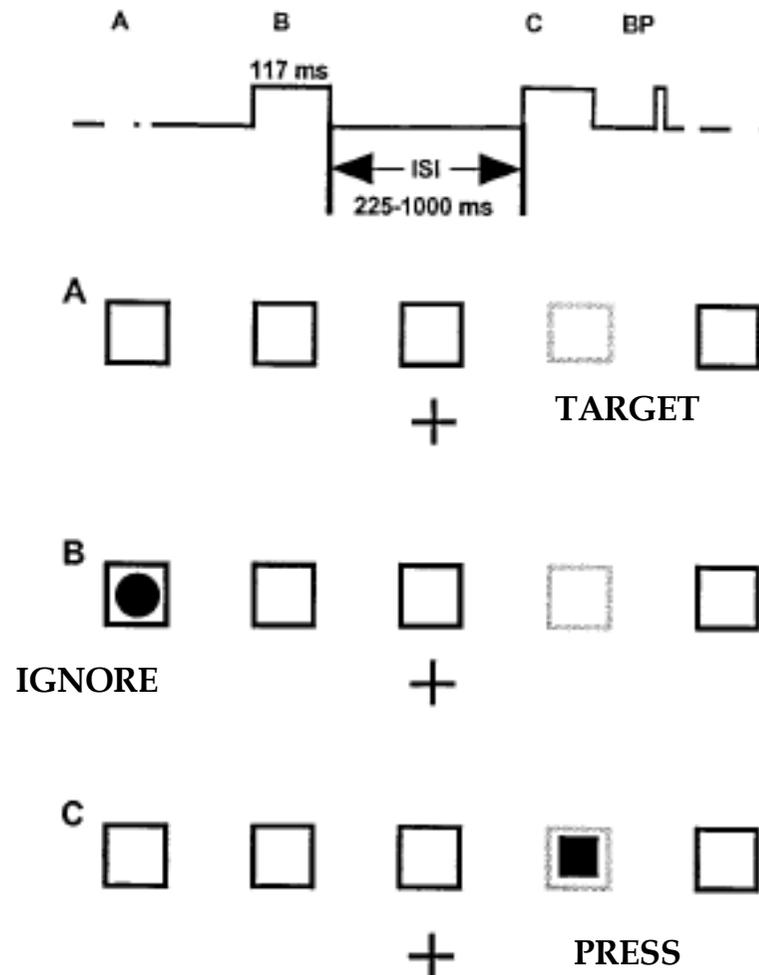


Figure 1. Schematic view of the task. The *top trace* shows the time line of a typical trial. *BP*, Button press. *A*, Screen before stimulation. The *cross* is the fixation point, and the *lightly shaded box* is the attended location during the ensuing 76 sec block. *B*, Appearance of a *filled circle* stimulus at an unattended location; no response required. *C*, Appearance of a *filled square* at the attended location in the discrimination task; button press required. See Materials and Methods.

SELECTIVE VISUAL ATTENTION EXPERIMENT

- Stimuli appear briefly in any of five squares arrayed horizontally above a central fixation cross.
- In each experimental block, one (target) box was differently colored from the rest.
- Whenever a square appeared in the target box the subject was asked to respond quickly with a right thumb button press.
- If the stimulus was a circular disk, he was asked to ignore it.

SCARICARE EEGLAB



UNIVERSITÀ
DEGLI STUDI DI TRIESTE

WIKI DI RIFERIMENTO PER EEGLAB:
https://sccn.ucsd.edu/wiki/Getting_Started

Download EEGLAB zip file (requires Matlab)

[Click here](#) to download the latest EEGLAB version.

EEGLAB latest version is version 14. EEGLAB older versions are available [here](#) and [here](#). Revision details are available on the [EEGLAB wiki](#). If you have a version of Matlab older than 7.6 (2008b), download EEGLAB version 4.5b [here](#).

To install EEGLAB

1. Unzip the EEGLAB zip file in the folder of your choice
2. Start Matlab
3. Change the Matlab path to the EEGLAB folder you have just uncompressed
4. Type "eeglab" and press enter on the Matlab prompt

Download EEGLAB development head (requires Matlab)

Using the development head requires a special software called Git available for free on the Internet. Using the development head is useful to benefit from the latest bug fixes and update your version of EEGLAB daily. Detailed steps to download the EEGLAB development head are available on the [EEGLAB wiki](#).

Download a compiled version of EEGLAB

EEGLAB compiled version for windows OS 32-bit does not require Matlab. If you have access to Matlab though, we recommend the versions above since the EEGLAB compiled version is quite old (2009) and does not have all the features of the Matlab version. Download the [zip file here](#) and follow instructions on how to install the EEGLAB compiled version on the [EEGLAB wiki](#).

APRIRE EEGLAB IN MATLAB



The screenshot shows the MATLAB R2012a environment. The Command Window contains the following commands:

```
>> cd /data/common/matlab/eeglab11_0_3_1b/  
fx >> eeglab|
```

The Command History window shows the following commands:

```
%-- 07/27/2012 04:41:58 PM --%  
| cclear all;clc  
| cd /data/common/matlab/eeglab11_0_3_1b/
```

The Current Folder window shows the following files and folders:

- external
- functions
- plugins
- sample_data
- sample_locs
- 1ST_README.txt
- Contents.m
- eeglab.m
- eeglablicense.txt

NB: EFFETTUARE PROCEDURA DI Set Path PER INSERIRE LA CARTELLA IN CUI È SALVATO EEGLAB TRA QUELLE PREDEFINITE (non serve il comando cd...)

IL MENU PRINCIPALE



EEGLAB v11.0.3.1b

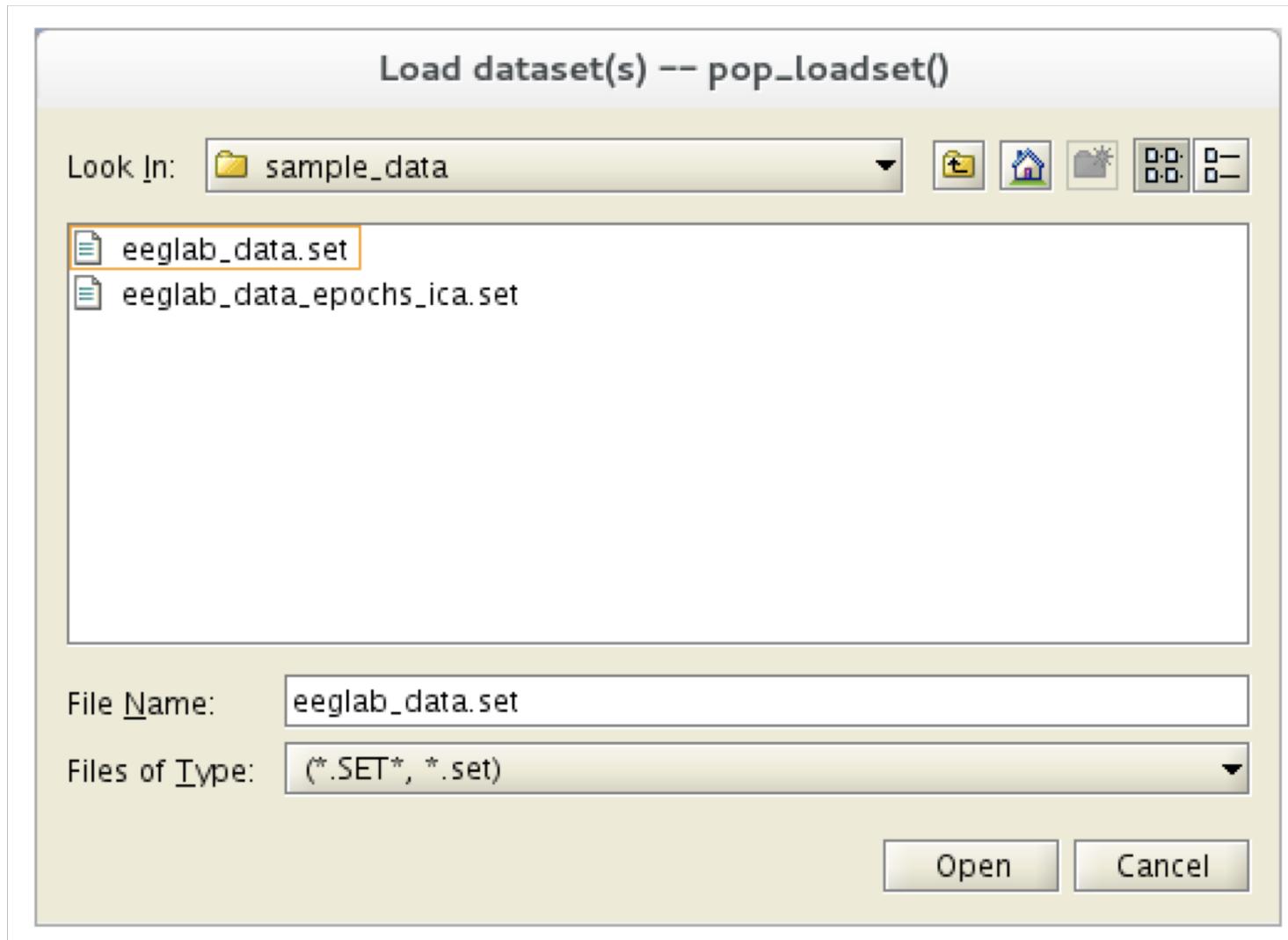
File Edit Tools Plot Study Datasets Help

