



Applicazioni cliniche dell'elaborazione del segnale EEG e dei potenziali evocati ed evento-relati

dott. ing. Ferruccio Panzica - INN Besta - Milano

- ❑ Sviluppo e applicazione di tecniche di analisi dei segnali neurofisiologici, sia in ambito clinico che sperimentale
- ❑ Applicazione alla diagnostica neurofisiologica di tecniche innovative
- ❑ Gestione e analisi statistica informazioni relative a pazienti con epilessia
- ❑ Collaborazione allo sviluppo di percorsi diagnostici e scientifici
- ❑ Attività di supporto alla Direzione scientifica per progetti di bioingegneria e informatica medica, in particolare:

Sviluppo e gestione database/archivi scientifici relativi a patologie rilevanti per i progetti/attività dell'Ente

Integrazione dati scientifici e clinici





Applicazioni cliniche dell'elaborazione del segnale EEG e dei potenziali evocati ed evento-relati

dott. ing. Ferruccio Panzica - INN Besta, Milano



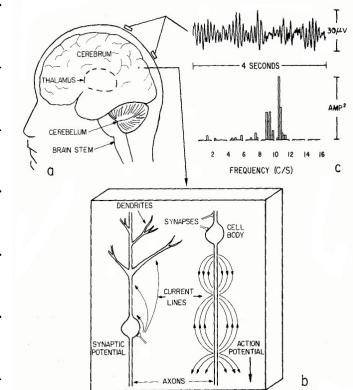
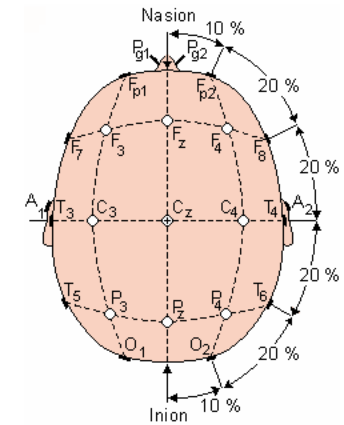
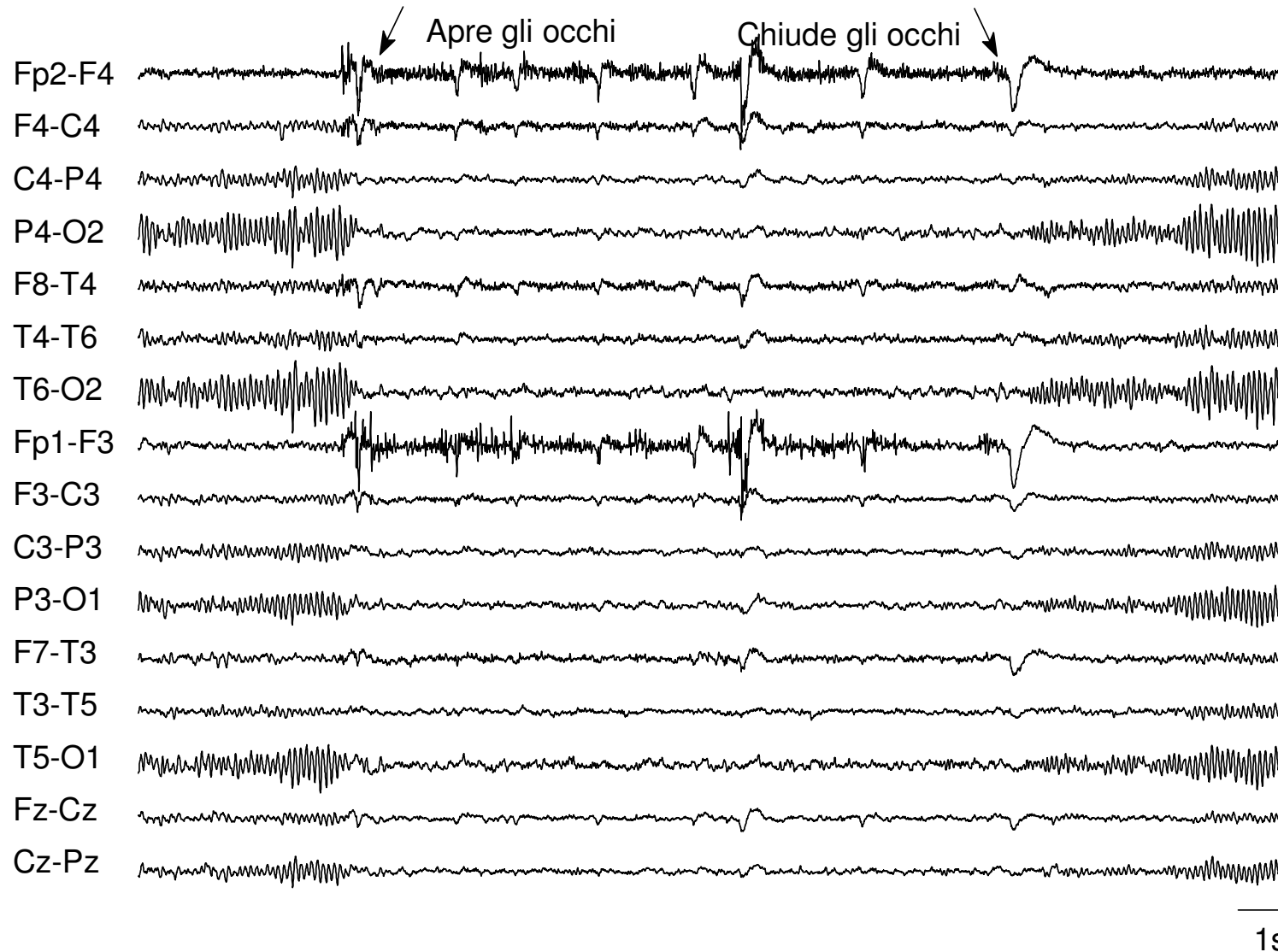
- Meccanismi di base - Avanzamento delle conoscenze
- Contributo alla diagnosi
- Contributo al trattamento terapeutico



3 LAVORI/PROGETTI

- Analisi spettrale EEG-EMG
- Potenziali evocati: studio singola sweep
- TESI

EEG: misura delle variazioni del potenziale elettrico dalla superficie dello scalp, generato dal movimento di ioni a livello cellulare.



Movement-activated myoclonus in genetically defined progressive myoclonic epilepsies: EEG–EMG relationship estimated using autoregressive models

F. Panzica, L. Canafoglia, S. Franceschetti*, S. Binelli, C. Ciano, E. Visani, G. Avanzini

Objective: To study electroencephalography (EEG-EMG) relationships in patients with different forms of progressive myoclonic epilepsies (PME)



CRISI EPILETTICHE: episodi accessuali generati da scariche patologiche di neuroni (ipereccitabili) della corteccia cerebrale

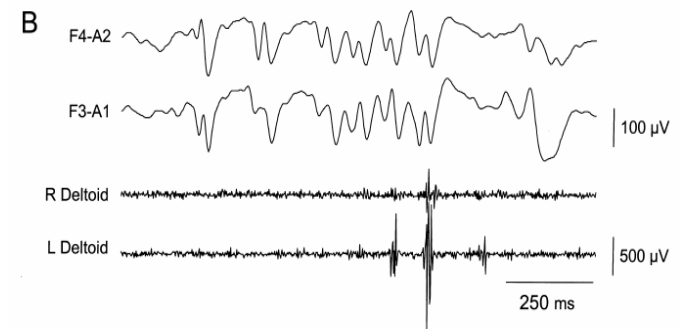
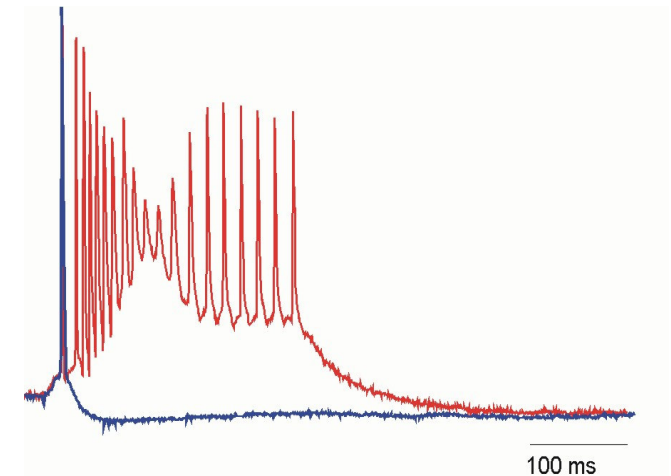
EPILESSIE: condizioni in cui crisi epilettiche tendono a ripetersi in modo spontaneo, assumendo andamento cronico.

