

Brain-Computer Interface

Overview, methods and opportunities

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Overview

- BCI : application, structure, **challenges, opportunities**
- Two examples of BCI : P300 and ERD/ERS
- ERD/ERS BCI – Methods
- ERD/ERS BCI – Our Work

Please don't sleep, we will watch videos

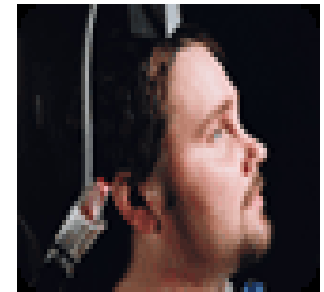
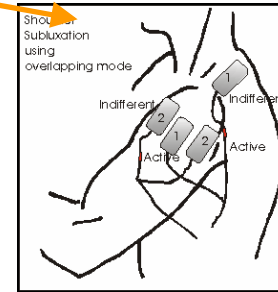
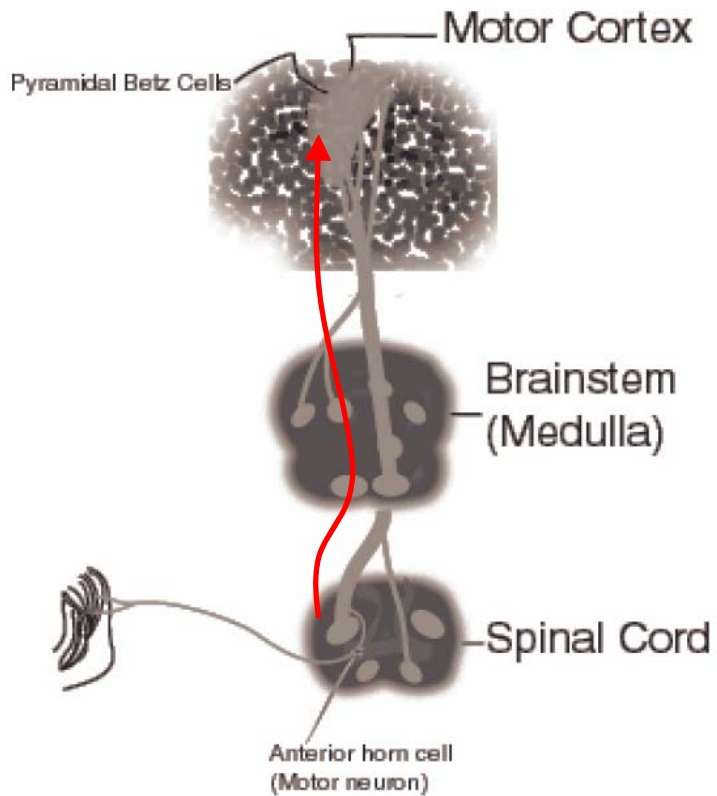
<http://www.youtube.com/watch?v=NIG47YgndP8>

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

Why a Brain-Computer Interface?

Locked-in Syndrome
Amyotrophic Lateral Sclerosis
Multiple Sclerosis

1. Use the capabilities of remaining pathways
2. Detour around the points of damage (**FES**)
3. Or if you have enough time to kill, use **BCI**