No current dataset

- Create a new or load an existing dataset:
Use "File > Import data" (new)
Or "File > Load existing dataset" (old)
- If new,
"File > Import epoch info" (data epochs) else
"File > Import event info" (continuous data)
"Edit > Dataset info" (add/edit dataset info)
"File > Save dataset" (save dataset)
- Prune data: "Edit > Select data"
- Reject data: "Tools > Reject continuous data"
- Epoch data: "Tools > Extract epochs"
- Remove baseline: "Tools > Remove baseline"
- Run ICA: "Tools > Run ICA"

0 users in Chat

SAMPLE DATASET



“ABOUT THIS DATASET”



EEGLAB Tutorial Dataset

During this selective visual attention experiment, stimuli appeared briefly in any of five squares arrayed horizontally above a central fixation cross. In each experimental block, one (target) box was differently colored from the rest. Whenever a square appeared in the target box the subject was asked to respond quickly with a right thumb button press. If the stimulus was a circular disk, he was asked to ignore it.

(Reference: Makeig et al.. J. Neurosci. 19:2665-80, 1999)

[eeglab_data.set](#)

- Concatenation of three-second epochs from one subject, each containing a target square in the attended location ('square' events, left-hemifield locations 1 or 2 only) followed by a button response ('rt' events).
- Data stored in continuous data format to illustrate the process of epoch extraction from continuous data.

EDIT EVENTS



Edit → Event Values

Dialog box: Edit event values -- pop_editeventvals()

Edit event field values (currently 154 events) Delete event

Type	square
Position	2
Latency (sec)	1.0001

Event Num

Insert event << < 1 > >> Append event

Re-order events (for review only)

Main sorting field: No field selected Click for decreasing order

Secondary sorting field: No field selected Click for decreasing order

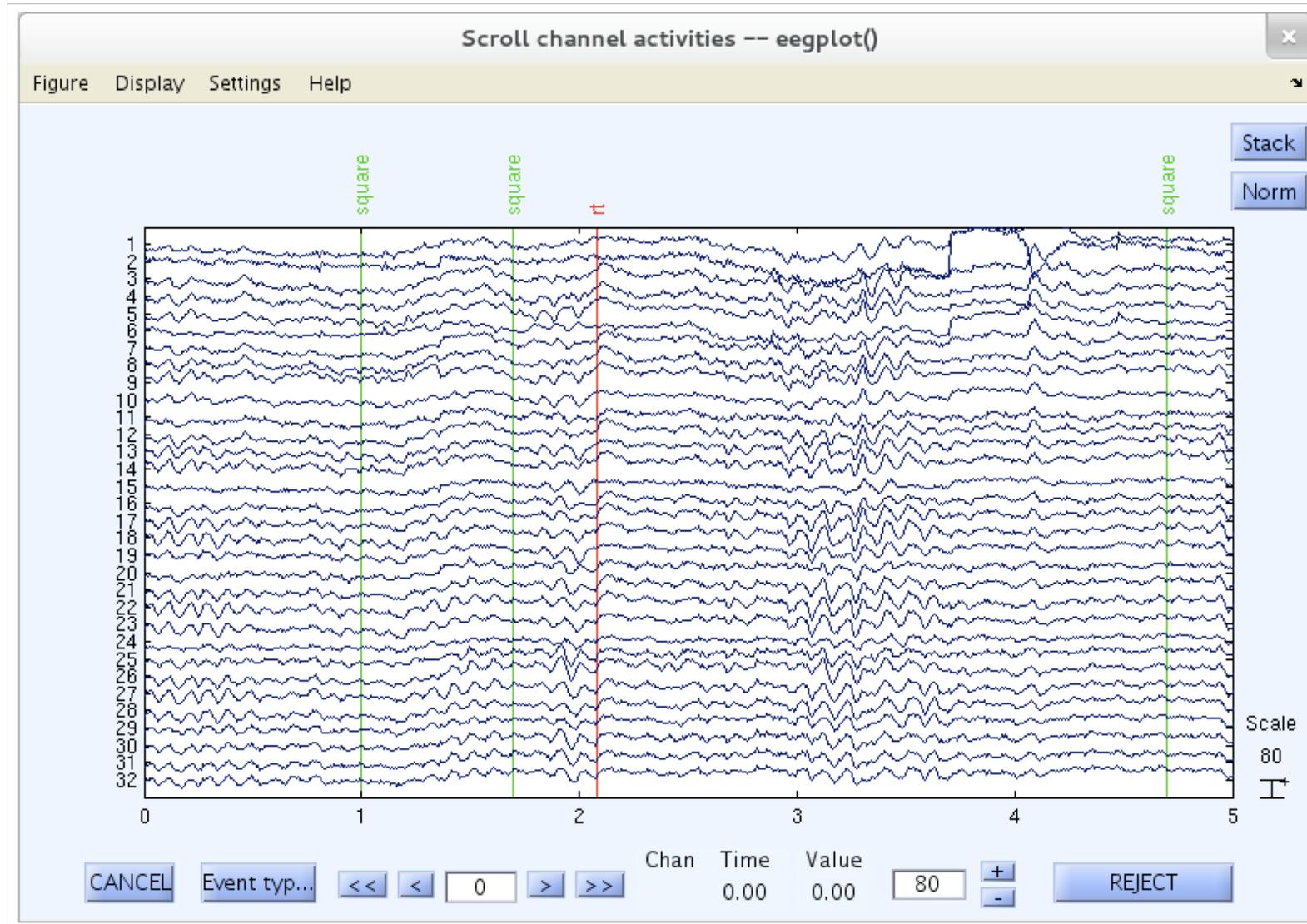
Re-sort

Help Cancel Ok

VISUALIZE DATA



Plot → Channel data (scroll).



CHANNEL LOCATION



Edit channel info -- pop_chanedit()

Channel information ("field_name"):

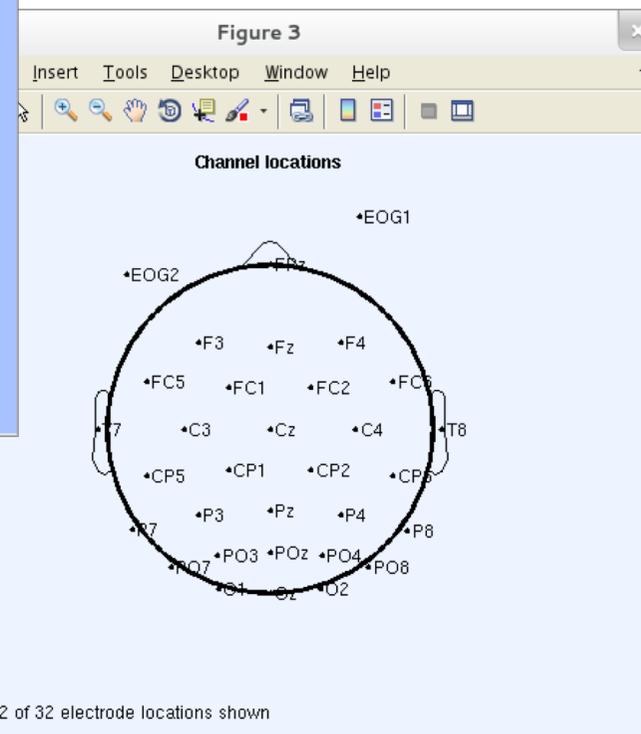
Channel label ("label")	FPz	Opt. head center
Polar angle ("theta")	0	Rotate axis
Polar radius ("radius")	0.50669	Transform axes
Cartesian X ("X")	0.99978	XYZ -> polar & sph.
Cartesian Y ("Y")	0	Sph. -> polar & xyz
Cartesian Z ("Z")	-0.021016	Polar -> sph. & xyz
Spherical horiz. angle ("sph_theta")	0	Set head radius
Spherical azimuth angle ("sph_phi")	-1.2042	Set channel types
Spherical radius ("sph_radius")		Set reference
Channel type		
Reference		
Index in backup 'urchanlocs' structure	1	
Channel in data array (set=yes)	<input checked="" type="checkbox"/>	

Delete chan **Channel number (of 32)** Append chan

Insert chan << < 1 > >> Plot radius (0.2-1, []=auto) Nose along +X Plot 3-D (xyz)

Plot 2-D Read locations Read locs help Look up locs Save (as .ced) Save (other types)

Help Cancel Ok



CHANNEL SPECTRA AND MAPS



Plot → Channel spectra and maps.

