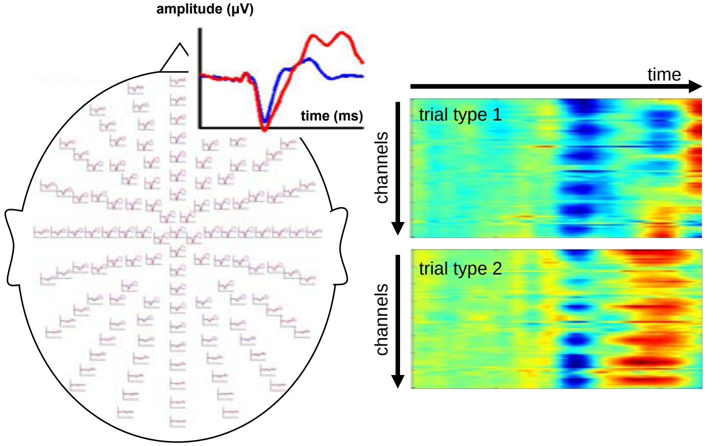
Dynamic Causal Modelling for M/EEG

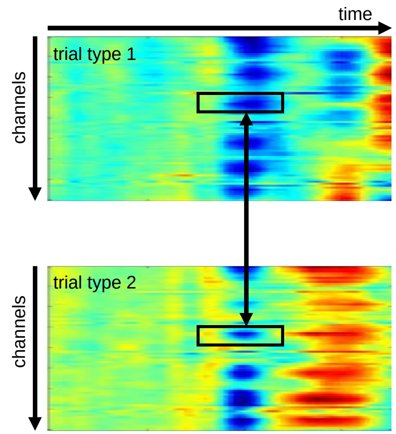
C. Phillips, Centre de Recherches du Cyclotron, ULg, Belgium

Based on slides from: S. Kiebel

Electroencephalography (EEG)



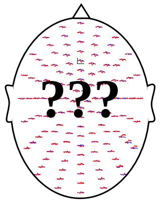
M/EEG analysis at sensor level



Approach: Reduce evoked response to a few variables, e.g.: The average over a few channels in peri-stimulus time.

Different approach that tells us more about the neuronal dynamics of localized brain sources?

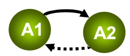
Dynamic Causal Modelling



Dynamic Causal Modelling

Build a model for spatiotemporal data:

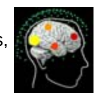
Assume that both ERPs are generated by temporal dynamics of a network of a few sources



Describe temporal dynamics by differential equations

$$\dot{x} = f(x,u,\theta)$$

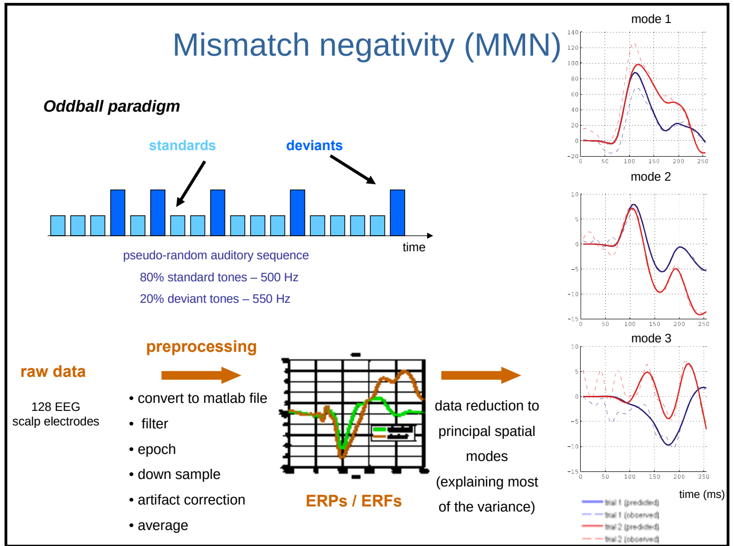
Each source projects to the sensors, following physical laws