Diverse per età di esordio, prognosi, gravità intrinseca, deficit associati

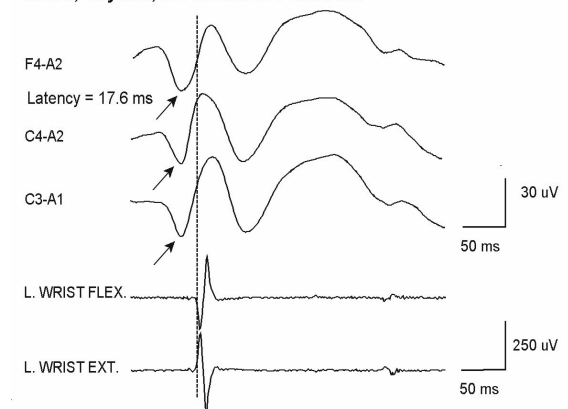
L'espressione clinica di una crisi dipende dalla sede di origine, dall'andamento temporale e dalla modalità di propagazione della scarica

MIOCLONO = improvviso, rapido, “**shock-like**” e irregolare movimento involontario che ha origine dal **SNC**. Può essere correlato con l'attività motoria o può occorrere in condizioni di riposo. Spesso è stimolo-sensibile

E' presente in diversi disordini neurologici. Una corretta classificazione del mioclono è utile per diagnosi, prognosi e trattamento

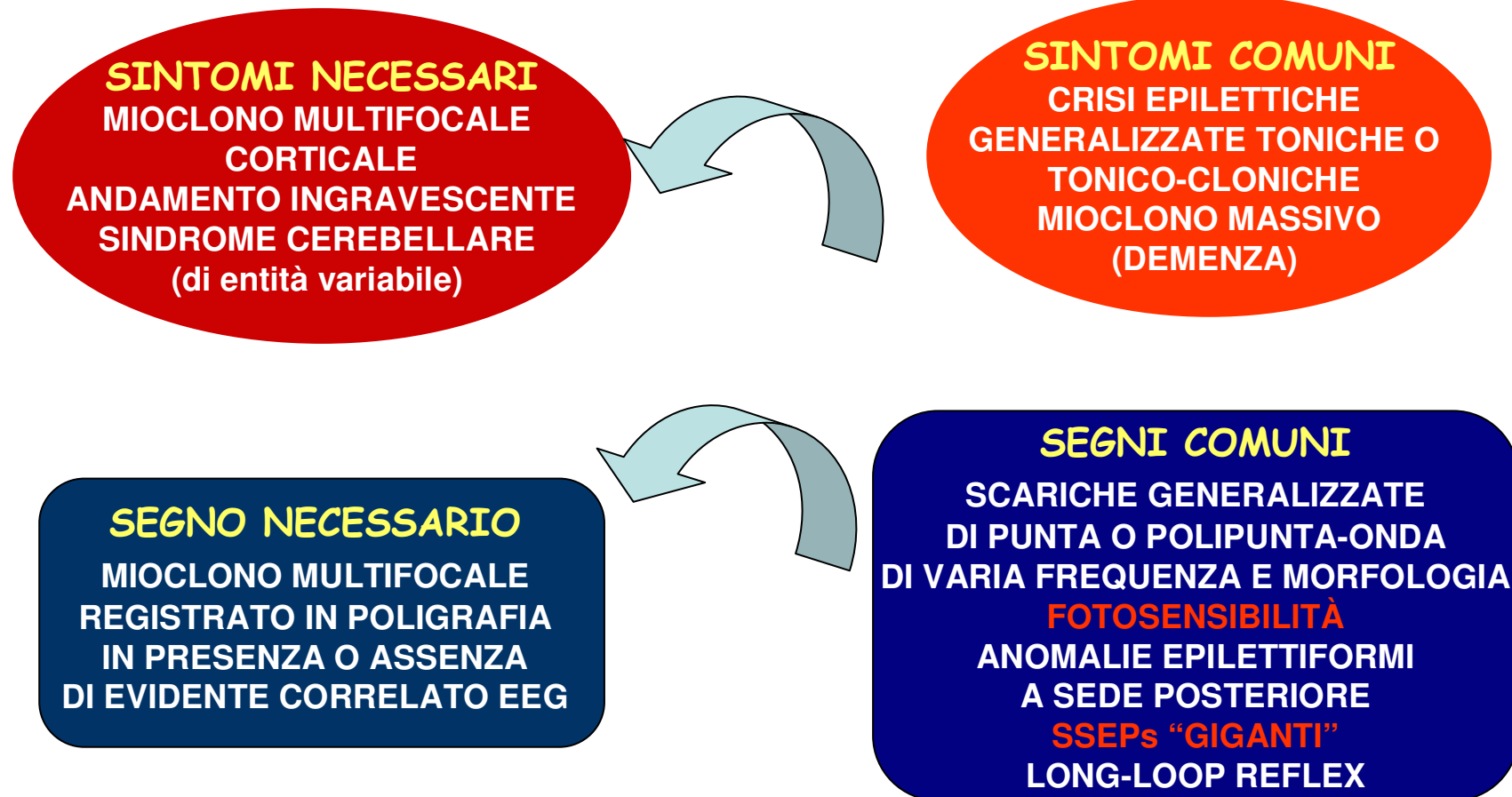


M.A.A., 19 years, LAFORA BODY DISEASE



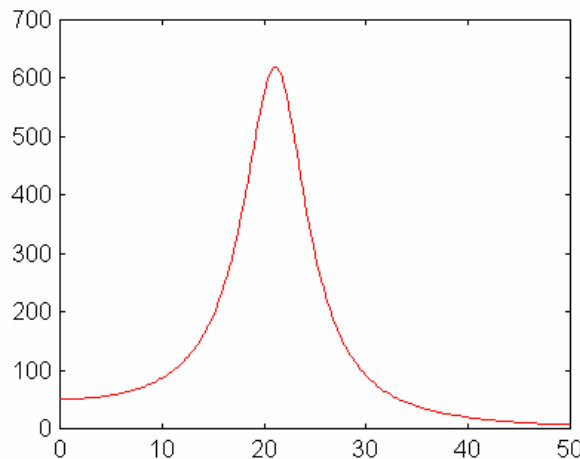
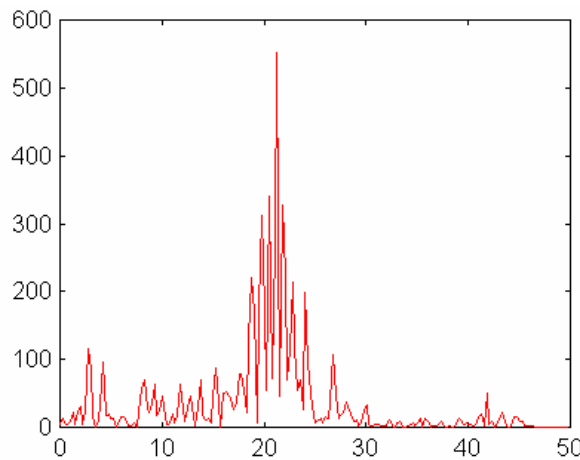
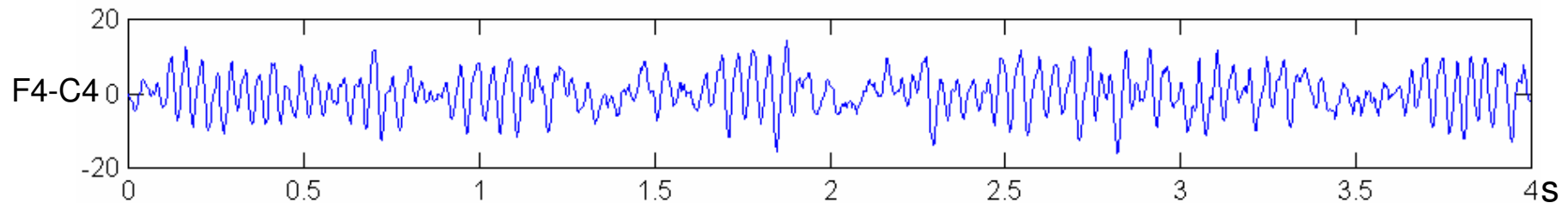
MIOCLONO EPILESSIE PROGRESSIVE

malattie a carattere primitivamente progressivo che si presentano nella seconda infanzia, adolescenza con crisi epilettiche, mioclono, sindrome cerebellare, (deterioramento psichico)





Methods: EEG-EMG **auto-spectra**, coherence and phase function were estimated by means of a bivariate and time varying **autoregressive (AR) models** in 15 patients.....



$$\hat{y}(n) = a_1 y(n-1) + a_2 y(n-2) + \dots + a_p y(n-p) = \sum_{i=1}^p a_i y(n-i)$$

$$E_p = \frac{1}{N} \sum_{n=1}^N (e_{pn})^2 = \sum_{n=1}^N (y(n) - \hat{y}(n))^2$$

$$PSD(f) = \frac{\sigma^2 T}{\left| 1 - \sum_{i=1}^p a_i z^{-i} \right|^2}_{z=\exp(j 2 \pi f T)}$$

- ◆ Improvement in frequency resolution
- ◆ AR spectra can be obtained without windowing the data
- ◆ AR spectrum is smooth, its shape depends only on the values of the coefficients → No averaging
- ♠ Choice of model order

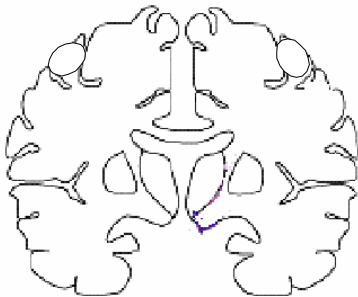
Methods: EEG-EMG auto-spectra, **coherence and phase** function were estimated by means of a **bivariate** and time varying autoregressive (AR) models in 15 patients.....

$$Coh_{xy}(f) = \frac{|C_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$

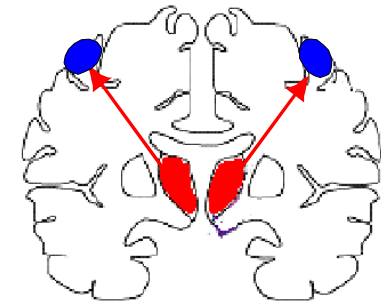
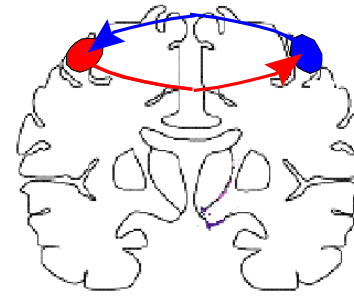
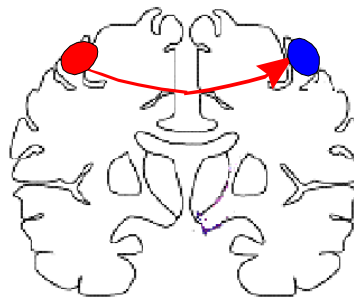
$$CL(\alpha) = 1 - \left(1 - \frac{\alpha}{100}\right)^{\frac{1}{N \bullet gl - 1}}$$

Measure of the linear dependence between two signals in the frequency domain. Bounded between zero and one: one → perfect linear relationship; zero → the two signals are not linearly related at that frequency