Channel spectra and maps -- pop_spectopo()

Epoch time range to analyze [min_ms max_ms]: 0 238304.6875

Percent data to sample (1 to 100): 15

Frequencies to plot as scalp maps (Hz): 6 10 22

Plotting frequency range [lo_Hz hi_Hz]: 2 25

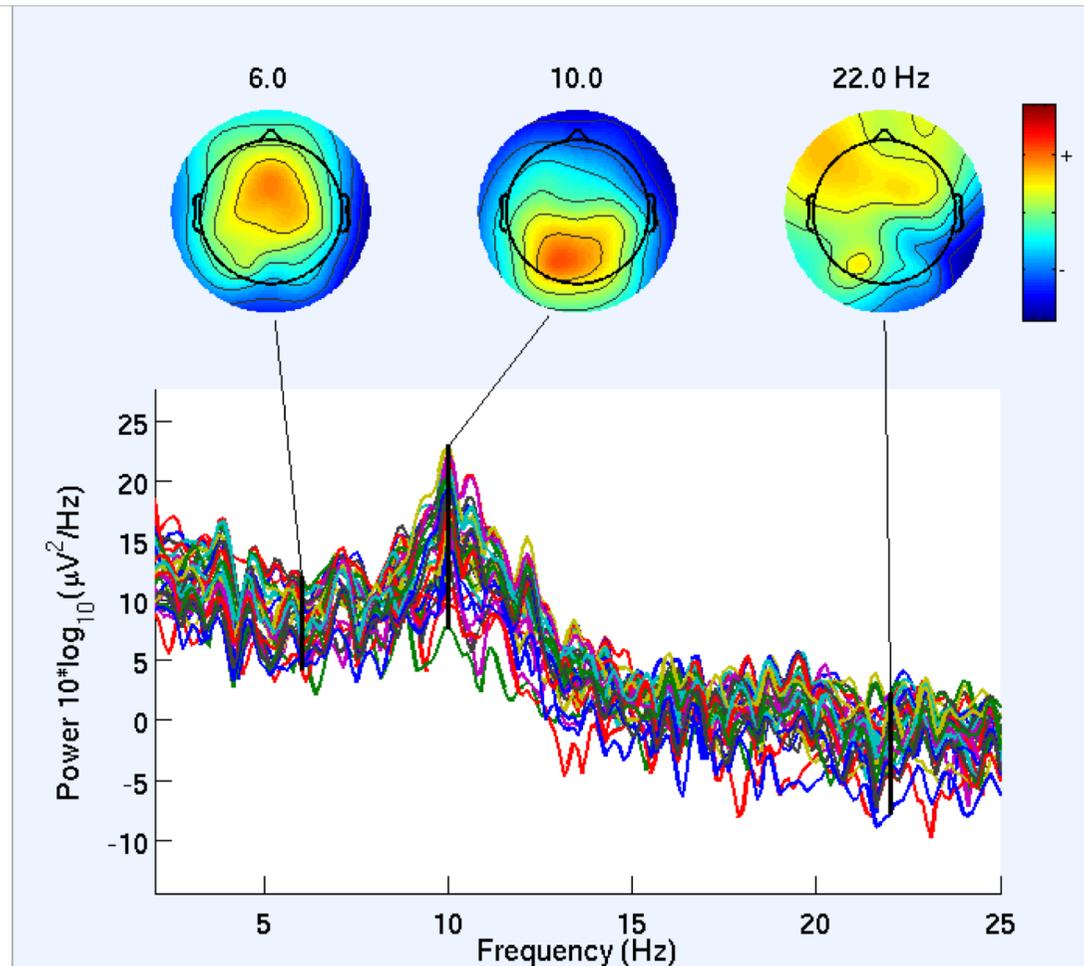
Spectral and scalp map options (see topoplot): 'electrodes','off'

Help Cancel Ok

CHANNEL SPECTRA AND MAPS

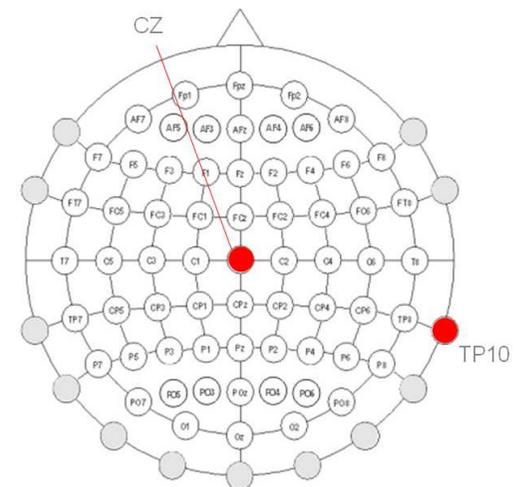
Plot → Channel spectra and maps.

```
Pop_spectopo: finding data discontinuities  
Computing spectra (window length 512; fft length: 1024; overlap 0):  
.....  
Plotting scalp distributions: ...  
Click on each trace for channel/component index
```



PRE-PROCESSING

- Change sampling rate
- FIR filtering
- Change EEG reference:
 - Average reference: when the electrode montage covers nearly the whole head (as for some high-density recording systems) → the advantage of average reference rests on the fact that outward positive and negative currents, summed across an entire (electrically isolated) sphere, will sum to 0 (by Ohm's law).



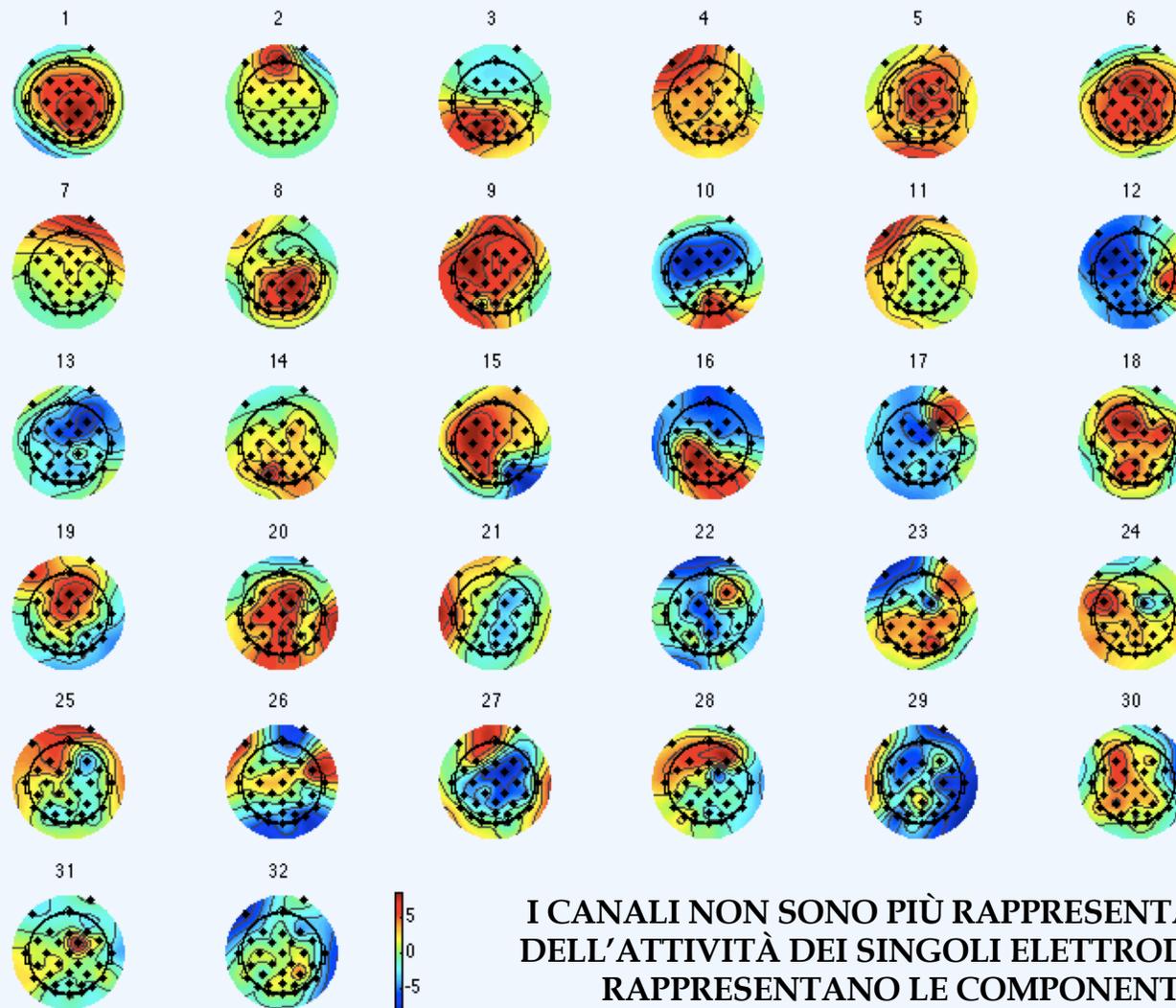
INDEPENDENT COMPONENT ANALYSIS

- Tecnica utilizzata per separare sorgenti che, in principio, sono tra di loro INDIPENDENTI
- Utilizzata per separare ARTEFATTI dal SEGNALE REALE
- Implementata in EEGLab tramite il comando