Military Applications



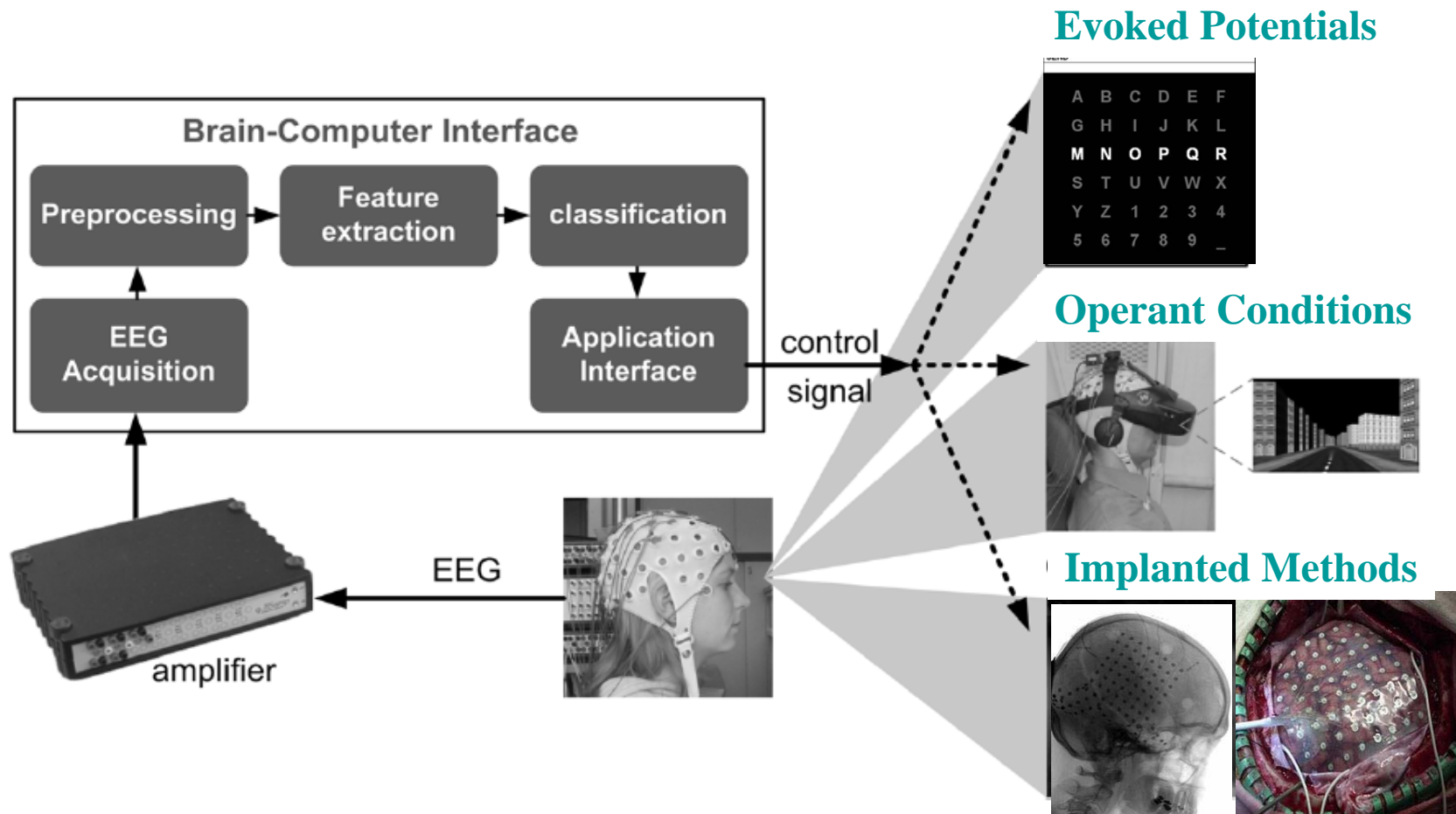
Other Fancy Use



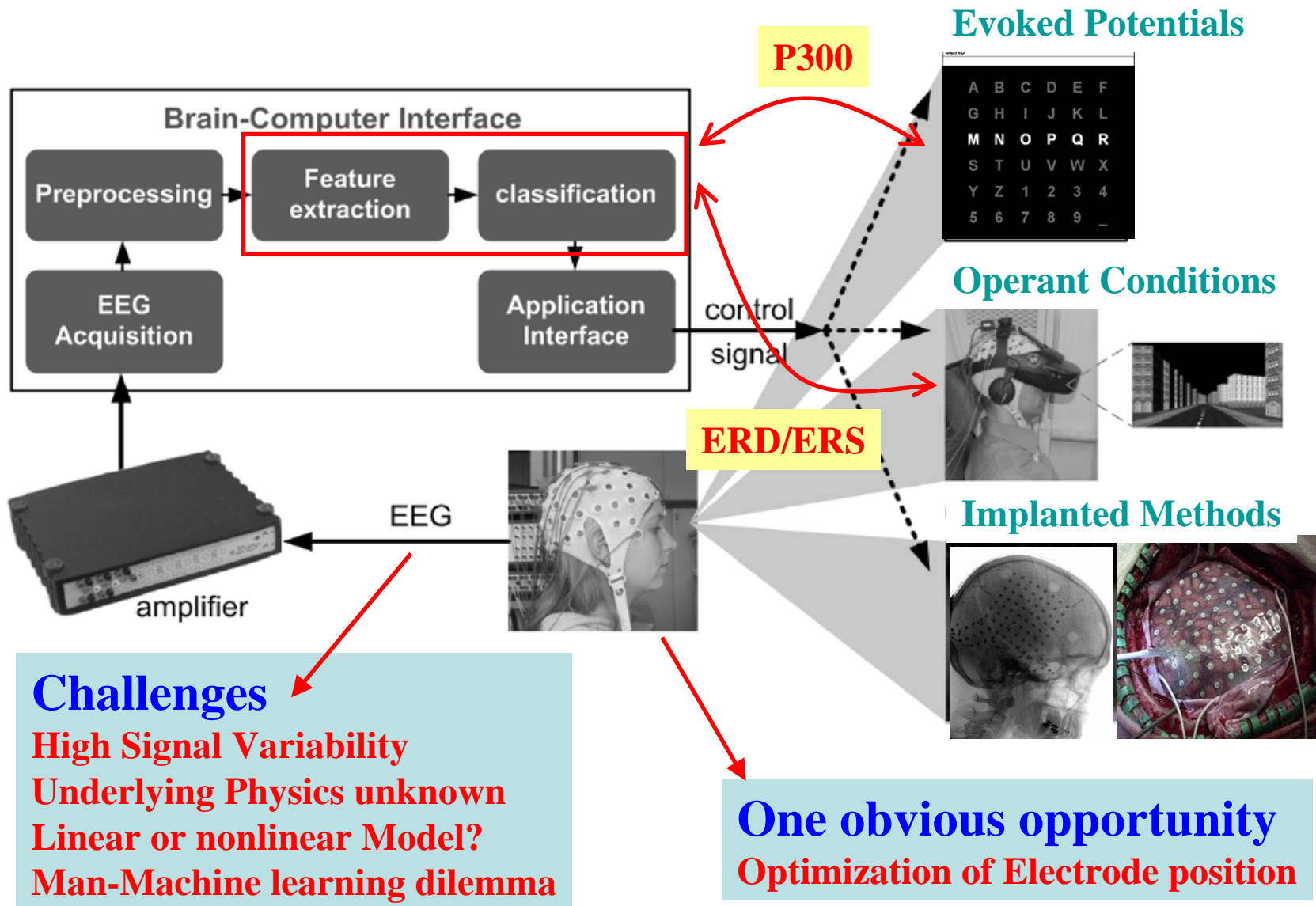
Why a Brain-Computer Interface?



A General Brain-Computer Interface (BCI)