Coerenza ~ 0



Coerenza ~ 1

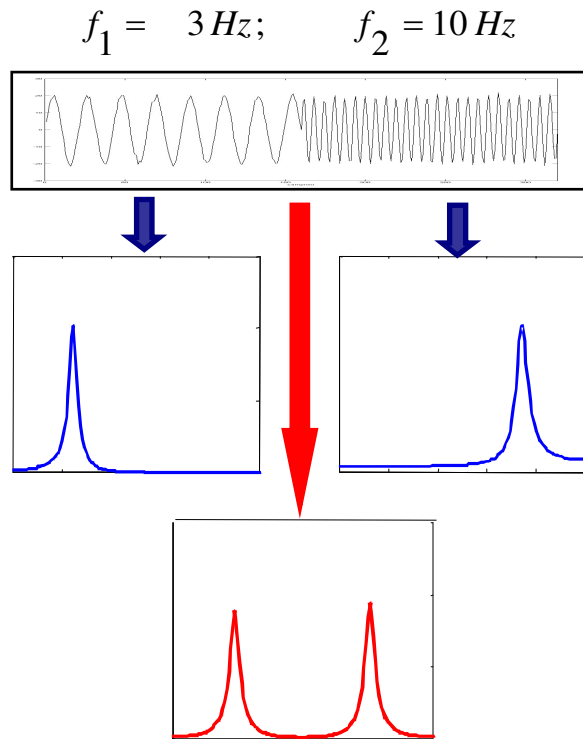


The phase difference can provide an estimate of the temporal delay

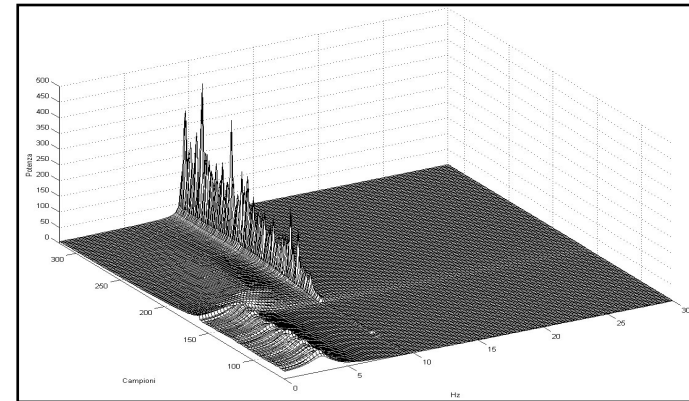
$$Ph_{xy}(f) = \arg(C_{xy}(f)) = \arctg \frac{\text{Im}(C_{xy}(f))}{\text{Re}(C_{xy}(f))} \quad Ph_{xy}(f) \pm 1.96 \left[\frac{1}{N} \left(\frac{1}{Coh_{xy}(f)} - 1 \right) \right]^{\frac{1}{2}}$$

$$Ph_{xy}(f) = \frac{360}{1000} t \bullet f + k$$

Methods: EEG-EMG auto-spectra, coherence and phase function were estimated by means of a bivariate and **time varying autoregressive (AR) models** in 15 patients.....



Stationarity of the signal
No information about the time at
which a frequency pattern occurs



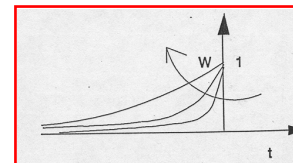
$$\varphi(t) = [y(t-1), y(t-2), \dots, y(t-p)]^T$$

$$\mathbf{a}(t) = \mathbf{a}(t-1) + \mathbf{K}(t)e(t) \quad e(t) = y(t) - \hat{y}(t)$$

$$\hat{y}(t) = \varphi^T(t) \mathbf{a}(t-1)$$

$$\mathbf{K}(t) = \frac{\mathbf{P}(t-1)\varphi(t)}{w + \varphi(t)^T \mathbf{P}(t-1)\varphi(t)}$$

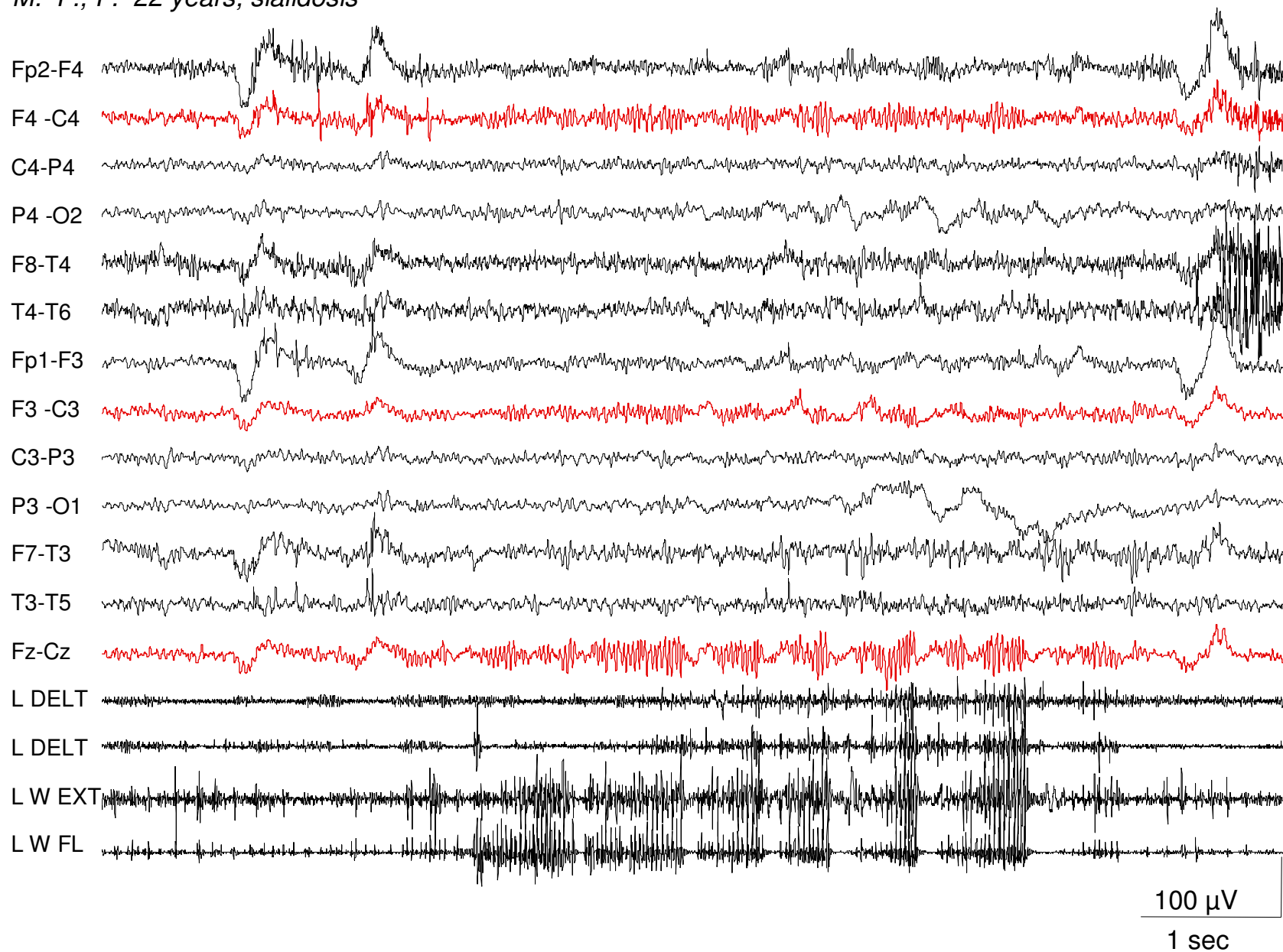
$$\mathbf{P}(t) = \frac{1}{w} \left[\mathbf{P}(t-1) - \frac{\mathbf{P}(t-1)\varphi(t)\varphi(t)^T \mathbf{P}(t-1)}{w + \varphi(t)^T \mathbf{P}(t-1)\varphi(t)} \right]$$