Tools → Run ICA



RISULTATO



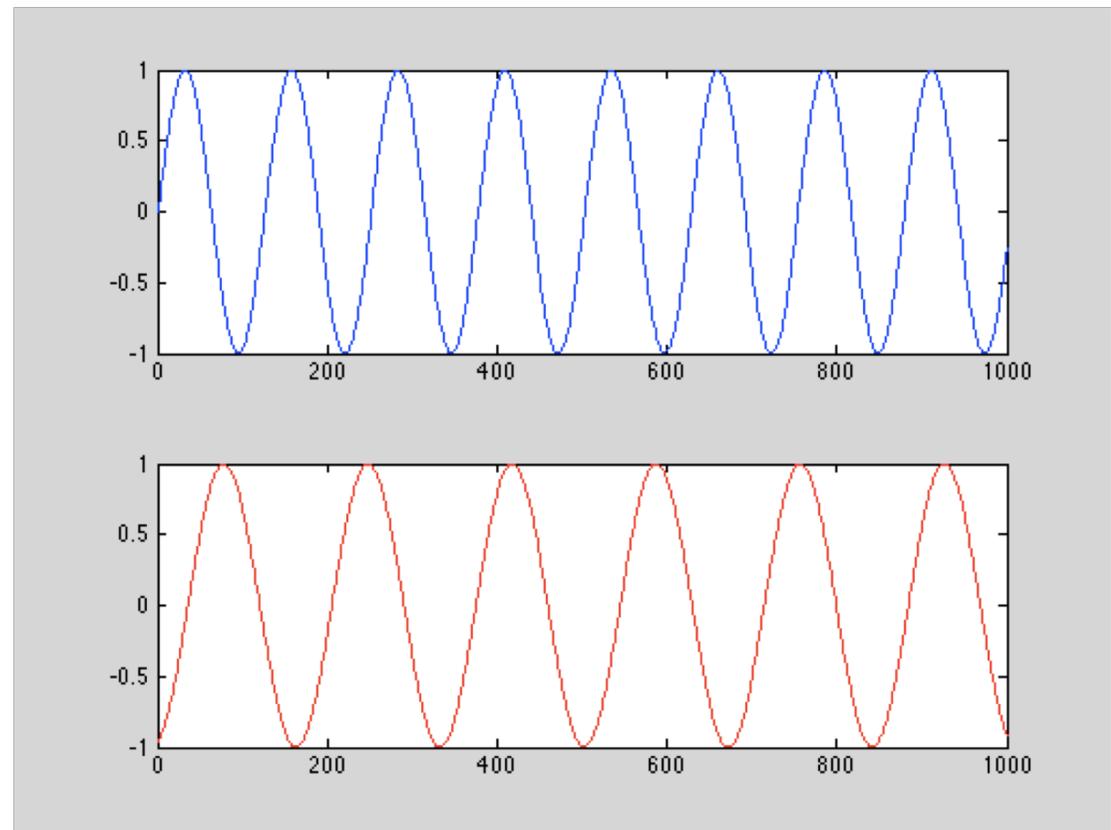
**I CANALI NON SONO PIÙ RAPPRESENTATIVI
DELL'ATTIVITÀ DEI SINGOLI ELETTRODI, MA
RAPPRESENTANO LE COMPONENTI
INDIPENDENTI**

ESEMPIO



Creiamo due segnali sinusoidali, usando la funzione “sin”

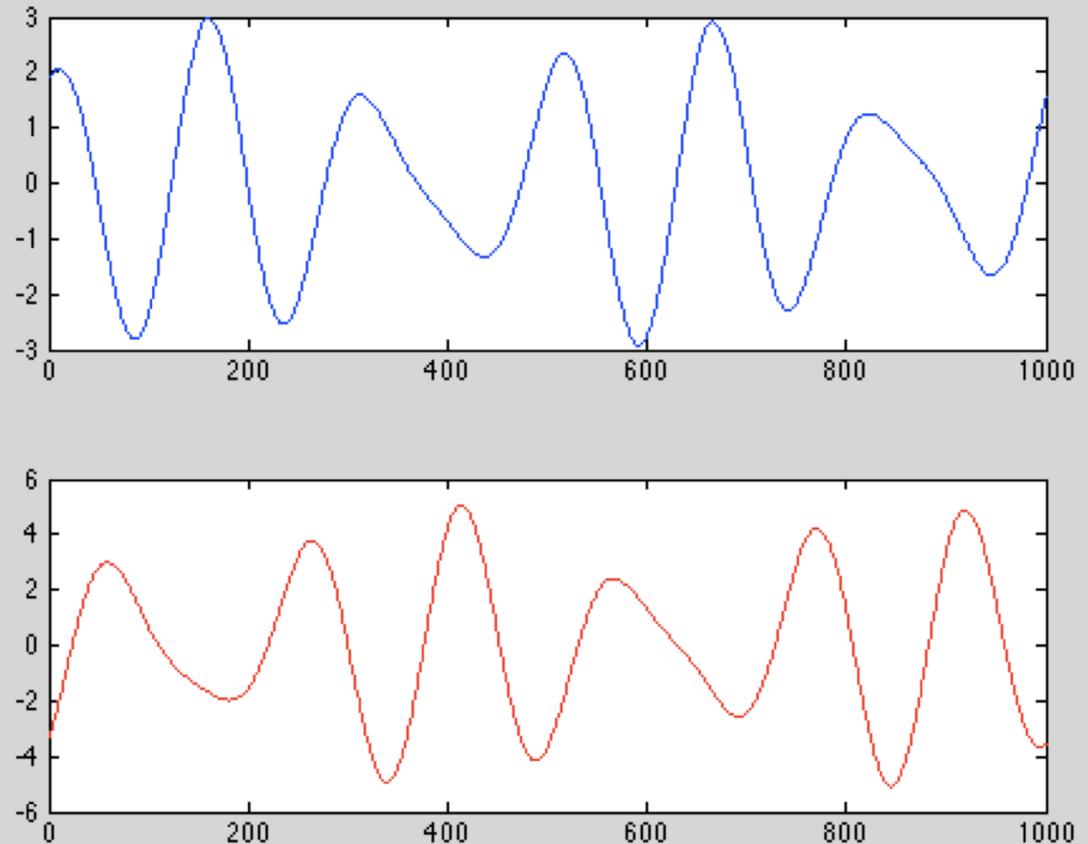
```
A = sin(linspace(0,50, 1000)); % A  
B = sin(linspace(0,37, 1000)+5); % B  
figure;  
subplot(2,1,1); plot(A); % plot A  
subplot(2,1,2); plot(B, 'r'); % plot B
```



ESEMPIO

Creiamo due combinazioni lineari di questi segnali:

```
M1 = A - 2*B;           % mixing 1  
M2 = 1.73*A+3.41*B;    % mixing 2  
figure;  
subplot(2,1,1); plot(M1);  
subplot(2,1,2); plot(M2, 'r');
```