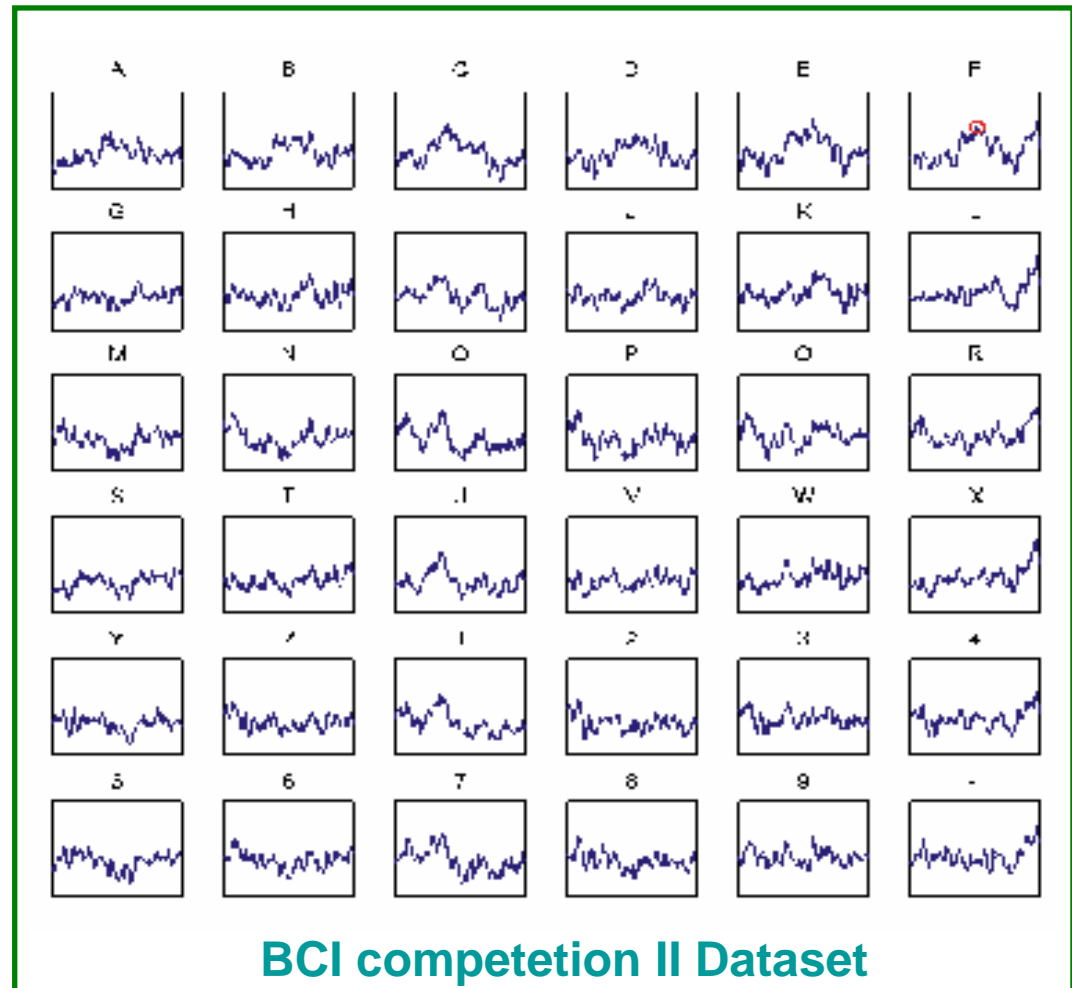
BCI: Challenges and Opportunities



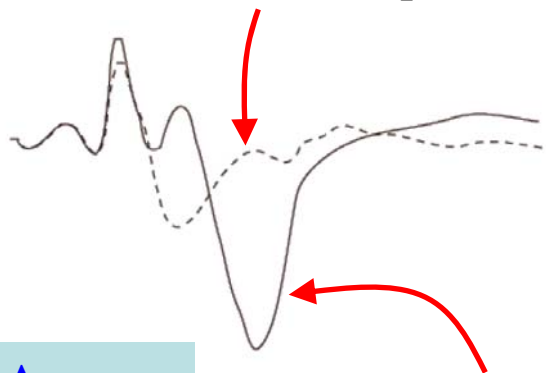
P300 BCI



Sequential data, Discrete o/p, Correlation based models



Non-task relevant response



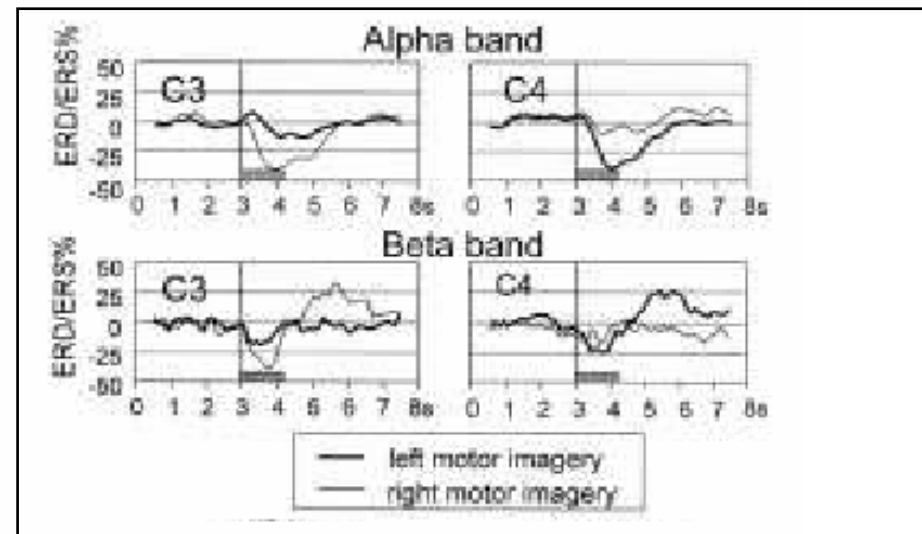
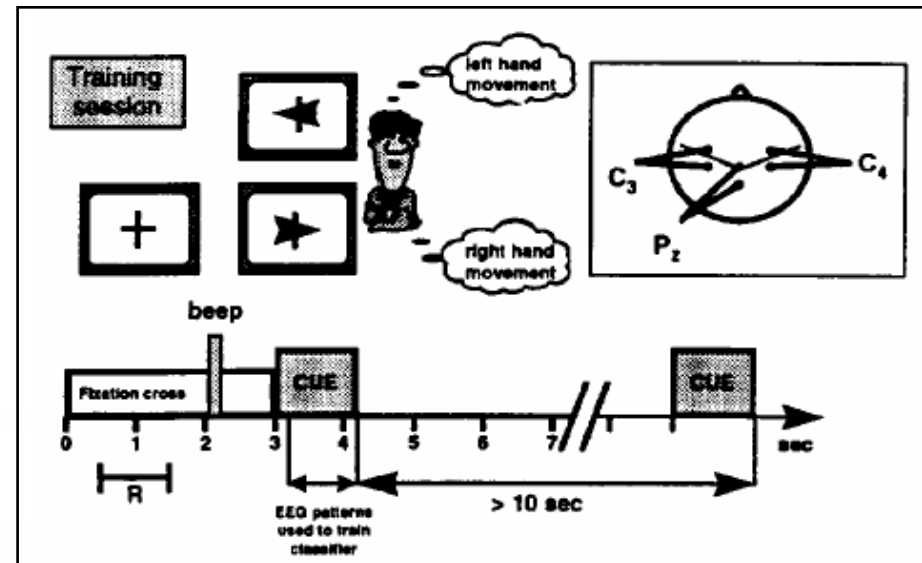
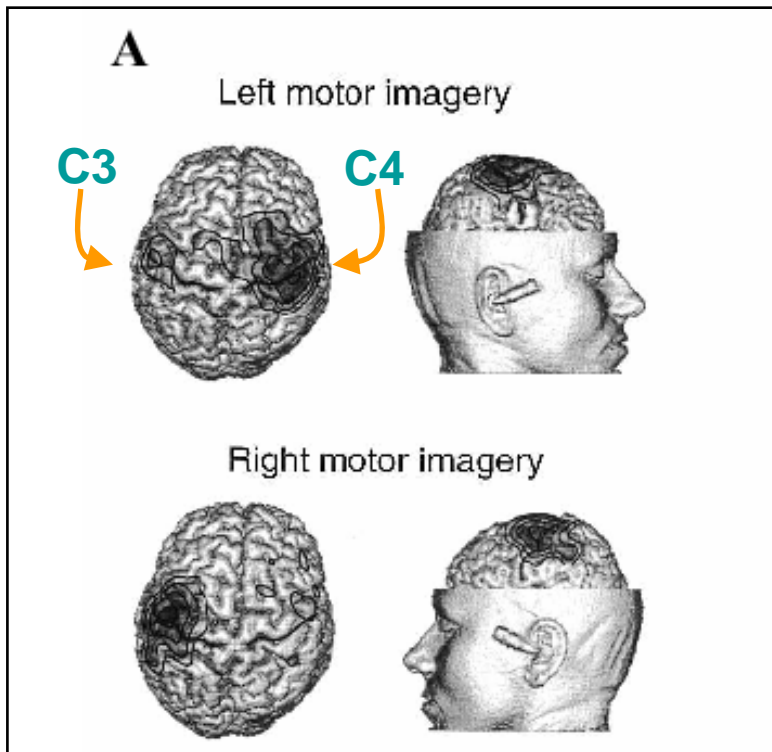
Average