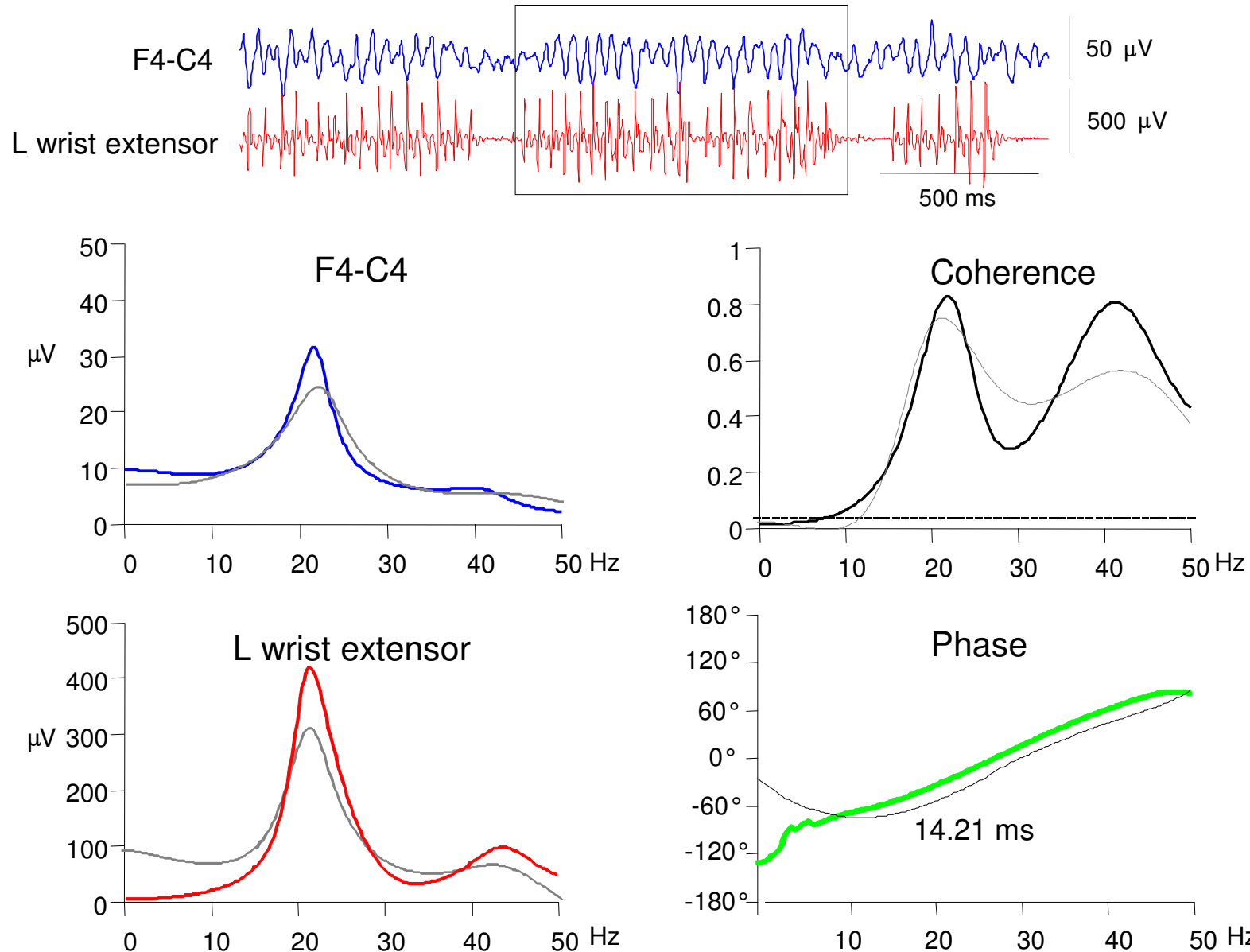


$$N = \frac{1}{1-w} \quad \begin{cases} w=1 & \text{all samples} \\ w=0.99 & 100 \text{ samples} \\ w=0.98 & 50 \text{ samples} \end{cases}$$



M. F., F. 22 years; sialidosis



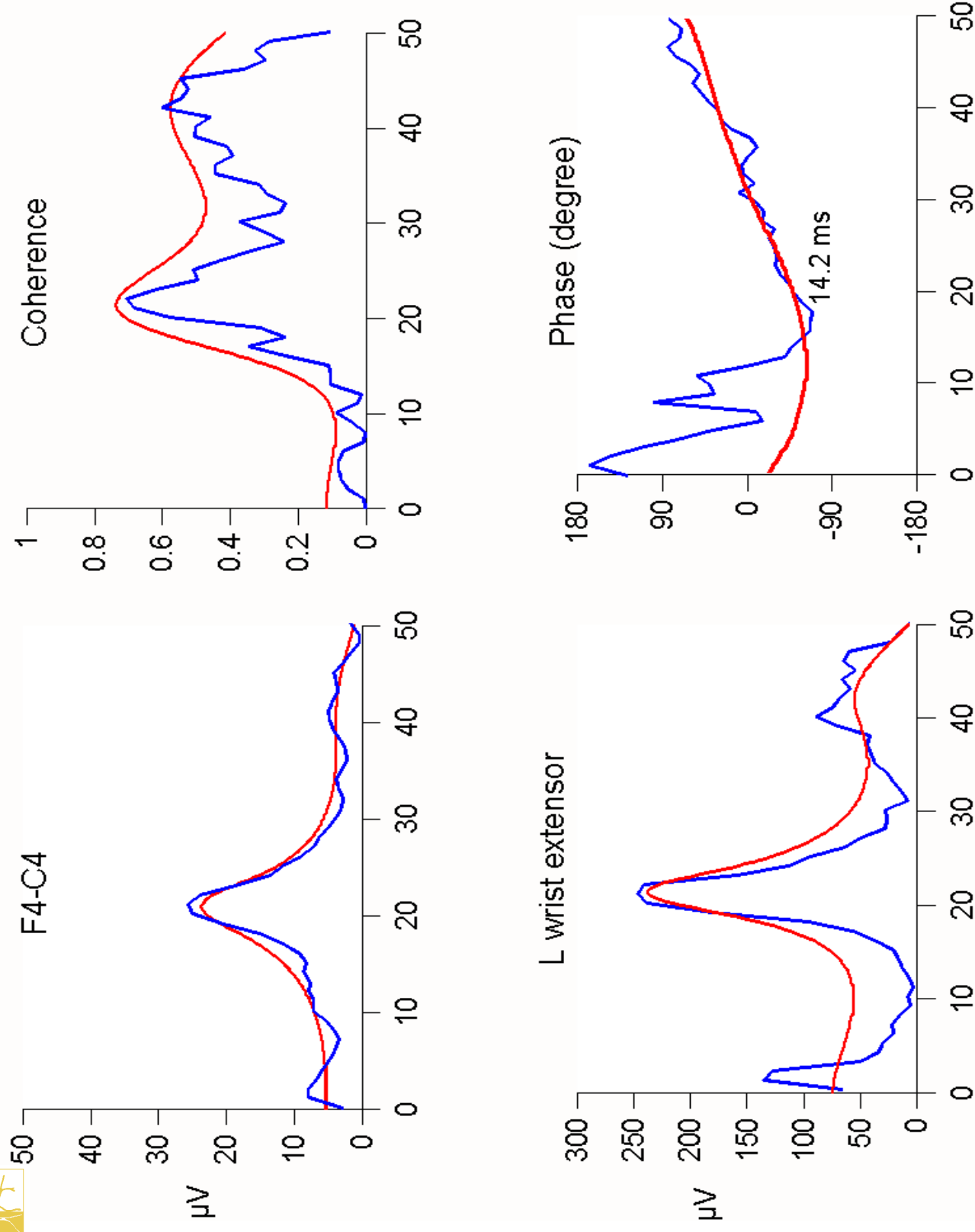


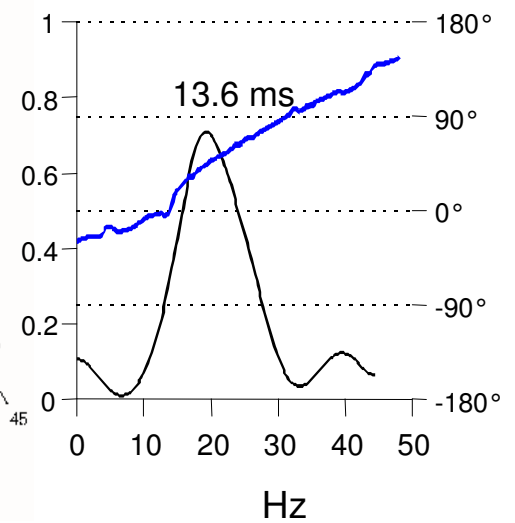
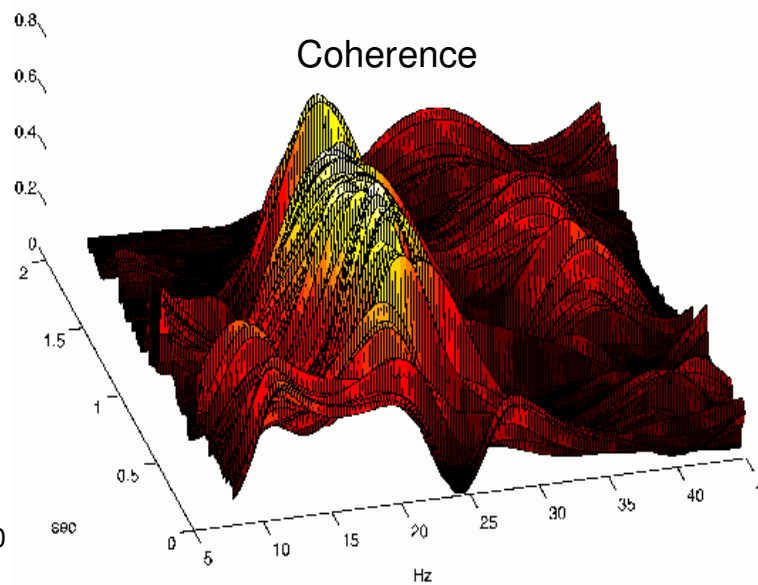
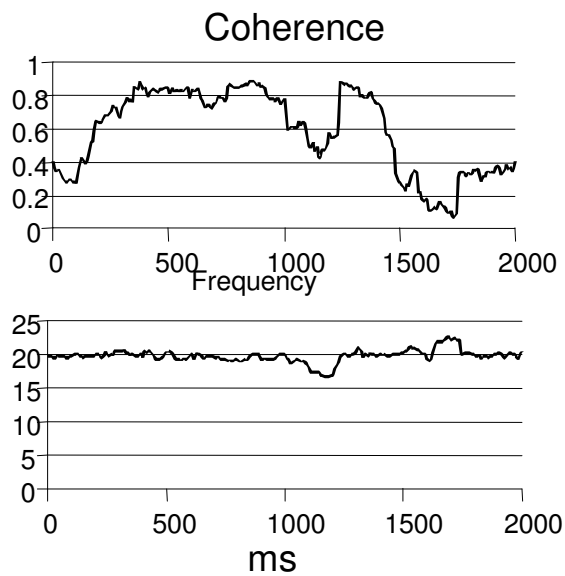
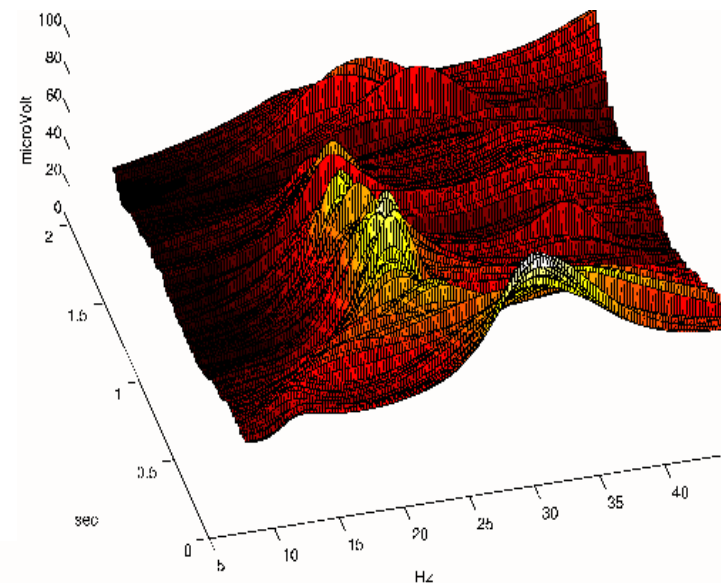
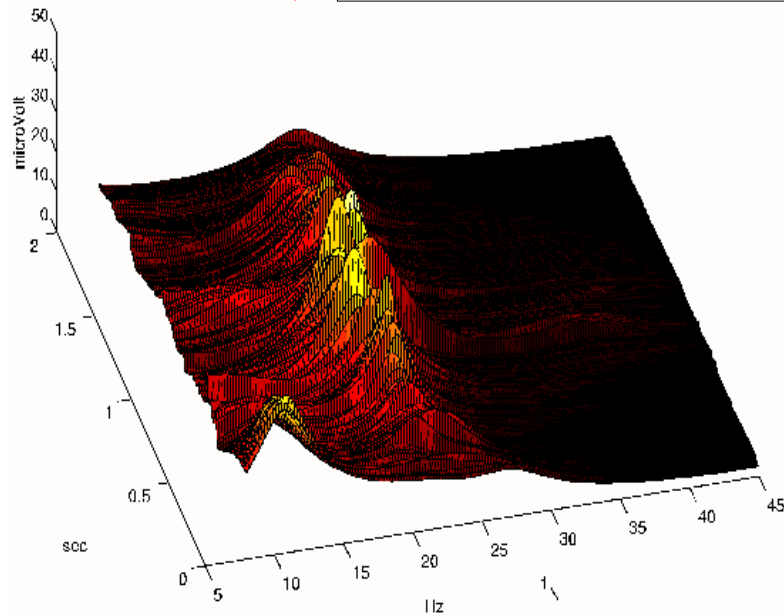
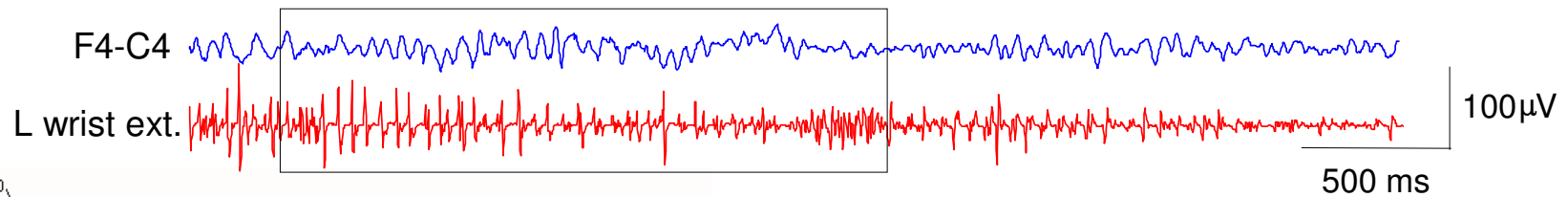
A time delay between two signals can be reliably estimated only if:

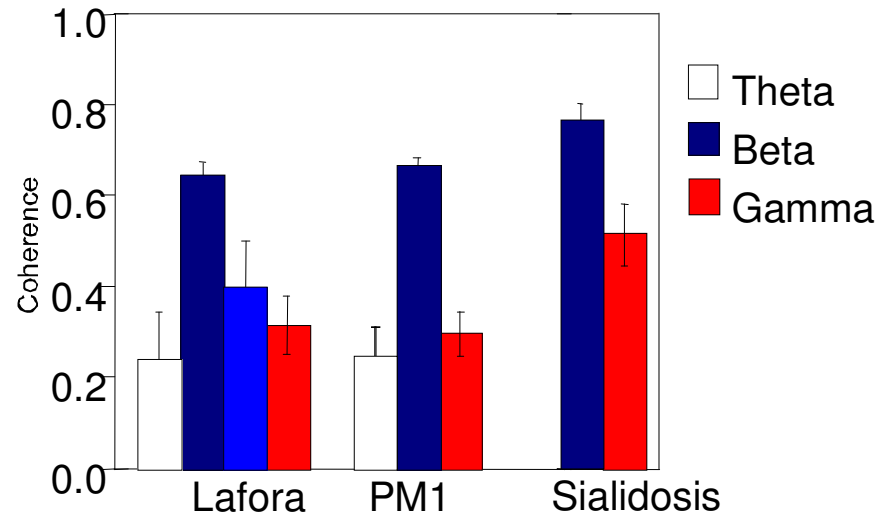
- ☐ the coherence is significant over a certain frequency band
- ☐ there is a linear relationship between phase and frequency within the same range



AR versus FFT average of 98 epochs







Results: Regardless of the type of PME, the coherence spectra of EMG epochs including action myoclonus and contralateral frontocentral EEG derivations showed a main beta peak (average coherence: 0.60-0.79).

The time lag from cortex to muscle was 13.0-21.3 ms.

Significantly coherent gamma activity was consistently found only in the three patients with sialidosis

Periods of normal muscle contractions were characterized by the presence of an EEG-EMG beta coherence peak on the same frequency found in case of action myoclonus, but with a lower coherence value.

Conclusions: AR models were capable of describing the EEG-EMG relationships in patients with PME, indicating that coherent cortical and EMG beta oscillations are crucially involved in the generation of myoclonus.

They could detect uneven spectral profiles characterizing different forms of PME



Clinical Neurophysiology XXXX;XXXXX-XXXX



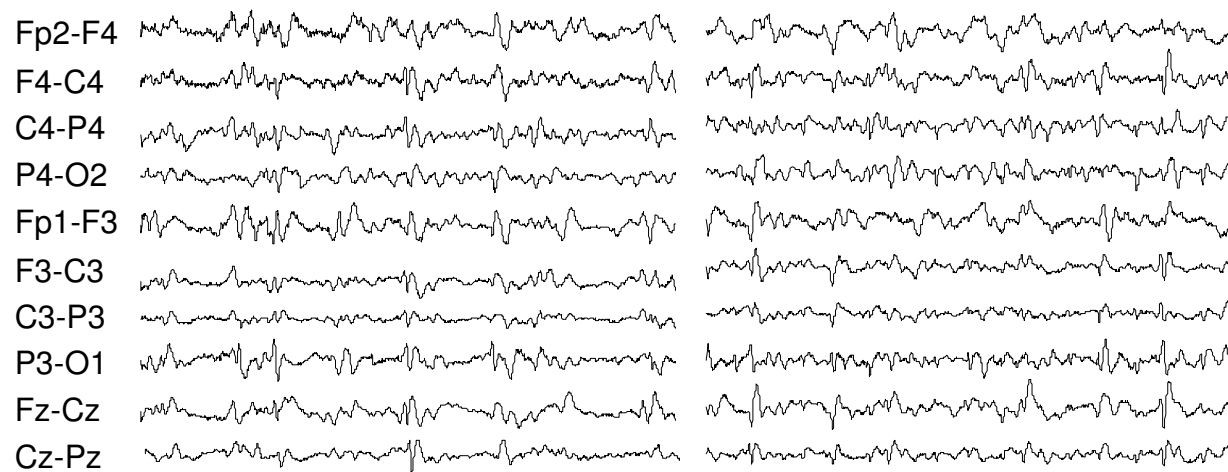
www.elsevier.com/locate/clinph

FVEPs IN CREUTZFELDT-JACOB DISEASE: WAVEFORMS AND INTERACTION WITH THE PERIODIC EEG PATTERN ASSESSED BY SINGLE SWEEP ANALYSIS

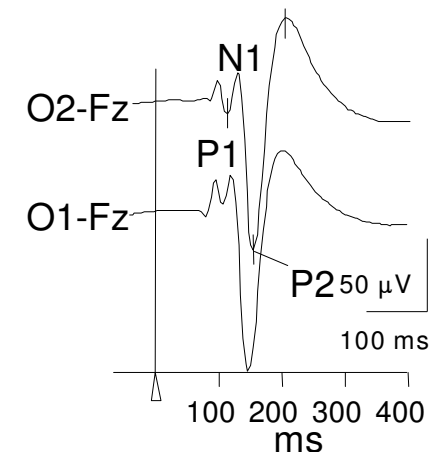
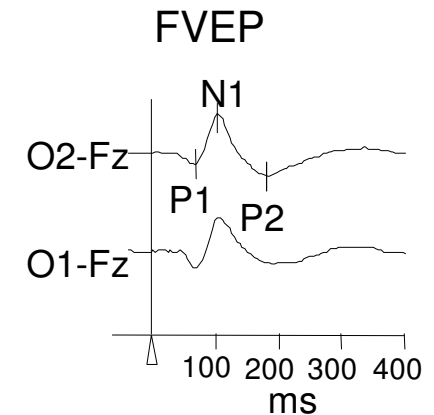
E. Visani, P. Agazzi, V. Scaioli, G. Giaccone (*), S. Binelli, L Canafoglia., F. Panzica, F. Tagliavini (*), O. Bugiani (*), G. Avanzini, S. Franceschetti.

Objective. To characterize flash visual evoked potentials (FVEPs) in 20 patients with Creutzfeldt-Jacob disease (CJD), and assess the relationships between spontaneous EEG patterns and the responses to individual stimuli.

La malattia di **Creutzfeldt-Jacob** è un'encefalopatia trasmissiva spongiforme associata, dal punto di vista neuropatologico, all'accumulo nel cervello di una proteina patologica (prione). In più del 60% dei pazienti CJD, è stata riscontrata un'alterazione della funzionalità visiva fin dai primi stadi della malattia. La relazione tra PEV e i complessi periodici che caratterizzano l'EEG, non è stata ancora stabilita.