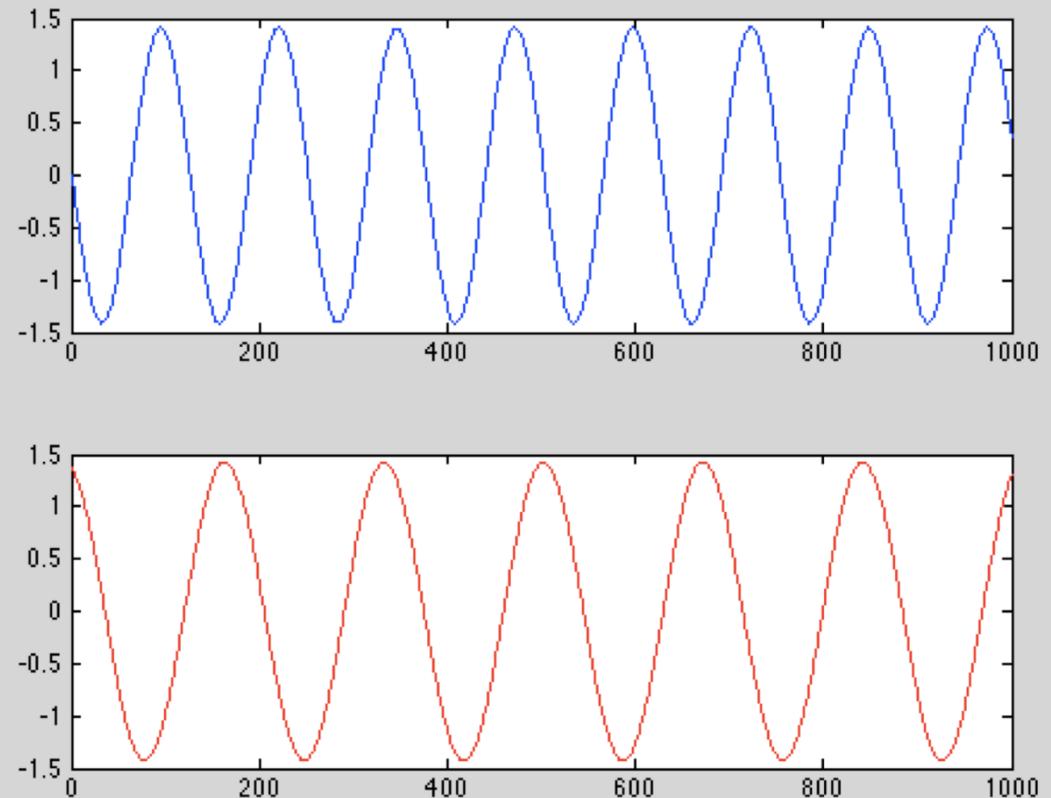


ESEMPIO

L'applicazione di un algoritmo di ICA mi permette di ricostruire i due segnali di partenza

```
figure;  
c = fastica([M1;M2]);           % compute and plot unminxing  
using fastICA  
subplot(2,1,1); plot(c(1,:));  
subplot(2,1,2); plot(c(2,:), 'r');
```

NB: download the
FastICA toolbox at





DATA WHITENING

- Il processo di ricostruzione delle componenti indipendenti richiede uno step di “data whitening” → viene rimossa ogni correlazione nella matrice dei dati
- La matrice di covarianza viene portata ad essere la matrice identità → data la matrice dei dati D , cerco una trasformazione V tale che

$$\text{Per } P=V*D \rightarrow \text{Cov}(P) = I$$

Considerando $Z = D - \text{mean}(D)$ {matrice centrata} →

$$\text{Cov}(D) = \text{Cov}(Z)$$

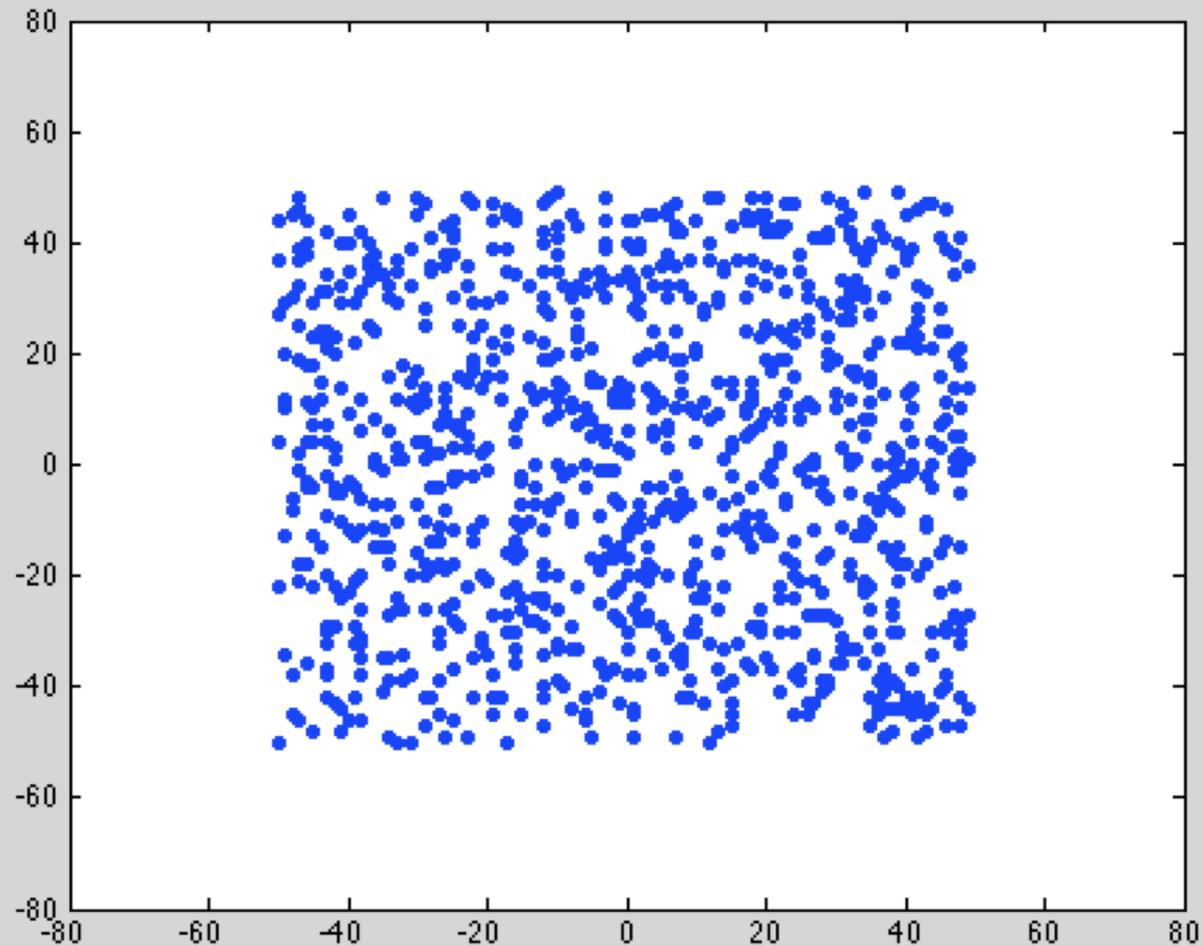
$$\text{Ponendo } C=\text{Cov}(D) \text{ e } V=C^{-1/2} \rightarrow \text{Cov}(P) = I$$

$$\begin{aligned} \text{Cov}(P) &= \text{Cov}(V*D) = \text{Cov}(C^{-1/2}*Z) = C^{-1/2}*Z*Z'*C^{-1/2} = \\ &= C^{-1/2}CC^{-1/2} = C*C^{-1} = I. \end{aligned}$$