Task relevant stimuli

ERD/ERS BCI

Amplitude **attenuation/ enhancement** in the **specific frequency bands**

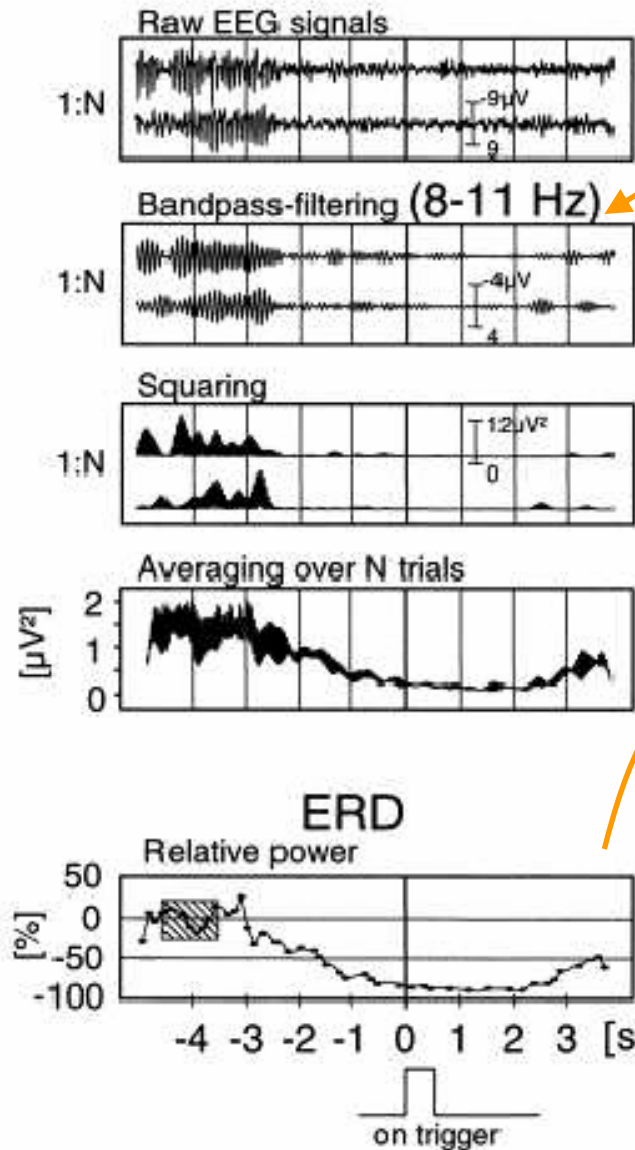
Sequential data,
Continuos o/p,
Strong Spectral characteristics