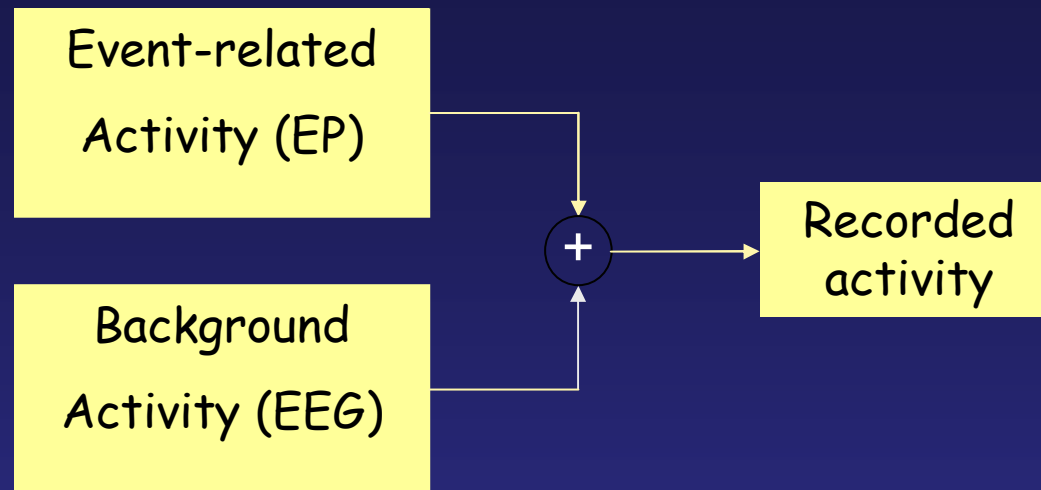


1 s 100 μ V





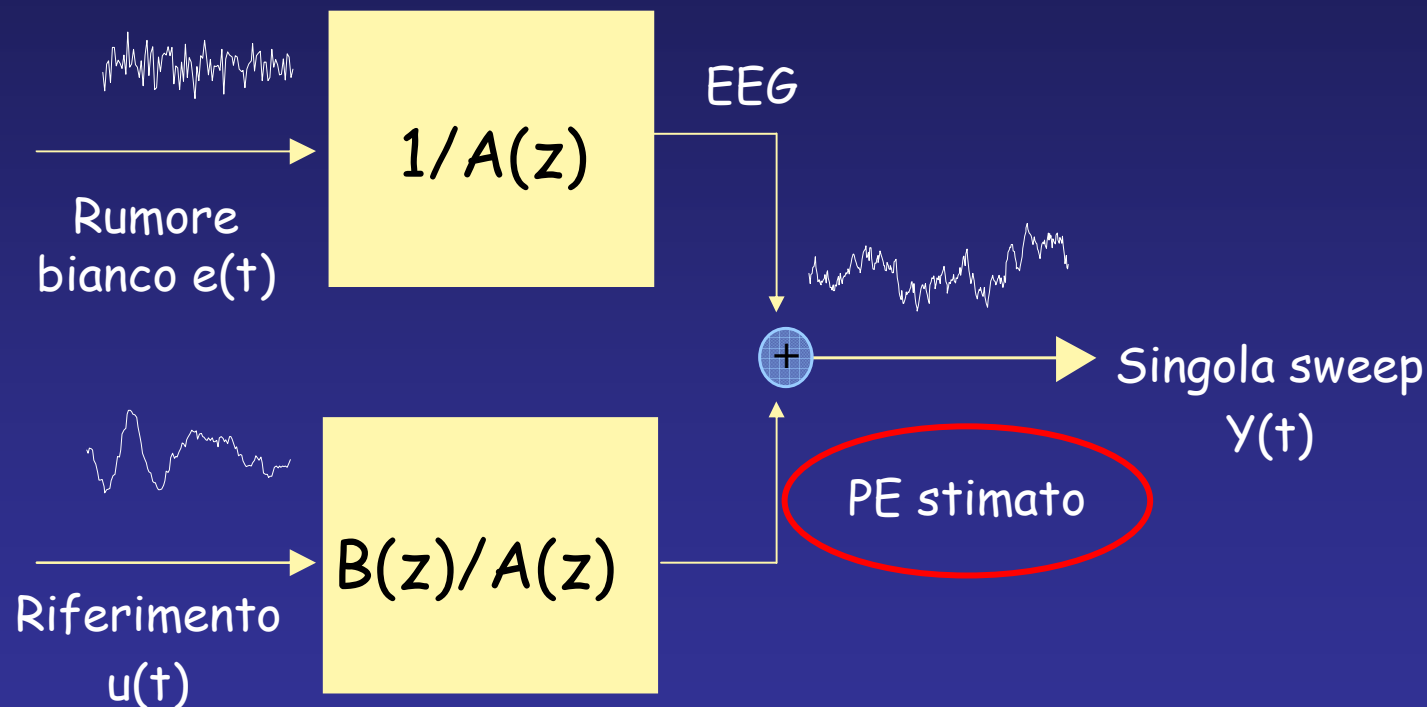
Potenziali evocati



- Numero elevato di stimolazioni per ridurre il rapporto segnale-rumore (pazienti poco collaboranti, monitoraggio intraoperatorio)
- Dinamica del segnale
 - Variazioni latenza e ampiezza componenti
 - Presenza/assenza di risposta

Methods. In nine patients, we applied an algorithm based on an **autoregressive model with exogenous input (ARX)** to estimate responses to individual random flashes and their interaction with periodic sharp wave complexes (PSWCs)

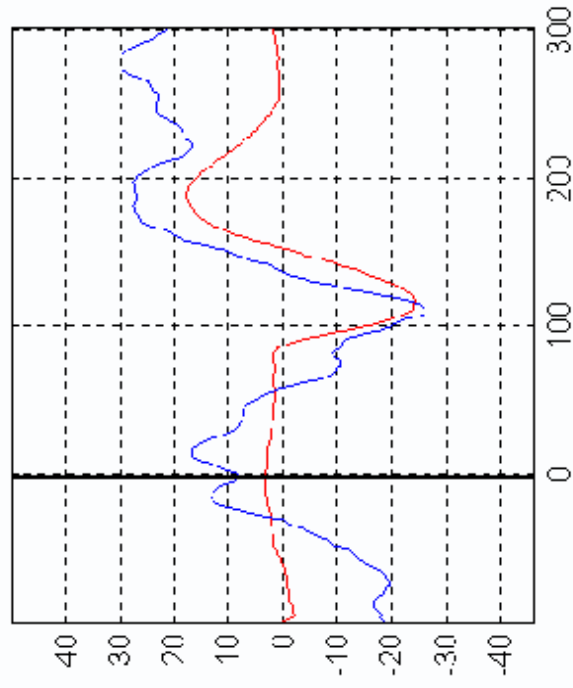
ARX identification model



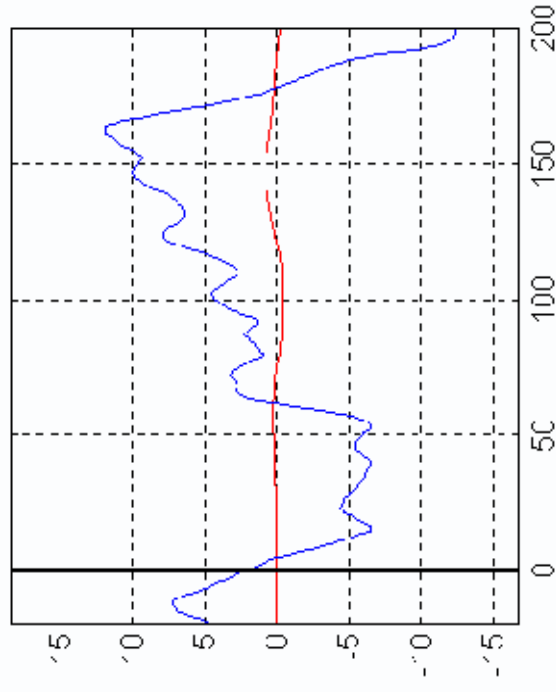
$$y_i(t) = s_i(t) + n_i(t) = \sum_{j=1}^p a_j y_i(t-j) + \sum_{k=0}^{q+d-1} b_k u(t-k) + e_i(t)$$