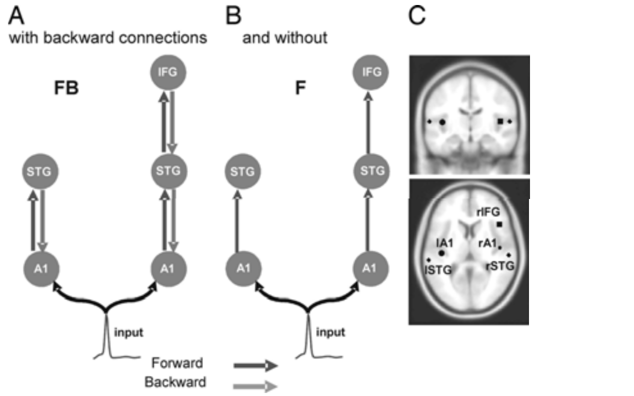
Solve for the model parameters using Bayesian model inversion

$$p(\theta \mid y,m)$$
$$p(y \mid m)$$

Mismatch negativity (MMN)

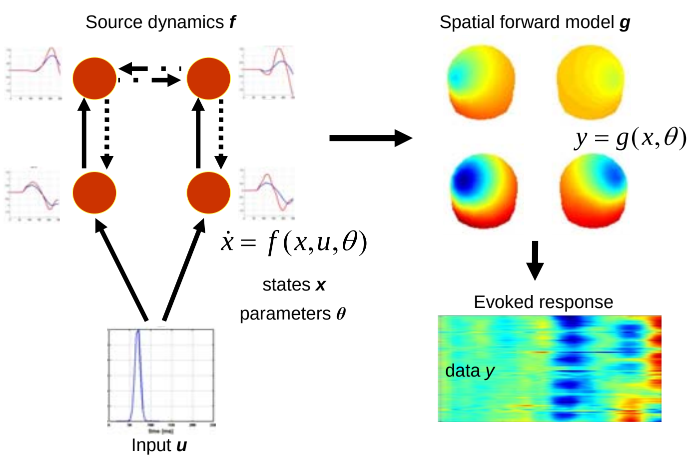


Model for mismatch negativity

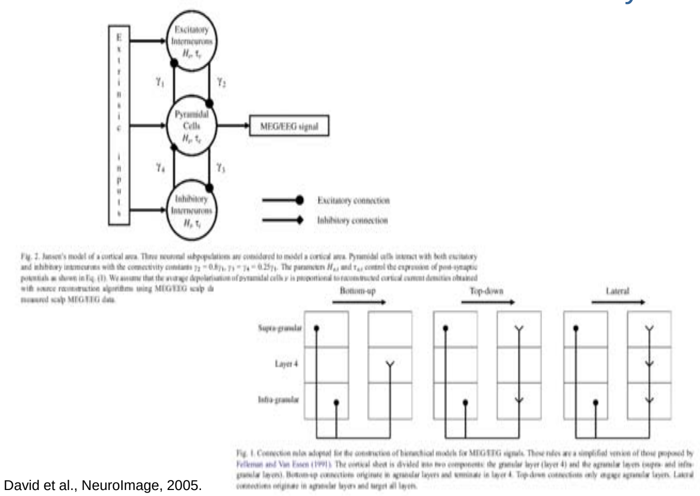


Garrido et al., PNAS, 2008

The generative model

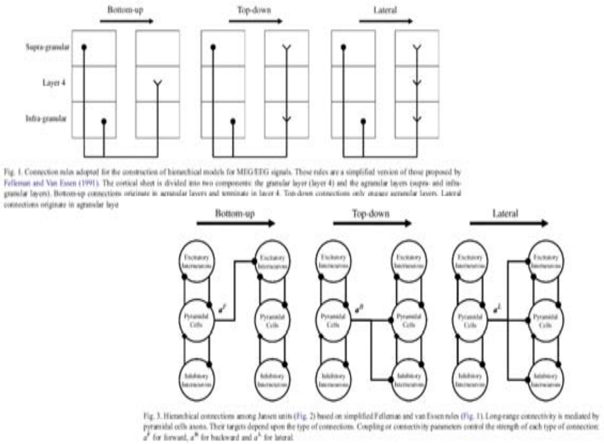


Neural mass equations and connectivity

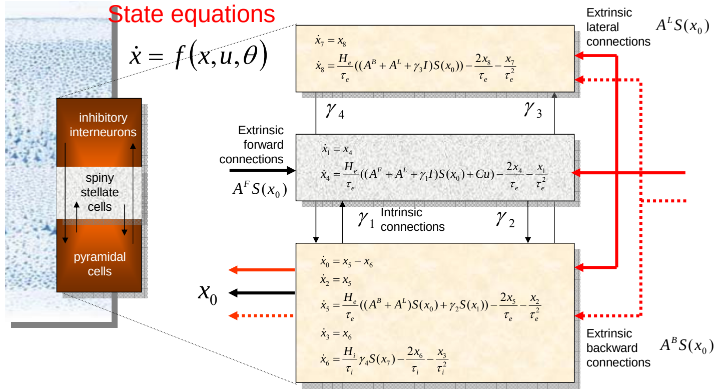


David et al., NeuroImage, 2005.

Neural mass equations and connectivity



Neural mass equations and connectivity