Photographs from Pfurtscheller 2002

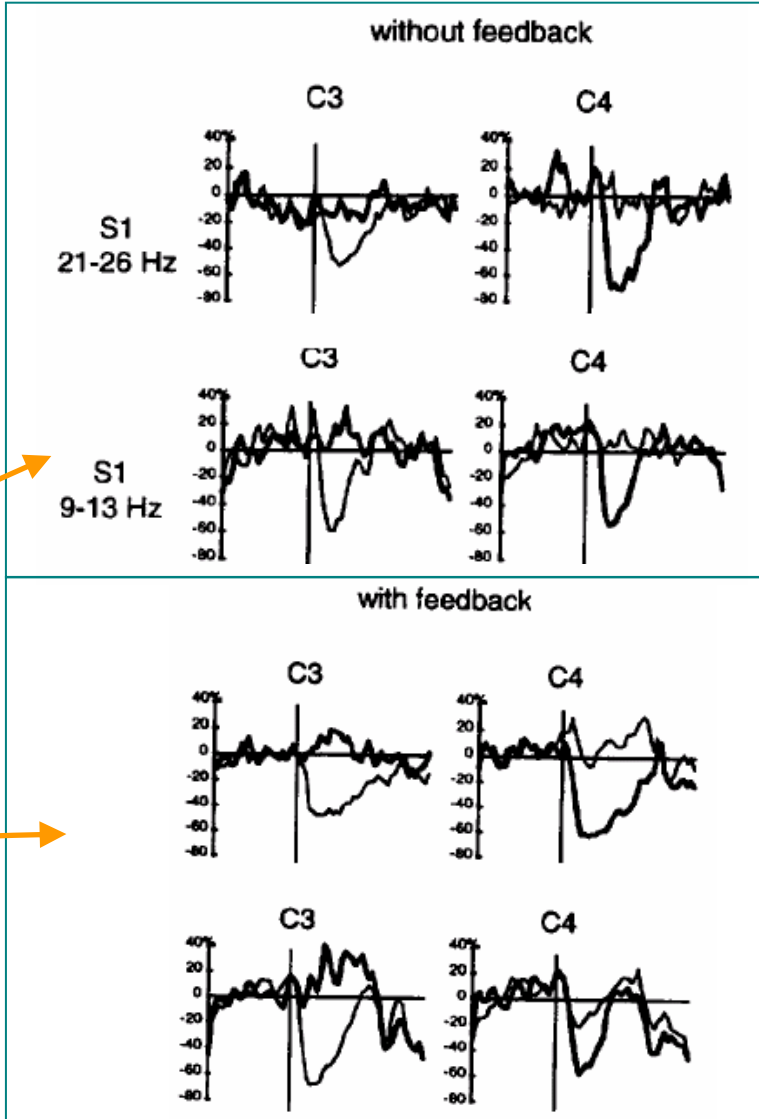
ERD/ERS – Methods

Inter-trial Variance (IV) Method



Sensitive to frequency band selection

Only offline



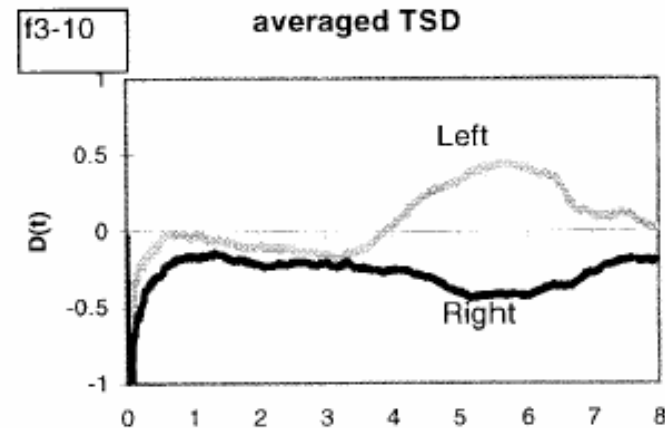
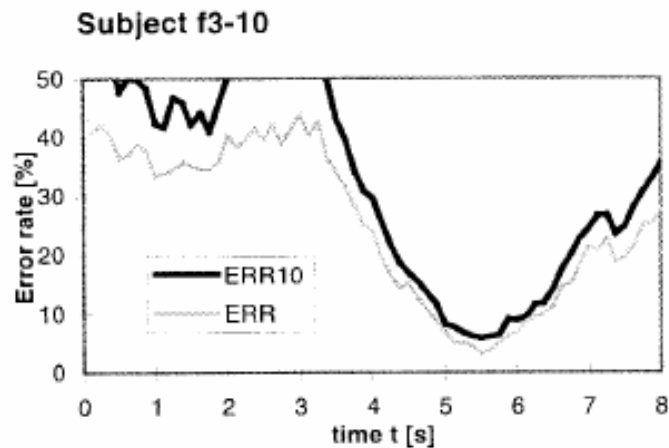
RLS Approach

Adaptive Autoregressive (AAR) Model

$$y_t = a_1^t y_{t-1} + a_2^t y_{t-2} + \dots + a_p^t y_{t-p} + v_t$$

observation noise

Solved with **Recursive least square** (RLS) algorithms and features classified with **Linear Discriminant Analysis** (LDA)



