Abstract

- In neuroscience, phase-amplitude coupling (PAC) refers to the interaction between the phase of a slow neural oscillation and the amplitude of high frequencies, within the same signal or across two signals.
- To model PAC, we use new parametric driven auto-regressive (DAR) models. These generative statistical models provide non-linear spectral estimation of the signal, and are able to capture the time-varying behavior of PAC.
- We show that they are more robust to detect PAC in short signals than two state-of-the-art empirical PAC metrics.

Phase Amplitude Coupling (PAC)

Coupling between:
- Phase of a slow oscillation
- Amplitude of high frequencies

Driven Auto-Regressive (DAR) models

\[ y(t) + \sum_{i=1}^{p} a_i y(t-i) = \varepsilon(t) \]

\[ a_i(t) = \sum_{j=0}^{p} a_{ij} x(t-j)^j \]

\[ \log(\sigma(t)) = \sum_{j=0}^{p} b_{ij} x(t-j)^j \]

Maximum Likelihood Estimate:
- Linear system for the AR coefficients \( a_{ij} \)
- Newton-Raphson for the gain coefficients \( b_j \)

\[ L = \prod_{t=p+1}^{T} \frac{1}{\sqrt{2\pi\sigma(t)^2}} \exp \left( -\frac{\varepsilon(t)^2}{2\sigma(t)^2} \right) \]

Power spectral density

\[ S_p(x_0)(f) = \left| \sum_{i=0}^{p} a_i(x_0) e^{-j2\pi f t} \right|^2 \]

Signal and driver

No PAC

PAC

Robustness to short signals

Simulation:
- 100 signals of length 1.2s, 2.4s and 4.8s with a PAC between 3 Hz and 50 Hz
- For each signal, we select the frequency with the maximum measured PAC

Results:
- DAR models are able to select the correct frequencies even with short signals

References