$x_i \equiv$ mean trans-membrane potentials and currents of the different neuron populations.

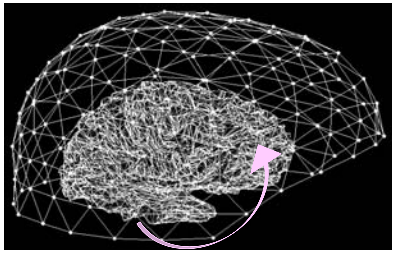
neuronal (source) model

Spatial model

x_0 Depolarisation of pyramidal cells

$L(\theta^L)$ Spatial model

→ Sensor data y



Bayesian model inversion

Measured data

Specify generative forward model (with prior distributions of parameters)

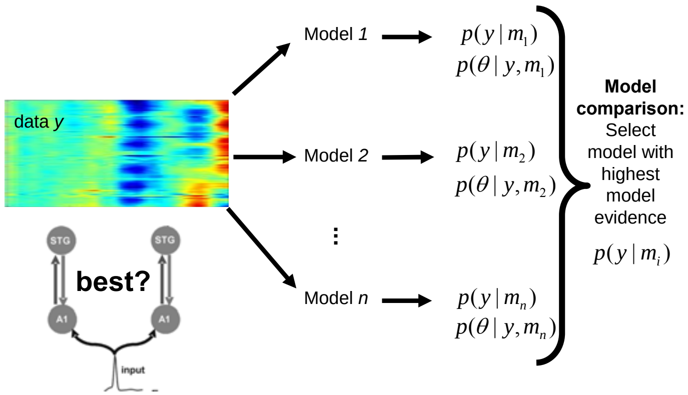
Expectation-Maximization algorithm

Iterative procedure:

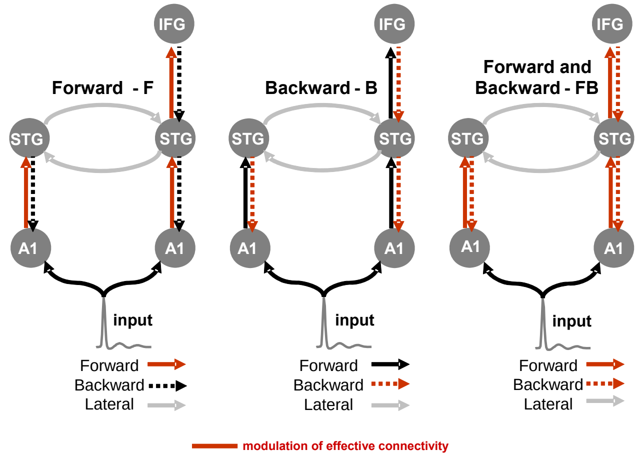
1. Compute model response using current set of parameters
2. Compare model response with data
3. Improve parameters, if possible