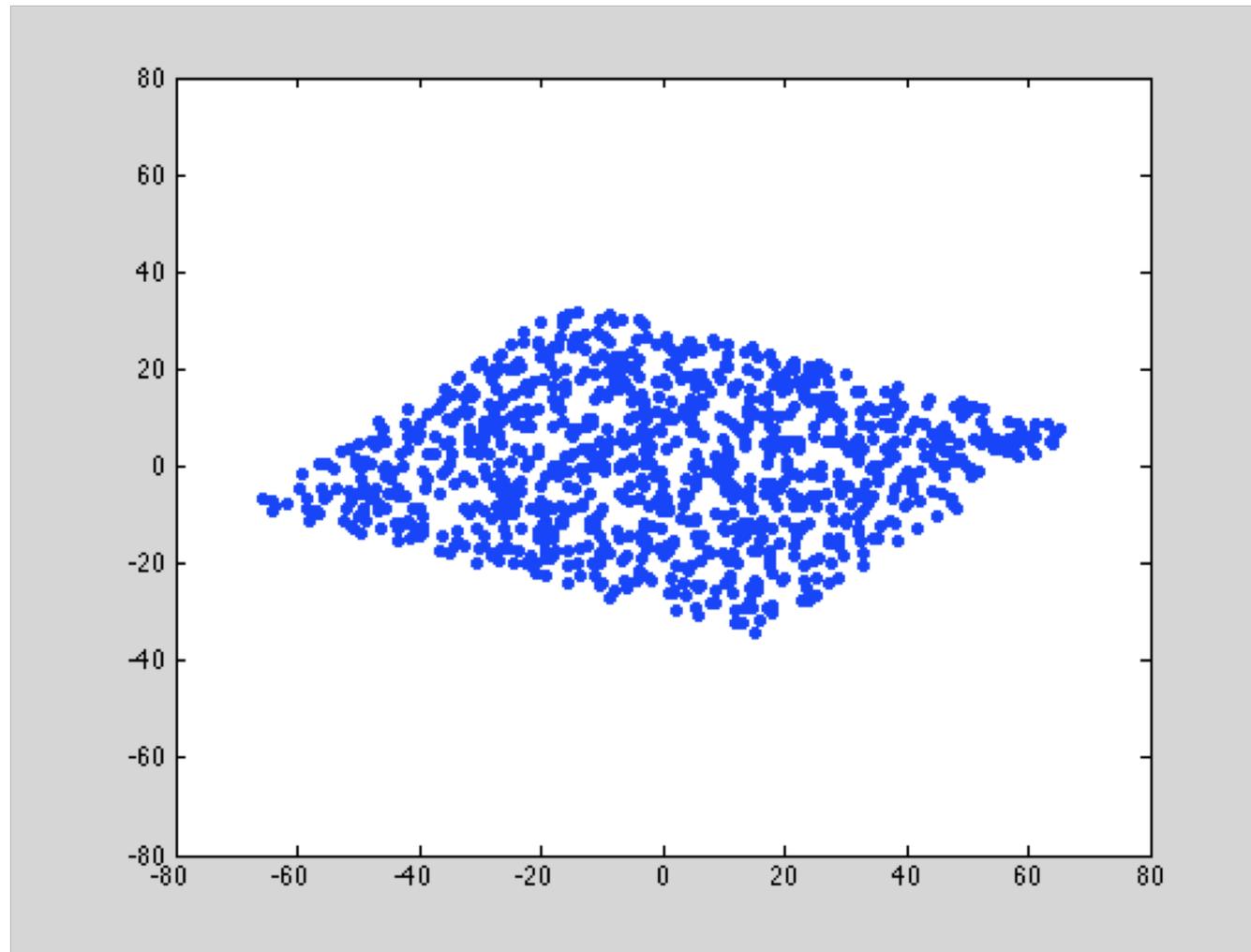
DATA WHITENING: ESEMPIO

- Scatter plot di due variabili casuali indipendenti



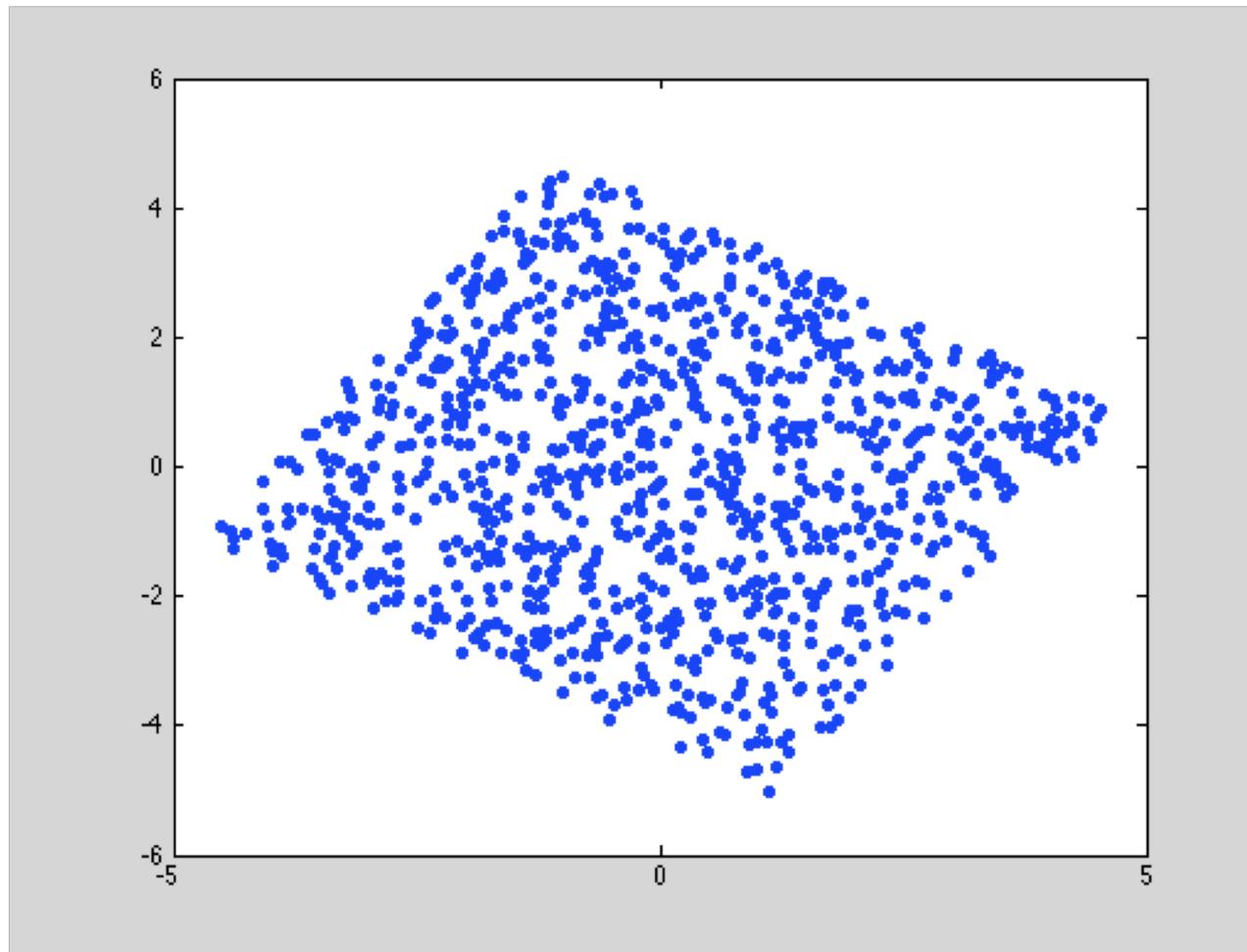
DATA WHITENING: ESEMPIO

- Scatter plot di due ottenute dalla combinazione lineari di due variabili casuali indipendenti