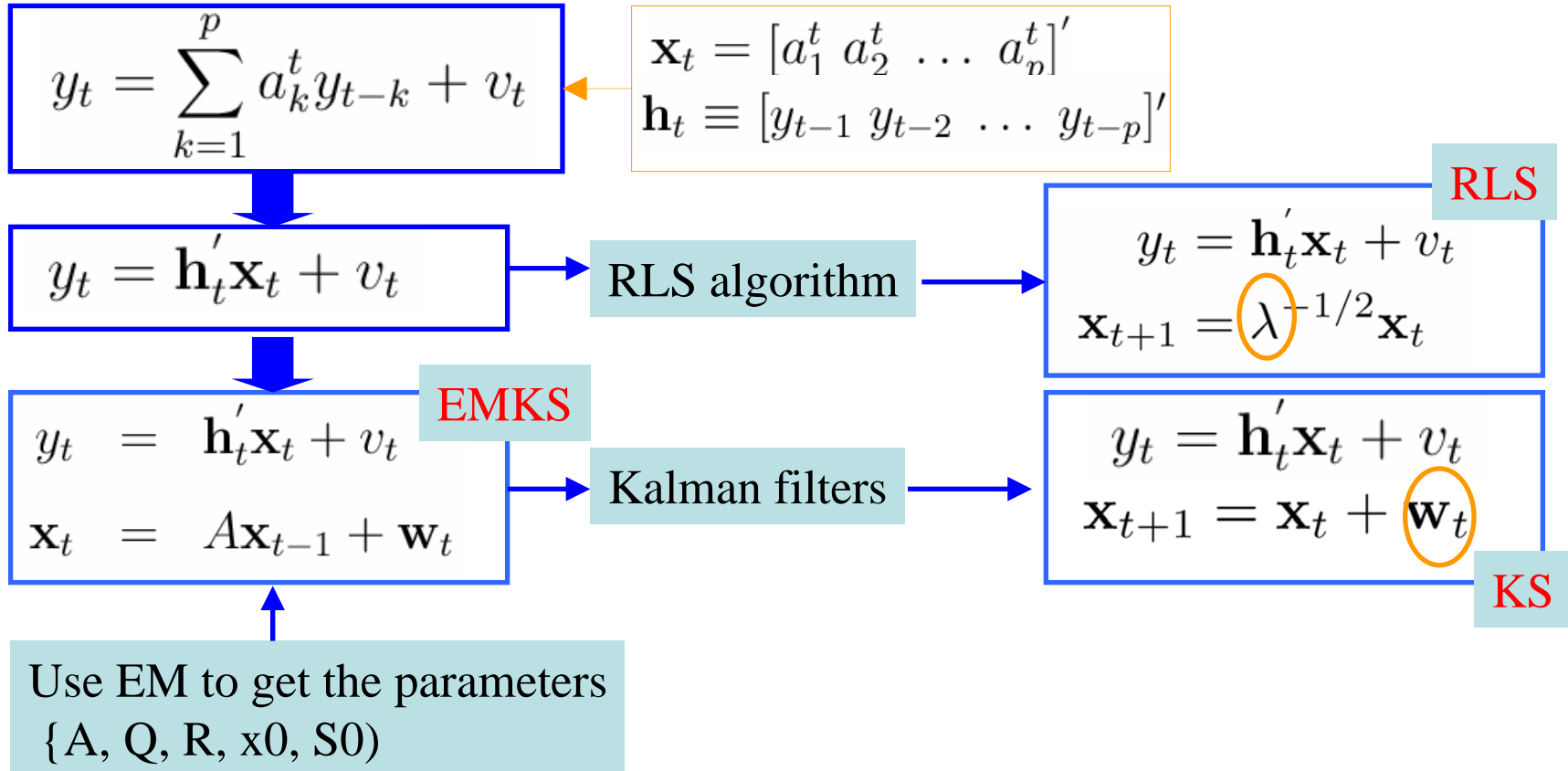
Our Work

Done at the Indian Institute of Science, Bangalore, India
in 2002-04

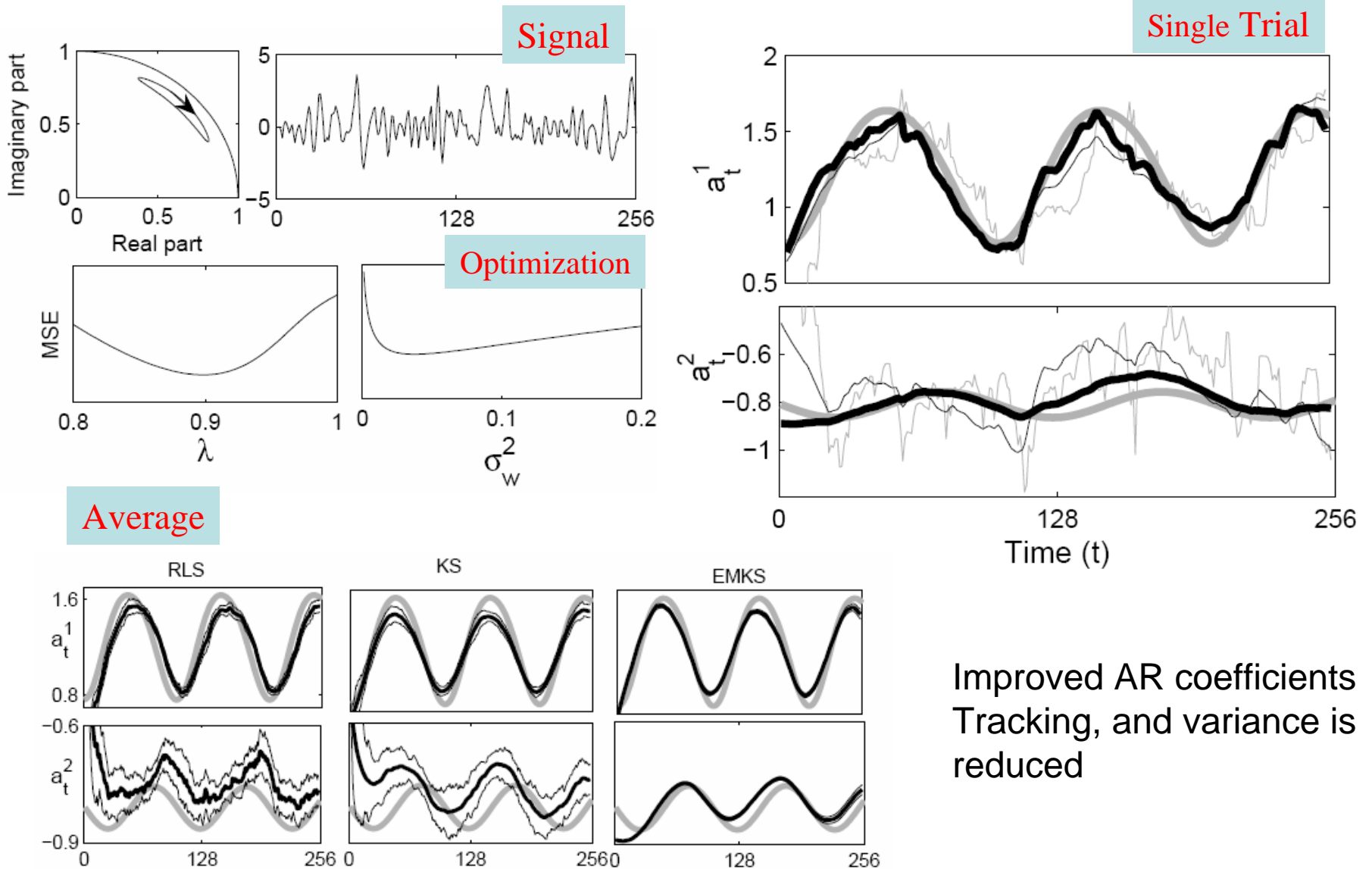
Published

M. E. Khan and D. N. Dutt, "An Expectation-Maximization Algorithm Based Kalman Smoother Approach for Event-Related Desynchronization (ERD) Estimation from EEG", Vol. 54, No. 7, July 2007, IEEE Transactions on Biomedical Engineering

Time-varying AR Model



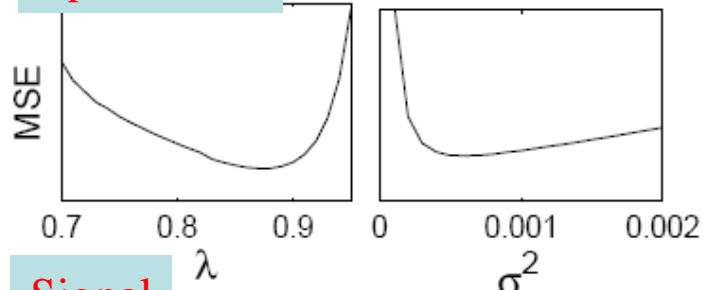
Effect of EM Learning on Tracking



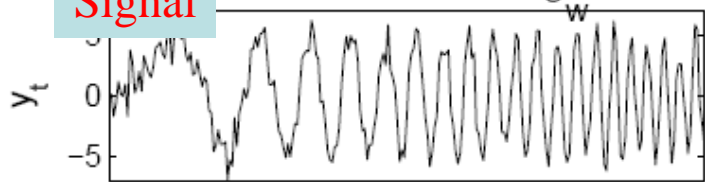
Improved AR coefficients
Tracking, and variance is
reduced