1. Posterior distributions of parameters $p(\theta \mid y, m)$
2. Model evidence $p(y \mid m)$

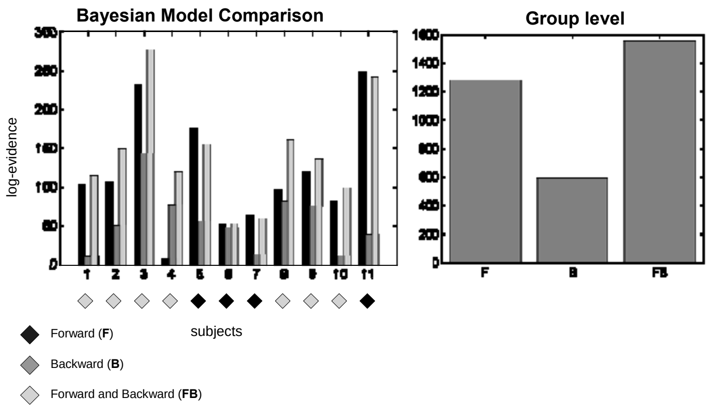
Model comparison: Which model is the best?



MMN example



Group model comparison



Garrido et al., (2007), *NeuroImage*

Evoked and induced responses

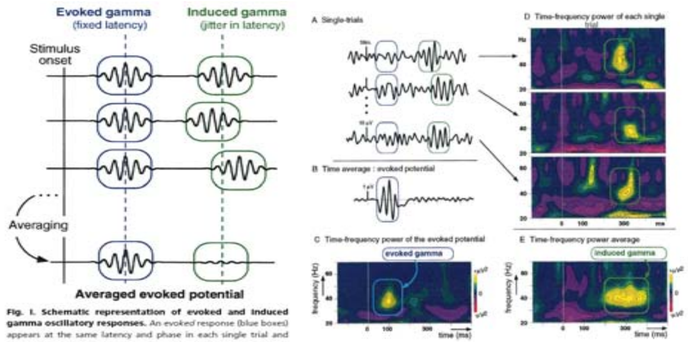
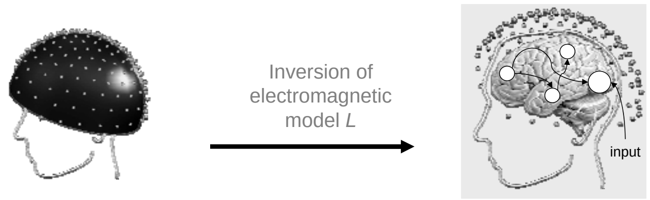


Fig. 1. Schematic representation of evoked and induced gamma oscillatory responses. An evoked response (blue boxes) appears at the same latency and phase in each single trial and hence can be detected in the averaged evoked potential. An induced response (green boxes) appears with a jitter in latency from one trial to another, centred around a given latency (green line). It therefore tends to cancel out completely in the averaged evoked potential. Specific methods must therefore be used in order to characterize induced activities (see Box 2).