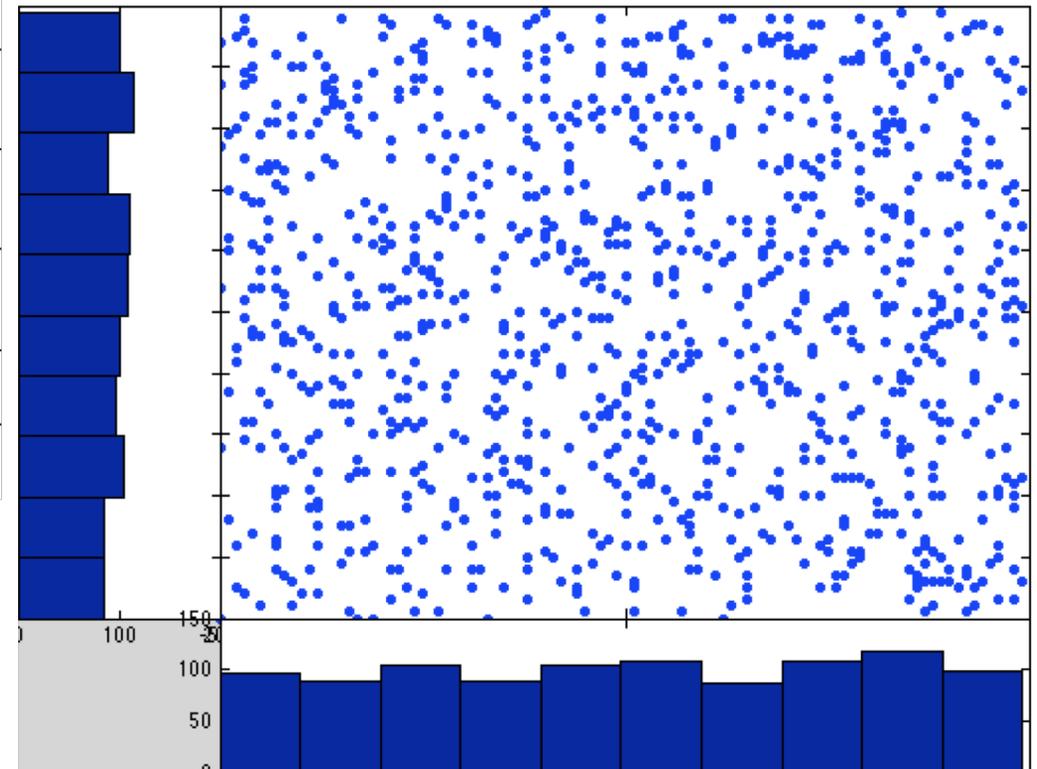
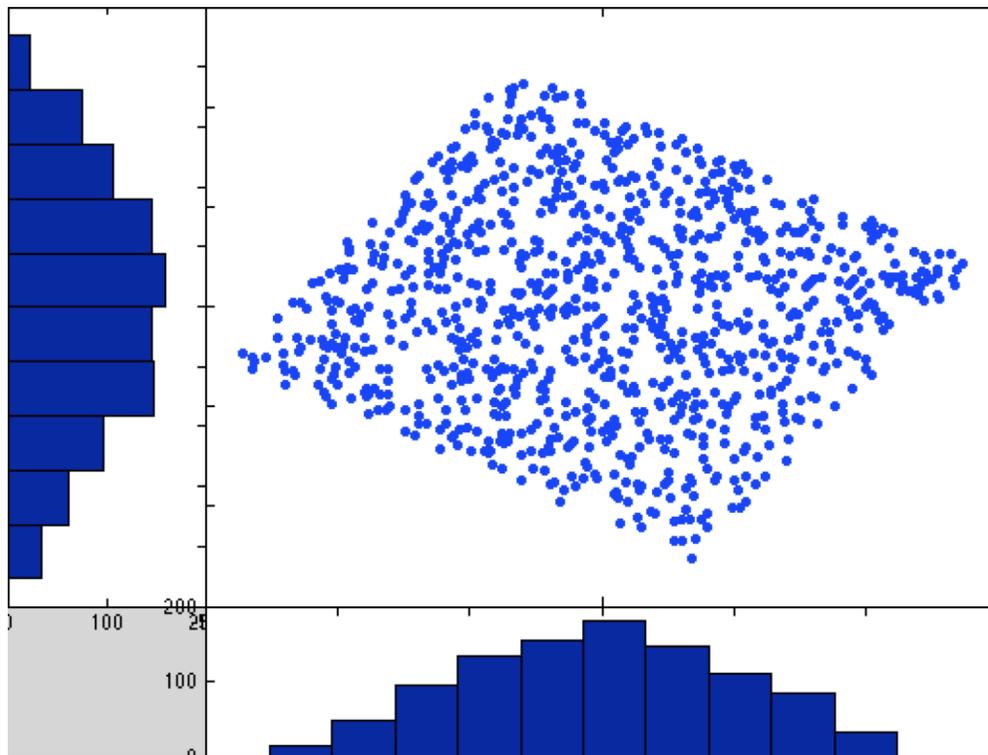
DATA WHITENING: ESEMPIO

- Scatter plot di due ottenute dalla combinazione linear di due variabili casuali indipendenti dopo aver applicato il procedimento di whitening

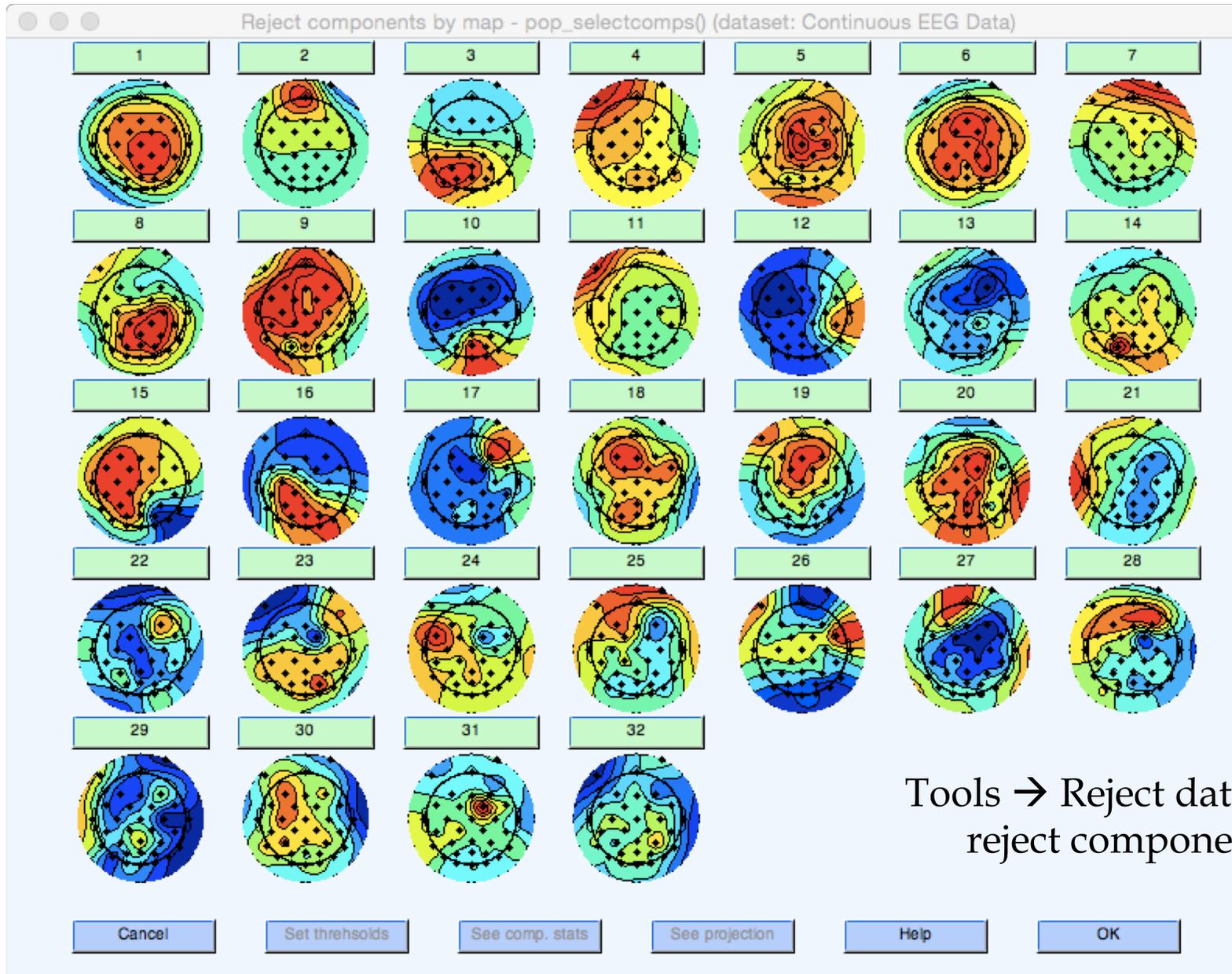


ICA COMPONENTS

- Le componenti indipendenti si ottengono minimizzando la gaussianità delle proiezioni sui due assi



REIEZIONE DELLE COMPONENTI ARTEFATTUALI

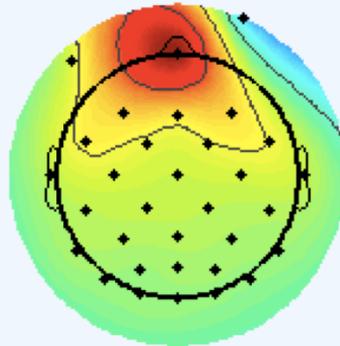


Tools → Reject data using ICA →
reject components by map

REIEZIONE DELLE COMPONENTI ARTEFATTUALI



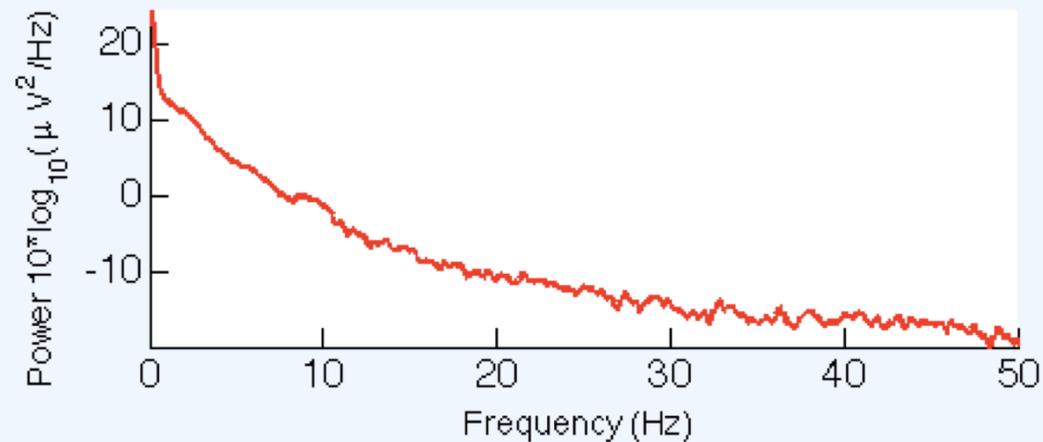
Component 2 map



Lo spettro discendente e la localizzazione frontale sono tipici dell'artefatto oculare

No erpimage plotted for continuous data.