Spectrum Estimation

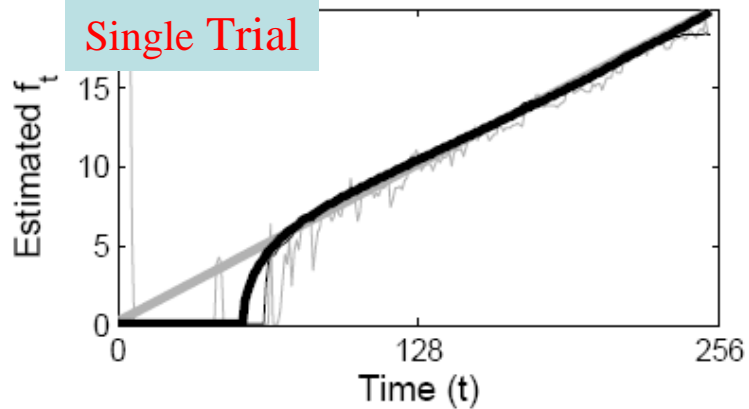
Optimization



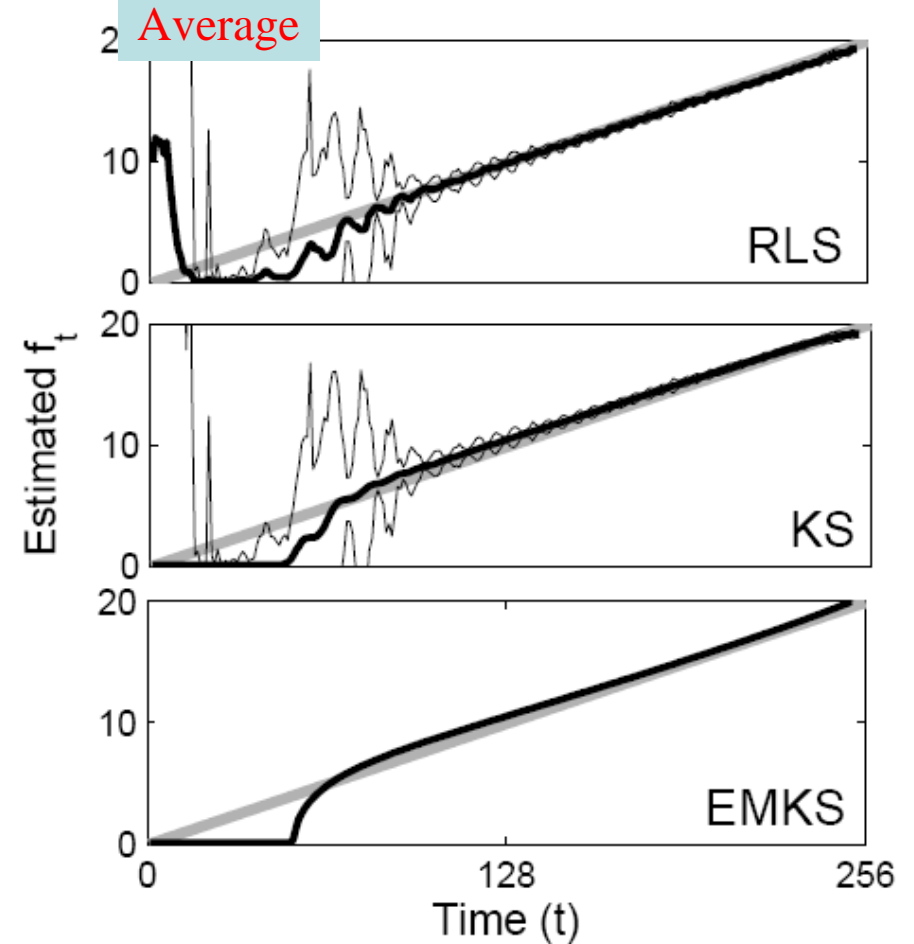
Signal



Single Trial

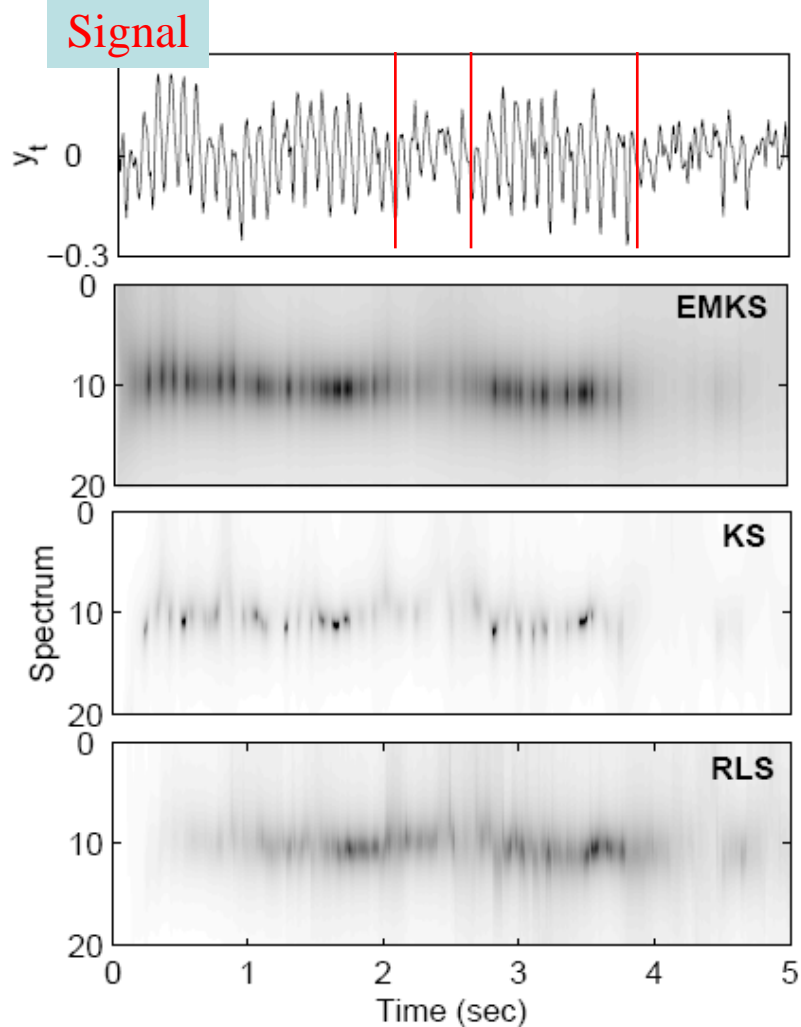


Average

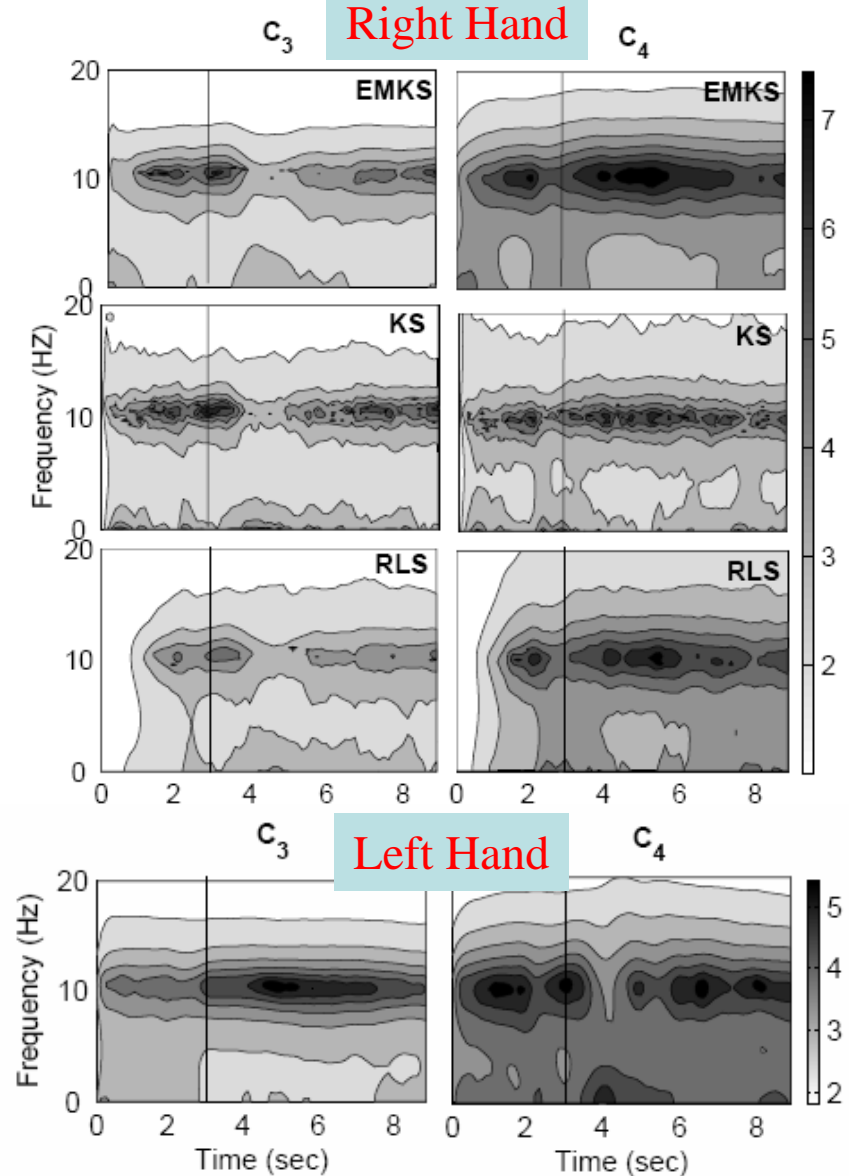


Improved Frequency Tracking
Variance is reduced

Motor Imagery Data: Spectrum estimates



Single Trial Spectrum Estimate

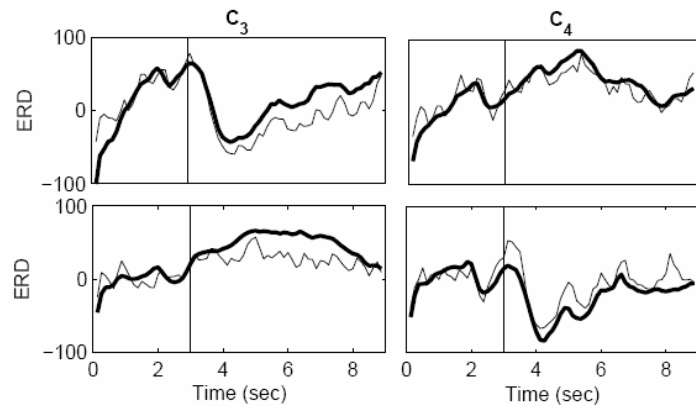
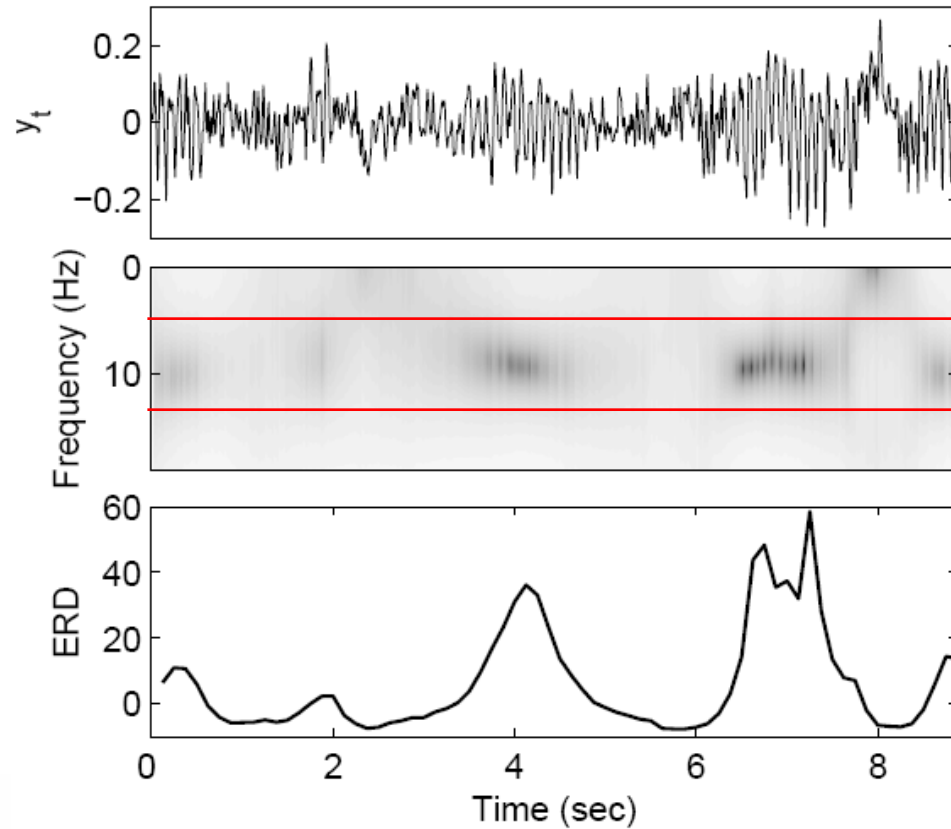


Motor Imagery Data : ERD estimation

$$H(t, f) = \frac{\hat{\sigma}_v}{|1 - \sum_{i=1}^p \hat{a}_t^i e^{-2\pi i f / f_s}|}$$

$$P_B(t) = \sum_{f=f_1}^{f_2} H(t, f)^2$$

$$ERD(t) = \frac{P_B(t) - P_{ref}}{P_{ref}}$$



Final Comments

- BCI datasets provide opportunity to test new algorithms
- Every two year there is a BCI competition. Some free datasets can be found there (just google BCI competition)
- Do it for fun and blame it on humanity!!