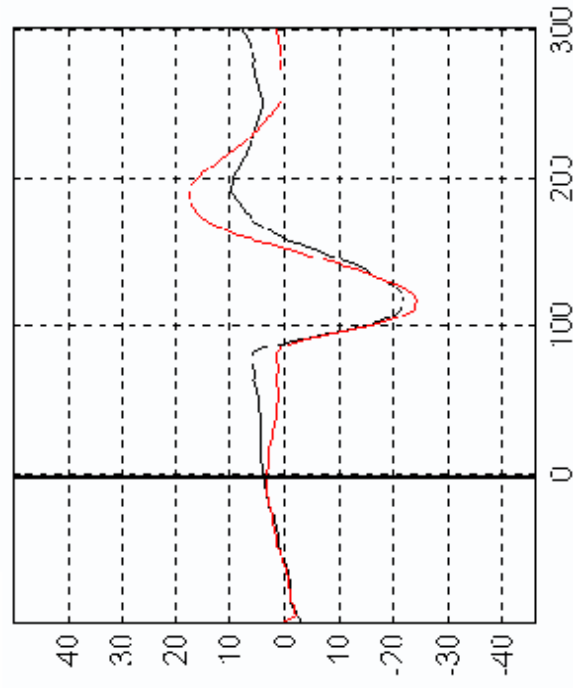
SINGOLA - SINGOLA FILTRATA



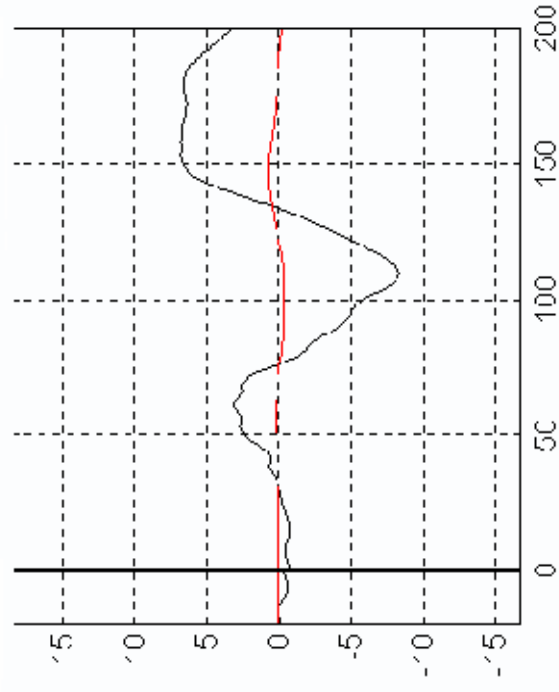
SINGOLA - SINGOLA FILTRATA

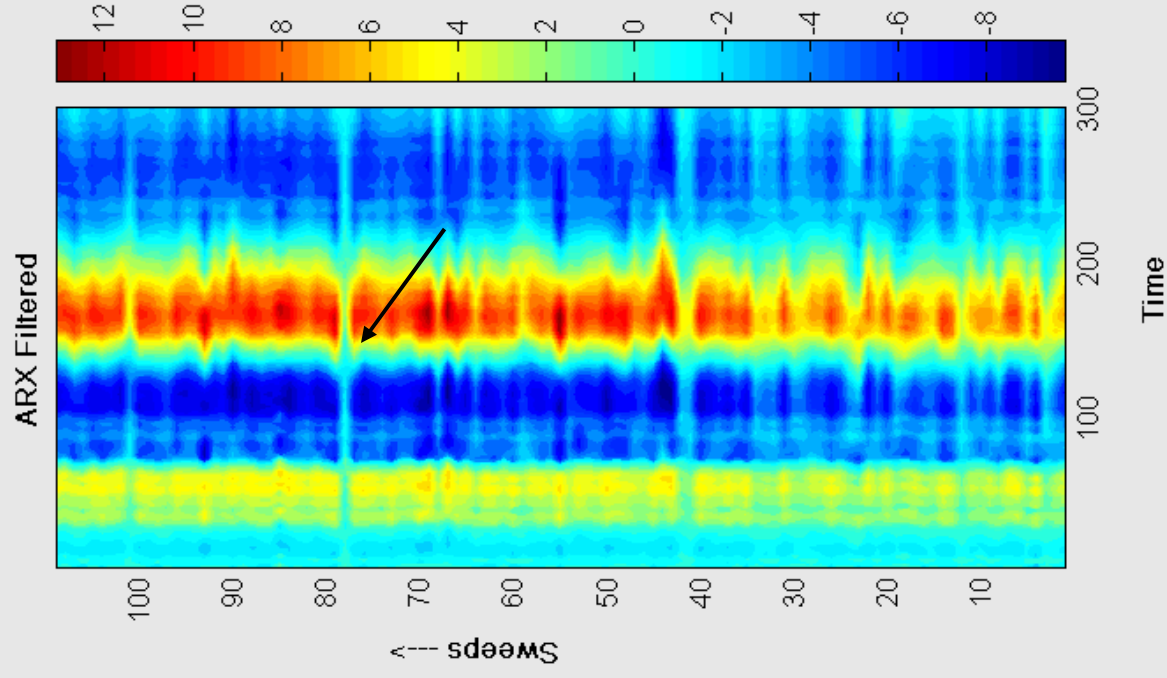
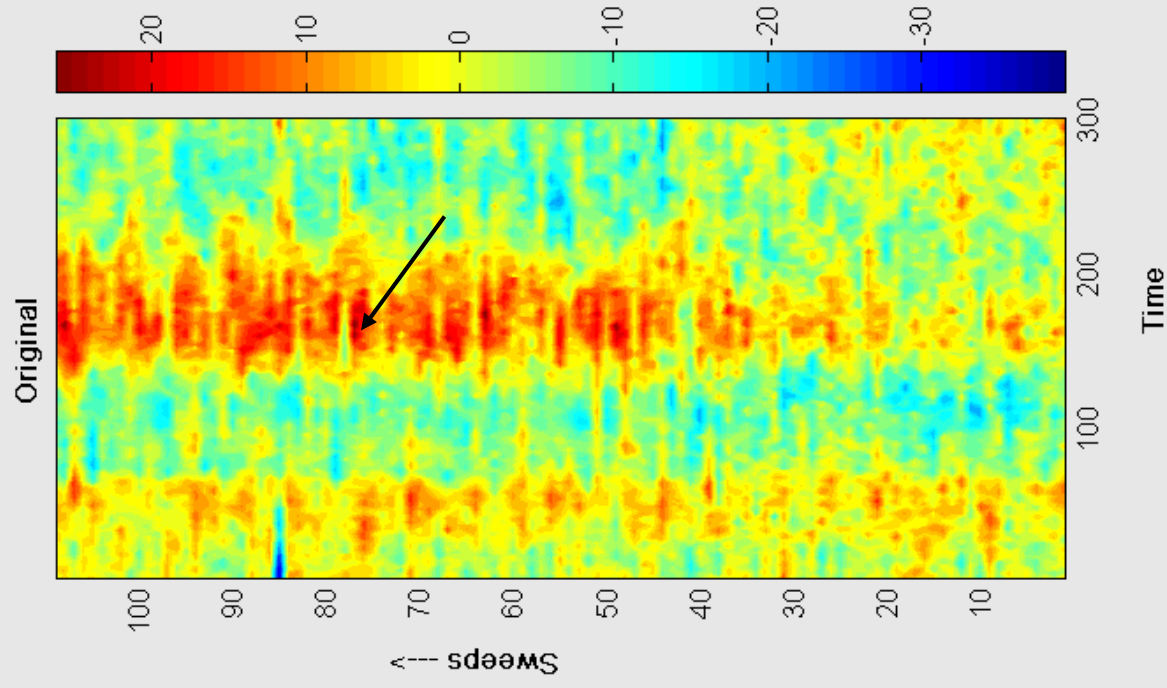