Trends Cogn Sci. 1999 Apr;3(4):151-162

Modelling of induced responses



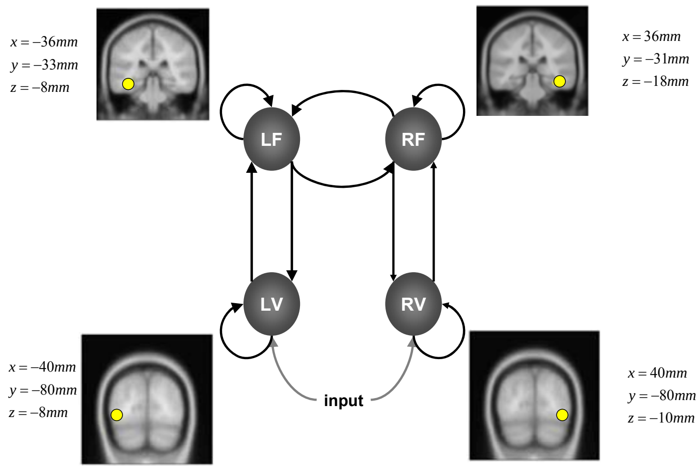
Time-series data in channel space

Dynamic power data in source space

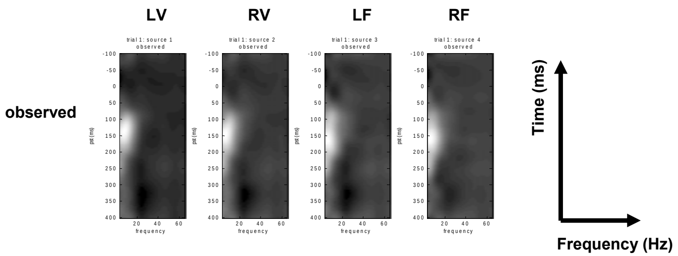
Aim: Explain dynamic power spectrum of each source as function of power input from other sources.

Chen et al., Neuroimage, 2008

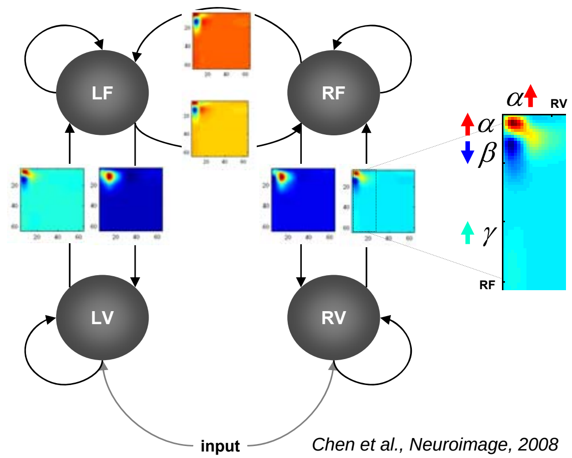
Face data (EEG): Network of four sources



Observed power spectra

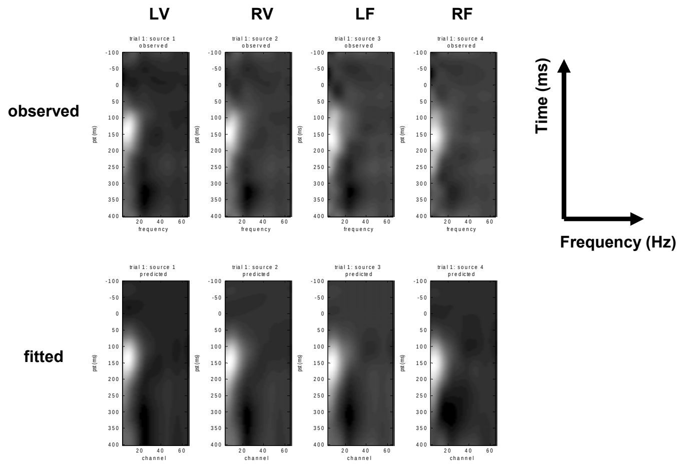


Single subject results: Coupling functions



Chen et al., Neuroimage, 2008

Observed and fitted power spectra



Summary

DCM combines state-equations for neural mass dynamics with spatial forward model.

Differences between responses acquired under different conditions are modelled as modulation of connectivity within and between sources.

Bayesian model comparison allows one to compare many different models and identify the best one.

Make inference about posterior distribution of parameters (e.g., effective connectivity, location of dipoles, etc.).

Many extensions to DCM for M/EEG are available in SPM8.

Thanks to

Karl Friston

Marta Garrido

CC Chen

Jean Daunizeau