Activity power spectrum



Cancel

Values

ACCEPT

HELP

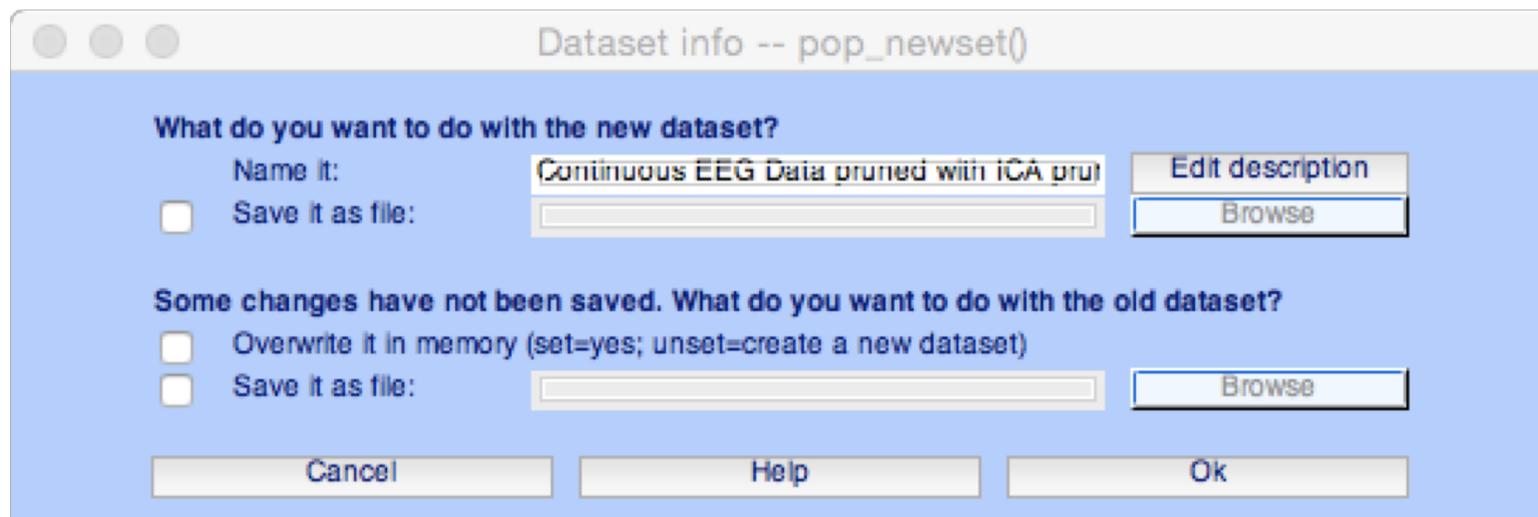
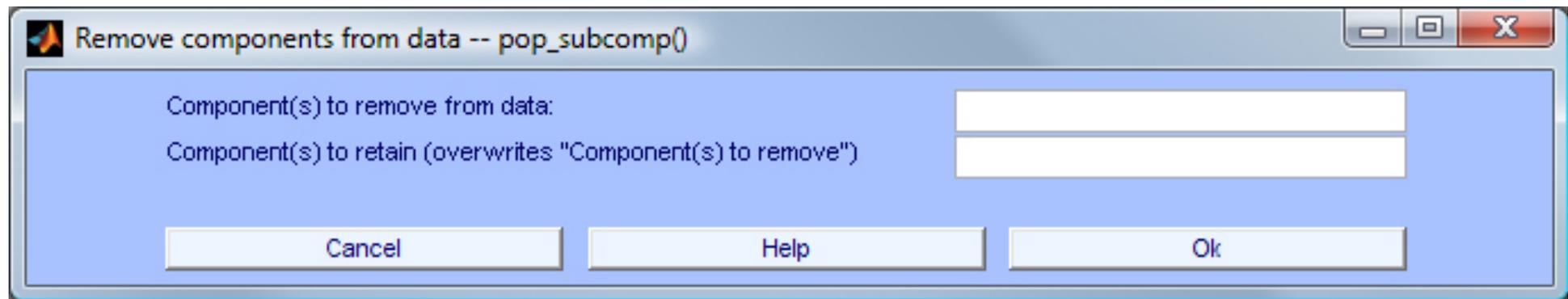
OK

Click su "Accept" per farlo diventare "Reject"
→ premere OK

SOTTRAZIONE DELLE COMPONENTI ARTEFATTUALI



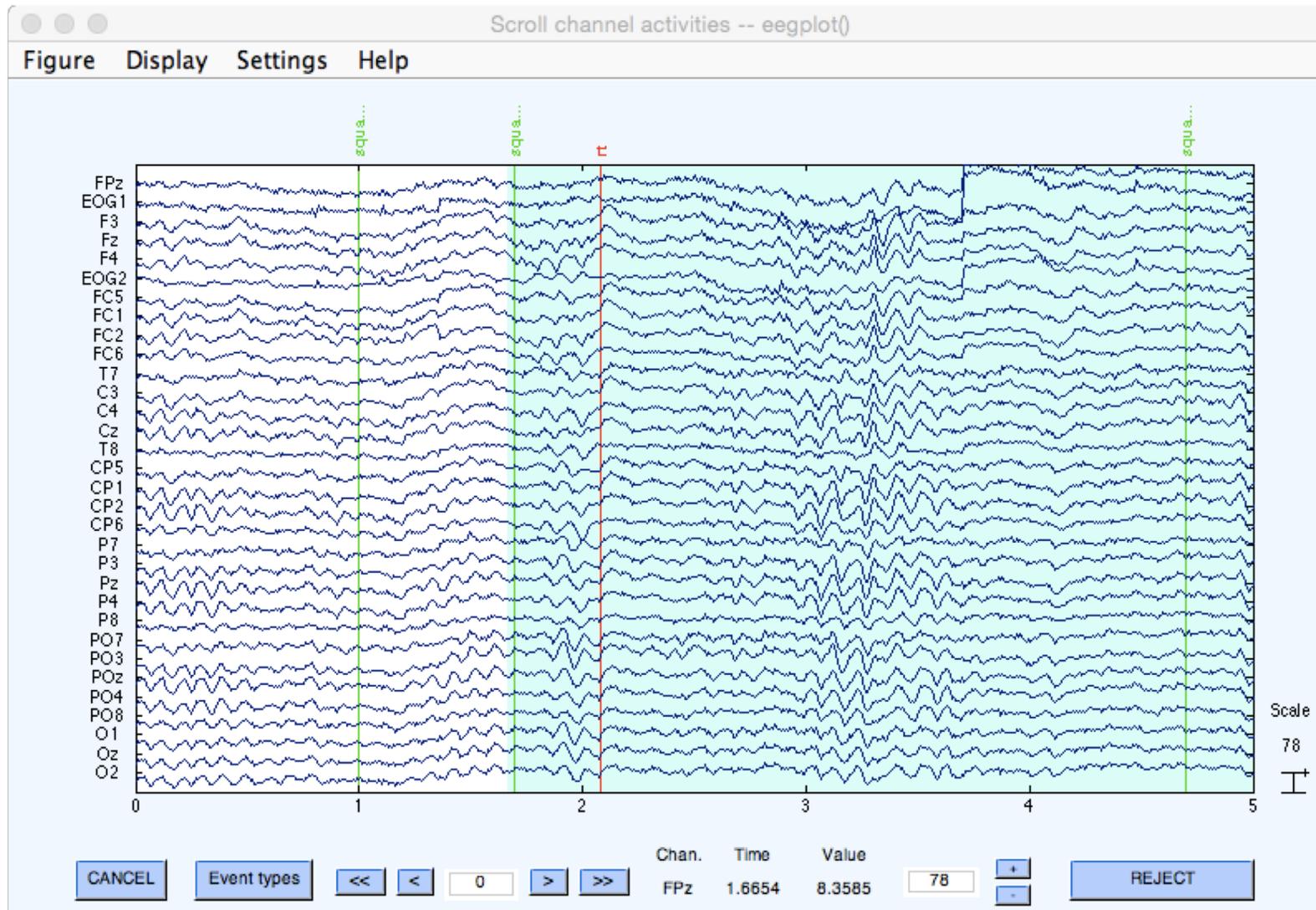
Tools → Remove components



VISUALIZE NEW DATA



Plot → Channel data (scroll).



CONFRONTO CON I DATI ORIGINALI