AVERAGE - SINGOLA FILTRATA



AVERAGE - SINGOLA FILTRATA

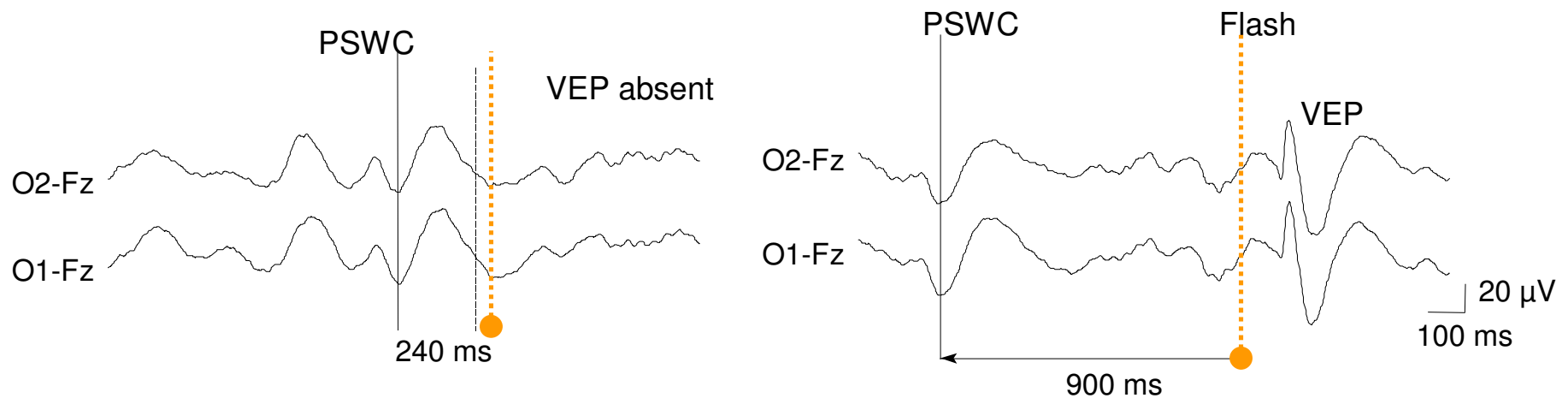


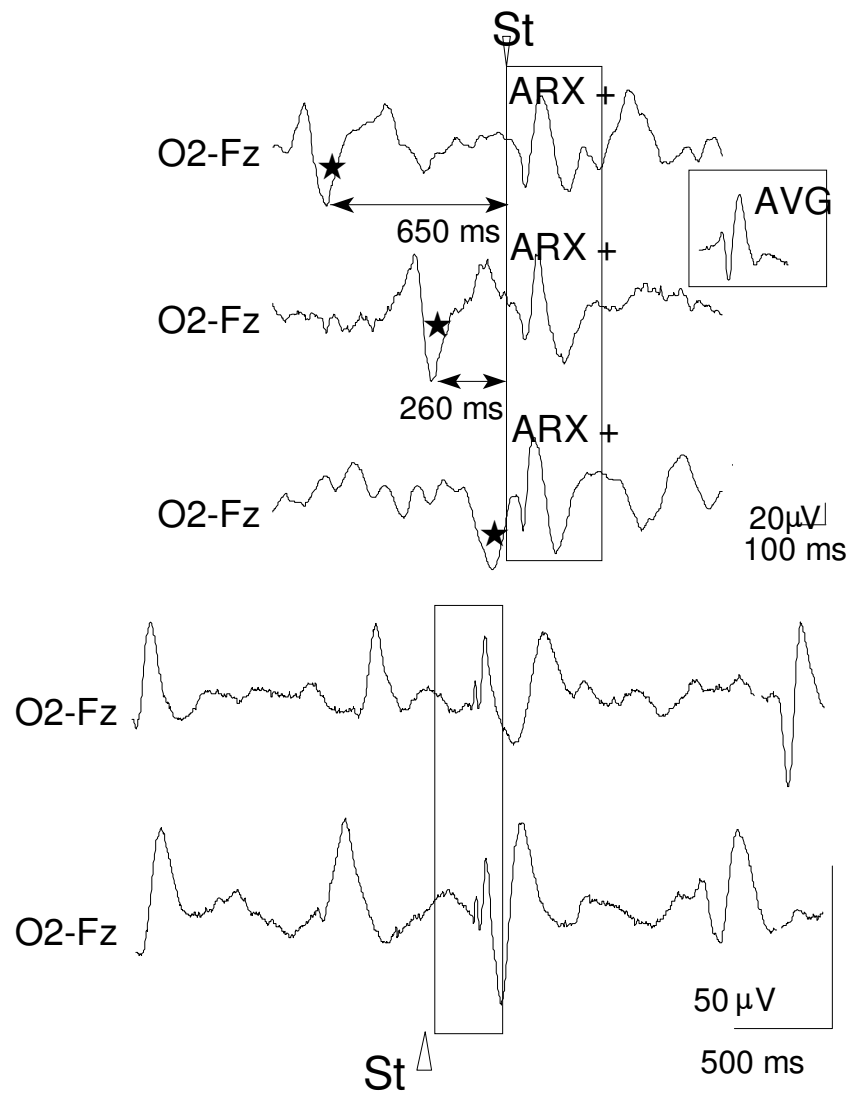
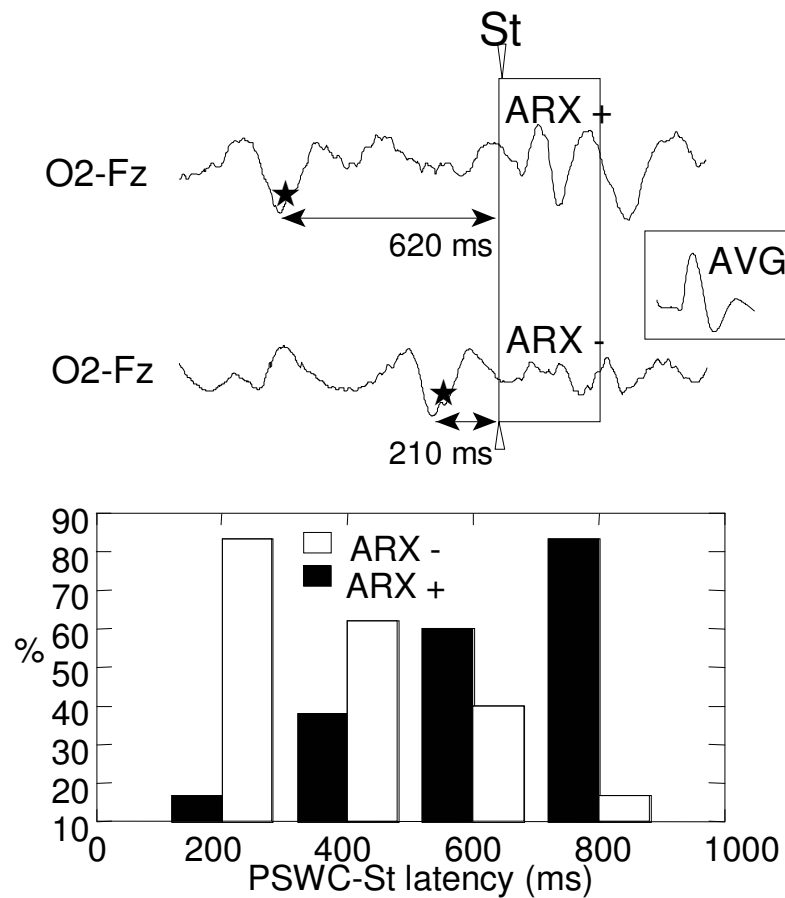


Methods. In nine patients, we applied an algorithm based on an autoregressive model with exogenous input (ARX) to estimate responses to individual random flashes and their interaction with periodic sharp wave complexes (PSWCs)

E' stato eseguito il protocollo di stimolazione luminosa a frequenza random (da 40 a 120 stimoli).

La risposta ad ogni stimolo è stata valutata singolarmente e classificata sulla base della presenza o dell'assenza di un VEP. E' stato quindi misurato l'intervallo di tempo tra lo stimolo e il principale picco positivo del PSWC che lo precedeva.





In 5 patients, with normal or slightly enlarged average N1-P2 amplitude, ARX revealed a period of relative refractoriness following individual PSWC.

In 4 patients with “giant” FVEPs, individual responses occurred irrespectively to the interval between stimulus and previous PSWC, but their amplitude had an inverse relationship with the interval length.

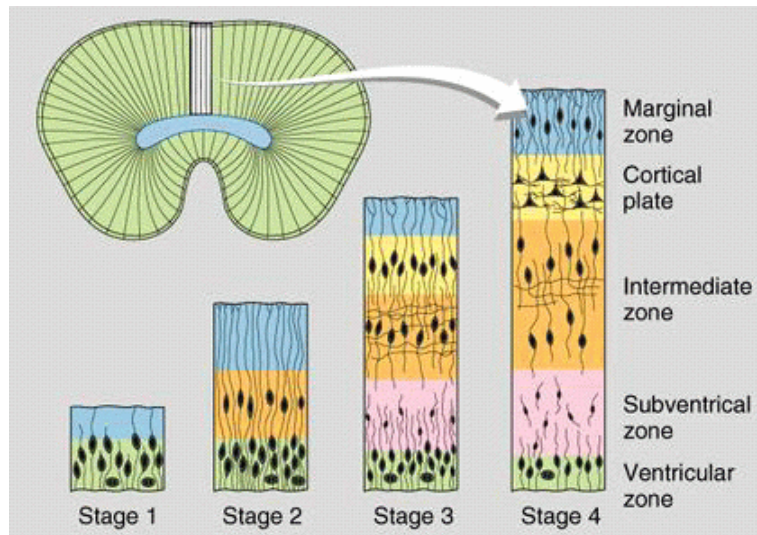


POLITECNICO DI MILANO
Facoltà di Ingegneria
Corso di Laurea in Ingegneria Biomedica
Dipartimento di Bioingegneria

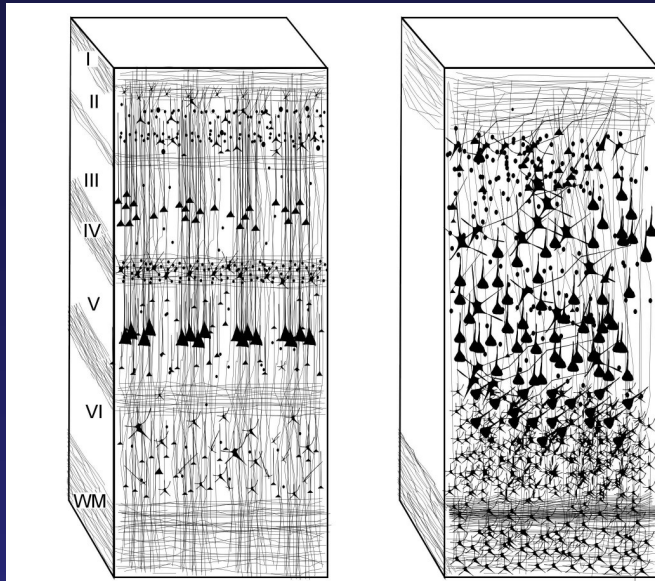
In collaborazione con :
ISTITUTO NEUROLOGICO NAZIONALE
“C.BESTA”
- Milano -



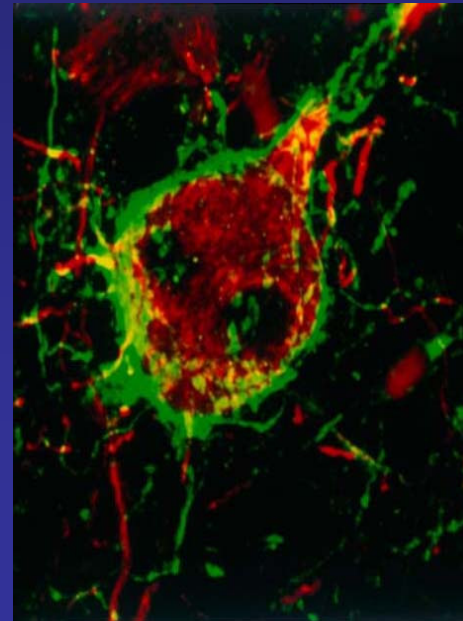
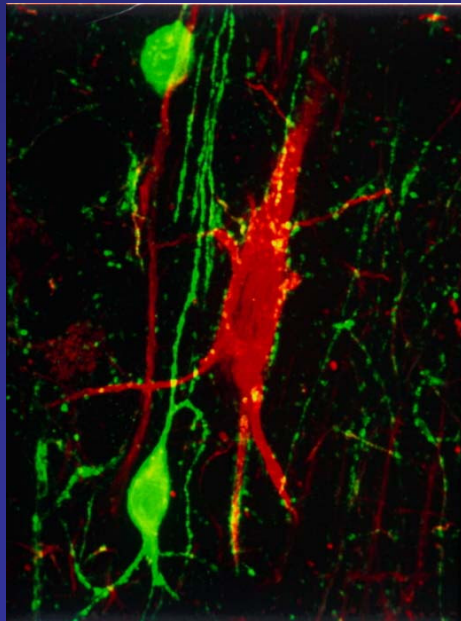
Analisi attività EEG ottenuta da registrazioni intracraniche



L'organizzazione finale della corteccia è il risultato di alcuni processi di sviluppo prenatale: proliferazione di cellule indifferenziate; migrazione dei neuroblasti; differenziazione cellulare. Perturbazioni di uno di questi processi (difetto genetico, influenza ambientale esterna), possono risultare in malformazioni dello sviluppo corticale (NMD), che si manifestano con difetti neurologici, deficit cognitivi e particolarmente con epilessia (8-12% dei casi non trattabili farmacologicamente sono associati con NMD).



La displasia di Taylor è una displasia corticale focale caratterizzata dalla presenza di neuroni giganti dismorfici e cellule “ballon” associata a distruzione della laminazione corticale



-0.40232

0 triggers

N1
N2
N6
N7
N8
N9
N10
N11
N12
M1
M2
M6
M7
M8
M9
M10
E1
E2
E3
E4
E6
E7
E8
E9
E10
E11
E12
E13
E14
E15
L1
L2
L3

